Unpacking Platform Business Scaling in the Digital Age

by

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This is a pretty emotional moment for me when I write down the first sentence of this acknowledgement. Born in a remote mountain village, I never expected to go so far in my life — learning English, studying aboard, pursuing a PhD, and further working on academic research. Look backing now, I only have endless gratitude to everyone who supported me over this long journey. First, I wish to express my profound gratitude to my supervisors, Professor Ola Henfridsson and Professor Joe Nandhakumar, the two giants who listened to my undeveloped thoughts, inspired me with extraordinary research enthusiasm, and encouraged me when doubt set in. Without them, I would have never made it. I have been touched with and benefited a lot from their words and deeds in research and teaching, which is priceless to my road ahead.

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It is a hard time to pursue this PHD in the COVID-19 pandemic period. I wish this milestone could support, guide, and shine on my way forward.

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Abstract

Today's increasingly pervasive digital technologies have radically transformed the competition landscape of the business world. To succeed in the digital age, digital businesses must establish and strengthen their ecosystem positions through rapid scaling. While extant literature in platform ecosystems identified the urgency of scaling for focal platforms, there is little recognition that non-focal actors (i.e., complementors) typically pursue their own growth ambitions. If successful, these ambitions may even shift the complementor's position as a non-focal to a focal actor in the digital ecosystem. While such a scaling process opens new possibilities for the complementor, it also challenges its relations with focal platforms in the ecosystem on which it depends. This is what we refer to as the complementor's dilemma: how can a non-focal actor pursue growth ambitions while maintaining favourable relationships with the focal platforms on which they grow?

To address this research problem, a sequential mixed-method project combining qualitative research approaches with computational techniques was conducted. Developing on an in-depth embedded case study of the Chinese short video platform Douyin from its inception as a complementor in 2016 to its rapid establishment as a focal actor in 2018, we further test and generalise the findings for the entire social networking ecosystem in China. This allows for new empirical and theoretical perspectives on the navigation process of digital business scaling through identity projection.

The findings suggest that non-focal businesses must continually locate and re-locate who they are in the moment and the trade-off of two, or multiple, future scenarios regarding their relationship with focal platforms, to cope with the complementor's dilemma as they grow. Four identity projection strategies are further conceptualised as a powerful toolkit for balancing growth ambitions and dependency on other ecosystem actors during the scaling process.

These findings contribute to the platform literature by offering a process model for non-focal businesses' identity projection as they grow in digital ecosystems. The model offers important implications for our understanding of complementarity as a dynamic process involving purposeful identity re-projection, as non-focal businesses attempt to navigate tensions with focal platforms in digital ecosystems during growth. It also contributes to our understanding of digital business scaling beyond a high-growth consequence of firm size — a turbulent, uncertain, messy process to economies of complementarity in digital ecosystems.

Preface

This thesis explores how this century's digital revolution requires radical rethinking and reconceptualization of scaling for digital enterprises. Born in 1994, I am fortunate to be part of the new generation of digital natives who have been surrounded by and using computers, video games, mobile phones, digital music players, and other devices our whole lives. I witness how these unprecedented digital technologies are transforming my daily life, my family, and — more spectacularly — my country. Comparing today's China with twenty years ago, more and more digital unicorns and giants such as Alibaba, Tencent, Didi, Xiaomi, Meituan, Baidu, Bytedance, and Huawei continue emerging in this land and creating digital innovations that profoundly change and re-energise Chinese life. This magnificent landscape of digital revolution motivates my devotion to a PhD in the domain of digital innovation, entrepreneurship, and transformation.

As I pursue this research in both academia and practice, one digital phenomenon repeatedly attracts my attention. It is the "wakes of innovation" in Boland et al.'s (2006) 3D building projects; the "winner-take-all dynamics" in Eisenmann et al.'s (2006) platform competition; the "thousand flowers bloom" in Boudreau's (2012) handheld computer platforms; the "growing on steroids" in Huang et al.'s (2017) WeCash digital venture; and the "open-ended value landscape" in Henfridsson et al.'s (2018) IS research agenda. Digital businesses are earning their positions over a surprisingly short window of time through a qualitatively different organising logic in comparison with incumbent industrial firms. Such rapid scaling is rooted in digital enterprise, materialised through digital innovation, and embodied in digital transformation. However, in the extant literature there is a lack of systematic elaboration of what the nature of the scaling and how to realise it for digital businesses. While most relevant studies in IS focus on leading enterprises standing at the centre of the digital revolution, this thesis calls for more attention to non-focal businesses as building blocks forming much of the digital economy. While a single flower does not make spring, one hundred

flowers in full blossom bring spring to the garden. The full potential of digital technologies can only be unpacked if we energise each digital enterprise in the world.

The research presented in this thesis addresses this question by studying the rapid growth of the Chinese short video platform Douyin, from its start-up as a complement to an established focal actor in the mobile internet market. By doing so, it takes a first step towards understanding non-focal digital business scaling in empirical settings. I hope this study will help emerging start-ups, incumbent organizations, policy makers and regulators, and engaged citizens to better navigate the challenging business world of the digital era.

1. INTRODUCTION

The permeation of digital technologies into all aspects of the business world has fundamentally transformed the landscape of entrepreneurial scaling in the digital age. Early evidence claims that "the scaling of digital enterprises is qualitatively different from the type of scaling documented by Chandler in his classic case studies of industrial enterprises (e.g., Du Pont, General Motors, Standard Oil, and Sears)" (Henfridsson 2020; Huang et al. 2017). Parallel with recent academic work in information systems, entrepreneurship, and strategy, there are an increasing number of entrepreneurs, managers, and policymakers who recognize the relevance and significance of scale-ups, being scalable, or having scalability in their daily practices (e.g. Coutu 2014; Hellmann and Kavadias 2016; OECD 2007). Despite current use of scaling-related terms, these constructs remain under-defined and have not been meaningfully measured or explored. What is scaling in the digital age? What is the role of digitalisation in scaling? How do digital ecosystems influence firm scaling? How do firms leverage digital ecosystems to scale? To better explore these questions, this thesis conducted in-depth studies of the scaling process of digital platform businesses in the social networking ecosystem in China. Unpacking the underlying interdependency dilemmas during scaling, the thesis contributes to the understanding of how platform businesses can navigate their scaling process through identity projection.

This chapter develops the research motivation and scope of this thesis. It then formulates the research questions and presents the research objectives and adopted approach. We This chapter closes with specific contribution targets before moving on to literature review.

1.1 Research Motivation

In recent years, there has been mounting interest in digital business scaling from academia and practice. Just comparing the top 10 firms in the 2020 USA Deloitte Fast 500 ranking, as measured by annualised growth rate of revenue, with the same list ten years ago reveals a large shift. While the term scaling refers to a high-growth firm in

size (Chandler 1962, 1977) with annualised growth greater than 20% over a three-year period (OECD 2007), new giants who build their business upon digital infrastructures (e.g. Brynjolfsson and McAfee 2014; Henfridsson and Bygstad 2013; Tilson et al. 2010; Yoo et al. 2010) have increased their clock speed (cf. Fine, 1998) far beyond the traditional reference point — i.e., at rates of 1000% or higher.

Underlying the apparent quantitative difference in growth rate is an on-going profound change in the meaning, driver, means, and related parties of scaling in the digital age. In contrast to modern industrial enterprises which scale up their businesses through massive production and distribution in supply chain integration (Chandler 1977), digital businesses leverage the power of platform architecture to scale up digital innovation and user interaction in a carefully orchestrated ecosystem (Jacobides et al. 2018; Parker et al. 2016; Yoo et al. 2010). As such, instead of supply-side economies of scale and scope in production, digital business scaling is driven by demand-side economies of scale (Eisenmann et al. 2006; Parker et al. 2016) and scope of innovation (Gawer 2014; Teece 2018). This shift from internal economies to ecosystem-level economies fundamentally disengages the limit of scaling beyond its optimal size (Nason and Wiklund 2018; Penrose 2009); complicates the process of scaling to platform ecosystem governance (Tiwana et al. 2010; Tiwana 2013); re-characterises the metrics of scaling to user base and engagement (Huang et al. 2017; Parker et al. 2016; Prasad et al. 2010); and re-defines the meaning of scaling as a process by which the operational efficiency in platform innovation and interaction increases during growth (Henfridsson 2020). Accordingly, scaling now is about more than a particular firm size state or a strong growth from one size to another in given conditions. We need to know more about how to scale, for example, in ecosystem penetration or expansion — beyond how much growth in firm size — as the incidental consequence. As Coviello (2019) suggests: “You can’t be a scale-up without growing but you can be growing and not be a scale-up” (pp. 15).

Looking closely at the extant literature in IS, entrepreneurship, and strategy, most studies remain focused on high-growth firms in terms of employee number, revenue

level, or market share as equivalent to the firms being scalable (e.g., DeSantola and Gulati 2017; Duruflé et al. 2017; Gulati and DeSantola 2016). Scaling is mainly deemed to be an endogenous effort within the organisation, without consideration of the broader digital ecosystems in which it is embedded. An emerging digital business, usually starting as a complementor, is characterised by its interdependent relationship with focal actors in digital ecosystems. First, complementors are crucial for the viability of digital ecosystems (Jacobides et al. 2018; Teece 2018). Complementors help increasing the scope and diversity of the digital ecosystem through innovation (Gawer 2014; Ghazawneh and Henfridsson 2013; Teece 2006). The digital ecosystem benefits from heterogeneous innovation capability and knowledge resources (Boland et al. 2007; Yoo et al. 2010), shared innovation risk (Boudreau 2012), and network effects (Farrell and Saloner 1985; Parker and Van Alstyne 2005). Second, the digital ecosystem with its focal platform/s is highly significant for complementors. Complementors can enjoy low-cost innovation as they use the platform's technical resources (Ghazawneh and Henfridsson 2013; Yoo et al. 2010) and distribution resources as they leverage the existing user base of focal platforms (Parker et al. 2016).

However, the interdependence is not necessarily stable over time. Complements often have growth ambitions themselves (cf. Constantinides et al. 2018; Huang et al. 2017; Schilling 2002), his creating a dynamic relationship where the complementor's ambitions continually change its position and dependency relative to focal platforms. For example, consider how PayPal started as a complement business by piggybacking on the eBay platform — but eventually established itself as a focal platform in payments itself.

Most studies in platform literature focus their efforts on focal platforms. One category of scholars emphasises their character as innovation hubs that hold and dominate core elements (e.g., technology, product, or service) as the foundation on which other ecosystem actors build their innovation (e.g., Gawer and Cusumano 2002; Gawer and Henderson 2007; Ghazawneh and Henfridsson 2013). Another group of scholars describes focal platforms as network centres devoted to cultivating and

governing positive network effects in the ecosystem (e.g., Claussen et al. 2013; Iansiti and Levien 2004; Parker and Van Alstyne 2005). However, there exist a few studies (e.g., Selander et al. 2013) and conference tracks (Smolander et al. 2020) that offer perspectives on non-focal actors such as platform complements. For instance, Selander et al. (2013) portray the non-focal actor as "an ecosystem participant who is at the periphery of a digital ecosystem" (pp. 183) and highlight the importance of closer examination of the process by which such actors search and redeem capabilities across ecosystems. Yet, in seeking growth, a complementor inevitably come across tensions in its relationship with focal platforms of the digital ecosystem, representing moments of self-doubt (e.g., Am I a complementor or not?) due to its changing position vis-à-vis the focal platforms during growth. Complementors cannot grow in a vacuum but must build on the focal platforms to materialise their growth ambitions in a digital ecosystem. Yet it is inevitable for a complementor to prioritise its own ambitions. The complementor needs to strike a balance, and this is what we label as the complementor's dilemma.

Under this context, scaling is about more than consequent change in firm size measured by traditional growth metrics — it refers to growing the affiliated ecosystem members (i.e., end-users, third-party developers, and partner firms). Similarly, the scaling process has nothing to do with leveraging internal resources to achieve an optimum size. Rather, it asks for building persistent ecosystem legitimacy and momentum from diverse participants over time. To this end, deeper conceptualisation of the scaling process of digital businesses as well as viable scaling strategies specific to the interdependency dilemma mentioned before have to be carefully identified in future studies.

In summary, the motivation of this thesis is the inadequacy of extant theoretical perspectives in explaining how non-focal businesses can navigate their scaling process in digital ecosystems over time. This allows for new empirical and conceptual perspectives on defining and understanding scaling in the context of digitalisation and digital ecosystems. In the following, I shall introduce the research questions driven by the research motivation.

1.2 Research Question

The previous discussion depicts an underlying tension confronted by non-focal digital businesses as they seek growth. In essence, it has to deal with two types of relation prudently in digital ecosystems. First, non-focal actors need to communicate their desirability, appropriateness, and competence relative to others (Gioia et al. 2013a; Tripsas 2009), in order to stand out from the competition for focal platforms' support (Navis and Glynn 2011; Whetten 2006). However, to grow they risk antagonizing focal platforms by relaxing, collapsing and even reversing existing interdependency, and thus provoking retaliation. Consequently, non-focal digital businesses pursuing growth ambitions confront the complementor's dilemma: gaining the support of the focal platforms they alienate.

Second, digital businesses are characterized as a highly socialised object with a layered modular architectural structure (Yoo et al. 2010), the function of which is subject to collective assignment by ecosystem members. As such, spontaneous user-driven innovation may continually generate and signal new growth paths that is out of the expectation of digital business owners (Henfridsson et al. 2018). For this reason, the complementor's dilemma enacts in an emergent and iterative process in a context of high uncertainty and ambiguity, which requires the non-focal digital business to periodically reflect on what it is and what it wants to be in the future (Huang et al. 2017).

All in all, the scaling of non-focal digital businesses is embedded in the wider digital ecosystems and co-shaped by diverse ecosystem actors. The key to understand this scaling process is to unpack the mechanisms for navigating the interdependency dilemma in digital ecosystems. I therefore formulate the research question as following:

What is the process by which non-focal businesses navigate their scaling process in digital ecosystems?

To answer this question, it is necessary to solve three sub-questions in sequence:

1) The growth trajectory of digital businesses displays a unique interdependency challenge for non-focal actors in digital ecosystems, with a lack of explanation and

theorisation in existing literature. This raises the issue of how to understand digital business growth from the non-focal perspective, addressed by the first sub-question:

Q1: What is the complementor's dilemma process during the growth of digital businesses?

2) Following the first question, we must understand the mechanisms for driving this complementor's dilemma process, especially the strategies viable for non-focal actors to navigate this process. This issue is addressed by the second sub-question:

Q2: How does non-focal businesses navigate the complementor's dilemma process in digital ecosystems?

3) Based on the answers to the preceding questions, we can gain a deeper understanding and conceptualisation of business scaling in the digital context, especially how it scales up to generate and sustain ecosystem-level economies as it is growing. Hence, the third sub-question is articulated as:

Q3: What is scaling in the digital age and how is it materialised?

To address the research question and sub-questions, I now move on to elaborate and discuss the research objective and approach in detail.

1.3 Research Objective and Approach

The main objective for this thesis is to conduct empirical inquiries to depict, explain, and extend current understanding and theorising of digital business scaling, especially the identity projection dynamics playing out in the scaling process. Recognizing IS as a practice-based research discipline that encompasses sociotechnical phenomena pertaining to both natural science and social science (Carlsson 2003, 2005; Mingers 2004; Venkatesh et al. 2013), this thesis adopted critical realism (CR)-led mixed research methods which enable moves between situated narrative process and computational associations in populations in order to uncover generative mechanisms and make more robust meta-inferences (Minger et al. 2013; Venkatesh et al. 2013; Zachariadis et al. 2013).

Process-tracing and econometrics approaches are adopted in theory development and theory generalisation respectively in this thesis. First, I carried out a longitudinal

embedded case study of the Chinese short video venture Douyin (internationally known as TikTok) to study its spectacular growth from inception as a complement in 2016 to its establishment as a focal actor in 2018. I examine closely the three shifts of Douyin's projected identity and the ways it successfully redefined its complementarity to focal platforms such as Weibo and WeChat in China's platform ecosystem of social networking. Conducting an iterative, grounded, four-step process-tracing analysis by combining both quantitative and qualitative archive digital trace data between the years 2013 (three years before Douyin launched) and 2020 (the year that the international version TikTok was banned by the US government), multiple data points are collected and mutually corroborated — in comparison to single input-output methods, where only one measurement per task is available. By doing so, I examine the intervening causal process — the causal chain and causal mechanism — between platform positioning and platform growth at Douyin, from non-focal complement to focal actor in the Chinese social networking ecosystems. This process model uncovers the nature of complementor growth as a battery of identity trade-offs in platform ecosystems, co-shaped by end-users, focal platforms, and wider contextual conditions over time.

Building upon the process model developed in this single case study, I further test and generalise it for a broader population. I carried out a natural language processing and survival analysis of the social mobile apps in the iOS app store in China between 2014 and 2019. Using the lexicon (Berente et al. 2019) provided by extant literature and mechanisms uncovered in preceding chapters as the pre-theoretical reference, I conceptualised three identity projection strategies available for non-focal businesses in digital ecosystems and empirically tested their influence on the probability of business survival. By doing so, I build the causal weight/effect of the interested phenomena which complements the intensive qualitative method to generate a more comprehensive and valid casual explanation and theory of digital business scaling. The result shows that app developers need to actively enhance and maintain their identity in all three strategic directions pertaining to both conformity to focal actors' expectations and distinctiveness within a defined membership to be competitive, survive, and further

scale up in the social networking ecosystem.

In summary, the scope of this thesis is delineated as applying CR-led, computational-intensive mixed methods to explore the identity projection process, through which I aim to uncover how growing platform businesses navigate their interdependency dilemma in digital ecosystems. I discuss the expected contribution of this thesis in the following section.

1.4 Targets for Contribution

This research contributes to the platform ecosystem literature by developing a process model of non-focal businesses' growth in digital ecosystems. First, it challenges the specification of complements as non-focal actors by revealing three adjacent interdependence dilemmas that a complementary platform will confront during growth — niche complement or main complement, dependent or independent, and integration or competition. Second, it extends current understanding of platform identity in digital ecosystems. Beyond an endogenous effort from non-focal businesses themselves, an identity forming process in digital ecosystems is highly contingent on the understanding of heterogeneous ecosystem actors over time. Therefore, platform identity portrays the interdependency of an actor in ecosystems, helping navigate the interdependence dilemma process. Third, it suggests digital complementarity in a platform ecosystem context. Rather than self-contained with non-focal or focal value, the position of an actor requires identification from other participants in ecosystems. In this regard, complementarity in digital ecosystems is different from existing literature in the sense that the value of digital artifacts is not well-defined but rather has to be confirmed with other artifacts over time. I aim to contribute to the understanding of digital business scaling as a qualitatively different process in comparison with incumbent industrial enterprises.

From the practice perspective, this thesis aims to identify viable, promising identity projection strategies for digital business scaling. More generally, I expect to refresh practitioners' perceptions and understanding of digital business strategy in terms of its scope, scale, speed, and value source. Furthermore, through rich and empirical inquiry

using both quantitative and qualitative methods and techniques, I hope to push the boundaries of IS research by embracing CR-based mixed methods to leverage digital trace data in generating more robust and creative theorising. This matches with the nature of our discipline as "devoting to investigating complex sociotechnical settings that require us to make sense of large amounts of data that pertain to the interaction of the social and the technical" (Berente et al. 2019, pp. 62).

1.5 Structure of the Thesis

Directly following this introduction, chapter 2 reviews the literature on digital business scaling, complementarity in platform ecosystems, the complementor's dilemma during scaling, and the theoretical lens of platform identity adopted in this thesis.

Based on the literature review, chapter 3 presents the philosophical foundation for the research inquiry and the sequential mixed method that directs two empirical studies. Specific data collection and analysis procedures implemented in identity-related digital phenomena are described in detail. Chapter 4 then presents the empirical study which uncovers the underlying identity projecting mechanisms that navigate the complementor's dilemma process, and hence, facilitate platform business scaling in digital ecosystems.

Developing on this study, chapter 5 further tests and generalises the developed theory in the broader social networking ecosystem through a complementary computational approach. Three identity projection strategies are conceptualised at the end by which non-focal actors are able to acquire new positions in an ecosystem in order for a higher chance of survival in early saturated digital markets.

Linking with the two empirical study chapters, theoretical, practical, and methodological implications of this thesis are presented in chapter 6. Finally, conclusions are drawn in chapter 7 before the thesis ends with reflections on possible avenues of future studies.

2. LITERATURE REVIEW

This chapter reviews existing literature on platform business scaling. As a representative type of business form in the digital era, digital platforms share essential characteristics with digital enterprises which draw on and add to digital infrastructures, but also show distinctive features in an interactive ecosystem context. Before going into detail, this chapter will first review the theory of scaling in terms of its definition, enablers, drivers, and manners. While the entire scaling theory seems to have been established in the industrial age, I argue that the digitised world paves the way for a new type of enterprise scaling and therefore calls for a rethinking of scaling theory for future studies. I focus on platform-based businesses, manifested in both semi-market and technological architecture, to reveal the transformation of scaling sources from internal economies and administration to ecosystem-level economies and governance.

At the core of this context of ecosystem economies and governance in platform, the concept of complementarity is discussed in detail based on two fundamental research streams in economics and innovation. While existing IS literature tends to take the role of complementors in platform ecosystems for granted, I argue that this interdependency structure is dynamic as platform businesses aspire towards growth, leading to the complementor's dilemma issue during scaling. Following on from this, I introduce a platform identity lens grounded on the case findings and expound how it may help navigate the complementor's dilemma process.

To provide an overview of the conceptual framework of this thesis, Table 1 summarises the key concepts with short definitions introduced in this chapter. Next, I move to review the platform business scaling literature to provide an overarching theme for the object of interest of this research.

Table 1. Key Concepts Used in the Thesis

Concept	**Definition**	**Example References**
Digital Platform	An evolving organization composed of a layered modular technological architecture that enables value-creating interactions of actors and resources	Tiwana et al. (2010) Yoo et al. (2010) Gawer (2014) Parker et al. (2016)

Platform Ecosystem	A collective of firms that is inter-linked by a common interest in the prosperity of a digital technology for materializing their own product or service innovation	Selander et al. (2013) Tiwana (2015) Ghazawneh and Henfridsson (2015) Jacobides et al. (2018)
Economies of Complementarity	A firm becomes more valuable with growing affiliated/complementary actors in platform ecosystems	Ghazawneh and Henfridsson (2013) Adner (2017) Teece (2018)
Digital Complementarity	the value of A has to be confirmed with B in platform ecosystems, where A and B are only contingently bounded over time	Rosemann et al. (2011)
The Complementor's Dilemma	Complementors must build on focal actors' technologies as they materialize their growth ambitions in platform ecosystems	Selander et al. (2013) Eaton et al. (2015) Nambisan et al. (2017) de Reuver et al. (2018)
Platform Identity	A firm defines who it is and what it does in terms of the technological architecture and market profile in a platform ecosystem	Cennamo (2021)
Identity Projecting	A firm uses the perception of its current position in the platform ecosystem to envisage its future position	Gioia et al. (2000)
Platform Scaling	A process by which the operational efficiency in innovation and interaction at a digital platform increases as it boosts the affiliated ecosystem members	Thomas et al. (2014) Huang et al. (2017) Henfridsson (2020)

2.1 Overarching Theme: Platform Business Scaling

Drawing on his classic case studies in Du Pont, General Motor, Standard Oil, and Sears, Chandler (1962) documents a spectacular scaling history of modern industrial enterprises in America. Further developed in later works (Chandler 1977, 1990), Chandler's seminal view of scaling based on the infrastructure revolution in transportation and communication still inspires present thinking about scale and growth in various disciplines such as management, economics, entrepreneurship, and information systems.

However, recent studies implicate that the scaling of digital enterprise is

qualitatively different from the scaling form described by Chandler (Huang et al. 2017; Tilson et al. 2010). Just comparing today's global Fortune 500, as measured by revenue, with the same list from 20 years earlier shows a huge difference. We see earlier giants such as Ericsson, Coca-Cola, and P & G building their dominant position after decades of development and then suffer a significant eclipse. We also witness the birth of new giants based on digital infrastructures such as Apple, Facebook, Alibaba, and Tencent, which establish their dominance over a surprisingly short window of time. What is the difference between scaling in the industrial and digital ages? What are the key features of digital enterprises that lead to such a difference? In what follows, I answer these questions by reviewing and comparing theories of scaling in different eras.

2.1.1 Scaling in the Industrial Age

What is scaling? The term of scaling, as explained in the dictionary, denotes an increase in size. Before 1850, there is no ambiguity about what size means for a firm since most industrial enterprises were small family affairs and no managerial complexity existed. Consequently, firm scaling at that time merely referred to traditional statistical proxies such as assets, market shares, or labour force. However, the later emergence of modern industrial enterprises across the Europe and United States, administrated in a hierarchy structure with multiple operating units (Chandler 1962), significantly refreshes the definition of firm scaling. As Chandler noted in his book, "statistical proxy cannot convey either the complexity or the nature and functions of modern industrial enterprises" (Chandler 1990, pp. 15). As a result, scaling must include a new dimension in terms of the addition of new organisation units permitting long-term operational efficiency by decreasing the overall costs of production and distribution, by producing more products to satisfy increasing demands in given markets, and by transferring existing facilities and skills to new profitable markets. In short, scaling for a modern industrial enterprise means a process by which the operational efficiency of the enterprise increases as it adds new operating units.

What enables and drives scaling? Having clarified the definition of scaling, it becomes critical to understand why and how modern industrial enterprises scale in this way. Chandler points out that the change of underlying infrastructures (i.e., transportation and communication networks) paved the way for scaling industrial firms. Before the 1850s the railroad in America was rarely more than 50–100 miles in length, leading to segmented local markets across counties. As the main transportation still depended on the powers of animal, wind, and other natural conditions, the speed and volume of material flow through a plant (i.e., throughput) was too restricted, uncertain, and irregular to maintain efficient production. Booming construction of the railroad, telegraph, steamship, and cable in the 1870s that enabled enterprises to reach out to new national and increasingly urban markets by maintaining a stable and substantial level of throughput.

To fully exploit the unprecedented throughput potential brought by this infrastructure revolution, new productive technologies were created to realise mass production. In Chandler's (1990) work, such cost advantage is termed as economies of scale in production in the sense that the cost of per unit production decreases more quickly with more volume of materials being processed. Through large investment in fixed costs such as machinery, furnaces, stills, and other equipment, enterprises in different industries (e.g., tobacco, chemicals, and electricity) drove down the marginal cost of given products with optimal operation size (i.e., the scale of operation to reach the lowest cost per unit). Meanwhile, these productive technologies open new opportunities to jointly produce many products by sharing the same materials and processes in one factory, which significantly reduces the unit cost of each product and therefore achieves the economies of scope (Chandler 1990).

In addition to the scaling of production, new infrastructures also stimulate the scaling in distribution and further the vertical integration of distribution and purchasing in a firm. As the railroad, telegraph, steamship, and cable make it possible to do high-speed, high-volume, and regular transportation, new mass distribution enterprises emerged from the 1850s such as wholesaler jobbers, mail-order stores, and department stores buying finished goods directly from a great number of individual producers and

selling to even larger numbers of individual consumers. The impact of new communication and transportation innovations on distribution was documented vividly by Lewis Atherton. For example, “the railroad brought the goods the merchant now could order as he needed; no longer did he buy the bulk of his supplies for the year at one time; no longer did he take the risk of loss of goods like in the days of river transportation. Therefore, the railroad ushered in the days of modern merchandizing” (Chandler 1977, pp. 216). As those intermediaries handled a greater volume of products from multiple manufacturers than any one manufacturer did, they were able to enjoy lower cost per unit in distributing single lines of products — in other words, economies of scale in distribution. By further investing in a single set of facilities to handle multiple related product lines, they could also achieve economies of scope in distribution (Chandler 1990).

However, the rise of mass distribution enterprises did not exhaust the scaling potential of manufacturers, particularly after the innovation of productive technologies. Because a manufacturer now can achieve mass production — which decreases the cost of storing, transportation, and distribution — at a level like the intermediary through volume economies, it becomes more beneficial for manufacturers themselves to integrate these distribution processes. As the products become more technologically complicated (e.g., power machinery, traction equipment, and electric lighting), more product-specific customised facilities and skills are required in marketing and distribution for each product line, which highly reduces the cost advantages of joint distribution through a standardised process. Thus, the increasing dependence on product-specification investment makes manufacturers the sole candidate to achieve distribution in volume. Based on similar logic, more manufacturers are motivated to integrate backward into purchasing.

The revolution of transportation and communication systems pave the way for new and improved production and distribution. To enjoy the potential economies of scale and scope brought by these new infrastructures, the competition among entrepreneurs changes from price to market share and profit through functional and strategical

effectiveness. They succeed by improving their production, marketing, and distribution process, and strategically by targeting growing markets. These organisational capabilities in turn provide the internal stimuli for the on-going scaling of modern industrial enterprises.

How do firms scale? After providing an overview of the history of modern industrial enterprises, we can now examine the scaling process in the industrial age. Specifically, three steps of interrelated scaling were made by entrepreneurs. First, large investments in production facilities were made to exploit the potential economies of scale and scope in production, including numerous technological innovations (Chandler 1977) in power sources, machinery, materials, and other artifacts to expand the volume of output. These new high-volume technologies of production are also termed as *productive technologies* in Chandler's (1990) work. Second, large investments in product-specific distribution and purchasing networks at the national and international levels were made, so that the volume of sales and material procurement could catch up with the increasing volume of production. At this step, enterprises scale through geographical dispersion and vertical integration of new type of functions. Third, to fully take advantage of these investments in production and distribution, entrepreneurs must invest heavily in administration by recruiting and organising new managers to supervise the enlarged facilities and personnel in both production and distribution, to coordinate those two essential activities, and to project and allocate resources for future production and distribution based on dynamic market conditions and technological changes. Such scaling in governance structure came from organisational innovation (Chandler 1977), through which artifacts are arranged and activities of personnel are coordinated and controlled.

Is there a limit to firm scaling? As we have seen earlier, when exploiting new productive technologies, the first stage that those enterprises frequently focus on is the optimal operation size for given products rather than the invention of new products or processes. However, such economies of scale or scope at the product line level do not restrict the

scaling capability for the whole enterprise. At the core of this argument, firms should no longer be treated as a price-and-output decision maker for given products in economics. Rather, a firm is both a collection of productive resources and an administrative organisation that is free from any products it chooses (Penrose 2009).

In Penrose's work, the theory of scaling or growth should be revised for two reasons. First, there are always unused productive services[1] within the enterprise. Consider the process of mass production and mass distribution, with a number of products produced and distributed jointly by combining the same bundle of resources (i.e., facilities, materials, and distribution channels) in different ways. Resources available in an enterprise are in fact versatile in that they can be recombined to generate a bundle of possible services more profitably. However, the range of recognised services in most cases is confined by management's existing idea about the possible recombination at a given time. As a result, new productive opportunities always underlie existing resources as firms increase their knowledge. For example, the continuing growth of modern enterprises from joint production of by-products to product diversification. If any resources are not exploited and used fully in current operations, there is an impetus for enterprises to scale up further.

Second, as the size of firms continues scaling, their operation will not drop into diseconomies automatically. While an individual's capability to manage a bigger and more complex firm is limited, administration should not be regarded as a fixed factor because the administration structure of modern industrial enterprises is autonomous based on a hierarchy of multiple managers, as discussed earlier. Scaling, in such a case, is based on a series of planning, allocation, and coordination of resources and personnel deliberately and elaborately. Therefore, management is the key driver rather than the cost of continuing growth. It is the existence of this governance structure that makes the activities and operations of the whole enterprise harmonious, productive, and more than the sum of its operating units. It is only for those incapable of adapting their managerial

[1] Services here, defined by Penrose (2009), represent the contributions that physical resources can make to the productive operations of the firms. They include both material and immaterial goods/outputs in a firm.

structure to the requirements of larger operations that an optimal size is postulated.

The agency power in scaling. The evolution of modern industrial enterprises demonstrates that scaling does not take place automatically. It is the outcome of innumerable decisions made collectively by individual entrepreneurs, managers, and owners (Chandler 1990). This matches with the human agency position suggested in organisation science, which states that individuals are relatively free to take actions to change organisational roles, structures, and processes. For example, Feldman and Pentland (2003) revealed that human agency involved in the daily performance of organisational routines permitted the subsequent change of these routines. In our case, it is those senior and middle managers engaging in the daily operations that created managerial innovation by enacting new governance structures. This permitted successful scaling through the coordination between new production and distribution processes. Similarly, although human actors are subject to individual understandings and social influence, they still have the capability to exercise discretion in terms of resource use and improvisation (Orlikowski 2000). As we have seen, in resource recombination entrepreneurs may be restricted in their existing knowledge temporally and contextually, but there is always the possibility of new productive services that deviate from plans.

Human agency therefore engages in emerging choice situations with an awareness of the past, the present, and the future through imagination, habit, and judgment (Emirbayer and Mische 1998). In Penrose's terms, this process is highly dependent on the entrepreneurial versatility, ambition, and judgement toward scaling, which may not be practical but is filled with imagination and vision shaped by technological (e.g., new machinery following the transportation revolution) and market (e.g., the demographic shift from rural to urban areas) changes. As noted in modern industrial enterprises, "for these decision-makers the choices among alternatives were limited and the outcomes uncertain in specific situations (i.e., industries, nations, time periods), but almost always there *were* choices" (Chandler 1990, pp. 9). It is thus the capability of different entrepreneurs to act that determines why some firms can keep scaling and others cannot.

In this regard, we should focus more on scaling as a process instead of the size as a resulting state of the scaling object, since partial discussions on the net advantages of being a particular size or moving size do not answer the essential question how either one could be realised through the scaling process.

2.1.2 Digital Platform

Reflecting on the past two centuries, there are good reasons to think that the new revolution and wide availability of digital infrastructure paves the way for a new type of scaling. Consisting of computing and network resources which permit the orchestration of service and content needs among multiple stakeholders (Constantinides et al. 2018), digital infrastructure is increasingly pervasive in our daily life. Examples at the individual level include smartphones, personal computers, and tablets. At the industrial level, more advanced digital technology tools and systems have been applied, such as cloud computing, 3D printing, data sensors, open standards (e.g., IEEE 802.11 and USB), and 5G stations. At the global level, the mass scaling and combination of different digital infrastructures greatly decreases the access threshold of use, creating ubiquitous computed human experience (Baskerville et al. 2020; Yoo 2010), transforming incumbent industrial firms, and cultivating new digital enterprises.

Consider how those highly successful industrial giants mentioned before (e.g., General Electric and LG) are now embracing digital-first thinking through significant investment in platforms for the industrial internet of things. Their platforming has broken the existing industrial structure and competitive landscape, leading to new scaling opportunities. Similarly, emerging digital native companies such as Uber and Airbnb create new platform business models based on existing infrastructure resources such as smartphones, the internet, and geographical positioning technologies. As one essential feature shared in these cases, diverse participants with different motives and goals are frequently involved in the venue orchestrated as a complex ecosystem. In what follows, I shall give a detailed review of this platform-based business in terms of its definition and key features in different research streams. I then discuss how this type of

digital enterprise refreshes the theory of scaling.

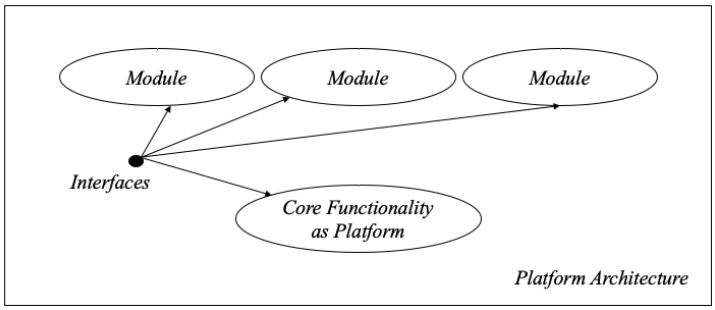
2.1.2.1 The Engineering Design Perspective: Platforms as Technological Architecture

The engineering design perspective of platforms can be traced back to new product development literature. With more complex products and systems (e.g., automobiles and semiconductors) being developed since the twentieth century, a set of new design logics were proposed based on Simon's (1962) idea that hierarchical and decomposable systems reduce the impact of complexity. As the foundation of these literatures, Clark (1985) documents a hierarchy of design following the evolution of the US auto industry from 1985 to 1940. In his description, the complex product development follows a specific ordering pattern from major components to sub-components, instead of an integral production once for all. Each component pertains to a functional domain, where multiple design options are available for designers. For instance, although an automobile consists of various components such as engines, transmissions, and tires, they are not equally significant for the automobile design. It is only after the dominance of gasoline engines over steam and electric engines that transmission innovation boomed. In this case, engines are core to auto development since the choice dominates and sets the agenda for all other components. In this view, each component displays certain qualities which necessitate and determine its place in the design hierarchy.

At the foundation of this part-whole production logic, modularity enables and facilitates the decoupling of a product into components that can be re-combined (Schilling 2000). Characterised by a one-to-one mapping between functional elements and physical components (Ulrich 1995), a modular architecture decreases complexity and enhances flexibility in design by breaking up a product into discrete components interconnected through pre-specific and standardised interfaces (Baldwin and Clark 2000). Compared with integral architecture that requires tight coupling among components through unstandardised interfaces (Ulrich 1995), changes in one part of a product in modular architecture do not affect the rest of components, which could be put back together again and continue to function as before. As a typical example, a

customised car can be designed (i.e., adopt a different engine and tires) with little loss of functionality in the new configuration. This reduces the scope of information for designing modules and nourishes autonomous innovation within modules.

Developing on modular architecture, product platforms further share the core-peripheral production logic — which is both modular and structured around a core and a periphery (Baldwin and Woodard 2009). In this regard, "a platform architecture partitions a system into stable core components and variable peripheral components" (Baldwin and Woodard 2009, pp. 24). (Figure 1). The platform itself, composed of the common core assets of the product system (Krishnan and Gupta 2001), therefore can be used and re-used as templates to generate product families (Sanderson and Uzumeri 1995) and innovate more systematically and rapidly.



Adapted from Tiwana et al. (2010)

Figure 1. Digital Platform as Technological Architecture

However, digital technologies — man-made technological objects that include non-material, computed, and algorithmically organized components (Faulkner and Runde 2019) — exhibit new characteristics with a layered architecture. First, re-programmability enables the separation of product function from its physical body (Yoo et al. 2010). For example, the music player function is digitalised by coding into an API, which can be further installed into different devices such as smartphones and smart TVs. Second, homogenisation of data makes any digital data (e.g., word, video, audio, and picture) able to be accessed, stored, and transmitted through any digital device (Yoo et al. 2012). In this way, digital technology further separates digital contents from the medium holding them, enabling the recombination of different data to delivery new

functions. For example, Rightmove provides house renting services by combining map meta-data and information on houses for rent.

Based on these two characteristics, digital products exhibit a four-layered architecture of device, network, service, and content (Benkler 2006; Farrell and Weiser 2003). These layers interact with each other based on a strict ordering relation. While each layer depends on the layers below (Gao and Iyer 2006), the design hierarchies for digital technologies are multiple and heterogeneous because they are layer-specific rather than product-specific. Furthermore, the rapid diffusion of digital infrastructure at lower layers (i.e., device and network) makes such dependence trivial. Consequently, unlimited combinational innovation can be pursued by assembling components from the same or different layers.

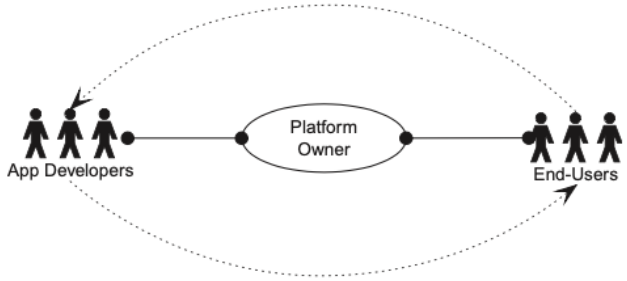
Digital platforms, as one manifestation of digital technologies, embed digital components into physical products and give rise to a layered modular architecture. The layered modular architecture violates both part-whole and core-peripheral production logic. With traditional product platforms, relationships between the product and its components are usually bounded by a single design hierarchy. While a car can be customised according to different user needs, the car is still a car. In other words, the flexibility in design brought by modularity is within a fixed product boundary. However, components in a digital platform no longer require product-specific knowledge. Instead, they are product agnostic (Yoo et al. 2010) in the sense that their functionality is not pre-determined. Google Maps, for instance, can be used both as a single-stand service and combined with heterogonous apps (e.g., Uber, Airbnb, and Booking.com) and devices (e.g., iPhones, iPads, and laptops) simultaneously in different application settings.

In this regard, each component belongs to a specific layer with the potential to be part of multiple value paths horizontally. While unlimited recombination opportunities exist on a digital platform, platform designers cannot exploit them fully but require diverse actors to innovate in an ecosystem structure (Adner 2017). As such, the core-peripheral relations between components in a layered modular architecture are

obligatory in a contingent fashion since digital complements are capable of redefining existing interdependency with the platform core given their versatile potential in functionality. As an example, Microsoft ultimately took over leadership from RealNetworks in the streaming media platform market.

2.1.2.2 The Economics Perspective: Platforms as Market

The economic perspective of platforms developed from the early 2000s uses terms like "two-sided markets" or "multisided-markets" (Evans 2003; Rochet and Tirole 2003, 2006; Rysman 2009). In this view, a digital platform performs as a market to enable the value-creating interactions between external consumers and producers (Parker et al. 2016) (Figure 2). While some platform businesses develop as a semi-market in which physical assets are heavily invested, such as Apple's platform with iOS and hardware products, most digital native platforms are asset-light and even without physical assets. Consider how Airbnb transforms the hotel industry by enabling direct transactions between guests and individuals with spare rooms. Instead of owning any rooms, Airbnb works as a transaction intermediary and transfers its supply role to the community, which used to be only the demand side. In this regard, platform businesses unlock new sources of supply and value creation that are free from the ability to deploy capital and manage fixed pipeline relationships (Parker et al. 2016). Users in the world of digital platforms may play the role of producers, consumers, or both. Similarly, value can be created, exchanged, consumed, and changed in a variety of ways across time and space, all because of the support of platforms in a network structure.



adapted from Tiwana et al., (2013)

Figure 2. Digital Platform as Two-Sided Market

In view of the multi-sided feature of platform markets, the key activity of platform owners changes from product design and innovation to cultivation and management of a network of users. The power of a platform underlies the existence of network effects, emphasising the size of the network of users that a product or service encompasses (Afuah 2013; Parker and Van Alstyne 2005; Katz and Shapiro 1986). For instance, Parker et al. (2016, pp. 18) define it as "the number of users of a platform has on the value created for each user". Classic examples include the telephone and fax machine network. Network effects trigger self-reinforcing feedback loops that grow the user base, often with little investment or effort from the platform owner. Therefore, most models regard network effects as fixed and exogenous. For instance, more drivers on the Uber platform will motivate more passengers to be willing to use Uber due to shorter wait times, which, in turn, will attract more drivers to provide car service on the platform due to highly decreased downtime.

The literature further distinguishes between direct network effects and indirect network effects. First, direct network effects, or same-side network effects, arise when the number of users in one group benefits those users (Gawer 2014). For example, in social media platforms such as Facebook, the value of users builds upon the relationship with other Facebook users. Similar examples include Skype, Twitter, and QQ. Second, indirect network effects — also called cross-sided network effects — are defined as the benefit for each user in one side depending on more users joining from the other side (Hagiu and Wright 2015). For instance, when initial large numbers of players are achieved on video game consoles (e.g., Nintendo Wii), more third-party developers will be willing to offer complement video games for the console. This, in turn, attract more players to adopt the platform.

Cross-sided network effects are not necessarily symmetrical. On Uber, a single driver increase is more vital than a single passenger. On Quora, people who ask questions are more vital than those answering questions. It should be further noted that network effects can also be negative, in the sense that the growth of less-managed communities on platforms will reduce the value of each user. As explained by the dating

match platform OKCupid, the unmatched issue that men tend to approach more attractive woman will aggravate with scaling men, which drives away participants from both sides. As a result, coordinating adoption from both parties is more important than pure network size scaling. What matters most is activity — the number of users who interact and engage on a platform appropriately (Parker et al. 2016). In other words, user commitment is more important than user acquisition for platform development.

Besides focusing on network size, Afuah (2013) also suggests the significant impact of network structure and conduct on the value of network users. A network's structure is defined as "the number of members, the relationships among them, and the heterogeneity and relative characteristics of members and their relationships" (Afuah 2013, pp. 261). In this view, members in a network also take central or peripheral positions, determined by the number of transactions they can bear and their uniqueness in bridging transactions between sub-networks. Position, in this case, is about more than inherent attributes possessed by a member, it is dynamic according to each members' capability to explore their unique resources and conduct — including opportunism, reputation effects, and trust. In addition, the nature of transactions and the external environment also play important roles in network value creation and capture. From this perspective, endogenous intervention at platforms is required to coordinate actors' interaction over time in order to sustain positive network effects.

Recent research interest also turns from the size-driven network effect to the data-driven network effect, given the advance in Artificial Intelligence (AI) and the growing availability of data on platforms. Data network effect is defined as "the more that the platform learns from the data it collects on users, the more valuable the platform becomes to each user" (Gregory et al. 2020, pp. 2). Digital platforms not only mediate transactions by providing connectivity and possibilities of exchange among users, but also give rise to the scale of data-driven learning and improvements with the help of AI. With more existing data about the past and present, digital platforms can facilitate more informed, accurate, and real-time matches between its demand and supply in the future (Agrawal et al. 2018; Chen and Horton 2016; Gregory et al. 2020). In Afuah's words,

this platform AI capability will significantly increase the degree of transaction feasibility in a network and further contribute to user value. In the example of OKCupid, the introduction of algorithm-driven matching based on a vast ocean of platform user behaviours not only reduces negative network effects, but also leverages the benefit of positive network effects since the platform now navigates the dating between comparable men and women with win-win results.

2.1.3 Scaling in the Digital Age

What is scaling now? Recall that scaling in the industrial age refers to the increasing operation efficiency in production and distribution as it is growing. Digital enterprises, however, exhibit a qualitatively different scaling pattern since they have a digital architect at the core of their market offerings. Digital architects are "products or services that are either embodied in information and communication technologies or enabled by them" (Lyytinen, Yoo, and Boland, 2016, pp. 49). Such information-based products or services operate differently from physical goods due to their perpetual embodiment (von Briel et al. 2018a; Yoo 2010) in nature. Considering the conceptualisation of digital platforms, both technological architectures and markets exist in a logical state without intrinsic physical being. In this nonmaterial state (Faulkner and Runde 2019), the lack of spatial attributes such as locations, volume, shape, and mass makes a digital platform free from mass production and distribution. For instance, once the source code for the Uber app has been written and uploaded to the internet, it can be downloaded instantaneously unlimited times. This design scalability (Henfridsson et al. 2014) confirms that "ephemeral components of a digital artifact have infinite expansibility since they can be (re)produced and distributed rapidly and at marginal to no cost" (von Briel et al. 2018a, pp. 283). Consumers, in this context, do not need to compete, as the available digital resources are practically infinite, or in other words non-rivalry in use (Faulkner and Runde 2011; Rosemann et al. 2011). For example, one person's use of YouTube will not be limited by the number of other users who can do so simultaneously.

It is further noted that such a significant difference in scaling is impossible without

the pervasion of digital infrastructures. As a basic feature of digital artifacts, they must be inscribed onto, contained within, or borne by other objects to be accessed, stored, used, or passed to others (Faulkner and Runde 2019). In Henfridsson's (2020) words, a digital enterprise must draw on and add to digital infrastructure. For instance, the rapid growth in Uber downloading would not be possible without building upon existing infrastructure resources such as smartphones, the internet, and geographical positioning technologies. In the virtual mobile network industry, China Mobile provides network services based on Huawei's 5G base station infrastructure. Similarly, the non-rivalry at YouTube depends on the large data centres of Google or cloud-based infrastructure offered by third parties. In all cases, the unbounded (re)production and distribution of firms' offerings are attributable to ubiquitous digital infrastructure available for both enterprises and potential users.

Since production and distribution are no longer an issue for digital enterprises, scaling now is given new meanings. As we have seen in platform-based businesses, the increasing innovation capability and interaction among users becomes the new determinant for their success. Scaling for a digital enterprise, therefore, implicates *a process by which the operational efficiency in innovation and interaction increases as it boosts its user base*. In the following subsections, I closely examine the drivers of scaling and explain why it is characterised by user base in the digital age.

What enables and drives scaling? The two main scaling drivers for industrial modern enterprises are supply economies of scale and production economies of scope. By analogy, two new scaling drivers are derived from platform businesses as technological architecture and market.

First, consider how modularity fundamentally changes the innovation landscape for a platform enterprise. When the complexity of one part of components exceeds a certain threshold, it can be isolated in an abstraction which hides the complexity and can be accessed and connected with other parts through a simple interface (Baldwin and Clark 2000). As the interface allows each component to be easily invoked without knowing

how the inside works, there is no need for a firm to capture and control the whole picture of design and production through vertical integration. Instead, by opening its interface to external agents, the design and production activities are distributed to a network of specialised firms (Nohria and Eccles 1992).

Further supported by the layered architecture of digital technologies, platform businesses have design flexibility (Henfridsson et al. 2014) in the sense that no pre-specification is required for production. As the components are free from product boundaries, they can be repurposed for other products in a way that complementary innovation compatible to the interface generates across different markets. Firms then operate in an even larger network which is not necessarily based on buyer-supplier relationships, also termed as "innovation ecosystems" (Adner and Kapoor 2010). In this regard, a digital platform becomes "a building block, providing an essential function to a technological system – which acts as a foundation upon which other firms, loosely organized in an innovation ecosystem, can develop complementary products, technologies or services" (Gawer 2009, pp. 2). The key source of value creation for platform businesses therefore changes to the *economies of scope in innovation* when the cost of joint innovation of multiple products by sharing the same modules is lower than independent innovation (Gawer 2014).

Compared with joint production in modern industrial enterprises, joint innovation is about more than internal economies. As the unused productive services attributed to digital resources within a firm are much more profound than the physical resources at the time of Penrose's writing, full exploration of innovation potential must draw on a wider set of distributed heterogeneous knowledge and accessible external capabilities (Chesbrough 2003). As such, a digital platform offers generativity, representing "a technology's overall capacity to produce unprompted change driven by large, varied, and uncoordinated audiences" (Zittrain 2006, pp. 1980). Joint innovation therefore requires coordination at the ecosystem level (i.e., the collection of both platform owner and other actors participating in platform innovation) beyond the internal administration (e.g., the coordination among different function units). I term this "ecosystem-level

economies".

Second, in view of digital platform as market, the positive network effect is derived from *demand economies of scale* (Parker et al. 2016). While supply economies of scale are attributable to technological innovation in production efficiencies, demand economies of scale take advantage of digital infrastructure pervasion on the demand side. They are particularly driven by "efficiencies in social networks, demand aggregation, app development, and other phenomena that make bigger networks more valuable to their users" (Parker et al. 2016, pp. 19). Benefiting from positive network effects, a platform with the largest active user base can generate the highest value for each participant, endowing the business with unparalleled competitive advantage in markets — also termed as a winner-take-all outcome (Eisenmann et al. 2006; Parker et al. 2016). In this regard, early entry of a new technology is essential for its future path as the dominant design (Schilling 2002). Indeed, a platform provider with early network advantage is hard to catch up with at a nonlinear growth pace, even for those competitors with superior performance or technology. Such impact is more significant with data network effects since platforms with more users will generate more data, making algorithm-driven learning and prediction more accurate and informed. Consequently, initiating and cultivating multi-sided user networks (Parker et al. 2016; Parker and Van Alstyne 2005) while avoiding the "chicken-or-egg issue" (Caillaud and Jullien 2003) becomes fundamental for the success of a platform, around which diverse actors are organised as an ecosystem.

Now we can conclude that both economies of scope in innovation and economies of scale in demand are *ecosystem-level economies* (*of complementarity)*. That is, a platform business becomes more valuable with growing affiliated/complementary ecosystem actors (i.e., end-users, third-party developers, and partner firms). Similarly, the organising logic for platform businesses changes from the internal-level coordination of different operation units to ecosystem-level coordination of a multilateral set of innovators that needs to interact (Adner 2017; Yoo et al. 2010). At Amazon's e-book platform Kindle, for example, firms from book retailing, the

computer industry, publishing, telecommunications, internet search, and consumer electronics are aligned together into a complex ecosystem. It is a platform ecosystem configuration that radically transforms the traditional 200-year book publishing industry with a phenomenal scaling pace. In the next subsection, I deal with how such scaling is achieved.

How do firm scale? Since the scaling for digital enterprises is driven by ecosystem-level economies, traditional scaling ways for modern industrial enterprises must be revised. First, expansion of volume and geographical-level scaling do not account for platform scaling given the design scalability (Henfridsson et al. 2014). Second, vertical integration also becomes irrelevant, as the layered-modular architecture leads to vertical disintegration (Yoo et al. 2010) in the sense that higher innovation efficiencies and value are realised by decentralising a firm's design and production functions. Third, diversification took on new meaning since innovation in scope is no longer done by platform owners themselves. Instead, it spreads to heterogeneous innovators in the ecosystem. As a result, the ecosystem-level economies can only be achieved through scaling the user base (Oliva et al. 2003; Prasad et al. 2010; Sun et al. 2004) which contributes to the number of ecosystem actors participating in the innovation and interaction at a digital platform. Correspondingly, the productive techniques that firms can apply to leverage the "growing on steroids" at digital platforms are also re-shaped from being material-driven (i.e., power sources and machinery) to being data-driven (i.e., machine learning and cloud computing) (Huang et al. 2017).

Is there a limit to firm scaling? As unused productive services in digital enterprises are developed based on digital resources, there are good reasons to think that a limit to digital enterprise scaling is different from that in modern industrial enterprises. As digital resources are information-based — manifesting in diverse architects with digitised components, tools, applications, or media content (Ekbia 2009) — they are more versatile than physical resources and serve as building blocks in value creation

and capture in digital innovation (Henfridsson et al. 2018). While each digital resource belongs to a specific architecture layer (i.e., content, service, network, or device), it has the potential to be part of multiple design combinations. As a result, digital resources by nature are product-agnostic, in the sense that their meaning is largely defined by their contingent relationships to other digital resources (DeLanda 2006; Um 2016). For instance, an iPhone can not only be used as a telephone, but also as a camera, video player, word processer, health monitor, and many other ways by combining it with different apps. Although it has physical materiality (Yoo et al. 2012), it is still distinguished from traditional physical resources due to the embedded digital capabilities which greatly expand its affordances, that is, an action potential offered by the resources. Therefore, more productive opportunities exist for digital enterprises, and they have more impetus to continue scaling compared with modern industrial enterprises.

However, since full exploitation of innovation potential at a platform business must involve numerous external agents with diverse goals, interests, motives, and capabilities, their activities may not always align — leading to deceleration or even a cessation of scaling. For instance, if a platform is too open to third-party developers it is likely that poor-quality service providers will appear on the site, reducing the incentive of other developers and customers to join the platform. Consequently, appropriate platform governance is necessary for continued scaling of a platform business. Platform governance is the blueprint of ecosystem orchestration. It is broadly defined as the mechanisms through which a platform owner exerts its impact on users who participate in the platform's ecosystem (Schilling 2000). It refers to who decides what in a platform ecosystem (Tiwana 2013). While the layered modular "architecture can reduce structural complexity, governance can reduce behavior complexity" (Tiwana 2013, pp. 118). Platform governance therefore helps to successfully leverage the innovation divisibility made possible by digital platform architecture (Boudreau 2010; Rochet and Tirole 2003; Tiwana et al. 2010). Specifically, three governance dimensions can be designed in terms of decision right partitioning, control (i.e., gatekeeping, process,

metrics, and relational control), and pricing policies (Tiwana 2013).

As a key feature in platform governance, participants in a platform ecosystem are not employees of the platform, where a legitimate hierarchy authority of platform owner over users is accepted. Instead, in most cases, they are highly autonomous with specialties that are outside of the platform owner's knowledge. In this situation, there is no way for the platform owner to command or control their activities — rather it can only shape or influence its ecosystem. A recognised challenge, for instance, is that ecosystem agents who have innovated as complementors to the platform may start innovating in a way that competes with the platform (Gawer 2014). Since complementary or substitutive technologies keep emerging and converging with the domain of the ecosystem, both complementors and platform owner have the chance and autonomy to expand into each other's domain as part of the multi-product bundle (Eisenmann et al. 2006; Tiwana 2010). In such cases, the governance structure in terms of who makes what decisions pertaining to the platform ecosystem (Constantinides et al. 2018) is not a constant state but keeps changing over time. A previous complementor in part of the module developer community may develop its own platform to overturn the existing governance structure of the ecosystem.

In the view of platform as market, good governance is also vital to platform scaling. Considering negative network effects, one main source comes from the increasing number of multi-sided actors also making it difficult or impossible to find the best match. Without carefully filtering, controlling, and limiting the access of users to the platform, the activities they participate in, and the connections they form with other users, a flood of worthless matches will occur which demotivate users to keep interacting on the platform (Parker et al. 2016). This curation strategy is important for maintaining the consistency of a platform community when heterogeneous actors tend to voluntarily act for their own purposes.

In summation, the scaling capability of firms is further liberated in the digital age. However, to sustain rapid scaling appropriate platform governance towards ecosystem actors is required. As the platform owner does not have direct authority in a platform

ecosystem, complementors have the chance to break free from and reshape the existing governance structure by developing their own platforms. In this thesis, we take the lens of complementors to explore how they scale their platforms through appropriate governance and further how they reshape the governance structure of the ecosystem built by incumbent platform owners.

The agency power in scaling. Contrary to modern industrial enterprises which are mainly regarded as human-organized entities, a digital platform business exhibits a duality as it is both an organization and a particular digital technology. Platform scaling in this case therefore depends on both material and human agency which represents the "capability for action" (Giddens 1984). First, digital platforms have material agency in the sense that they can be assigned functional capability for action without users' direct or complete control (Faulkner and Runde 2009; Leonardi 2011; Orlikowski and Scott 2008). Consider that a platform is born as a market which can facilitate double-sided interactions and further network effects innately from the economics perspective. Such material agency is later referred to as the specificity of digital technologies in innovation studies, describing their capability to enable and constrain user enactments based on their inherent features (von Briel et al. 2018b). In this view, digital technologies determine the type of resources as inputs and how they are transformed and offered as output. High specificity generally means that the technology is bounded in performing a unique task. As a result, although digital technologies are product-agnostic, their adaptability and malleability (Ekbia 2009; Kallinikos et al. 2013; Zittrain 2006) are still restricted by their specificity. For instance, while 3D printing platforms enable the creation of diverse physical objects, their input and output formats are tightly defined in programming routines such as Scratch and Python. The interaction on the platform is also usually concentrated to those with superior programming skills. In contrast, social media platforms enable various tasks such as communication among a variety of users, writing blog posts, and distributing different content. Therefore, the scaling capability in innovation and interaction at a platform business is influenced by

the inherent agency embedded in the digital technology.

Second, IT's organisation consequences cannot ignore human agency in the sense that "humans are relatively free to enact technologies in different ways" (Boudreau and Robey 2005, pp. 3). From this perspective, digital technologies can support a variety of potential uses, both interpretively flexible and socially constructed (Orlikowski 1992). The focus should not be on the specific features that a digital artifact possesses. Rather, it is more important to look at how a digital technology is used and repurposed by different actors or engenders diverse innovation outcomes in different contexts (Nambisan et al. 2017). In this regard, human agency view does not deny the potential malleability and constraints embedded in digital technologies, but stresses on the dynamic interaction between human actions and material agents in different times and spaces. As Jones (1999) argued, the material and human agency affect and transform each other in an emergent fashion.

For instance, the same software applications may be used by different organisations in different ways in response to their local experiences and needs (Robey and Sahay 1996). Similarly, users in a specific scenario may interact with IT applications in ways that deviate from designer expectations (DeSanctis and Poole 1994). In extreme cases, human agents may be versatile enough to break all material constraints and make any technology generative. As such, platform governance is important for boosting and orchestrating actors' innovation and interaction activities in the ecosystem. In summary, digital platform scaling enacted in enterprises must incorporate both material and human agency constraints dialectically.

2.2 Complementarity in Platform Ecosystems

This part turns attention to one of the fundamental attributes of digital platform businesses — interdependence among platform participants. As we have seen, ecosystem-level economies form the key driver of platform scaling, which requires deliberate coordination among different platform actors. We now focus on this idea, particularly the relationships between platform owners and complementors from two streams of literature.

2.2.1 Interdependency in Platform Ecosystems

Borrowed from biology, the term ecosystem starts with a scenario that a group of interacting firms depend on each other's activities. In the platform context, the ecosystem can be seen as "a collective of firms that is inter-linked by a common interest in the prosperity of a digital technology for materializing their own product or service innovation" (Selander et al. 2013, pp. 184-185). In this regard, platform ecosystems consist of interacting firms that are influenced by each other's activities as they pursue their own goals. This multilateral nature of platform ecosystems is embedded in the self-referential attribute (Yoo et al. 2010) of digital technologies. For the development of software applications developers must use existing digital technologies such as computers. Digital technologies therefore are fundamentally interdependent and rely on at least one interaction with other social or technological actors to enact their agency (von Briel et al. 2018b). During these interactions, digital technologies are both outcomes and enablers of entrepreneurial endeavours (von Briel et al. 2021) in the sense that a digital technology created as an outcome by one enterprise can further perform as a building block enabling the emergence of new ventures. As an example, Snapchat enables other ventures to use its story feature as a part of their own value offerings through API connection. Firms in the ecosystem are therefore organised in a network structure (Afuah 2013) which cannot be decomposed into an aggregation of bilateral relationships.

Consequently, a platform ecosystem represents a complex interdependence structure among a set of relationships of activities, actors, links, and positions (Adner 2017). This ecosystem-as-structure view starts with a focal value proposition which defines the general promised benefit targeted by the joint effort in the ecosystem. To materialise the focal value proposition, sporadic, parallel, and heterogeneous activities must be identified and enacted across a layered modular architecture (Yoo et al. 2010) requiring the engagement of numerous and evolving actors who may have diverse goals, capabilities, and motives (Nambisan et al. 2017). During this value co-creation process, a variety of contents are transferred and exchanged across actors, including information,

goods or services, or some forms of currency (Parker et al. 2016). To align these activities and links among actors, participants must achieve a threshold level of coordination by locating at different positions in the flow of activities across the ecosystem, which may be varying, incomplete, and contested. Platform ecosystems therefore represent a unique setting that requires focal platforms to align members' positions and activity flows among them via shared or open-source technologies and/or technical standards (Ghazawneh and Henfridsson 2015; Jacobides et al., 2018; Selander et al. 2013). Some actors, such as platform owners, can be considered as focal actors of a platform ecosystem, while the majority, such as individual third-party developers, can be considered as non-focal actors who are at the peripheral of the ecosystem (Selander et al. 2013). In this regard, there exists an asymmetric interdependence among ecosystem partners.

Although the interdependence structure in ecosystems is not limited to a focal/non-focal relationship, it forms the most important interdependency in platform ecosystems and also frames the complementarity between platform owners and their complementors who develop complementary products or services. In what follows, I shall review the literature in complementarity and review its implications in the platform ecosystem context.

2.2.2 Economic Stream: Edgeworth Complementarity

The specific nature of the complementarity that platform actors exhibit is divided across the two main streams of platform literature (Table 2). First, complementarity can be seen in terms of the extent to which more of A will make B more valuable. Sometimes referred to as Edgeworth complementarity, this view of complementarity originates in economics (Edgeworth 1897), which defines it as the marginal value of one variable rising with another variable. For instance, the utility of consuming both bread and milk is greater than that of consuming them in isolation. While Edgeworth typically considered complementarity in the context of consumption of goods, it could also be applied in production, manifested as the co-investment in both products yielding

higher returns or lower costs than that of investment independently (e.g., Arora and Gambardella 1990; Cassiman and Veugelers 2006; Lee et al. 2010). For instance, the permeant-employment policy supports the hiring policy of recruiting only at the bottom, making it more valuable than it would otherwise be in Japanese economic organisations (Milgrom and Roberts 1994). It is further noted that this type of complementarity can be two-way or one-way, in the sense that more of A may make B valuable, but not vice versa.

Table 2. Complementarity Types and Definitions

Complementarity Type	Edgeworth complementarity	Unique complementarity
Research Streams	Economics	Innovation
Foundational Literature	Edgeworth (1897) Milgrom and Roberts (1994)	Rosenberg and Frischtak (1983) Teece (1986)
Definition	More of A makes B more valuable, where A and B are two different products, assets, or activities	A doesn't function without B/ the value of A is maximized with B
Example References in IS	Parker and Van Alstyne (2005) Claussen, Kretschmer, and Mayrhofer (2013) Tan, Anderson Jr, and Parker (2020)	Tiwana, Konsynski, and Bush (2010) Ghazawneh and Henfridsson (2013) Hukal, Henfridsson, Shaikh and Parker (2020)
Examples	Tesla's electric car becomes more valuable to users as the charging station network expands.	Apple IOS platform won't realize full innovation potential without the participation of third-party developers

In the platform literature, such complementarity is manifested in both engineering and economics perspectives. First, the complementarity in production is shown in the economies of scope in innovation. As platform owners and complementors co-invest in the complementary innovation (e.g., platform owners contribute to core functionality and API; complementors contribute to specialized knowledge and skill), the total cost of innovation decreases compared with each innovating separately. Second, the complementarity in consumption is represented in the form of platform ecosystems as

multi-sided markets that serve as mediums of exchange for different type of complementors. Another way of referring to this complementarity is the concept of indirect network effects (e.g., Parker and Van Alstyne 2005; Rochet and Tirole 2003; Rysman 2009), where the growth of complements makes the platform more valuable for each user. The prospect of lucrative network effects therefore motivates focal platforms to rapidly realise abundant complementors through diverse launching and pricing strategies (e.g., Boudreau and Jeppesen 2015; Cennamo and Santalo 2013; Tan et al. 2020). For instance, Huawei's Harmony OS started with subsidising the third-party developer side before launching it to all Huawei smartphones. With more third-party apps available in the Harmony OS, Huawei users will be more willing to replace Google's app store. Similarly, by deeply discounting the platform access charge or launching marketing campaigns to influence complementors' expectations and beliefs, a digital platform can launch successfully by triggering positive network effects (Parker et al. 2016).

Complementors, in turn, are forced to compete for the attention of focal platforms, since dominant platforms with strong network effects create and capture most of the value in the platform ecosystem. Earlier is better, research has shown, since complements that are launched early in the growth of the platform ecosystem tend to be adopted by more users than those launched at a later stage (Rietveld and Eggers 2018). Recent studies also point out that the quality of complementors varies over time and affects the value of focal platforms for users, showing the heterogeneity of network members in platform ecosystems (e.g., Cennamo 2018; Hilbolling et al. 2020a; McIntyre et al. 2020). This view corresponds to the emphasis on network structure (Afuah 2013) beyond network size. As a result, platform owners are usually at the network centre and the governor of an ecosystem while no one complementor is irreplaceable and decisive for triggering and maintaining positive network effects.

2.2.3 Innovation Stream: Unique Complementarity

Another type of complementarity builds on the technological relatedness among

products (Teece 1986). Technological relatedness implies that many new innovations would not work without complementary technologies. In mathematical expression, this represents a relationship that A does not function without B. More generally, the value of A is maximized with B. For instance, automobiles require various technological infrastructures including networks of roads, gasoline stations, and repair facilitates (Rosenberg and Frischtak 1983). We refer to this type of complementarity as unique complementarity. Unique complementarity can be two-way in the sense that the innovations of A and B require each other. Or one-way in the sense that the innovation of A requires a particular or asset-specific component B, but not vice versa. In Teece's work, these two types of complementarity are delineated as co-specialised and specialised complementary assets. For instance, specialised software is needed to support the introduction of computer hardware, both for applications and operating systems. They are more co-specialised due to the mutual dependence of innovations. However, the dependency of container shipping on trucking is more than that of trucking on container shipping since trucks can be easily decoupled from containers with flat beds at low cost.

However, Teece (1986) also noted that complementarity can be generic in the sense that a complementary asset does not need to be tailored (i.e., asset-specific) to the innovation in question. As such assets are standardised enough, they are fungible across applications along a production chain and thus there is no need to coordinate in specific ways (Jacobides et al. 2018). For instance, the internet is required for nearly every digital innovation, but the fact that it could be accessed and used generically indicates that this complementarity does not give rise to alignment issues. Innovators therefore do not need to invest in coordination scheme to enable the value originated from the internet. Since this type of complementarity does not require alignment structure, it is outside this thesis's discussion. Yet, it should be further noted that generic complementarity can be converted into unique complementarity through deliberate strategy by firms. For instance, more advanced smart city applications and devices specifically require the support of 5G infrastructure, which create a tightly integrated set

of actors bounded together by new network standards, signal receivers, and so on.

With the advent of digital technologies, the scope of unique complementarity increases to the degree that the platform is open-ended (Henfridsson et al. 2018). Consider that digital technologies offer design flexibility (Henfridsson et al. 2014) and make generativity possible (Yoo et al. 2010; Zittrain 2006) in platform ecosystems, primarily because they are reprogrammable (Langlois 2007; Yoo et al. 2010) and editable (Kallinikos et al. 2013). Since platform design is no longer limited to pre-specification and is open to unbounded value paths through recombination over a layered modular architecture (Lyytinen et al. 2016; Yoo et al. 2010), unique complementarity is no longer about two specific items or actors. Instead, it is about interdependence between two different layers of the digital platform architecture mostly through standard interfaces (Gao and Iyer 2006). As such, the innovation potential on focal platforms cannot be fully unpacked without the participation of diverse complementors (Boudreau 2012; Hilbolling et al. 2020b) at different layers. This is what underpins the idea of technological complementarity — "unlocking some or all of the value of an innovation requires additional innovation in one or more horizontal, lateral, or vertical complements" (Teece 2018, pp. 1374).

Moreover, unique complementarity in platform ecosystems is only contingently obligatory in the sense that focal platforms must continually identify relevant complements to respond to undefined and evolving user demands over time (Nambisan et al. 2017; Teece 2018). Such a decrease of technological relatedness is further enabled by economies of scope in innovation (Gawer 2014), as joint innovation becomes inexpensive in platform ecosystems by re-using the modules shared across a family of products or services. Therefore, innovation in platform ecosystems requires a wide scope of complements with contingent interdependency over time (Boudreau 2012). To this end, focal platforms take the role of an innovation hub and steer complementors' innovation activities — for example, through stimulating content generation (Ghazawneh and Henfridsson 2013; Hukal et al. 2020) or selectively entering complementary markets (e.g., Foerderer et al. 2018; Gawer and Henderson, 2007; Li

and Agarwal, 2017; Zhu and Liu 2018). While non-focal actors have a unique role in facilitating digital innovation in the ecosystem, no one single complementor is indispensable and enduring for the innovation bloom.

In sum, platform ecosystems provide a structure within which different types of complementarities in production and consumption can be entertained and coordinated without the need of hierarchy governance. Although non-focal actors must affiliate with focal platforms — that is, consciously making necessary investments specific to focal platforms so as to innovate and interact with each other in the ecosystem (Hagiu and Wright 2015) — they do have some degree of freedom to make their own decisions (e.g., design, pricing, multi-homing).

2.2.4 Focal and Non-Focal Actors in Platform Ecosystems

Recall the idea of focal and non-focal actors. Despite being inter-linked, ecosystem actors are not of equal weight (Jacobides et al. 2018). Specifically, given the complex interdependency structure in platform ecosystems, there must be an ecosystem leader to align partners' value creation activities as an orchestration. It takes a "hub and spoke" form by "setting, and often enforcing, the governance rules, determining timing of value creation, and often reaping the lion's share of gains after the ecosystem is aligned" (Adner 2017, pp. 48). An ecosystem follower then consents to these terms and defers to the leader's vision of ecosystem structure. In some cases, such platform leadership is easy to distinguish since it is exclusive to a single firm or platform owner (e.g., Apple's iOS store). A platform ecosystem consists of an array of peripheral firms connected to the central platform (Jacobides et al. 2018). In other cases, however, the platform leadership is hard to clarify as it could be shared among several focal actors and change over time, especially when there are multiple platforms participating in the ecosystem. For instance, the standards battleground between Microsoft's Windows and Apple's Macintosh for personal computer operating systems. Even when firms agree on the ecosystem structure, they can still disagree on the positions in the ecosystem. To understand this leadership issue, platform ecosystems need to be reconsidered from the

complementarity perspective — that is, a group of firms that must deal with both unique complementarities in platform innovation and Edgeworth complementarities in network effects.

First, recall that focal actors are the innovation hub of a platform ecosystem. An actor who obtains the leading position must design at least one foundation technology or service that is essential for a broader technological system and market. In other words, it is the foundation on which other companies build their innovations (Gawer and Cusumano 2002). Further, it must be easy to be built upon or connected by diverse and even unintended users to expand the complementary innovations. One way to check this is to see whether external actors have begun or succeed in developing complementary products or services. As such, focal actors are those platforms that have considerable influence over the livelihood of developers of complements and define the forward evolution of the ecosystem (Gawer and Henderson 2007). It should be further noted that the innovation hub in a platform ecosystem could be multipolar. For example, Microsoft and Sony are both focal actors in the game console ecosystem since they both developed core products as a foundation for playing video game and platforms that attract numerous game developers to develop compatible or exclusive video games.

Non-focal actors, on the contrary, do not hold such core elements (i.e., technology, product, or service) that will influence a large proportion of parts of the ecosystem. Specifically, as non-focal actors are restricted to the domain expertise, sector knowledge, and locally relevant solutions (Ghazawneh and Henfridsson 2015; Saadatmand et al. 2019; Selander et al. 2013), their capability to expand product functionality and meaning must build upon focal actors' infrastructures, which otherwise would be inaccessible within their own innovation space (Henfridsson et al. 2018; Verganti 2009; Yoo et al. 2010). Therefore, the ecosystem's survival does not depend on any single non-focal actor's participation — but non-focal actors' innovation and development must draw on the resources provided by the focal actors. This comprises a one-way unique complementarity, in the sense that a particular non-focal actor cannot function without focal actors, but not vice versa.

Second, recall that focal actors are the network centre of a platform ecosystem. Focal actors then are the "keystone" firms that are the hub of a network (Iansiti and Levien 2004). They have the capability to manage the overall positive network effects (i.e., nourish participant diversity and interaction) within the existing ecosystem structure (Leong et al. 2019). In this regard, they have to go beyond their own boundaries by giving priority to the management of the health of the whole ecosystem. To attain such platform leadership, potential focal actors must create dependencies that are indispensable for other actors. These dependencies can be either technical-driven (i.e., unique complementarity) or network-driven (i.e., Edgeworth complementarity). To further maintain a focal position, it must constantly grow its networks. Focal actors therefore build ecosystem momentum that favours their platforms, exhibited as gaining control over double-sided parties in the ecosystem (Gawer and Cusumano 2008). As such, focal actors can be measured by the number of connected actors (Parker et al. 2016), the platform-switching cost (Eisenmann et al. 2011), and the level of market dominance (Evans and Schmalensee 2016). It should be further noted that the network centre can also be multipolar, in the sense that multiple platforms generate strong or nearly-matched positive network effects without one clear winner — for example, Web browsers like Chrome, Safari, Firefox, Edge, and so on.

Since a few focal actors create and capture the majority of value derived from network effects in the ecosystem (Iansiti and Levien 2004; Leong et al. 2019; Parker and Van Alstyne 2005), non-focal actors — that is, the majority of ecosystem participants who do not hold network centre positions — have to compete for their attention in order to take advantage of their distribution resources (e.g., their user base) and monetisation means which otherwise would be inaccessible within their own innovation space (Ghazawneh and Henfridsson 2015; Parker et al. 2016; Selander et al. 2013). Any single non-focal actor's participation does not determine the positive network effects in the ecosystem. This comprises one-way Edgeworth complementarity, in the sense that a particular non-focal actor becomes more valuable with support from focal actors but not necessarily vice versa. To best leverage the external capabilities and

resources offered by various focal actors, non-focal actors tend to actively search and participate in multiple ecosystems in a cherry-picking fashion (Boudreau and Lakhani 2009; Henfridsson et al. 2018).

2.3 Complementor's Dilemma during Scaling

As the focal and non-focal roles of ecosystem members are typically taken for granted in existing complementarity literature, a vital dynamic aspect of platform ecosystems is latent in that research and typically restricted to changes in interdependence structures among actors in the same role. For instance, the coopetition between platform owner and third-party complementors (Eaton et al. 2015; Ghazawneh and Henfridsson 2013; Zhu and Liu 2018) or the coopetition between third-party developers within or across different complementary markets (Ceccagnoli et al. 2012; Cennamo et al. 2018; Hilbolling et al. 2020a). While individual actors emerge or are replaced by others, the current structural alignment of multilateral positions is not affected. In this regard, it is important to focus on complementarity in the platform context as roles of ecosystem actors change (Adner 2017; de Reuver et al. 2018). Complementors in platform ecosystems may confront a significant dilemma as they change position relative to the focal platforms during growth.

2.3.1 Growth Ambitions of Platform Complementors

Consider that high-growth ambitions are imperative for complementors in platform ecosystems (Huang et al. 2017). In "winner-take-all" markets (Eisenmann et al. 2006), complementors eagerly pursue their own goals as they seek to benefit from first-mover advantages (cf. Schilling 2002). Consider the iOS platform ecosystem, where the payoff towards third-party apps is very unevenly distributed. Only 4% made over one million dollars, while 25% of app developers made less than $200. Similarly, the top 250 apps on the iOS and Android platform ecosystems capture an average of approximately 52 million daily users. Complement development is therefore an ecology that leads to only a few winners (Strietfeld 2012). In such hit-driven complement markets, the prospect of a huge payoff and the modest investment by building upon focal platforms attract abundant rival entrants in the ecosystem. A complementor with temporary advantage

therefore is eager to continue scaling in innovation (e.g., introducing new features) faster than rivals who can copy them, to survive and potentially be competitive within the original complementary market (Tiwana 2013). This leads to the red queen effect, meaning "all the firms end up racing as fast as they can just to stand still relative to competitors" (Derfus et al. 2008, pp. 61). Gawer and Henderson (2007), for example, find that complementors are forced to race for innovation due to the higher competition pressure in the complementary market injected by Intel.

Since complementors in this situation are struggling to deal with a continuous, escalating, and evolutionary contest, they are eager to reinforce their competition barrier through scaling beyond a single complementary market. Actors in stronger focal positions will be less affected by and even isolated from the red queen competition (Barnett and McKendrick 2004). Consider that platform leaders control more digital resources for engaging in more effective search and innovation (Ghazawneh and Henfridsson 2013). They therefore can keep acting faster, more frequently, and with more complexity — which helps them to maintain and defend their ecosystem positions. Similarly, they can enjoy significant scale effects in terms of innovation and network that small rivals cannot obtain. For instance, the cost of search, learning, and innovation can be spread over a mass of participants through value co-creation (Lusch and Nambisan 2015). Also, the success of digital offerings becomes more difficult to imitate due to the dominant positive network effects. Rivals, in turn, are deterred from attacking the leading firms because of the fear of retribution (Derfus et al. 2008).

There are two ways for complementors to promote their ecosystem positions: horizontal envelopment and vertical envelopment. First, a complementor can expand into the domain of adjacent but unrelated complementary markets by incorporating their functionality as part of multi-product bundles (Eisenmann et al. 2006). This is further facilitated by technological convergence in the digital age (Tiwana 2010). Drawing upon existing infrastructural resources of focal platforms (Constantinides et al. 2018; Hukal et al. 2020), this horizontal envelopment allows a complementor to either segment its existing user base or gain access to fresh end-users without creating new

market space. Since the expanded native functionality and user base of the complementor also have value to other complementors, they can potentially evolve into a new core infrastructural component for others to build upon (e.g., by introducing its own APIs). For instance, Twitter and Dropbox conducted this form of envelopment movement and eventually grew as a nested "platform within a platform". Second, by adding to existing infrastructure through boundary resources, a complementor can selectively incorporate functionality originally provided by focal platforms into its offerings that leverages the shared user relationships. This vertical envelopment mainly expands the functionality of a complementor upstream into focal platforms' core components (Tiwana 2013). When it is sufficiently useful for other ecosystem participants, the complementor also has the chance to evolve into a focal actor. For example, Xiaomi and Huawei fork on Google's Android platform to create parallel platform business in smartphone operation systems (Karhu et al. 2018). Consequently, today's non-focal actor can become tomorrow's focal platform by performing a series of envelopment moves.

2.3.2 Interdependency dilemma with Focal Platforms

As complementors' growth highly depends on the existing user base and technological infrastructure of the platform ecosystems, they will increasingly threaten the leadership of focal platforms and even reverse their relative positions. Such a scenario would, in extreme contexts, make the complementors replace the established focal actors in a platform ecosystem. Consider that both horizontal and vertical envelopment strategies tend to serve more common user bases by developing similar technological architecture (e.g., core components for the ecosystem). These rival actions have a greater negative influence on leading platforms than other non-focal actors in ecosystems. In the words of Derfus et al. (2008), "the larger they are, the harder they fall". A typical example is the web browser battle between Netscape and Windows. While one of Microsoft's strengths is eliminating heterogeneous computing environments, Netscape adopts "judo strategy" (Kwak et al. 2001) to use an opponent's

weight and strength against them. Since Microsoft with its monopoly vision has no incentive to support other existing operating systems (e.g., UNIX), Netscape becomes the only browser that can be deployed companywide. Such cross-platform support successfully leverages Microsoft's dominance in PC operating systems into a liability. As a focal platform's response is more likely to influence all actors in the ecosystem, it then will be costlier for the leader than for non-focal firms. For instance, to cope with Netscape's cross-platform strategy, Windows has to accelerate its monopoly pace in computing environments, which is both costly and risky due to fierce thwarting from other players in the ecosystem (e.g., Apple, Nintendo, Sony).

As a response, focal platforms will likely try to secure their power asymmetry towards complementors when they grow (Eaton et al. 2015; Ghazawneh and Henfridsson 2013; Leong et al. 2019), leading to decreasing support and even a retaliatory downstream envelopment attack from the focal platforms (Tiwana 2013). We therefore see a coopetition dynamic where complementors and focal platforms cycle through different degree configurations of simultaneously cooperating and competing (Bengtsson and Kock 2000; Brandenburger and Nalebuff 1996).

Balancing growth ambitions with dependency on the focal platform is what we call the complementor's dilemma. On the one hand, it is inevitable for a complementor to keep pushing its own growth ambitions in a platform ecosystem, which cannot be materialized in a vacuum but must build on the focal platforms due to their asymmetric interdependency. On the other hand, in seeking growth, the complementor will inevitably come across tensions in its relationships with focal platforms because the growth ambitions continually drive complementors to deviate from their set position in the ecosystem. A complementor will therefore keep confronting identity uncertainty during growth. If it continues as a complementor, the firm can sustain the win-win relationship with focal platforms in a sub-market but gives up the opportunity to grow further. If it re-projects as a focal actor, the firm can fully explore its growth potential but is forced into direct competition with focal platforms, both hazardous and remunerative. This is a situation in which a choice must be made between alternatives

that will all have undesirable results. To balance between the interdependence with focal platforms and growth ambitions, complementors must continually reflect upon their identity in terms of who they are and what they want to be in platform ecosystems.

2.4 Theoretical Lens: Platform Identity

To disentangle the complementor's dilemma during scaling, non-focal actors must balance their growth ambitions and their dependency on the focal platforms in ecosystems. Continuing growth ambitions require complementors to be able to constantly identify and implement viable growth opportunities through appropriate strategic decisions. However, complementors must gain necessary support from focal platforms in order for their growth ambitions to materialise. In this part, I shall review the concept of identity to show how it can facilitate non-focal actors solving this dilemma. While the identity perspective is introduced at the outset of the thesis, it earns its place through an inductive process in the empirical study one. Two streams of literature in organisation and IS are elaborated to match with the dual nature of digital platforms as both organisations and digital objects. Combining both perspectives, I then conceptualise the idea of platform identity as the theoretical lens for this thesis.

2.4.1 Organizational Identity

Prior work notes that identity deeply resonates with strategic decision processes in organisational lives (Clark et al. 2010; Gioia et al. 2013a; Santos and Eisenhardt 2004). Pioneered by Albert and Whetten (1985), organisational identity is defined as those features that "are central to the organization's character, make the organization distinctive from other similar organizations, and are viewed as having continuity over time" (Gioia et al. 2013a, pp. 125). Organisation identity is about who or what an organisation is believed to be or claims to be (Ravasi et al. 2020).

First, the essential features that are core to an organisation manifest in key values, products, services, practices, etc. (Whetten 2006). For platform-based businesses, identity therefore embodies in the digital platform — which is both the business model (Parker et al. 2016) and core offering (Henfridsson et al. 2018) that bears the key value

of the organisation in its core interaction design — and platform governance, which constitutes the key practice of the organisation by managing the delicate balance between generativity and control in the platform (Yoo et al. 2012). These strategic decisions in terms of what an organisation does or intend to do to achieve superior performance (Ravasi et al. 2020) therefore conveys that an "organization may enact and express a valued identity through strategy and may infer, modify, or affirm an identity from strategy and the responses it evokes" (Ashforth and Mael 1996, pp. 33). As an example, Facebook identifies itself as a social networking platform to help users connect and share with the people in their lives. Such an intertwined relationship between being (identity) and doing (strategy) is further manifested in the internal configuration between "who we are" and "what we are good at" (Burgelman 2002), through which identity aids nascent ventures in leveraging their resources in growth with competitive strength (Santos and Eisenhardt, 2005).

Second, defining distinctive attributes positions the organisation in a social space in which it is different from other members outside a category or industry (e.g., we are a social networking business rather than e-commerce business) (Glynn and Navis 2013), and specifies how it is different from other similar organisations within the same category or industry (e.g., unlike other social networking businesses, we are a short video social networking business) (Whetten 2006). Identity is therefore a relational concept that helps an organisation locate its position strategically within the industry (Porac et al. 1995; Porac and Thomas, 1990), trace group rivals (Reger and Palmer 1996) and delimit industry boundaries (Clegg et al. 2007). By analogy, identity helps a platform business to locate its position in the ecosystem, which facilitates the selection and execution of organisational doing (strategy) to maintain a favourable position (Stanske et al. 2020).

By projecting (Gioia et al. 2000) an identity different enough from other members in a category, the organisation can convey a desired competitive growth vision that they would like insiders and outsiders to see and help them achieve. First, such departure from identity attributes of the exemplars (or prototypes) in the category serves as a filter

to guide the search of growth strategies in a manner that is more sensitive to unique and novel cues (Wry and York 2017). For instance, identity informs boundary decisions (e.g., whether to enter a new market or incorporate a new customer segment) through directing internal members' search and perception on what is suitable in comparison to other alternatives in ambiguous environments (Kogut and Zander 1996). Second, external investors prefer to support these novel enterprises (Navis and Glynn 2011). In platform ecosystems, such novelty or distinction implicates the capability of a complementor to make unique contributions towards the innovation potential at focal platforms or strengthen the network effects in the ecosystem by reaching new users. Therefore, a complementor with a unique identity is more likely to win the competition for the focal platforms' attention.

However, organisational identity influences the realisation of survival prospects and growth trajectories by affecting external stakeholders' judgment of organisation legitimacy. Recall that complementor growth requires drawing on the infrastructure resources in the ecosystem. The motivating factors for external actors to provide support is their belief or feeling that the complementor is indeed competent, appropriate, proper, and desirable within the ecosystem. This legitimacy reflects the endorsement of an organisation by powerful institutional actors (Singh et al. 1986) (i.e., focal actors) and therefore highly relates to the likelihood of a firm's survival and growth (Aldrich and Fiol 1994; Delmar and Shane 2004; Martens et al. 2007). The ecosystem, in this regard, represents a social system within which a complementor has to demonstrate legitimacy in its identity in terms of regulatory, normative, and cognitive dimensions (Zimmerman and Zeitz 2002).

First, the most important regulatory legitimacy in the ecosystem involves the expectations created by focal platforms in terms of the non-focal position of complementors. In other words, focal platforms expect other actors to support their leadership in the ecosystem rather than threaten their focal position. Second, a complementor has to demonstrate its normative legitimacy by exhibiting the capability to contribute to the focal value proposition relative to competitors in the ecosystem (i.e.,

explore the innovation potential or expand the network effects at focal platforms). Third, cognitive legitimacy solves widely held beliefs and taken-for-granted assumptions which provide the framework for daily practices. In platform ecosystems, this means obeying the aligned ecosystem structure (e.g., activities, roles, and links) co-defined by the diverse actors.

As such, identity construction based on organisational categories (Negro et al. 2010) provides legitimacy which allows further latitude in the pursuit of growth opportunities over time. By defining the membership of broad groups of like organisations, organisational identity aligns with taken-for-granted, already-legitimated logic and practices that define the category. It works with the category-related expectations about "appropriate" and "inappropriate" investments and activities (Anthony and Tripsas 2016) that serve as a filter to guide growth strategies in a manner consistent with institutionalised conventions. Discrepancy from external perception of identity will lead to negative feedback from relevant stakeholders (Gioia et al. 2000) and highly restrain the effectiveness of growth strategies, since current strategic decisions directed by identity do not align with the legitimate actions (Hannan et al. 2006; Hsu and Hannan 2005) expected from institutional context. To pursue resource requisition in the ecosystem, complementors therefore experience strong pressure to gain identity recognition (i.e., what we will do and who we will become) from focal platforms and behave in a manner that aligns with their expectations arising from the institutionalised conventions (Zuckerman 2004, 2000).

In this regard, an organisational identity is more likely to be judged as plausible by focal platforms in the ecosystem when it is legitimately distinctive — that is, it "incorporates institutionalized beliefs in ways that introduce novelty but still evidence some conformity" (Navis and Glynn 2011, p 480). This corresponds to Brewer's (1991) "optimal distinctiveness", wherein an organisation's identity is different enough from others in a category but still not so different that it is seen as a member of other categories. In other words, a complementor with growth ambitions must project an identity that is perceived as a good risk by focal platforms. Identity helps generate

interest and commitment from focal platforms by connecting the broader ecosystem context in such a way that the proposed endeavour seems distinctive and original. But this distinctive identity must maintain the soundness by reducing the perceived uncertainty associated with the exploitation of the growth opportunities in such a way that the threat of undermining the position of focal platforms following growth is under control.

Third, while Albert and Whetten emphasised one key feature of identity as either enduring or having continuity over time, identity becomes more dynamic for digital enterprises by representing a continuously shifting process as "recurring definition of what they do and who they are" (Huang et al. 2017, pp. 9). This process view highlights two unique attributes of identity in the digital venture context. First, digital venture identity shows continuous change which involves periods of change punctuated by episodes of perceived stability. As evolving actors with diverse goals, capabilities, and motives participate in the digital innovation space (Nambisan et al. 2017), organisations may "betray" their existing identity to cater to competing market imperatives — that is, the expectation of what an organisation should be to compete with other organisations (Gioia et al. 2013a). For instance, Tripsas (2009) showed how a digital photography firm is forced to change its identity to remain competitive when faced with new identity-challenging innovations. Relatedly, to serve a shifted consumer profile and preferences such as the "rise of a young, affluent social class", managers may pursue strategies that deviate from current organisational identity (Ravasi and Phillips 2011). Such strategy/identity misalignment then provides strong impetus for changes in organisational identity (Altman and Tripsas 2015; Ravasi et al. 2020).

Moreover, the interaction process with multiple stakeholders (e.g., users, investors, and potential buyers) may keep lightening new identity aspirations in terms of "what an organization could be", leading to "aha" moments for managers to think about the organisation in a novel way (Oliver and C Vough, 2020). The resulting discrepancy between the perception of "who we are now" and "what we want to be" then motivates organisations to initiate and embrace identity change through extended periods of

incremental adjustment followed by brief periods of perceived stability (Gioia et al., 2013a). The identity process can emerge from the shared interpretive schemes that diverse actors collectively construct. In the digital age, this identity co-creation idea is more prominent since end-users who were once the end point of value offerings now actively participate in value co-creation (Lusch and Nambisan, 2015), co-defining a platform business's key practice, interaction, and more. In this regard, identity is not only about us in the narrow sense as individuals and organisation insiders (Gioia 2008), but also about us in the wide sense as all platform participants in the digital ecosystem context.

The change of digital venture identity can be accomplished rapidly, even without warning. Based on an open-ended value landscape (Henfridsson et al. 2018), the key features of digital enterprises (e.g., core interactions and offerings of the digital platform) can shift quickly due to design flexibility incurring negligible marginal costs without a complete overhaul of the existing design (Henfridsson et al. 2014; Kallinikos et al. 2013). Identity in this context then should also be malleable and capable of shifting in the short term. Such an identity shift could exhibit in two forms. In social construction view (Gioao et al. 2000; Ravasi and Schultz 2006), platform business identity is a self-referential concept residing in a member's cognitive frame in terms of who they are as a platform to themselves as well as outsiders. Identity shift then focuses on the meanings and labels members use to depict themselves and their key attributes. In social actor view (Whetten and Mackey 2002), platform business identity is also a self-referential concept, but emphasises platforms as entities making assertions about who they are as actors in ecosystems. Identity shift then is substantiated by platform attributes enacted in the overt claims towards audiences. In line with Gioao et al. (2013), it is therefore through identity that a complementor makes a reflective consideration of the existential questions, "Who are we as an organisation? Are we still a complementor or not?" This taps deeply into the fundamental need of ecosystem actors to locate and articulate their positions when confronting the complementor's dilemma during growth.

2.4.2 Technical Identity

Besides regarding digital platforms as organisations, we should bear in mind that digital platforms are also digital objects (Faulkner and Runde 2019) composed of several distinct bitstrings parts that are arranged in a layered-modular architecture. A social networking platform, for example, comprises physical devices (e.g., smartphones, data storage, and computer systems), 4G/5G network infrastructure, mobile applications, and various content mediums (e.g., text, images, short video), that are all structured in the four-layered architecture of device, network, service, and content (Yoo et al. 2010). A digital platform is therefore a hybrid that comprises both material and non-material components. Continuing with this example, we then further arise another question: what makes this digital object a particular kind of social networking platform and how has this digital object come to occupy such generally stable and readily identifiable roles in platform ecosystems? The key to answering this question is the concept "technical identity" (Faulkner and Runde 2009, 2011).

Developing from the dual-nature conception of technology (Kroes and Meijers 2006; Meijers 2000), the identity of a digital object is comprised of its function and structure. Function is agentive in the sense that it is the use which members of a relevant community impose on a digital object in pursuit of their practical interests. 63his view is in line with the value co-creation (Lusch and Nambisan 2015) concept — rather than intrinsic to a digital platform, the function is collectively assigned by actors in the platform ecosystem. For example, the function at Facebook to allow people to interact and share information is co-defined by the participants at the platform. The same digital object may be assigned different functions, leading to multiple technical identities in different communities. For example, Facebook may become a music or game application in certain communities. As such, users may voluntarily create their own value paths and foster new identity aspirations that are outside of the expectations of the platform owner's initial design (Henfridsson et al. 2018).

Regarding the structure of a digital object, the object must generally possess a structure required to perform a function. Recall that structure refers to the constituent

parts of an object, their arrangement, and their interactions. For material objects, it represents physical components and capabilities required to perform a function. For digital platforms, the structure is the four-layered modular architecture and related digital resources as building blocks (Henfridsson et al. 2018). It is this open-ended value landscape that enables a platform to perform diverse functions and possess different technical identities in different communities. So long as participants in a community use a digital platform in a manner that is consistent with the function collectively assigned to it, they contribute to sustaining that function and its technical identity. As such, the continuity of a platform's identity depends on the platform participants' use practices (i.e., value-in-use). At the same time, the structure of the platform also helps sustain the participants' use practice. For instance, a specific platform architecture design to shut down social-irrelevant API connections will restrict the functions assigned by participants in social interaction. As such, platform owners are also able to influence the assigned technical identity of a platform.

To summarise, the technical identity of a digital object implies a certain type of social rule, expressed as "digital objects with such-and-such structures are for this purpose in such-and-such a situation." For example, a digital platform that designs short video sharing as a core interaction is for complementing social interaction at Facebook and Twitter in the social networking ecosystem. This social rule involves roles, activities, and positions, the performance of which is highly associated with and expected of the participants in the ecosystem. It therefore represents a normative force embedded in the ecosystem structure that both enables and constrains human practices in certain ways (e.g., the appropriate growth strategies for platform owners; the appropriate usage scenario for end-users; and the appropriate interaction mode with focal platforms and other complements in ecosystems). As such, human practices presuppose the social rules contained in technical identity, which at the same time are constantly reproduced as an on-going consequence of these practices (Faulkner and Runde 2011). Technical identity therefore tends to adopt the institutionalist view, which treats digital platforms as highly socialized objects subject to the strong influence of

institutional forces. As a result, the identity of digital platforms is collectively defined by ecosystem participants and independent of any individual actor.

While the continued reproduction of social rules accounts for the relative stability of technical identity, it does not mean that identity cannot change. A new technical identity may emerge in two ways. First, when there is a significant change of the digital object structure to which a particular function is assigned (e.g., the transformation from industrial company to digital enterprise). Second, when there is a significant change in the function assigned to a digital object with a particular structure (e.g., the change from social media app to music app). User-driven innovation in function plays a key role in technical identity shift (Faulkner and Runde 2009). Although platform owners have a close engagement with the digital platform in design and production, this spreads across a variety of activities from design to distribution. End-users though have more direct engagement with the platform as a means to achieving their individual purposes in a wide range of contexts. As a result, end-users can generate far greater varieties of emergent functions for existing platform objects than platform owners.

This comparative advantage in innovation in function is further facilitated by the flexibility and malleability of digital objects (Kallinikos et al. 2013; Yoo et al. 2010). Use is no longer a discrete act but is about actively selecting and recombining digital resources offered by the same or different platforms without detailed knowledge and skills, leading to rethinking their usage and purpose (Henfridsson et al. 2018). For instance, users may voluntarily replace Microsoft's default Bing Maps in the Microsoft Outlook contacts app with Google Maps to create a different value path. As the new assignment of function emerges from the user side, platform owners do not need to invest in promoting that new function significantly. Moreover, as the new function is further cultivated and recognised spontaneously among platform users, it is harder for competitors to copy such novel use or the technical identity of the digital platform without possessing similar consensus in its social community.

Further, user innovations in function usually represent the spontaneous emergence of new markets for an existing digital object. It is greatly advantageous to platform

owners with growth ambitions since they invest nothing to generate such additional markets. The scale of the benefits is well-facilitated in the platform context due to the fluid boundary of digital innovation (Nambisan et al. 2017). Consider that a new function (e.g., listen to music via an app) is not restricted by the community assigning that function; it is potentially attractive for all internet users. The additional demand generated for the new technical identity by users is therefore likely to be large by having a significant impact on the overall size of the markets concerned. Because of user innovation, there is always the possibility of the emergence of a new technical identity for an existing digital object. It may take time though before the new function assigned to it becomes a matter of general currency and the corresponding technical identity becomes well-established.

2.4.3 Conceptualizing Platform identity

Developing on the dual nature of digital platforms as both organisations and digital objects, Cennamo (2021) formally proposed the concept of platform identity. The starting point is the fact that as digital becomes more central to organisations, a firm's competitive advantage becomes more dependent on platform competition (Cennamo and Santaló 2013). Such competition is totally different from traditional markets where organisations were usually targeting products at similar customers. Instead, platform competitions are always product-agnostic across market boundaries. In this situation, a digital enterprise that wants to be competitive must identify its identity domain by taking the platform as a basis for analysis.

Recall that a platform business can be framed as an organisation with a layered-modular architecture or a market. In Cennamo's view, it is more than just a pure hybrid between organisation and market that should be regarded as a new form of generative organisation (Yoo et al. 2010) requiring collaborations from diverse parties in ecosystems. Consider the meaning of identity in market and organisation respectively. As the key information issues (e.g., the lemon problem) in markets mainly focus on coordinating demand and supply sides (i.e., value, product, price, quality, and

boundary), consensus about these market attributes can be easily reached with economic tools and without need for identity. With regard to an organisation, the key information issues (e.g., stakeholder agency issue) are inside the organisation, where significant tensions among members to perform in their own interest exist. To make products or services for market in the first place, organisations have to jointly realign their interests by requiring an identity to build the collective understanding of who they are. In this regard, organisational identity is more about internal members' perception and is more likely to endure. Digital platforms, however, are not designed by a single organisation. Rather, they can only function with other actors in the ecosystem. With heterogeneous motive, capability, and interest, tensions among ecosystem participants will always exist and are impossible to aligned completely. The identity constructing process then becomes more dynamic and harder to define, since there is no longer a sole best practice, product, or service to represent the identity of a platform, similar to the functionality assigned to the platform itself. Consequently, Cennamo (2021) suggested refreshing the metrics to delimitate platform identity.

A digital platform can build a distinctive identity or become a specialist in given ecosystems in terms of platform architecture and scope. First, platform architecture is the technological capability of a platform, and the way platform technological components function and connect platform participants. It depicts the structure of a digital platform and delimitates the essential features core to the platform. For instance, it determines the core interaction at a platform by enabling a set of actions for producers and consumers to engage in repeatedly to derive value out of the platform (Parker et al. 2016). It also draws the key practice partitioning pertaining to platform owners and other participants by defining the core components and boundary resources (Ghazawneh and Henfridsson 2013) available at the platform, each of which accounts for one or multiple product/service domains due to design flexibility.

Second, platform scope depicts the market positioning of the platform along the map of the consumers' preferences and relative to competing platforms. Since the functionality of a digital platform is socially assigned, this target user profile directly

defines the relevant social community expected to matter for platform identity (i.e., who we are). Digital platforms, as a new form of organisation, no longer regard users as external stakeholders but as core shapers of identity, including complementors who innovate on the existing platform and end-users who interact with each other. At the same time, as platform owners deliberately target a specific group of users, emergent identity assigned by irrelevant social communities and accompanying growth opportunities may be ignored. However, this does not mean platform identity is an enduring concept. By comparing with user profiles of competing platforms and focal platforms, platform owners could strategically widen their platform scope through horizontal or vertical platform envelopment (Tiwana 2013). Some platforms may instead choose to specialise their offerings to satisfy particular user needs, like the continuing user highlighting towards females at the Meipai short video platform. As mentioned before, such platform scope shift is also possible when unexpected user innovations rapidly diffuse at a platform and become a matter of general currency. In each of these ways, the degree of platform distinctiveness in users' minds changes over time (Cennamo and Santaló 2013; Seamans and Zhu 2014).

Cennamo's platform identity concept emphasises distinctiveness purely from platform competition logic. While platform size and the triggered positive network effects remarkably dominate in platform competition due to winner-take-all logic, many instances in platform ecosystems show the coexistence of competing platforms in the same markets. In some cases, platform owners rule out some users they do not want to serve, such as the online dating platform eHarmony. In other cases, platform owners enhance the innovation burden and cost for complementors to control the complement quality, such as Apple iOS mobile platform. Platform owners in these examples do not expand their platform size endlessly but try to set up various screening mechanisms to build distinct platform identity. Users may also value a specific platform attribute and adopt it despite its size (Zhu and Iansiti 2012), or value a few specific complements with exceptional quality more than complement variety, and eventually adopt such platforms (Binken and Stremersch 2009; Cennamo 2018). Recent studies have exhibited

that such differentiation advantage in platform competition can be gained based on unique platform architecture capabilities (Schilling 2003; Zhu and Iansiti 2012), unique platform scope positioning (Bresnahan et al. 2014; Cennamo and Santaló 2013), and unique platform offerings (Cennamo and Santaló 2013; Seamans and Zhu 2014).

With regard to architecture capabilities, platform owners' architecture design decisions (e.g., interface openness or the degree of modularity) influence the core offerings to users (Schilling 2003; Zhu and Iansiti 2012), innovation opportunities open to complementors (Claussen et al. 2013; Eaton et al. 2015), and platform access and monetisation choice for potential participants (Parker et al. 2016; Wareham et al. 2014). These structural elements of platform distinctness are usually constrained by path dependence punctuated with path creation through digital innovation (Boland et al. 2007; Henfridsson and Yoo 2014), leading to higher difficulty in replication by competitors — at least in the short term. With regard to platform positioning, identity distinctiveness can be traced back to the consumer market space, such as segmenting the market by targeting at high-end (e.g., the iOS mobile platform) vs. low-end markets (e.g., the Android mobile platform) (Bresnahan et al. 2014) and positioning different consumer preferences with different complement portfolios (e.g., PS4 and Xbox) (Cennamo and Santaló 2013). Since digital platforms are non-excludable (Rosemann et al. 2011) with fluid market boundaries, this differentiation advantage derived from market positioning is usually unsustainable with a low competition barrier. As a supplement for this strategy, platform owners can attract exclusive content or complements that are unavailable on competing platforms (Cennamo and Santaló 2013; Hermalin and Katz 2013).

In view of these discussions, platform identity should not be simply regarded as the opposite competition logic of "winner-take-all". Instead, it is an important prescription to help platform businesses "get big fast". Consider Google's growth in the competition with other information portals such as Yahoo!. Instead of providing diverse functions and services to cover all potential users, Google exceled in its core technological capability — information search — by offering more relevant information and

responding more quickly to user queries, leading to wider adoption and ultimate dominance in the search engine market (Gawer and Cusumano 2008). During the scaling process, to reach more potential users beyond the student community, Facebook stuck to its identity by restricting the amount of information exposing to users. Although this rule may negatively impact the scale of content creation and sharing by content creators, Claussen et al. (2013) found that it increases the innovation of more engaging apps and user rating scores at Facebook. Platform businesses with ambiguous identity may easily fall into the trap of "winner-take-all" logic. For instance, to respond to the competition from Facebook, MySpace later attempted to both satisfy different user preferences by providing customised content and reinforce its platform size by keeping the platform open for unfiltered content contributions. This hybrid growth strategy finally led to user outflow to Facebook (Cennamo 2021). Similarly, the pursuing of a dual strategy by offering both a wide range/variety of content and exclusive deals to high-end consumers led to the online coupon platform Groupon stalling in the middle and finally alienating all platform parities. In this regard, platform identity significantly facilitates the platform avoiding "platform traps" (Cennamo and Santaló 2015) by directing a clear strategic focus during growth, positioning user groups in either mass or niche markets and aligning the value propositions of key platform partners.

One limitation for Cennamo's platform identity framing is that he restricts the value source of a platform business to the demand side. In other words, platform value is mainly dependent on how users perceive the benefit of using the platform and consuming the complement products or services. In this situation, platform identity — the determinant of platform value — emphasises the co-constructing process and the competition logic for platform users (e.g., complementors and end-users). However, this presumption ignores a pervasive scenario where a platform is also a complementor in platform ecosystems. In such cases, the platform not only needs to compete for the potential users in a digital market, but also must compete for the support of focal actors in the ecosystem. This shortcoming can however be overcome in a relatively straightforward manner, by transforming the four competitive scenarios into the

legitimacy scenarios for a complementary platform in the ecosystem. In particular, two dimensions of its legitimate identity domain need to be considered: platform architecture similarity defines the degree the platform architecture of the two platforms share the same functionalities, capabilities, and technological attributes; and platform user commonality defines the degree the two platforms share the same type of users, particularly from the focal actors' perspective (e.g., common users/users at focal platforms).

These two dimensions largely define whether a platform business obtains legitimacy from focal platforms in the ecosystem. An emergent platform then can deliberately project its identity and corresponding position by designing the platform architecture and user targeting. These scenarios can also depict the potential legitimacy dynamics in platform ecosystems because of emerging interactions with focal actors ensuing from the independent growth strategies taken by platform owners. For instance, for a platform business thinking to compete with focal platforms on the same technological account, it will realise architecture similarity and a higher possibility that focal platforms will treat it as direct competitor with less endorsement. Further, after a platform business decides to change to a new legitimacy scenario, it could take pre-emptive strategies/actions to be competitive for the legitimacy domains that it will inevitably lose. Therefore, the platform identity domain helps to explain why and when a platform business may reshuffle its growth strategies to reflect what it wants to be in the future. I discuss each scenario in the following parts (Figure 2).

High user commonality/high architecture similarity → competitive identity domain overlap platforms with high user overlap and architecture similarity relative to focal platforms will largely compete in the same competitive identity domain and be perceived as direct competitors and a threat to focal platforms' existence. Under this high overlap in terms of users and technological attributes, platform legitimacy and the endorsement from focal platforms are unlikely to occur since their interactions escalate into winner-take-all battles. Given that a small difference may lead to a big impact on the network size and finally tip the market to the favour of one platform, focal actors

will take revenge on the platform by blocking the interface connections, making multi-homing harder for users, and conducting platform envelopment through mimicking its move on both technological design and market network. As such, any move from the platform can damage the network strength and size of focal actors and no cooperation room will be left, triggering off a series of competitive countermoves to prevent their users from migrating to the platform. Accordingly, the platform expecting to move to such a position can only materialise its growth ambitions by adopting aggressive "get-big-fast" strategies and reinforcing its competitive standing before focal actors' react, such as user subsidising (Clements and Ohashi 2005; Hagiu 2006), platform envelopment (Eisenmann et al. 2011), or exclusivity licensing to lock-in their users (Cennamo and Santaló 2013). Note that these strategies are more effective in the context where users value more the opportunities to interact with many other participants than interaction with a small number of acquaintances (Lee et al. 2006). This is likely the case for the social networking market, where users particularly value extensive communication opportunities on the platform.

High user commonality/low architecture similarity → asymmetric domain

platforms with high user overlap but low architecture similarity relative to focal platforms can build their legitimacy in the ecosystem through distinctive positioning. Even with serving the same type of users, focal actors may not directly regard a platform business as a competitor given their dissimilar architecture and leveraging of different platform capabilities. Specifically, focal actors may continue to support its growth for three reasons. First, focal actors can still hold different beliefs about the relevant market. For example, although Facebook and TikTok overlap in the same market for users with social interaction needs, they may still see themselves as competing in different domains: Facebook tries to dominate in social networking service and TikTok focuses more on AI-driven content distribution. Consequently, focal actors may be less aware of other actors' actions outside the identity domain (Livengood and Reger 2010). Second, even if focal actors monitor the wider competitive environment, they may still be moderate in reacting to competitive moves by other

ecosystem actors if the threat of undermining their focal position is under control. For example, while Facebook and TikTok provide similar social interaction functions, their priority for their firms is different in the sense that instant message is the core offering at Facebook but only at the periphery for TikTok. As a result, TikTok will develop asymmetric resources and capabilities (e.g., trendy short video creation and sharing) according to its distinctive platform architecture, which both complement Facebook's current offerings and constrain its capability to directly attack Facebook's dominant position (i.e., diverse complementors and networking technologies at Facebook). Accordingly, focal actors will only react to others' actions in their identity domain — that is, the particularly salient "competitive arena that best demonstrates and reinforces organizational identity in the marketplace" (Livengood and Reger 2010, pp. 48). As long as an ecosystem actor maintains an asymmetric identity domain, its interaction with focal actors is less likely to evolve into intensive head-to-head competition for winning the whole market.

The legitimacy of a platform business with a distinctive identity domain can be further sustained with its limited incentive to attack focal actors focusing on network size logic in the ecosystem. Since the platform may take opposite actions — such as screening users and increasing participation costs for certain user groups to enhance its distinctive position in the ecosystem — these strategies do not lure users at focal platforms and further threaten their leadership, like the case of eHarmony vs. Match.com. Moreover, the potential platform trap issue (i.e., the trade-off between platform size and platform identity) may make the platform fail to both keep its distinctive identity and acquire users from focal actors when directly competing with them through winner-take-all logic (Cennamo 2018). At the same time, we should recognise the potential of user innovation to intensify the competition between focal actors and non-focal actors in the ecosystem. Given the high overlap in terms of the social communities that assign function to platforms, similar value paths are highly likely to be developed by users voluntarily at both non-focal platforms and focal platforms, leading to competition in the same track. This legitimacy concern from focal

actors can grow with asymmetric user overlap (Eisenmann et al. 2011), in the sense that most users at non-focal platforms are participants of the focal platform but not vice versa. In this situation, focal platforms have limited motivation to envelop into the domain of non-focal platforms, but non-focal platforms have high motivation to envelop to expand their user base. Further, as a platform business can still materialise "get big fast" by sticking to its distinctive identity when doing envelopment (e.g., Google and Facebook), focal actors will only provide qualified legitimacy for its growth.

Low user commonality/high architectural similarity → contested domain

platforms with low user overlap but high architecture similarity relative to focal platforms can more easily gain legitimacy at the start-up stage but cannot sustain it during growth. While they provide similar platform capabilities and offerings, their initial user targeting is different and thus operates in separate markets. In this situation, the platform is more likely to be regarded as a beneficial complementor by reaching out to users outside the ecosystem boundary, leading to strong endorsement from focal actors. However, due to the high architecture similarity, the platform has the potential to envelop into the focal actors' domain by leveraging their functionality across distinct markets and enlarging their user network. As a result, once the undermining threat from complementor growth is not seen as controllable (i.e., strong network effects to defend counterattack), focal actors will rapidly change to competitive attack by entering the neighbour market. Consider the case of Taobao vs. JD in China. Although both of them attempt to facilitate similar user interaction at their platforms (commodity buying and selling), JD focuses on a very different user profile compared with Taobao: JD specialises in facilitating the transaction of books and digital products (e.g., smartphones, computers, headsets) in the first-tier cities while Taobao is more generalised in other transactions (e.g., clothing, daily necessities, beauty makeup). Such distinctive market targeting allows JD to rapidly scale without much obstruction from Taobao. However, as JD further grew by diversifying its transactions into other categories, Taobao responded by introducing digital product zone at the platform. Taobao also retaliated by restraining the application of Alipay to the Taobao platform

only. As a defence, JD launched its own payment platform, JD wallet, to simplify the transaction process at JD. In recent years, such mutual contesting has been pervasive across the fresh food, logistics, and finance markets, creating a highly convergent competitive domain between the two platforms.

Such escalating rivalry reflects the multimarket contact theory (e.g., Chen 1996; Fuentelsaz and Gomez 2006; Gimeno 1999; Ketchen et al. 2004), which claims that the increasing competitive behaviours due to higher interdependence between both parties in overlapping markets will continue until they establish mutual forbearance on the threat of mutual retaliation. Due to the similar platform architecture, complementors with strong growth ambitions are highly likely to expand into more overlapping markets with focal actors or identify new markets that are also promising for focal actors to reinforce their network effects. In either case, complementors' growth will continually threaten the leadership of focal actors in the ecosystem, leading to decreasing support and even retaliation in the complementors' own markets. Such mutual envelopment across identity domain will eventually lead to market convergence with a new and re-defined competition landscape (as in the case of Taobao and JD). In this situation, the aggressive contest will not end unless complementors quit the ecosystem or build a strong focal position parallel with incumbent focal actors. In the latter case, mutual forbearance takes effect given the well-matched strength to influence each other's platform performance.

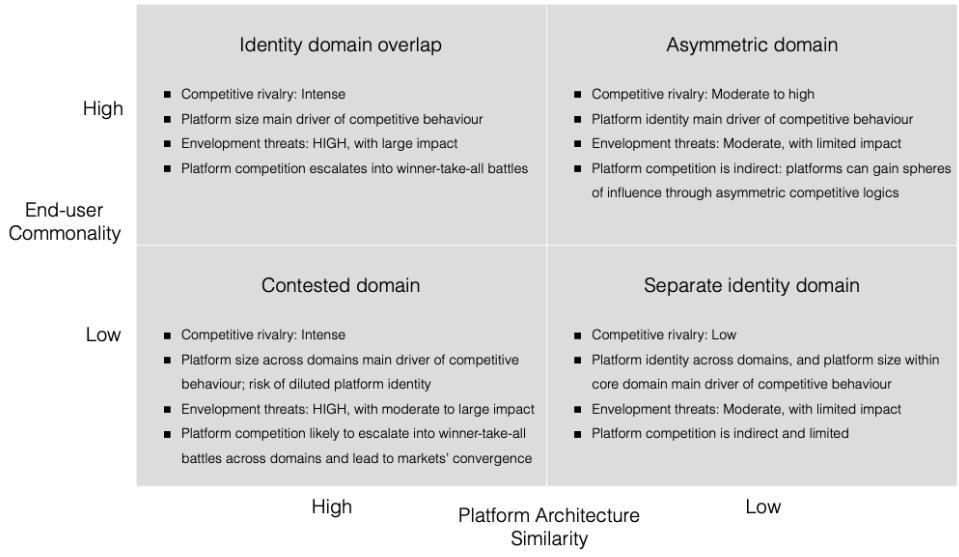
As complementors take high risks when getting into this contested identity domain, they should defer such escalating rivalry as long as possible. In particular, the similar platform architecture design for a complementor is a double-edged sword. On one hand, it makes the complementor's envelopment into focal actors' market easier. On the other hand, it also makes the complementor more vulnerable to focal actors' envelopment. As such, an emergent complementor should take more effort in exploiting its separate market before enveloping into focal actors' markets. By expanding its user base outside the ecosystem and developing distinctive technological capabilities, the complementor can reinforce both its legitimacy and competitive barrier in the ecosystem. In this way,

complementors could build mutual forbearance faster with lower risk by shifting the contested identity domain to the asymmetric identity domain when doing envelopment.

Low user commonality/low architecture similarity → separate domain platforms with low user overlap and low architecture similarity always address different types of users by providing different technological capabilities. Therefore, they operate in separate platform markets with limited interdependency or complementarity between each other. Platforms in such separate identity domains have less direct competition regardless of their strategic focus (e.g., platform size or distinctive identity). In this situation, platforms are more likely to take different roles in the same positions in the ecosystem, and therefore do not need legitimacy from each other.

Consider the case of WeChat and Weibo in China. They both operate in the social networking market and take winner-take-all logic in competition. However, there is limited rivalry between the platforms. This is because they in fact project in separate identity domains in the same market. WeChat built its core offerings and platform capability in instant message systems and decentralised social interaction. In this way, it mainly targets users who requires instant messaging (e.g., ring up, texting, video connection) with acquaintances, reflecting strong tie connection among users. Weibo is a social media platform at which the main interface is about content with centralised social interaction. It caters to users who require current affairs and other information about society. Most users at the platform are information receivers who are surrounding minority key network nodes, reflecting weak tie connection among users. Although users may multi-home on both platforms, they will tend to affiliate with a sole platform when trying to address defined needs. As such, the two platforms operate in separate markets, within which they can coexist and even dominate in their respective market and identity domain. Their distinctive platform architectures with strong network effects in the market highly constrain the capability and effectiveness of aggressive competitive moves such as platform envelopment in the short term. This is the case of WeChat and Weibo, in the sense that both actors become focal platforms in the social networking ecosystem.

While the intensity of competition in the short term is low, platform businesses may move to other identity domain scenarios in the long run by launching new platforms in each other's market, due to technological convergence (i.e., the integration of content, service, software and hardware) in the digital age. This is the case of Bytedance, who entered the social networking market by leveraging its AI content distribution capability in social interaction; Alibaba who leveraged its e-commerce service in the logistics industry; and Baidu, who leveraged its information search and processing capability in automatic driving. In this situation, new complementarity will emerge, and new legitimacy challenges must be solved. Since the emergent platforms are able to build upon the resources and capabilities owned by the same firm in the original market (e.g., piggyback the users from original separate market), identity domain shifts across different scenarios may become more rapidly and frequent during their growth trajectories.



adapted from Cennamo (2021)

Figure 3. Platform Identity Domain Analysis

2.5 Summary of Literature Review

We are witnessing a new era where pervasive digital technologies are fundamentally reinventing the theory of growth for digital businesses. In this part, we review the meaning of scaling in both the industrial age and the digital age. By depicting two

theoretical perspectives of digital platform businesses as both architecture design and market, we reveal five dimensions to differ scaling in different ages. First, while scaling in the industrial age refers to the increasing operational efficiency in production and distribution as it is growing, its meaning in the digital age is refreshed as a process by which the operational efficiency in innovation and interaction increases as it boosts its user base. Second, the main driver of scaling in the industrial age is organisation-level economies in terms of supply economies of scale and production economies of scope. The main driver in the digital age changes to ecosystem-level economies in terms of economies of scope in innovation and economies of scale in demand. Accordingly, the means of scaling also change from internal innovation in terms of technology and organisation to the scaling of the user base which contributes to the ecosystem-level innovation and interaction. It is further noted that digital enterprises' scaling capability is further liberated due to the existence of more productive opportunities compared with modern industrial enterprises. In this situation, besides human agency as highlighted in the industrial age, material agency also takes a key role in platform business scaling. A deliberate platform governance becomes important for aligning different parties when pursuing scaling ambitions.

At the core of these ecosystem-level economies, platform ecosystems represent a unique interdependence structure that requires focal platforms to align members' positions and activities flows among them via shared or open-source technologies and/or technical standards. Such focal—non-focal relationships can be further elaborated in the complementarity between ecosystem actors according to the research streams in economics and innovation. Focal actors hold the platform leadership position and are the innovation and network hub of the ecosystem, while non-focal actors are ecosystem followers who have to affiliate with focal actors — and none are decisive for the ecosystem evolution in terms of either platform innovation or network effects. Given this asymmetric interdependency between focal actors and non-focal actors, we further reveal one specific growth dilemma confronted by complementors in the ecosystem, that is-how to balance the growth ambitions and the dependency on focal

actors during scaling. On the one hand, it is inevitable for a complementor to keep pushing its own growth ambitions in a platform ecosystem, which cannot be materialised in a vacuum but must build on the focal platforms due to their asymmetric interdependency. On the other hand, in seeking growth, the complementor will inevitably come across tensions in its relationship with focal platforms because its changing position will increasingly threaten their focal position in the ecosystem.

To disentangle the complementor's dilemma during scaling, we propose platform identity as the theoretical lens grounded from this thesis. In view of the dual nature of platform businesses as both organisation and digital object, we retrospect the literature of organisational identity and technical identity. First, organisational identity differentiates a complementor enough from others in a category which serves as a filter to search favourable growth opportunities, but still makes it perceived as a member of the same category which endows the complementor with legitimacy in the ecosystem. Focal actors therefore will continue to endorse its growth as "good risks". Second, the identity of a digital object is comprised of its structure and socially assigned function, both of which determine why it occupies its position in the ecosystem. Since a digital object is collectively defined by ecosystem participants, user-driven innovation in function plays a key role in the shift of technical identity. Combining both perspectives, we then conceptualise platform identity that differentiates a platform business from other actors in the ecosystem in terms of platform architecture and platform scope. By comparing its technological architecture similarity and end-user overlap with focal platforms, platform identity helps complementors define who they are by locating current position in the ecosystem and project what they want to be by weighing future legitimacy scenarios underlying potential growth trajectories. Co-shaped by multiple stakeholders in the ecosystem, this navigating process of the complementor's dilemma is still in development, which makes this thesis timely and pioneering in understanding the platform ecosystem dynamics from the complementors' perspective.

3. METHODOLOGY

Analysing complementor growth in the platform ecosystem represents a series of methodological challenges. As we have seen before, the complementors' growth is not just about wishful pursuing of growth ambitions. Instead, it is the result of the strategic game of all ecosystem stakeholders, because complementors are not an isolated island but have to draw on and add to existing ecosystem resources for growth. In other words, the complementors' growth trajectory is co-shaped by ecosystem actors, which is reflected in the platform identity constructing process of who they are and what they want to be. As a result, researchers have to trace not only the strategic decision-making process within the platform business, but also the perception/response of external parties (e.g., platform users, focal actors, and competitors) and wider ecosystem context dynamics throughout the complementor's growth process. Such a large volume of multifaceted, socially constructed data would be inappropriate to be theorised and examined using traditional research methods such as qualitative exploration based on single firm occasion or quantitative testing based on simplified correlations, both of which are biased and partial for focal research phenomenon (Venkastesh et al. 2013).

To solve these issues, this thesis develops a mixed research methodology based on digital-traced data, referring to the digital records of activity and events that involve information technologies (Berente et al. 2019; Howison et al. 2011). Given the abundant and ever-increasing digital trace data widely available now, they are particularly well-suited to develop a process lens within a research inquiry by recording multidimensional time-stamped sequences of activities/events of all key stakeholders in an ecosystem. In doing so, this chapter unfolds a refreshed process-tracing analysis approach based on longitudinal digital archive data, followed by a quantitative study to validate the developed theory. I process as follows. First, I introduce philosophical assumptions on which this thesis is based. It is then followed by a sequential research design of two empirical studies. I then depict the detailed data collection and analysis approach based on a process lens in study one and how it can be complemented with a computational approach in study two. This chapter closes with a summary of the mixed

method in this thesis.

3.1 Philosophical Assumptions

The underlying philosophical assumption of this thesis starts with an ambivalent ontology (Kallinikos et al. 2013) of digital platforms, in the sense that they are objects but lack the stability and adequacy afforded by traditional devices and items. Recall that a digital platform is embedded in wider and constantly shifting ecosystems such that it is increasingly editable, which allows for modification and updating in various forms (e.g., add/delete/modify elements or update function); interactive, through which a set of technology affordances can be explored by human agents in contingent ways (e.g., wide array of functions can be performed at same platform by different users); reprogrammable, in the sense of being accessible and modifiable by means of other digital platforms (e.g., digital platforms draw on and add to other digital platforms); and distributed among multiple sources and actors (e.g., it consists of various digital resources offered and recombined by diverse platform participants).

Objects with flux states like this are lacking a clear identity (properties or characteristics) to define themselves. As Ekbia (2009) describes, they violate two essential ontological laws of an object. First, the identity of indiscernibles describes that two objects X and Y will be identical if X and Y share all their properties. Consider the iOS and Airbnb platforms. While both share the features listed before, they have distinct implementations (innovation-driven vs. exchange-driven) drawing upon different infrastructure resources in different ecosystems (software vs. hospitality). Similarly, digital platforms do not conform with the indiscernibility of identities which portray if X is identical to Y, then every property of X is a property of Y. The same digital platform may have a large number of enactments by different human agents in digital ecosystems (i.e., use recombination), which are seldom exactly alike based on the layered modular architecture. It is therefore perpetually in design and intentionally incomplete, to be redeemed by use (Garud et al. 2008; Zittrain 2006).

In both cases, digital platforms are function-agonistic in the sense that their value and meaning in the use situation are contingent on a shifting web of relationships with

other platforms across specific contexts and organisations. Accordingly, we saw that the development and growth of complementors in digital ecosystems are not purely controlled by platform owners but are influenced by the interdependency structure co-founded by dispersed ecosystem actors, a condition making the management of platform scaling a complex technical and social undertaking. At the same time, digital platforms do not simply represent something external but are performative by constructing the interdependence relationships with others in ecosystems. Such ambivalent ontology manifested in the dynamic characters of digital platforms, the fluid nature of platform participants, and the shifting interdependence relation relative to other ecosystem actors therefore significantly challenge our previous understanding of the nature of things, which gives rise to the adoption of critical realism in this thesis.

3.1.1 Critical Realism

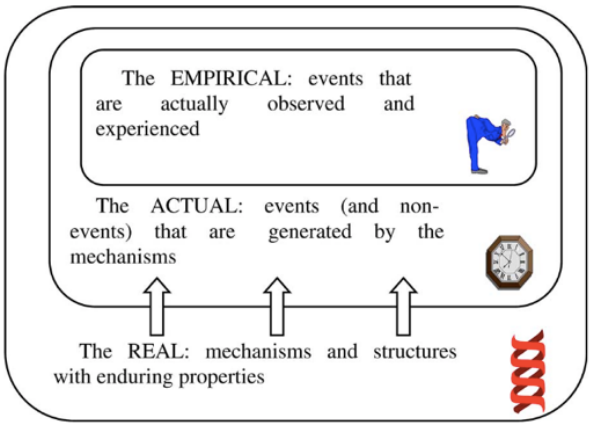
Ontological realism. Given the unstable nature of digital platforms, researchers should no longer assume that the management of platform business can be planned, carried out, and evaluated with recurrent outcomes. Similarly, there are no stable positions and courses of action for platform businesses in digital ecosystems. Therefore, although we can empirically observe and measure some activities and events happen while complementary platforms navigate the interdependence tension with focal actors in the ecosystem, they only capture a fraction of the world and most domains of reality are outside of our perceptual experience. For example, there are many possible strategies and ecosystem positions that a platform business may take, driven by different social structures in the ecosystems. While most alternative scenarios may not be observable or actualised, they still exist. As such, we touch upon the *ontological realism* idea of critical realism (Bhaskar 1978), which asserts that there is an existing world independent of our knowledge or awareness of it. While critical realism also starts with some observable phenomenon similar to classic positivism and constructivism, it is different from the other two in the sense that the ontological domain (e.g., being, things, existents, reality, and objects of investigation) must be separated from the epistemological domain (e.g.,

knowledge, systems, thoughts, ideas, theories, and language). In other words, the statement of being cannot be simply reduced into human experience or knowledge of being. The nature of the known cannot be treated as afterthought. Instead, it operates transcendentally apart from what humans did and we have to ask what the world must be like for a particular phenomenon to occur.

In Bhaskar's words, it represents the intransitive domain (existing independently of individual's belief, action, and perception) of reality we attempt to know, which become objects of our knowledge. Within the realm of objects, multiple enduring entities in terms of the physical (e.g., atoms or organisms), social (e.g., family or market), or conceptual (e.g., ideas or categories) may exist that have specific causal structures (powers and liabilities) to frame objects' tendencies to act in particular ways (Mingers et al. 2013). These mechanisms are not based on causal necessity since their powers may need a particular context to be triggered and may not manifest in events due to the countervailing operation of other mechanisms at the same or different strata (Archer 1998). The picture of reality is therefore a series of "complex interaction between dynamic, open and stratified systems, both material and non-material, where particular structures give rise to certain causal powers, tendencies, or ways of acting" (Mingers et al. 2013, pp. 796). In this regard, these *generative mechanisms* (Bhaskar 1997, 1998) deriving from particular structures of objects act contingently and transfactually in the sense that "the event or events that they are the powers to instantiate may never actually be instantiated; the powers may remain unactualized, yet these powers remain in existence" (Fleetwood 2009, pp. 362-363).

Following this argument, critical realism makes clear distinction between the domain of the real (i.e., objects, entities, and structures), the actual (i.e., the events that are generated based on these mechanisms) and the empirical (i.e., the subset of events that are experienced/observed by humans) (Bhaskar 1979, 1998) (Figure 4). What is happening now, has happened, or will happen is not exhausted by our empirical knowledge or experience, nor does it exhaust the possibilities and categories of reality. The real is therefore complex, changing, and temporal. This is different from the

traditional understanding of causality made by Humean in the sense that the constant conjunctions of observable events experimented in a controlled and non-complex environment (i.e., a closed system) are not universally true in most of the reality (i.e., an open system). Event 2 does not always follow with event 1, since the occurrence of such conjunction has to consider certain contextual situations (e.g., historical or social). As a result, we should not reduce all enduring causal mechanisms to the events that are actualised. Similarly, we should not reduce all events to only those we can observe. The criterion of existence then is based on the causal effect on the world, regardless of actualisation and perceptibility.



Adpated from Mingers (2004)

Figure 4. The Three Domains of the Real

Epistemological relativism. Given the intransitive objects of knowledge, we must recognize that to speak or the desire to speak about "the real world" is either meaningless or naïve, as many of the determinate features of the world are not empirically verifiable or quantifiable and may in fact directly resist articulation into empirical scrutiny. Instead, we can only understand the real world and the underlying generative mechanisms mediately through theories, thought, model, results, anomalies, and conjectures. Bhaskar (1975) then proposes *retroduction* or *abduction* as the core critical realist scientific methodology to touch upon reality. We can start from "some unexplained phenomenon that is of interest of us and propose hypothetical mechanisms that, if they existed, would generate or cause that which is to be explained" (Mingers et al. 2013, pp. 797). In this way, we move from social phenomenon in the empirical domain to possible causal

mechanism inferences (possibly nonphysical or unobservable) in the real domain that are able to account for that phenomenon.

It is further noted that such hypotheses do not demonstrate that the proposed mechanisms do in fact exist, because the production of such knowledge is very much a human activity that is always historically, culturally, and socially located. They are articulated from diverse standpoints in the light of different interests and influences. In other words, the knowledge of objects is transitive — that is, context-, perspective-, and activity-dependent (Bhaskar 1989). Consequently, the hypothetical mechanisms are always partial, overdetermined or underdetermined, saying too much or too little, and dependent on language and existing theories which operate in conjunction with our practice. The epistemology in terms of how we know what we know is thereby biased and situated, and there is no neutral position to view the world. This epistemic relativity then admits that the ontological realism to entail a commitment to truth does not entail the truth of our account of the nature of the world. Our knowledge is fallible, leading to the necessity of pluralism in terms of research methods.

Methodological pluralism (Mingers 2001) refers to researchers using a range of methods in the same piece of research. To map the ontological characters of social reality, critical realism has to rely on a variety of epistemological method to access their different forms — such as material, social, and cognitive. This eclectic attitude towards research methods allows for triangulation, where qualitative and quantitative data can be produced to maximize the validity and reliability of our knowledge of objects. This openness towards diverse research methods (e.g., statistical, interpretive, and mixed methods) does not mean that critical realists approach causation indiscriminately. As we have mentioned before, using the partial facts, regularities, and events we experience in the social world as a springboard or window to understand the complex, contingent, and layered processes or structures that cause them, we cannot reduce the causation into constant conjunction forms in closed systems. Instead, we must bear in mind that a thick and robust understanding of causation is required to account for the complexity and heterogeneity of the social world. This has been represented in the confluence trend of

quantitative and qualitative methods in recent methodological papers, such as the computational-intensive theory development approach (Berente et al. 2019) and recent special issue of MISQ in "the next generation of IS theory" (Burton-Jones et al., 2018).

Judgmental rationality. The epistemology relativism recognises that there is no neutral position to view the world or assess theory. Since the real objects and structures are intransitive, there is always the potential for effects that go beyond us and are out of our control. In this situation, we may never know for certain whether a hypothetical mechanism exists or is just an interesting idea. However, this fallibility does not imply that all knowledge and views are equally valid and there are no rational ways to adjudicate between competing proposed perspectives. On the contrary, critical realism holds that we are required to, and able to, refine and improve our knowledge of intransitive objects over time, which is done by eliminating alternative explanations and supporting others through testing for their potential effects. The essential and complete methodological steps in critical realism studies thus can be described as: depicting the events of interest, retroducing explanatory mechanisms, eliminating false hypotheses, and identifying the correct mechanisms.

However, we then confront a challenge or issue: How do we make claims of the reality (or identify the correct mechanisms) which are justified based on relatively objective reasons, while still being historical, changing, and contingent? The answer can be embedded in Sayer's appeal to *practical adequacy*. In his words, "to be practically adequate, knowledge must generate expectations about the world and about the results of our actions which are actually realized" (Sayer 2004, pp. 69). While people may hold different knowledge about processes in the world, they can still be rationally judged in terms of their capability to explain and direct our activities to a certain extent. He further noted that the practical adequacy of different parts of our knowledge will vary according to different contexts. There would be one theory/knowledge that conforms most appropriately to a particular practical context, indicating that the world is

structured in particular ways and there are relatively objective criteria for choosing between rival theories. But the same theory/knowledge may not perform equally well or successfully in a different context, indicating that the world is differentiated and multifaceted.

Therefore, through investigation and reflection in the empirical domain, we can use one to sharpen the other — for example, by extracting and testing the implicit mechanisms within actions and events, and the implicit actions and events contained within the extracted mechanisms. We will then realise that not all aspects of a theory are necessarily relevant and may be wrong, redundant, or simply make no significant difference in different contexts. In such a contingent environment, certain parts of a theory advance while other parts are placed into new contexts, discarded, overlooked, or lost. Practical adequacy therefore does not require every part or element of our knowledge to be relevant in every situation. Instead, it is sufficient to highlight particular features of reality using particular theories with practical purposes in mind. In this regard, we can begin to touch upon the structured and differentiated aspects of reality and gain a greater and more complete picture of the complexity of the world.

A good metaphor for this practical adequacy of theory development is map building for sailing navigation. In this case, a map is not only pragmatic, with the purpose of navigating in mind, but also has to interpret and transpose certain features of the world in understandable knowledge, no matter accurately or not. Notice that such knowledge is highly dependent on our existing language, habit, custom, and thought, manifested in various scales, schemas, keys, images, and legends. In this way, we use diverse methods to access and re-present the multifaceted forms of the world (e.g., material, social, cognitive) indirectly, which will guide our future activities (e.g., sailing). It is further noted that a map does not represent everything and make everything precise. Different maps will point out different features of the world (e.g., island, mainland, wind direction, country) in different ways (e.g., using different drawing methods) with different degrees of accuracy (e.g., using different measuring scales) for different practical purposes (e.g., sailing, geography, and national maps), even when charting the

same context. Although they are fallible, partial, more or less redundant, and detailed, they are all bounded by the world they attempt to represent (ontology), the knowledge they use, the interpretation they endow (epistemology), and the empirical activities/events they attempt to appreciate and guide (practice) (Figure 5).

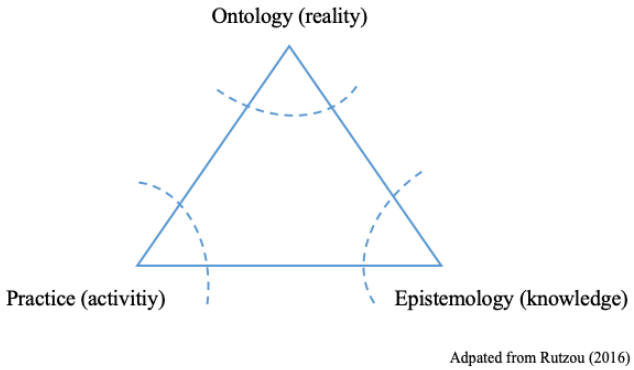


Figure 5. Triple Dialectic between Ontology, Epistemology and Practice

As such, when one of these elements is out of balance — for example, when a map is distorted it is unhelpful for interpreting an action or ceasing to direct an action — the others can be used to investigate and correct the excesses, lacks, and/or defects. Returning to the theory building process, researchers therefore must apply different methodologies and existing theories to investigate more empirical cases to reveal the truth of the world as far as possible. Similarly, when existing knowledge is no longer adequate to explain an activity, researchers must investigate new facts in existing empirical settings that were ignored or lost in proposed hypothetical mechanisms and improve them. Lastly, when existing theory cannot direct an emergent action, researchers must revise existing theory by proposing new hypothetical mechanisms and/or using new methodologies that match with new contexts and re-evaluate the application scope of existing theory and methodologies.

Critical realism in this thesis. Following critical realism, this thesis targets identifying the generative mechanisms as causal structures that generate the complementor's dilemma evolution. These mechanisms are characterised as "one of the processes in a concrete system that makes it what it is — for example, metabolism in cells, interneuronal

connections in brains, work in factories and offices, research in laboratories, and litigation in courts of law" (Bunge 2004, pp. 182). Our research question, about what mechanisms drive growing complementors to navigate the interdependence dilemma process with focal platforms in platform ecosystems, is partially geared towards defining the interdependence dilemma process (See the final process model proposed). I further recognise that the practical adequacy of such causal power is contingent and highly contextualised in a complex interaction of people, social practice, knowledge, and IS technology (Mingers 2001). As the complementor's dilemma is a social phenomenon which is co-shaped by diverse actors in digital ecosystems, the underlying intransitive social structures (i.e., the interdependence structure of digital ecosystems) are self-referential (Mingers 2004) in the sense that they enable social activities/events (e.g., platform scaling strategies and position shifts in ecosystems) and through these activities/events co-shaped by various ecosystem agents are themselves reproduced or retransformed. This confirms the previous argument about the self-referential attribute of digital platform and platform identity. As such, the particular nature of the social world (e.g., generative mechanisms) is a social product and therefore will be shaped by the social conditions of production, localised in both space and time (Bhaskar 1979).

Drawing on Hedström and Swedberg's (1998) work on mechanisms and its application in IS by Henfridsson and Bygstad (2013), we propose that the mechanisms driving the complementor's dilemma process are composites in the sense that they interconnect three types of components. First, the macro-micro mechanism components explain how digital ecosystems enable and constrain interdependency change among ecosystem actors. Second, the action-formation mechanism components explain "how a specific combination of individual desires, beliefs, and action opportunities generate a specific action" (Hedström and Swedberg 1998, pp. 23). In our case, that is how a complementor evaluates how its platform identity is perceived by diverse actors in the ecosystem (e.g., end-users, competitors, and focal actors), leading to identity re-projection. Third, the micro-macro mechanism components explain emergent behaviour — that is, how various actors interact with each other to shape their positions in the

ecosystem and consequently reshape the overall interdependence structure of the ecosystem at the macro level. These three levels of mechanism components produce positive or negative feedback loops beyond a single actor's control, leading to the dynamic complementor's dilemma process. It is further noted that both human agents and material agents (e.g., digital platforms) play active roles at all three levels of mechanism components.

Using the scheme of context-mechanism-outcome (CMO) (Pawson and Tilley 2009) as a basis, we can account for possible configurations of generative mechanisms and relevant context variation that result in a particular interdependency dynamic outcome for a complementor in the ecosystem. Figure 6 illustrates how we apply critical realism in this research through this CMO framework. The enduring, intransitive structures (e.g., resources, practices, relationships, and concepts) of digital platform ecosystems necessarily have specific causal powers and liabilities (generative mechanisms) to actualise certain events/actions over others. These tendencies can be depicted as "interdependency/complementarity dynamics" for a platform business in the ecosystem. However, the actual instantiation of such tendencies into empirical events requires the presence of a given set of contextual conditions (i.e., ecosystem conditions in this research), both social (e.g., competition status) and technical (e.g., technology change). One mechanism may thereby lead to qualitatively different outcomes — such as the raising, maintaining, or dropping of a platform business's position manifested in its scaling state — depending on its actualisation in combination with other mechanisms in different contexts. It is essential to map out the potential causal paths that explain how, in certain contexts, a combination of mechanisms may lead to successful navigation of the complementor's dilemma. However, it should be noted that these causal paths are only conjectural explanations, being the basis of further refinement. To this end, I adopted a process-tracing approach to analyse and theorise the interdependency dynamics in a platform ecosystem. The practical adequacy of the developed theory was then tested through a computational approach. Before explicating this mixed method in

more detail, the following section briefly addresses how critical realism responds to the recent call for a process lens to digital phenomena in the IS discipline.

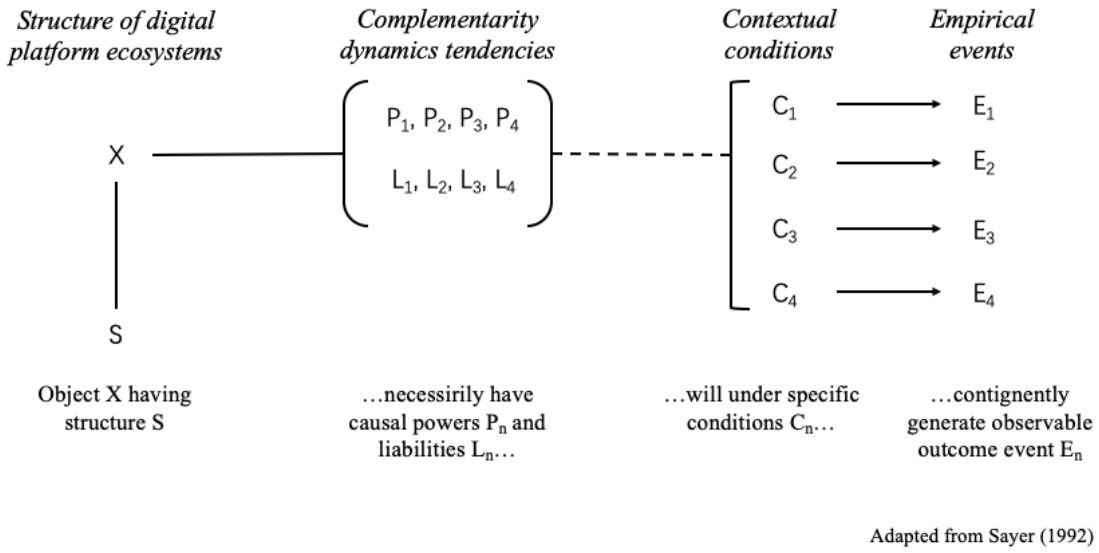


Figure 6. Overview of Context-Mechanism-Outcome Framework

3.1.2 A Process Lens to Digital Phenomena

Recall that pervasive digital technologies are non-excludable and non-rival in use. In this regard, contemporary digital phenomena become increasingly complex, dynamic, open-ended, and widespread, in the sense of being enacted in multiple and ongoing events and activities distributed across diverse and evolving human and material agents over time. As such, it is more appealing in the IS discipline to expand approaches to digital phenomena pragmatically — recognising that they are not only real, but also marked by intricate, contingent, and consecutive interaction effects in observed temporal progressions (e.g., Eaton et al. 2015; Henfridsson and Yoo, 2014; Huang et al. 2017). Central to this process lens is the constitutive role of situated causal stories in producing reality (George and Bennett 2005). At the ontology level, it echoes the self-referential premise of critical realism about social science — it is not just that enacted social structures constitute the ongoing social events/actions, but that the recurrent events/actions also constitute social structures. Specifically, social structures do not exist independently of the sequential events/activities they govern and the agents' conceptions of what they are doing. Instead, they "exist only in their effects and

occurrences" (Mingers 2004, pp. 96), through which they themselves are reproduced in space and time. However, this does not make social reality totally transitive — every time an ordered event or activity flow occurs it becomes intransitive relative to possible perceptions and explanations of it, driven by the existence of generative mechanisms. Therefore, to touch upon these mechanisms, researchers must engage with the sense-making of how those events and activities in the empirical are produced, reinforced, and shifted, and with intended and unintended consequences in focal contexts.

To explicate how a process lens can be combined with the adoption of critical realism in IS research, I now use the digital phenomenon in this thesis — the interdependence structure of platform ecosystems — as an instance. First, the interdependence structure of a platform ecosystem is enacted in an ongoing process. Once a platform ecosystem is established, the complementarity among ecosystem actors is not a fixed or given external state, but an ongoing enactment produced through recurrent interactions among platform businesses that compete and cooperate with each other, adopt different development strategies (e.g., entering, scaling, narrowing, or quitting particular activities in the ecosystem), and take different investment tactics in creating foundation or complementary products/services; ecosystem end-users who redefine the value of a platform business through use recombination, multi-home among different platforms, and voluntarily contribute to platform development through value co-creation; and the wider regulators who monitor, encourage, and punish particular platform businesses or activities in the ecosystem. Over time, this interaction process dynamically affects the positions of platform businesses as focal or non-focal actors, and thereby the interdependence structure of platform ecosystems. Mapping onto the CMO framework, this means that although interdependency structure is an enduring entity of digital platform ecosystems, it is not a once-and-done outcome but an ongoing enactment of interaction courses.

Second, interdependence structure is performed through multiple processes across time and space. Consider that each platform business in the ecosystem has its own interdependency scenario and tensions with other actors. For instance, in the social

networking ecosystem, complementors in the short video sub-market have less intensive competition compared with those in the instant message sub-market. Similarly, a complementor with a disruptive digital innovation may confront higher coopetition tensions with focal actors, triggering different coping trajectories — such as direct competition with focal actors through platform envelopment or alleviation of tension through integrating into the core offerings of focal actors. It is further noted that the interdependency trajectory for an ecosystem actor is contingent on different time periods. While the short video market is a niche market in 2016, it gradually scales up as one of the most competitive battlefields attracting a majority of end-users' and focal actors' attention until 2020. As such, a platform business in this market confronts completely different interdependence structures with distinctive growth episodes over those time windows. Consequently, the overall interdependence structure of platform ecosystems is not a pre-determined abstraction but is constituted differently through distributed, recurrent local processes situated in particular times and spaces. Mapping onto the CMO framework, this means the structure of digital platform ecosystems manifests in diverse empirical events and activities which are contingent on different contextual conditions.

Third, interdependence structure is a nonlinear achievement. Specifically, the enactment of interdependence structure embodies in both intended and unintended processes of value, scaling, and position shift for ecosystem actors. Consider that an offering designed by platform owners is continually re-defined by the end-users through use recombination. The emergent value paths are always outside of the expectations of platform businesses, which inspires new growth trajectories deviating from the current platform projection (e.g., user targeting, platform architecture design). Moreover, the shift of platform position proposed by end-users may be contested by focal actors in the ecosystems, leading to different reactions towards the platform re-projection. This emergent tension between growth ambitions and dependency on focal actors becomes more salient when the proposed growth path threatens their leading position in the ecosystem. It is apparent that such an interdependency dilemma not only occurs at the

local level for single actors but is widespread for all complementors in the ecosystem. As a result, the ongoing uncertainty associated with the interdependence structure continues shaping actors' evolution trajectories, with unpredictable peaks and valleys. Mapping onto the CMO framework, a process lens therefore calls attention to the emergent tensions that break the continuity in the events/activities, within which vital causal powers and liabilities manifest. In our case, that is the interdependence dilemma period confronted by a complementor.

Fourth, interdependence structure is entangled with socio-material processes. Consider that the interdependence structure in platform ecosystems is a social system in which platform businesses operate and within which they need to demonstrate legitimacy. However, such a social entity has no inherent attributes but requires forms, attributes, and forces for the interpenetration with digital technologies (Orlikowski and Scott 2008). This interdependency manifests in a sequence of platform architecture designs done by diverse actors as particular materialisations. For instance, the role of complementors manifests in their path channelling strategy (Henfridsson et al. 2018) by increasingly connecting more boundary resources of other platforms in their architecture design. Further, a specific design portfolio of technological architecture not only enables platform scaling, but also constrains the scaling boundary within certain offerings and markets (e.g., providing distinctive technological capabilities and functionality benefits to user groups, which are hard to modify — at least in the short term). As a result, every time a platform business attempts to shift its position in the ecosystem, the process involves an intertwinement with multiple platform architecture configurations. Similarly, the responses from other actors (e.g., accept or reject the legitimacy of its new position in the ecosystem) also largely manifest in the activities of platform connections (e.g., acquiesce or block boundary resource connections). As such, these ongoing socio-material processes shape the possibilities of what digital ecosystem interdependence structure is enacted and how. Mapping onto the CMO framework, a process lens requires concern for both human and material entities in the intransitive

domain of social world. Accordingly, both human and material agency will drive the complementarity dynamics in platform ecosystems.

3.2 Mixed Methods Research Design

As a realist philosophy, critical realism encourages a pragmatic approach driven by the research questions, objectives and contexts (Minger 2004; Zachariadis et al. 2013). Since platform scaling in digital ecosystems is a socio-technical phenomenon dynamically co-shaped by heterogeneous, evolving human and material agencies, it is necessary to employ different research methods to develop multifaceted insights with both depth and breadth. Specifically, given the limited theoretical foundation for the research inquiry, a qualitative study was conducted first to unearth the underlying mechanisms and processes, which further serve as the building block to inform the second quantitative study and add richness to the overall research. As such, I adopt a sequential combination of quantitative and qualitative methods in data collection, analysis and presentation within a single research inquiry to achieve developmental and corroboration purposes of mixed method research (Venkastesh et al. 2013). First, an exploratory study was used to unpack the constructs and mechanisms of complementor growth in digital ecosystems. Second, the underlying causality between platform identity projection and the interdependency dilemma process in digital ecosystems founded in qualitative study is further confirmed (e.g. boundary conditions) by a quantitative study in larger sample size. In what follows, the two empirical research designs are presented in detail.

3.2.1 A Process-Tracing Method for the Empirical Study One

To use the Context-Mechanism-Outcome framework in empirical studies, researchers are required to do so-called process-tracing analysis-that is, identifying "relevant, verifiable causal stories resting in differing chains of cause-effect relations whose efficacy can be demonstrated independently of those stories" (Tilly 1997, pp.48). Such causal stories depict the process of "which aspects of the initial conditions observed, in conjunction with which simple principles of the many that may be at work, would have combined to generate the observed sequence of events" (Goldstone 1991,

pp. 50). In this regard, the end of the process tracing is theory-oriented to develop and extract the intransitive generative mechanisms from ongoing events and activities, which conforms to both critical realism philosophy and the process lens to digital phenomena. In this part, I shall give a detailed explanation of this research method and how it can be applied in the research of digital phenomena by using the Douyin case as an illustration. Limitation and implication of this method are discussed at the end.

3.2.1.1 Grounding Causal Mechanisms through Process-Tracing

In the last few decades, process-tracing has been well recognized and used widely in the social science. Dating back to 1979, process-tracing method can be defined by its several key attributes. First, process-tracing try to identify the intervening causal process-the causal mechanism and causal chain-of a phenomenon being investigated. Instead of focusing on linear causality that consists of a direct, straightforward chain of events, process-tracing method recognizes the complexity nature of social world, characterized by the causal chains flowing from the convergence of several independent variables to the outcomes. In this case, the interacting causal variables are not independent of each other but linked in particular ways to constitute an explanation of the phenomenon.

In longitudinal case studies, such causal processes can manifest in a sequence of observable events, some of which steer the outcome in particular directions while foreclosing alternative paths in the development. Researcher therefore have to figure out such path dependency in order to construct valid explication for the case, for example by identifying branching points when key decisions are taken by strategy makers within an organization or other stakeholders. These branching points usually match with the time periods interested by process scholars, during which gaps, tensions, contractions or disruptions emerge to break habitual performances, generating problematic liabilities or constructive powers for certain outcomes. It is noted that a decision made at earlier points should not be assumed as decisive for the outcome. Rather, its possibility of occurrence will be further influenced by subsequent branching points. As such, the

causation assessed in process-tracing method is not about recording constant conjunctions of events in positivism, but about “to what extent and how possible outcomes of a case were restricted by the choices made at decision points along the way” (George and Bennett 2005, pp. 252). Consequently, such process-tracing analysis (e.g. decision-making sequence) at individual and organization level can be applied to the explanation of macro-phenomena (e.g. ecosystem-level dynamics).

Second, process-tracing adopts an abductive methodological steps in developing theory. More specifically, it starts from a detailed narrative or story of a phenomenon of interest, presented in a chronicle form which throws light on when and how an event came about. Such atheoretical narratives are necessary for theory building by suggesting the possible, relevant causal processes for later theoretical explanation. This is followed by developing and proposing explicit causal mechanism hypotheses for all intervening steps in a case, which can point out variables that were left out in positivism (e.g. only cares about statistically significant variables). Finally, while strictly controlled comparison in a closed system (e.g. find observations similar in every aspect but one) is not possible in the open, complex social world, causal inferences can still be generated by ruling out alternative explanations and identifying correct mechanisms on the basis of evidence found in a process-tracing procedure.

During this theory building process, process-tracing is noted for its capability to identify alternative outcomes consistent with a particular mechanism, and alternative causal paths that lead to a similar outcome. The former one refers to the multifinality (George and Bennett 2005), indicating that the causal power of a mechanism depends on the activation of other mechanisms in the same context. It supplements large-N statistical analysis when contradictory conclusions are obtained from similar observations. The later one refers to the equifinality (George and Bennett 2005), indicating that multiple mechanisms in different contexts may converge into a particular outcome. It also supplements large-N statistical analysis which is frequently insensitive to potential causal paths without statistical significance. Both contribute to the development of contingent generalizations that figure out the conditions under which

particular mechanism configuration actualizes and generates certain outcomes. As such, process-tracing is consistent with the CMO framework and complements other research methods by providing different causal inferences. In particular, process-tracing is highly useful for gaining an explanation for extreme or deviated cases, within which the outcomes are either unpredicted or unexplained by existing theories. In this thesis, for example, the rapid scaling of complementors and their capability to shift the interdependency structure of a platform ecosystem are contrary to the general observations and theories that take focal platforms' leading position as taken-for-granted. Process-tracing of such cases therefore offer an opportunity to differentiate and enrich existing knowledge about a particular phenomenon.

In addition to theory building, process-tracing is also an effective tool for theory testing. When the causal processes that lead to outcome are sufficiently specified in existing theories, they can generate predictions about what should be observed regarding to the process. In this situation, process-tracing can be used to assess whether the empirical evidence among variables matches with the prediction indicated by the theories. Specifically, process testing is able to "proceed forward, from potential causes to effects; backward, from effects to their possible causes; or both" (George and Bennett 2005, pp. 259). At the same time, process-tracing reminds researchers to consider the possible alternative hypothesized processes that are out of interest but still generate same outcome in question. Since there are always potential effects in intransitive real domain that go beyond of us and does not leave observable signature, it can be notoriously difficult to prove that a particular process did not occur in a case. In this regard, scholars may easily fall into a trap of type II error-that is, a causal process that leaded to the outcome but derived from other theories is not captured in a study. Similarly, alternative theories may complement with the hypotheses in interest, consistent with the same process-tracing evidence. In this regard, focusing too much on verifying single well-specified theory may overstate its causal weight and theory testing must ordinarily involve the attempts to test and eliminate/supplement alternative theories which generate the same outcome. When available theories were not

sufficiently developed to be able to specify the causal processes, process-tracing of cases relevant to the theories then can further contribute to theory development by ascertaining their underlying causal paths.

It is further noted that process-tracing is compelling not only for multiple case studies but also for single case study, both of which can generate strongly valid causal linkages in theory development and testing. This is mainly because that one case does not limit to single outcome but may actually contain multiple potential observations. As such, a theory can be "derived or modified based on the evidence within a case, and still be tested against *new facts* or *new evidence* within the same case, as well as against other cases" (George and Bennett 2005, pp. 260). When a new theory developed from one observation predicts some unique evidence which would be highly unexpected in the absence of the theory, the corroboration of this evidence in other observations within the same case will offer a strong causal inference for the theory. Thus, process-tracing has the capability for excluding some or even all explanations but one, for example, if a causal chain evidence predicted by that explanation would be unlikely or even impossible for some or all other theories. Such causal power confirmation is not based on the logic of sample size but heuristically derived within single cases following Bayesian logic. As for measurement error, process-tracing can intensively examine some variables across multiple qualitative dimensions within single cases instead of having to abstract and quantify variables applicable across cases. By intensively analyzing single or extreme cases, process-tracing may identify potential omitted variables that existing theories fail to explain in their most-likely cases.

3.2.1.2 Research Setting

To apply the process-tracing method, I conducted an in-depth, embedded case study (Gerring 2007; Scholz and Tietje 2002) of a Chinese short video platform called Douyin (also known as TikTok outside of China) from its inception as a complement in 2016 to its establishment as focal actor in 2018. Douyin has ranked as top 2 short video platforms in China at the end of this study, with daily active users over 250 million and

a yearly turnover of 20 billion RMB. Despite its short existence, Douyin has been recognized for its outstanding scaling process, starting as a niche complementor in social networking market and becoming a peer platform relative to the focal actors, WeChat and Weibo, in 2018. The case of Douyin is embedded in the social networking ecosystem in China since the position shift was largely co-shaped by diverse ecosystem actors (i.e. users, focal actors, competitors, non-focal actors) besides its endogenous endeavor.

The case study is noted as a research strategy to understand a dynamic phenomenon in single settings (Yin 2017). Grounded in abundant digital-traced data, I use embedded case study method to build theory inductively for two reasons. First, there is a lack of theory explaining the phenomenon that I studied. While current researches introduced multiple platform governance strategies available for focal actors to manage the ecosystem dynamics during scaling, little is known about how non-focal actors in the ecosystem navigate their continuing interdependence tensions with focal actors over time in order for scaling. Existing literature introduces platform identity as a mean to understand the complemetors' dilemma process, which provides a chance to develop new theory inductively. Second, the phenomenon in question is sequential and dynamic in nature. In the single case study design, there is more than one observation on the dilemma process during Douyin growth-that is, multiple dilemma transitions during scaling are transparently observable, making it possible to derive an emergent theory that is based on the evidence within a case and still testable through repeated verification against new facts/evidences across subunits within the same case. In this regard, the case study research further enhances the strength of theory as it often brings novel insights in coherent logic, which is likely to be empirically valid (Eisenhardt 1989). For this, I adopted process-tracing (George and Bennett 2005) to develop understanding of the causal mechanisms that lead to particular outcomes in the case context, and to help theorize the complementors' dilemma process in question.

Douyin was selected as an extreme case (Yin 2017) for a number of reasons. Fundamentally, due to the lack of existing theories, the core selection criterion for this

study is based on theoretical sampling instead of random sampling in the sense that the case is chosen for theoretical rather than statistical reasons. In particular, extreme case is argued to be highly useful for such theory generation since ideal or extreme types typically define theoretical concepts (Gerring 2007). Second, the development of Douyin was considered as an exemplar from a niche complementor to a focal actor in ecosystems: it scales up the monthly user base to 200 million and monthly average use time to 16 hours just within two years. Such unprecedented scaling was achieved after experiencing a series of trade-off among multiple promising interdependence scenarios vis-a-vis the focal platforms. It therefore has the potential for providing ample and transparent themes of complementors' dilemma process to study. Third, abundant retrospective archive data could be generated based on the popularity and high profile of the company, which allows for an in-depth empirical analysis. Within the Douyin case, I study the projection and shift of platform identity during complementor scaling.

3.2.1.3 Data Collection

I followed the best practice of Vaast et al. (2017) in developing an extensive research database to unfold Douyin's innovation journey within the broader context of the social networking ecosystem in China. The primary source of data was publicly available archival sources on Douyin, which prior research has shown to be formidable for analyzing longitudinal dynamics in platform ecosystems (Eaton et al. 2015; Ghazawneh and Henfridsson 2013; Karhu et al. 2018). Because all archival records had timestamps and went back as far as the birth of the short-form video market in China in 2013, I could trace in detail the growth trajectory of Douyin in and the other actors in the social networking platform ecosystem. By identifying and locating key ecosystem stakeholders, I was sensitized to their activities, related events, antecedents, and impacts in the study of Douyin's growth. This wide contextualized view would have been impossible if I had considered only Douyin's internal stakeholders.

Table 3 summarizes the five types of data sources including a app statistics platform, Douyin website archive, interviews, public speaking and presentation, and

published articles and blogs. First, I used an app statistics platform in China called Analysys to collect platform evolution data of all 40 main actors in the short video market between 2014 and 2019. Analysys acquires user data and does independent data mining through the cooperation with more than 1200 mobile internet firms and institutions. This data source hosts panel data (daily, weekly, and monthly) for 55 variables (i.e., active user base, average use time per user, average open frequency per user, user retention rate, active user overlap between two platforms, user portrait) which were further confirmed with other three similar app statistics platforms. For the purposes of this research, I primarily used the data to describe the relationship between user acquisition and user engagement visually. The data also corroborated with the findings generated from the qualitative data sources.

Second, the Douyin website and internet archives were another important data source that allow us to make sense of the key growth events identified by insider members of Douyin. Specifically, I identified, transcribed, and translated 23 long-text growth biographies and 65 brief reports published by Douyin to facilitate such examination.

Third, I collected 75 interviews with executives and employees of Douyin, its parent company Bytedance, and external stakeholders (e.g. content creators and consumers, investors, cooperators, competitors, consultants) in the social networking ecosystem. Conducted by journalists between 2014 and 2020, I systematically collected, transcribed, and translated these interviews to help us tracing how different actors within and outside Douyin understood its growth trajectory over time. Consistent with the principle of multiple interpretations (Klein and Myers 1999), this data source offered different narratives on the trajectory of Douyin from actors in the wider social networking ecosystem.

Fourth, I recorded and translated 31 public speaking and presentation made by the executives at Douyin and ByteDance between 2014 and 2020. In doing so, I was able to analyze how prominent actors would like outsiders to perceive and see the firm. Such communication to external audience in respect of its key value, practice, and strategies

provides a new perspective of understanding Douyin's identity projection and growth trajectory.

Finally, this study included a significant volume of published articles, blog posts, and technical reports with regard to Douyin, the social networking ecosystem, and the overall mobile internet market in China in the time span of 2013 to 2020. This data source helped corroborating the growth trajectory emerging from my analysis of the other sources, helping to create a richer understanding of the Douyin's evolution in the social networking ecosystem.

In short, my qualitative data and quantitative evidence combine to create a high quality, relevant and flexible information source. The dataset contains 2200 app statistics and 1414 archive entries that trace and visualize the events and actions taken by key actors during Douyin's growth. It enables rapid access, search, filtering, threading (Bar-Ilan 2005), and cross-checking of the data.

Table 3. Data Collection

Data sources	**Details**
App statistics at third-party app statistics platform (N=2200)	• Platform evolution data of all 40 main actors in the short video market between 2014 and 2019. Panel data of 55 variables including daily/weekly/monthly user base, daily/weekly/monthly use time and open times, monthly user retention rate, monthly user overlap, monthly user portrait (age, city, gender, consuming power distribution), app comments; industry-level average data in terms of user base, use time, open times and app numbers from 2014 to 2019 accessed from Analysys, Sensor Tower, iResearch, and App Annie
Douyin website and internet archives (N=88)	Tracing of key events: • 23 Douyin growth history reported by Bytedance official account, interior emails/speech by CEO, content algorithm books recommended by Bytedance executives • 65 Douyin news releases and update history in terms of logo, icon, slogan, claims, platform value, platform design (from founding to 2019) accessed from Qimai, Chandashi, App Annie etc.
Interviews (N=75)	• 11 video files or transcripts of interviews (ranging from 3 to 51 minutes and conducted between the period 2014-2020) of Douyin and ByteDance executives and industry analysts conducted by journalists (e.g., CCTV, Phoenix Technology,

	and China Entrepreneurs) • 26 video files or transcripts of interview (ranging from 3 to 20 minutes and conducted between 2016-2019) of Douyin content creators and users, Multi-Channel Network (MCN) organizations and investors conducted by journalists (e.g., Netease, Tencent, IQIYI, Dialogue, Bianews) • 38 interviews of Douyin, Taobao, Tencent, Weibo, and other competitors (e.g. Miaopai, Meipai, Kuaishou) executives, investors, employees published in news articles by the business press, trade press and online blogs (e.g., 36Kr, Sina news, Huxu, Character, China Entrepreneur, TMTPOST, Tencent)
Public speaking and presentation (N=31)	• 31 video files or transcripts of public speaking and presentation (ranging from 3 to 35 minutes and conducted between the period 2014-2020) of Douyin and ByteDance executives and industry analysts (e.g. Douyin Creator Conference, Douyin brand conference, Toutiao Creator Conference, Ocean Engine Conference
Published articles, blog posts and technical reports (N=1220)	• 1185 Articles and comments/commentaries published in the business/trade press and online blogs between 2013 and 2019, accessed from 36Kr and Huxu, and through extensive Baidu/Google searches • 35 Third-party China mobile internet industry analysts' reports and surveys on Douyin and short video/ social networking/ e-business/ entertainment/ game/ mobile internet markets published between 2016 and 2019 (e.g. QuestMobile, Qianfan.analysys.cn, URORA, TalkingData, iResearch, and Tencent Research)

3.2.1.4 Data Analysis

This study attempts to contribute to the process-tracing by explicitly explaining how this method can be applied in single case study. While process-tracing in multiple case studies have been well-established in social science, its benefit and application in single case still relatively stay at abstraction level without detailed instructions. This is particularly important for IS research since abundant, complex and multifaceted digital-traced data generated from digital phenomena make it possible and necessary to adopt process-tracing analysis based on single cases. Single cases in this condition include ongoing, recurring, diverse local enactments performed by various actors in multiple space and time which enable to build theory with strong causal inference. It is only through tracing and analyzing these situated process data that I can capture and

understand the complete picture of a digital phenomenon, and further produce contingent generalizations of theories. Thus, using the Douyin case as an instance, I shall represent an iterative, grounded, four-step process to derive process theory based on process-tracing of single case study.

Mapping platform growth trajectory. First, I mapped the growth rate of the monthly user base and monthly user engagement level over time (See Appendix 2.1) to examine the growth trajectory of Douyin between September 2016 and September 2018 (Table 4). Following the literature and using the metrics available in the dataset, I measured user base by the number of users who actively open the Douyin app at least once monthly. User engagement is measured by two indexes: the monthly average frequency of opening Douyin app per user and the monthly average time of using Douyin app per user. In addition to these main indexes that capture digital venture evolution over time, I also trace other indexes (e.g., user portrait, user retention rate, user overlap between apps) to facilitate the understanding of Douyin's strategy decisions and their ecosystem influence; I explain these indexes in the Findings section. I crosschecked the indexes with other third-party app statistics platforms.

Table 4. Step1: Examine the Growth of Douyin

Tasks	Outputs
Select the metrics to measure user base and user engagement for Douyin.	Measure of monthly active user base, monthly average frequency of opening Douyin per user, monthly average time of using Douyin per user, and their growth rate (Appendix 2.1)
Map the user base, user engagement and their growth rate to construct the development of Douyin over 2 years.	
Cross-check the user base, user engagement and their growth rate and slow-downs with other third-party app statistics platforms.	

Constructing case timeline. Second, I focused on the identification of key events in the growth of Douyin (see Table 5). I followed Van de Ven (1992) and Van de Ven and Poole (1995) who described development (growth in this case) as a progression of subsequent events that are marked by empirically observed changes in the form, quality, or state of

an entity. From the earliest interaction with data, we identified all available strategic activities and events that may have influence on the growth of Douyin over the two years, including both Douyin designers and other related ecosystem actors (i.e. users, focal platforms and competitors). (See Appendix 2.2) This activity timeline was further used to guide my open coding (Strauss and Corbin 1998). We concentrate on identifying the antecedents triggering a specific strategic action, its occurrence time and relevant interpretation, the main features, its contribution to the user base and (or) user engagement, and the consequential outcomes at organization and ecosystem level. All emergent codes are further triangulated across the different data sources.

We then visualize the event chronology in graphic form (Langley 1999) since it allows the simultaneous representation of a large number of dimensions of the process data, including event ordering, parallel tracks across different entities and their mutual effect over a passage of time. (See Appendix 2.3) In particular, we trace and identify the key decisions or activities taken by Douyin that foreclose certain growth paths in the development and steer the complementarity outcome in other directions over time (George and Bennett 2005). For example, the strategic activities of Douyin after May 2017 followed totally different logic comparing with the earlier time period, by expanding its target users and redefining its core offerings at platform. As such, Douyin was no longer developing as a complementor in niche market, but promoted its position in larger sub-market. These branching points therefore disrupt the continuity among linked strategic activities done by Douyin and are therefore referred as the criteria to decompose the Douyin evolution timeline into three successive adjacent periods: Douyin as performing short video community for the young; Douyin as entertainment short video community; Douyin as short video social platform.

These growth periods further enable the explicit examination of how Douyin was initially perceived in social networking ecosystem, which shapes its position projection vis-à-vis the focal actors embedded in its strategic activity pattern, and how these patterns evolved and further shaped the perception of ecosystem actors towards the role of Douyin. This, in turn, became the point of departure for the next step of bracketing of

Douyin's interdependency structure phase. Applying this bracketing strategy (Langley 1999), we make sense of the Douyin evolution process as three discrete but connected interdependency dilemma blocks/episodes-that is, niche complement vs. main complement; independence vs. dependence; competition vs. integration, separated by discontinuities in platform positioning. (Figure 8) Combining these emerging findings with the growth trajectory in Appendix 2.1, we employ non-theoretical terms specific to the case to construct a case storyline which depicts explicit causal chains of complementor growth in the ecosystem, especially the interaction process among ecosystem actors with regard to its position shift.

Table 5. Step 2: Construct Case Timeline

Tasks	Outputs
Identify specific activities made by Douyin designers and other related parties over the two-year period, which may have influence on Douyin development.	86 strategic activities/events (Appendix 2.2)
Identify each activity's antecedents, occurrence time, relevant interpretation, main features, contributions towards user base and (or) user engagement, and outcomes through open coding (Strauss and Corbin, 1998), which are further visualized as graphic form.	Douyin evolution process flowchart decomposed into three successive periods (Appendix 2.3)
Construct the process phases of Douyin growth from September 2016 to September 2018 through process-tracing (George and Bennett, 2005) and bracketing strategy (Langley 1999), which permit the constitution of comparative units of analysis for the further exploration and replication of theoretical ideas.	Case timeline with three interdependency dilemma blocks/episodes (Figure 8)
Enhance reliability and trustworthiness of open coding by triangulation of evidence.	

Identifying mechanisms that shape complementor's process. Third, in identifying the mechanisms to shape the interdependency dilemma process, the three case episodes were employed as analytical filters to furrow and categorize constructs (see Table 6). We use the most frequent and significant earlier codes to sift through the activities and events during Douyin growth. This coding process is iterative and emergent in the sense that some codes (i.e. user seeding) will unveil or illuminate implicit codes in other activities and events (i.e. campaign operation, user monetization, function optimization), which

requires to continually compare data to data and data to codes. In this way, single and well-defined constructs are converged from accumulating descriptive codes from diverse data sources. We then further sharpened the constructs by constantly comparing them with textual evidence and relevant literature. The key target at this stage is to further abstract their attributes and empirical substance by clustering and distinguishing them from each other. Three mechanisms stand out from this analysis and are labeled in terms of their characteristics as *identity projection, identity deviation, and identity evaluation* (as shown later in Table 13-15).

Table 6. Step 3: Identify Mechanisms that Shape the Complementor's Dilemma

Tasks	Outputs
Filter and categorize constructs by using the most significant and frequent earlier codes in three case episodes, querying: Do they make the most analytic sense to categorize the data incisively and completely?	3 mechanisms shaping interdependency dilemma process (Table 12-14)
Further abstract emerging constructs which derive mechanisms, and sensitize the emergent findings in light of case evidence and relevant literature.	
Consider how these mechanisms are related to, yet different from, each other, and how they relate to user base scaling and(or) user engagement growth, querying: are the three mechanisms distinctive according to conceptual and empirical dimensions? How are they related to each other? How do they relate to user base scaling and(or) user engagement growth?	
Derive the three mechanisms and each mechanism's relevant components.	
Enhance reliability and trustworthiness by establishing theoretical saturation.	

Generate model of complementor growth. The fourth stage (see Table 7) of analysis was to specify and conceptualize the possible relationships between mechanisms developed before, which were indicated by the earlier substantive analysis and therefore highly fitted to the data. For instance, the relationship between identity projection and identity deviation are enlightened by the codes "emerge", "unpredicted" and "self-driven".

Following this logic, we were able to identify the interplay among the mechanisms, their contextual enabler/constraint and consequence towards platform growth throughout the three case episodes. The outcome of this stage helps us tell an analytic story with coherence in explicit theoretical forms and finally generate a conceptual model of complementor growth, including all three level of mechanism components explained before. This process model further defines the complementor's dilemma as a process to continuously balance the growth ambitions and the dependency on focal actors in the ecosystem and thereby echoes with the definition of generative mechanisms proposed by Bunge (2004).

Table 7. Step 4: Generate Model of Complementor Growth

Tasks	Outputs
Generate conceptual relationships among the mechanisms and how they recursively work together to influence the growth of Douyin over the three case episodes, building on the finding emerging from Stage 3	Process model of Douyin growth (Figure 9)
Iteratively compare the emerging conceptual model with the case evidence and current literature on platform identity, complementarity in platform ecosystem and platform growth, querying: Is the conceptual model able to capture the unfolding of complementary platform growth at Douyin? Have these mechanisms been conceptualized by existing literature?	
Compare the newly generated complementor growth model with literature related to platform identity, complementarity in platform ecosystem and platform growth.	
Further enhance trustworthiness and reliability of findings by applying and matching the model with current growth of Douyin in 2019 and 2020.	

3.2.1.5 Limitations and Implications of Process-Tracing Method

Process-tracing method is not without limitation. First, process-tracing relies on an uninterrupted causal chain connecting the putative causes to the observed effects to develop a strong causal inference. As I mentioned before, all the intervening steps in a case have to be explained and predicted with hypothetical mechanisms. In practical

applications, this is both a strength (e.g. provide alternative way to make causal inferences) and constrain of process-tracing, particularly due to the ubiquitous gap between actualized events in the real domain and the ones that scholars can observe or perceive empirically. Although unobtainable evidence at a certain step of a supposed causal chain do not necessarily invalidate the use of process-tracing and its causal inference, there will be a serious dilution for its explanatory value.

In theory building, data at certain steps may be inaccessible or unavailable. In this situation, process-tracing can only reach provisional conclusions. Although this is not contrary to critical realism philosophy in the sense that all mechanisms developed from our knowledge are hypothetical without the necessity to exist in fact, it may be at a disadvantage when comparing with alternative theories developed from other methodologies. In theory testing, existing theories may not be well-specified for each step of a causal process, or process-tracing evidence is incomplete to assess the prediction of competing theories. In both situations, process-tracing is incompetent to achieve judgmental rationality by making firm conclusion on which theory fits better.

Second, even if each step of a causal path is observable, there may be more than one hypothetical causal mechanisms that are consistent with the given set of evidence in process-tracing. Scholars then confront another challenge to ensure judgmental rationality through assessing whether alternative explanations are complementary and eliminating the spurious ones. However, even though process-tracing may not be able to ensure absolute judgmental rationality by excluding all but one explanation in cases, it is still possible to exclude at least some explanations and thereby draw inferences that are useful for both theory testing and theory development.

I note that these two main constrains become more prominent in IS research, particularly due to the complex digital phenomena of the interest. In order to solve those problems, George and Bennett (2005) provided several useful suggestions such as careful attention to identifying all the alternative hypothesis in single case study; identifying additional testable and observable implications of competing interpretations of a single case; comparing various case studies of the same events that employ

different theoretical perspectives, and identifying the scope conditions for explanations of a case or category of cases. In addition to those advices specific to process-tracing method, different methodologies should be encouraged in research design to enhance causal inferences. Specifically, case comparisons through statistical analysis can be highly complementary to within-case methods such as process-tracing. While the later one establishes causal mechanisms component—independent stable factors that under certain conditions link causes to effects—of causal explanation, the former one is superior at building causal weight/effect component—the changes in outcome variables brought about by changes in the value of one independent variable—of causal explanation. Both are equally important for a causal theory. I shall apply the statistical methodology in studying the same phenomenon related to platform scaling in digital ecosystems in the second empirical study as following.

3.2.2 A Computational Approach for the Empirical Study Two

To compensate for the limitation of process-tracing method in theory generalization and further enhance the developed casual inferences, I shall apply the computational method in researching the same phenomenon related to complementor's dilemma in digital ecosystems in the second empirical study as following.

3.2.2.1 A Computational Approach to Complement Process-Tracing Analysis

In the empirical study one, I presented that process-tracing approach is particularly advanced in theory building in terms of casual mechanisms but relatively inferior in theory generalization. Specifically, as I choose extreme case Douyin to identify theoretical concepts in less well-defined domain, it is lack of representativeness of diverse populations. Instead of a limitation, this case selection method should be regarded as a trade-off between obtaining theoretical parsimony and establishing explanatory richness (George and Bennett 2005). As my purpose is to identify the conditions that an outcome occurs, the mechanisms through which it occurs, rather than how often the conditions and their outcomes arise, the case is necessarily to sacrifice

parsimony and wide application of theories for a high degree of explanatory richness within a type of contingent cases. During this process, case studies lead to identification of new variables or the refinement of concepts. As shown in Douyin's case, the concept of "identity" is extended from traditional organization context to digital ecosystem context, and proved to be vital to navigate the complementor's dilemma process in platform businesses, leading to complementor scaling. While the scaling process and underlying mechanisms may be specific to the particular ecosystem and time nodes, they provide new thinking on the way to facilitate platform development through various identity projection tactics.

More generally, single case study based on process-tracing are much stronger at identifying the scope conditions of theories (e.g. whether and how a variable is causally necessary or sufficient in particular cases?) than estimating the general causal weight/effect across different cases (e.g. how much a variable mattered across cases?). It is noted that whether a factor is necessary to the outcome in a case may not relate or contribute to its magnitude of the outcome (George and Bennett 2005). For instance, in Douyin's case, the specific identity projection tactic made by platform owners are necessary to materialize position shift and scaling in ecosystems, but it may not contribute as much as the resources (e.g. platform portfolio) and capability (e.g. AI-driven interaction) owned by the platform that preceded it. As a result, I require other approaches to further explore whether these identified variables and concepts are relevant to larger population of cases. This corresponds to the methodological pluralism (Mingers 2001) suggested by critical realism in the sense that real world is ontologically stratified and different paradigms each focus on different aspect of this situation. As such, it is necessary to combine multiple methods to gain full richness of the real world.

In particular, the abundant and increasingly pervasive digital trace data available now provide unlimited opportunities for a computationally-intensive research method (DiMaggio 2015; Lazer et al. 2009). As mentioned before, trace data refers to digital records of activities and events that are enabled by digital technologies. IS researchers have been analyzing trace data for decades such as email, transaction data, documents

from organization systems. Nowadays, digital trace data is no longer bounded within the organization systems, but increasingly spread across time and space. Given the wide adoption of ERP, content management system and other advanced productivity applications, most businesses now leave some trace data such as log file and document trails. The further popularization of digital infrastructures (e.g. 4G, mobile phone, sensor and tracing technologies, IOT) in the society dramatically increase the number and breadth of digital trace data. In the end, researchers can generate more accurate and richer insights of social life through direct computational approach to the abundant trace data, particularly in the form of novel visualization and pattern identification (Lazer et al., 2009).

Generally speaking, computational approach aims to extract patterns from data and learn higher-level models and representations (Glymour et al. 1996). Extant research has proved its efficiency in diverse fields such as econometrics, statistics and data mining (Varian 2014). The process of conducting computational data analysis can be summarized into the following four steps (Berente et al. 2019). At the first step, researchers choose a sample dataset for the phenomena of interest and have to justify why this dataset, both of which are the key of problem formulation. To be able to investigate the problem as great detail as possible, the data collection process should maintain the original perplexity existed in the raw sample (Venturini 2010). Digital trace data, in this context, highly match with this requirement since they are "found" data without the need to be constructed in specific data collection instruments like interview or survey protocol. Instead, researcher automate this process through programming language like R and Python to access and craw diverse data sources (e.g. website, database, mobile app). As such, digital trace data keep away from potential manual simplification in terms of the variety and complexity of patterns underlying the raw data.

Second, a taxonomy of concepts from observations is generated. Since the raw data are usually multifaceted and collected from different sources, they have to be firstly sorted into different units such as update history, official website, tweets, transaction

logs, third-party statistic platforms. In simple words, researchers have to consider which data slices should be added and analyzed. Subsequently, the data have to be coded into meaningful fractions based on one or more lexicons which provide ready-made constructs and statements of relationship shared by a community of researchers (Habermas 2003). In other words, they are the "pre-theoretic" grammar in literature, which could be built upon and extended for data sense-making and further theoretical contribution.

Third, quantitative or qualitative relationships and associations among concepts of the taxonomy could be identified with various data exploration techniques such as statistical regression and natural language processing (Chang et al. 2013). Once such relationship emerges from the third step, it will be further conceptualized based on pre-theoretic and theoretic understanding of existing lexicons in the relevant fields. In the end, insights and theory are developed from the computational analysis. All in all, the computational approach is automated rather than automatic. Intensive human interaction is vital in all stages (Gaber 2010). In particular, concepts are organized around people's knowledge, framing and theories about the world. As such, the computational approach "is not intended to supplant the role of the researcher, but to amplify it" (Glymour 2004, pp. 77).

To apply the computational approach in my research inquiry, I initiate a project to test and generalize the research findings in the whole social networking ecosystem in China. Specifically, given the vital role of platform identity in navigating non-focal actor development in digital ecosystems, I target at identifying potential identity projection strategies that could be applied to various non-focal platform businesses. Building upon the mechanisms figured in empirical study one, we developed a specific natural language processing (NLP) procedure to guide platform identity research in a computational approach. I now represent the full procedure in the following sub-sections.

3.2.2.2 Research Setting

To generalize the findings at Douyin properly, I deliberately focus attention on the mobile app market in China, in particular those app developers similar to Douyin in the social networking ecosystem within the same time period. In this way, I aim to test whether the identity projection mechanisms on solving the complementor's dilemma can be applied to other non-focal actors in digital ecosystems. Starting from the early twenty-first century, China' mobile app market experienced a high-growth period with the popularization of 3G and 4G infrastructure. After the total mobile internet users grew to more than 500 millions in 2014, China Internet Network Information Centre (CNNIC) reported a slowdown of the yearly growth rate for the first time, following by an on-going decline to less than 10% until 2019. This early saturation trend of market further manifested in the dominant position of platform giants including Tencent, Alibaba, Baidu and Sina. Controlling about 80% of the user base and app use time in the market, the four giants developed all-embracing platform ecosystems with unmatched competition barriers.

As the market became stable and concentrated on a few platform giants, more emerging and existing actors experience survival pressure and are forced to exploit momentum across sub-markets. In particular, by combining social computing features in core value interaction, these non-focal actors could further leverage the value creation and capture capabilities at apps in terms of user engagement, retention and monetization (Hu et al. 2015; Kapoor et al. 2018; Oestreicher-Singer and Zalmanson 2013) which lead to a sustainable competitive position in the matured market. As such, most app developers in the social networking ecosystem confront similar complementor's dilemma relative to Douyin: on the one hand, they have to go beyond the taken-for-granted, already-legitimated position in the ecosystem for survival. On the other hand, such development still requires consistent endorsement of focal platforms who set the existing interdependency structure of the ecosystem. Typical examples include Pinduoduo which combines e-commerce with social network (Zhu et al. 2019), Douyin

which combines short video with social network (Liu et al. 2018), and NetEase Cloud music which combines music content with social community (Oestreicher-Singer and Zalmanson 2013). These apps share similar ecosystem context with Douyin—that is, they are all non-focal actors in the social networking ecosystem dominated by Tencent and Weibo. Given the increasing diversity and universality of apps that took cross-ecosystem participation in this social networking ecosystem from 2014, I further conform it as the focal context of following data collection and analysis.

3.2.2.3 Data Collection

In the first step, I screened the apps at apple's iOS store in China between Jan 2014 and July 2019 from a third-party app statistic platform Analysys. I omitted long-tail apps that were not counted by Analysys due to their short life cycle less than one month and unstable monthly user base lower than ten thousand over the life cycle. I then identified all listed apps that include at least one social functionality in their update history as the participants in the social networking ecosystem. The final dataset includes 1949 apps across different categories at iOS store.

In the second step, I traced the apps' identity (re)projection activities during the 67 months. In order to maintain the original perplexity existed in the raw data sample, the dataset covers multiple data dimensions (e.g. app update log, monthly user base, app ranking, app rating, user comment, developer information) from diverse sources (e.g. iOS store, official website of app, third-party app tracing platforms, third-party analysis reports) through web crawler. However, due to the multifaceted nature of such digital traced data, I have to decide meaningful data slices I want to code based on appropriate lexicons. To this end, I refer to extant platform and identity literature discussed before and findings derived from the inductive case study in chapter four. In particular, platform identity manifests in both platform architecture and platform scope (Cennamo 2021) which are further refined into the identity projection mechanism in Douyin's case, consisting of platform architecture design, user targeting and user seeding. They help a platform business to communicate its position vision with ecosystem members

(e.g. end-users, focal platforms, other non-focal actors), and therefore are vital to the legitimacy acquirement during cross-ecosystem participation. As such, I take apps' update history log and category shift since establishment in iOS store as the main focus of data analysis. In addition, other relevant data dimensions that may influence the survival of platform businesses are also identified based on extant literature, such as network effects (Li and Agarwal 2017), portfolio effects (Boudreau 2012; Claussen et al. 2013), app quality (Lee and Raghu 2014), competitive position (Derfus et al. 2008; Giachetti et al. 2017).

In the third step, I identified specific identity projection strategies expressed in the selected data slices. Building upon the three hypotheses developed from literature review and empirical study one, I classified each app update record into one or more categories based on following labels: social function update *(S)*, non-social function update *(NS)*, function maintenance *(M)* and API connection *(C)*. I did this classification based on the fact that social functionalities are the core interaction (c.f. Parker et al. 2016) shared among the apps in the social networking ecosystem. Hence, social function update implies architecture assimilation that facilitate an app to be consistent to the membership of broad groups of similar apps in the ecosystem. By analogy, non-social function update implies the architecture dissimilation that differentiate an app from the exemplars in the ecosystem. Function maintenance directly links with the optimization and reinforcement of existing architecture design and therefore should be recorded separately as architecture maintenance. For API connection, I focus on figuring out the linkage with focal platforms in the ecosystem as explained in H1(a).

I did this text categorization task through semi-supervised learning based on BERT model (Devlin et al. 2018) (see Figure 7). Designed by Google, BERT is a pre-trained language modeling. Taking advantage of deep neutral network structure, it captures the common features of a language through unsupervised training from mass unlabeled texts. As a result, the pre-trained BERT model can be fine-tuned to a wide range of natural language processing tasks without substantial task-specific architecture modifications. BERT is a simple and powerful language modeling which had even

surpassed human performance in many text classification tasks. Since Google already opened the BERT model to the public, I can easily invoke the code and do fine-tuning based on the current text sample. In particular, I adopted an advanced pre-trained Chinese BERT model based on Whole Word Masking technique (BERT-wwm-ext) published by Harbin Institute of Technology in China. Beyond the initial training data source from Chinese Wikipedia (0.4B in total word count), BERT-wwm-ext further trained the model in other data such as encyclopedia, news, and question answering (5.4B in total word count). In general, the BERT-wwm-ext model accuracy in text classification task reached over 95% which is about 1% higher than the original BERT model[2].

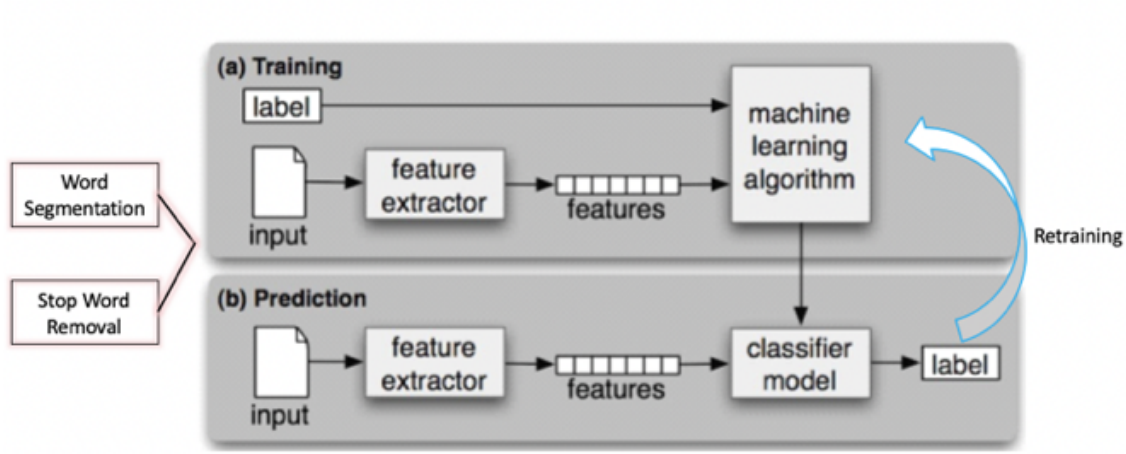


Figure 7. Text Classification Procedure

To apply BERT model in my research, I followed the steps in Figure 7. Although BERT model does not require for word segmentation, I added this step to manually mark some specialized vocabulary that may not be figured out by BERT such as API connection and specific focal platform names (e.g. Tencent, Weibo). In this way, I fine-tuned the model to better fit the dataset. Similar logic applies for specialized stop words in app update log (see Table 8).

Table 8. Sample Specialized Word Segmentation and Stop Word

Specialized Word Segmentation	Specialized Stop Word

[2] For more detail, please check github.com/ymcui/Chinese-BERT-wwm/blob/master/README_EN.md

微信, QQ, 微博, QQ 空间, 腾讯微博, 人人, 陌陌, 旺信, 易信, Facebook, Twitter, 飞信, 豆瓣小组, 知乎, SKOUT, 翼聊, 比邻, 百度贴吧	1-10, 【, 】, #, 《, 》, *, ~, “, ”, …, ……, (￣▽￣)”, ╮(￣▽￣)╭, ￣ω￣=, ^, >, <, ◇, ✔, ×

In the next step, I randomly selected 10% apps to label their update history manually which constitutes my initial training set to predict the remaining dataset. In particular, this research is a multi-label classification task in the sense that each app update log may belong to one or more labels (or features in Figure 7) mentioned before. As an example, the update content “add new function related to theme travel; add sharing function among users; repair several BUGs” relates to three labels including S, NS and M. To achieve this target, I train four binary classification model for each label. Table 9 explained the sample classification code I use. The first row represents the labels I use. The first column represents the sample app update logs. For each text, I classified four times in terms of each label where 1 represent ‘Yes’ and 0 represents ‘No’. The four labels would then be trained separately with independent algorithm model. I list the typical coding criteria and words for labeling in Table 10.

Table 9. Sample Text Classification Codes

X \ Y	S	NS	M	C
x1	0	1	1	0
x2	1	0	0	0
x3	0	1	0	0

Table 10. Sample Text Labeling Codes

Label	Overall Criteria	Sample Codes
Social function update (S)	Function directly contributes to user interaction, content sharing, or content community	Chat; topic; message; friend; emoji; @; sharing; record; group document; friend circle; video call; nearby; face-to-face; dating; contacts; reply
Non-social function update (NS)	Function does not contribute to user interaction, content sharing, or content	Map; trip; health; game; music; dance; wallet; interface; payment; weather; special effects; filter; beauty; AR; 3D; geography; travel; shopping

	community directly	
Function maintenance (M)	Function optimization and bug fix	Strengthen, optimize; fix; speed; bugs; collapse; crash; failure; compatibility; fluent; performance
API connection (C)	Connecting with other Apps or combing other Apps' function	Connect; synchronize; QQ; WeChat; Weibo; AliPay; third-party sharing; interconnect; Circle of friends; channeling; skip/jump; inbound links

After the first-round manual coding, I began to train the BERT model by separating the labelled data set into training set (60%) and evaluation set (40%). Based on the training set, BERT model will learn the classification logic by classifying the evaluation set as if there are no coded labels. Comparing the predicted label with true label in the evaluation set, BERT model will automatically adjust its algorithm until the prediction accuracy reaches to a satisfied level. This machine learning algorithm will then be applied to the remaining unlabeled data set, so called prediction set. Accompanying with this prediction process, BERT can also print the assessed accuracy for each text in prediction set (see Table 11).

Table 11. Sample Prediction Result Based on BERT Model

Text	Label S	Accuracy Probability
x1	1	0.990
x2	0	0.693
x3	1	0.863

Based on the accuracy assessment, I then selected the top 10% of data with highest uncertainty (or lowest probability score in Table 10) to do second-rounded manual coding. The newly coded text will be further added into the training set and evaluation set with same split proportion, followed by BERT model learning. After several rounds of similar processing, the prediction accuracy could reach to my expectation and I stopped. I call the whole process as a semi-supervised machine learning process. The analytical scripts can be reviewed in Appendix 3.

3.2.2.4 Measurement

I use two proxies to measure the dependent variable app survival according to two proxies. First, I created a dichotomous variable to indicate whether the app is removed (1) or still existed (0) at iOS store at the end of the observation period. I also counted the corresponding total month that an app is available at iOS store as *survival duration*.

For the main independent variable identity (re)projection, I measure each projection strategy according to the labels I classified before, given the apparent mapping between platform architecture design and its function innovation/optimization. Specifically, accumulated boundary resource connection each month is directly measured by the API connection claimed explicitly or implicitly in app update history. Accumulated social function update each month is used as a proxy to indicate architecture assimilation in the social networking ecosystem. Accumulated non-social function update each month is used to measure architecture dissimilation in the social networking ecosystem. Accumulated function maintenance each month is used to indicate architecture maintenance in the ecosystem.

As for the membership of an app claimed by its managers, I use the app category it chooses at iOS store as proxy. As Apple's official website explained, an app should consider its category in terms of three dimensions. First, the category should best describe the main function or subject matter of your app. Second, the category should help identify the user group that will naturally look for an app like yours. Third, the category should contain the same type of apps as yours. Consequently, category indicates target users and a membership of broad groups of platforms with similar core interaction (cf. Parker et al., 2016), with which an app developers attempt to affiliate in the social networking ecosystem. Specifically, there are total 26 categories (e.g. social, health, education, e-commerce, business, entertainment) that an app could choose and change during its launch period. I then measure *the accumulated number of category change each month* as the indicator of membership shift.

In addition, I control multiple variables in the analysis. *Network effect* refers to the

monthly active user and average monthly average use time per user at an app. *Portfolio effects* refers to the number of sister apps offered by the same developer in each month. Other control variables include *app quality* in terms of monthly user rating and accumulated user comment number each month, *competitive position* in terms of monthly ranking in both affiliated category and across categories, average app number in the affiliated category, app age and number of update history before the observation period. The descriptive statistics of those variables are presented in Table 12.

Table 12. Descriptive Statistics (N=1917 after dropping left-censoring)

Type of Identity Projection Strategy			Mean	Median	Variance
Identity conformity	API connection	API connection (C)	2.26	1	10.10
	Architecture assimilation	Social function update (S)	11.84	8	178.98
Identity differentiation	Architecture dissimilation	Non-social function update (NS)	14.51	9	237.87
	Membership shift	app category change (CC)	0.28	0	0.45
Identity Refinement	Architecture maintenance	Function maintenance (M)	26.12	20	522.11
Control variables	Network effects	Monthly active users (unit: 10,000) (U)	340.70	4.6	9527433
		Monthly average use time per user (unit: hour) (T)	3.12	1.5	24.66
	Portfolio effects	apps in same category (ASC)	1.81	0.1	32.89
		apps in different category (ADC)	6.99	0.2	926.18
	app quality	Overall user rating (1-5) (UR)	4.08	4	1.20
		Total user comments (UC)	6529.52	311	9.00
	Competitive position	Category ranking (CR)	702.09	501	405921.7
		Overall ranking (OR)	1895.97	2121	300195.4
	Number of update before observation (UBO)		2.25	0	41.95
	app Age		47.07	45	575.95

3.2.2.5 Data Analysis

Since my data are censored and nested around different app categories at iOS store,

I adopt a Cox proportional hazards (PH) model with a frailty term. The survival I model is the length of time of duration that an app remains in iOS appstore before removing off. The goal is to understand the relationship between the "risk" of experiencing an event ("death" or existing at iOS store) at time t and values of a variety of explanatory variables. A Cox PH model allows us to handle both categorical and continuous variables without specifying the baseline hazard. By including the frailty term, the model further accounts for unobserved heterogeneity at the app category level. I present the econometric specification as following:

$$H_i(t)=H_0(t)\exp\begin{pmatrix}\alpha_0+\sum_{j=1}^{J}\beta_{ij}\,IdentityConformity_i\\+\sum_{k=1}^{K}\gamma_{ik}\,IdentityDifferentiation_i\\+\sum_{l=1}^{L}\delta_{il}\,IdentityRefinement_i\\+\sum_{m=1}^{M}\theta_{im}ControlVariable_i\end{pmatrix}$$

I use the time-invariant explanatory variables by creating accumulated number for main independent variables and the average/median value for other control variables. To further test the validity of the result, I apply other two survival models in this paper, including a discrete-time logic random effect hazard model with time-varying variables and Weibull random effect hazard model. Overall, integrative findings with high validity were developed from the mixed method research in subsequent chapters.

3.3 Summary of Methodology

This chapter introduces the methodology used in this thesis. At the fundamental level, I adopt a critical realism with three philosophical assumption components. It takes a strong ontological realism that an intransitive, causal efficacious world exists independently of our knowledge and cannot be reduced to an empirically observed and measured domain. It also recognizes that our access to the world is always limited and mediated by our theoretical and perceptual lenses. In other words, our knowledge is always local, partial, historical and thereby transitive (epistemology relativism). However, this does not mean that all viewpoints are equally valid. Instead, we have rational grounds for choosing between alternative or competing explanations

(judgmental rationality). In order to achieve this, we have to adopt methodological pluralism to access the multifaceted objects in the reality (e.g. physical, social and conceptual). We also need to ensure practical adequacy when attempting to develop valid knowledge which is capable for explaining and directing our activities in the empirical to certain extent. Overall, critical realism matches with the call for a process lens to digital phenomena, that is- the enacted social reality constitutes the ongoing social events and actions, but that the recurrent events and actions also constitute social reality.

At the core of critical realism, we have to figure out the generative mechanisms that work as enduring causal structure to generate observable events. This is directed by a Context-Mechanism-Outcome framework which highlights the contingent attribute of mechanisms that will only actualize in certain contexts. Given the dynamic nature and contextual richness of IS-related phenomena, I adopt a mixed method characterized by an abductive reasoning procedure in generating and testing causal mechanisms of a research inquiry with multiple worldviews. Combining both qualitative and quantitative approaches, I made a sequential research design to maximize the validity of the results. Specifically, the first empirical study identifies causal mechanisms and builds a process model inductively at Douyin through a process-tracing method. The second empirical study further develops a computational approach to leverage and corroborate the findings from Douyin case in the larger social networking ecosystem it embeds. As such, a mixed method provides different but complementary insights on phenomena of interest, which go beyond the inference quality (e.g. accuracy of derived conclusions) from either qualitative or qualitative findings. Given the scarcity of theoretical foundation and the availability of abundant digital trace data for our research inquiry, I argue it is both feasible and desirable to spend greater effort in collecting, analyzing and validating both qualitative and quantitative data than work employing only one method.

As one of the key components of mixed method research, researchers need to effectively integrate findings from qualitative and quantitative studies (Venkastesh et al. 2013). I achieve this objective by presenting a coherent and systematic journey of

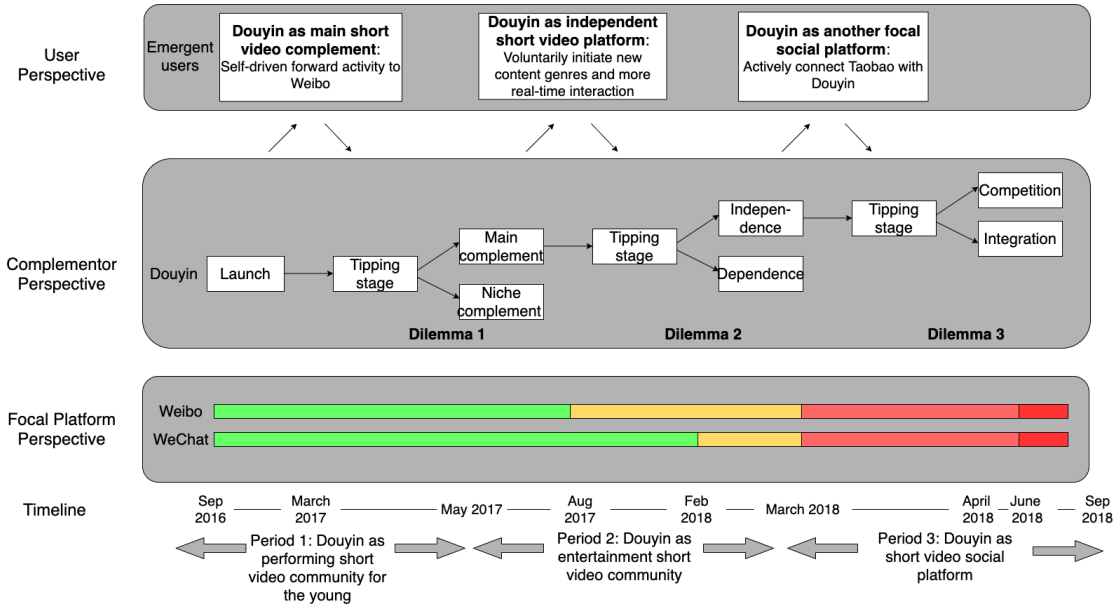
theory building and testing in next two empirical studies.

4. THE EMPIRICAL STUDY ONE: NAVIGATING THE COMPLEMENTOR'S DIEMMA AT DOUYIN

4.1 Research Findings

Experiencing dramatic changes and intensive competition since 1990s, the social networking market in China had evolved as a stable platform ecosystem that consists of an array of firms providing social, entertainment and life services, under the leadership of two focal platforms WeChat and Weibo. However, the introduction of short video medium is shifting the existing alignment of ecosystem actors in recent years. At the center of this change, Douyin grows from a niche complementor to a new ecosystem hub with more than 200 millions active users just within two years following its establishment in September 2016 (See Appendix 2.1).

Yet, this scaling process was not a smooth linear process. It was punctuated by three interdependency dilemma episodes (Figure 8), when Douyin has to balance growth ambitions and relationships with the focal platforms they grow upon. In what follows, I present Douyin's rapid growth trajectory, and apply the case findings to trace how the dilemma process is contingently shaped by three mechanisms: identity projection, identity deviation and identity evaluation.



Note: The colour in focal platform perspective box represents the attitude of Weibo and WeChat towards Douyin from support (green) to complete block (red).

Figure 8. Timeline of Douyin Growth

4.1.1 Niche Complementor or Main Complementor

The start-up of Douyin occurs at a specific time period when the parent company Bytedance took a very different perspective on short video market comparing with the focal social networking platforms WeChat and Weibo. On the one hand, focal platforms preferred to take short video as complement to the existing social networking service based on text and picture, rather than provided as core offering due to unclear target users and product design. A former member of Weishi[3] recalled the initial meeting with the team director: "He told us that we would build another Vine[4] in China. But when you asked his concrete plan, his answer became:" foreign countries have, so we must have." She further noted,

> *Weishi's main operation and social chain was simply piggybacked from WeChat and Weibo platforms. While a strong network effects could be developed in short term, it paid less attention to understanding true user demand at platform. The focus on 8s short videos cannot convey abundant and complete content, emotion and story, and can only be regarded as complement of social networking.*

The limitation of short video at that time was also recognized by Weibo. While short video was estimated by the technology and operation director to have great potential to create a bigger market in the future, it was still not easily accessible and well-recognized by Internet users in 2013 due to the lack of 4G infrastructure. Consequently, Weibo made close connection with Miaopai short video at the end of 2013 by embedding its functionality into Weibo platform, which highly alleviated the competition pressure (e.g. decreasing active user at platform) from WeChat since 2009.

On the other hand, ByteDance sets short video as next core competence ('all in short video') due to the observation of user preference change from text to short video on its information flow platform Toutiao, based on the improved digital infrastructure. As the

[3] Weishi was a short video app produced by Tencent in 2013, which is the parent company of WeChat.
[4] Vine was an American social networking short-form video hosting service where users could share six or seven second-long, looping video clips. It was founded in 2012.

General Manager of Douyin noted,

> *User-generated content (UGC) short video is a discipline that we already pay attention for a long time. The popularity of big-screen smart phone and the construction of internet infrastructure make more people, especially young people, to be used to expressing themselves through short video. Currently, short video has become the largest content form comparing with text and picture on Toutiao. The daily view counts are more than one billion times.*

As a result, a carefully considered short video App was launched by Bytedance on Sep 2016 with smooth support from focal platforms WeChat and Weibo (i.e. API connection and marketing activities). With precise user targeting (i.e. young, female and fashionable users) and user seeding, Douyin became dominant application in the short video niche market as a *performing short video community for the young* within half a year. As the founding team members explained,

> *We don't have big ambition initially. Our envision is just making a music short video community and we think it's enough to build a community. Most of our group members are the generation after 90s. At the launch stage, the 11th content you browse will repeat the first one. We therefore seek talent creators from art academy and other short video platforms, and make friend with them. If they cannot spell out their feedback online, we will invite them to visit us face to face. In this way, we target at the young preferring pop culture. The later content boom is just natural chemical reaction.*

It is further noted that the rapid success is impossible without a series of deliberate platform design that materializes the distinctive user targeting and motivate seed users to keep engaging at platform. As the general manager highlighted,

> *Before we made Douyin, short video products in market more tilt to photography tool or are not really attractive for young people. To solve this issue, we installed more than 100 short video products at home and abroad on smart phone and ask everyone in group to experience those short video products every day…We finally identity music, filters, special effect and video*

optimization as our competitive advantage in the first place and input lots of resources… Music is a tool with strong expression attribute. When music is combined with video, music is more like a filter which strengthens the expression part in short video content. This will breed community easier, rather than make product instrumental.

However, such flat growth was interrupted on March 2017 when a comedy star voluntarily forwarded a funny video on Douyin to the Weibo platform. Relying on their smooth connection established before, Douyin achieved its first round of explosive user scaling by piggybacking on the user base of focal platforms. As *Huxu journal* highlighted,

The unexpected forward activity of Yue Yunpeng on Weibo made the cold boost of Douyin. It is the promotion activities of these key sharers that break through the ceiling of target user groups, achieving the qualitative scaling from 0 to 1 and changing the direction of platform development. This star effect inspires the operation team to enhance promotion activities on Douyin by inviting more stars to participate, which expands the target users of Douyin from niche to broader groups. It could be said that without this forward activity, the growth of Douyin will be slower more than now.

At the same time, such unexpected user boost brought new challenge and opportunity for the future growth of Douyin. Initially, Douyin designers hesitated about whether to conform to the preference of emerging users in platform offerings. As these new users were piggybacked from Weibo looking for a unique complementary short-videos community for entertainment interaction, Douyin had to strengthen the entertainment features of contents but also offer distinctive social interaction features to try and engage and retain the users. However, since the user channeling from Weibo and WeChat to Douyin created an increasing overlap in their user bases, Douyin was risking to become perceived by the focal platforms, especially Weibo, as a threat, potentially triggering decreasing support for Douyin growth. Moreover, once more diverse user groups participate on platform, unexpected interaction activities may emerge on

platform again, which disrupts current platform projection and creates new issues. As one of the employees at ByteDance algorithm department explained,

> *The introduction of recommendation algorithm makes it play a key role in affecting content attributes and community features in Douyin. The algorithm definitely enhances the reading efficiency on platform by allowing users to consume more content in unit time. However, the meaning of "more" may include better, more useful, higher-quality, or nothing of them. It really depends on users' watching behavior (algorithm learns users' behavior) and the whole content pool created on platform.*

Considering the potential worsening of relation with Weibo and out of control of platform development, Douyin designers did not reflect on the user boost in time but simply did functionality optimization and added 3D shaking effect when sharing video on April 2017. As a result, current core interaction on Douyin (i.e. performing short video creation and sharing) were further refined, which only conformed to the preference of targeted user group before. As a result, lots of users from Weibo were not willing to multi-home on Douyin, leading to user outflow. As a third-party business report explained,

> *The outflow of users begins in next month. More than 44% of users attribute their leaving to the reason that they Douyin in the first place just for casual browsing. It's hard to expect users from Weibo to stay long time on Douyin. User will not cultivate social relation on a new platform just because there is convenience of content creation. Instead, they are more willing to create content here and share their works on existing social platforms such as Weibo and WeChat.*

Observing the trend of user outflow on platform, Douyin designers faced a dilemma between keeping to serve set users and embracing broader users, and were forced to make a prompt decision on future development direction. While sticking to current platform projection will signify stable support from focal platforms and dominance in niche short video market, it won't be attractive for new users piggybacked from focal

platforms to persistently engage on Douyin in the sense that offerings purely built on top of focal platforms were still complementary to the social interaction on WeChat and Weibo. Such decision tendency to embrace emergent users from focal platforms was further reinforced by their actions and market competition condition.

On the one hand, Douyin's concern for potential competition with focal platforms was highly alleviated due to the official closing of Weishi short video platform on April 2017 as it indicates that focal platform completely gives up trying short video as core offering. In other words, Tencent shifted its ground from directly competing in short video market to supporting sound competitive players as complementors. As Tencent Open Platform[5] recorded in its introduction: "We welcome and look forward to any innovative applications such as the categories of content, video, information." As such, further scaling of Douyin would be thought as good endeavor to contribute to ecosystem value. On the other hand, more intensive competition in short video market (57 players without dominator) forced Douyin to quickly leverage the growth opportunity indicated by the user boost, which will be grasped by competitors otherwise. This is particularly manifested in the faster growth pace of Kuaishou short video platform which gained the favor of Tencent with 3.5 hundred million investments in March 2017. After carefully trade-off between benefit and risk of two paths, Douyin decided to serve broaden user groups by partially creating value on top of focal platforms from May 2017.

4.1.2 Independence or Dependence

In order to embrace new target user groups, Douyin updated multiple specific strategies in terms of user seeding and platform architecture design. For instance, Douyin began to sign contracts with more stars who attract abundant fans to be on-board. "While the former promotion by Yue Yunpeng is self-driven event, current cases are platform-driven which wants to further strengthen such entertainment attribute at

[5] Tencent Open Platform is responsible for third-party application connections with Tencent products (e.g. WeChat, QQ, QQ Zone).

Douyin." *36Kr journal* commented. From June 2017, it further made multiple connection with long video platforms through big-bang marketing. As *TMTPOST journal* explained,

> *In 2017, Douyin totally cooperates with 16 variety shows (e.g. 'The Rap of China', 'Happy Camp', 'Day Day Up') across diverse video platforms such as Tencent Video, Mango Video, iQIYI. In this way, Douyin keeps strengthening its platform labels of "music", "entertainment", "cool", "beauty". Just within a half year, the app installment rate increase 789%.*

To direct content creation for those new on-boarded users, Douyin also launched a series of official challenge campaigns. "They include specific topics, shooting guidance and popular instances published by Douyin talents that match with the value system defined by us." Commented by the manager at Douyin. With the explosive scaling of content creators and user base from May 2017, Douyin further weaken its manual operation and strengthen algorithm recommendation system which is aimed to enhance the efficiency of high-quality matching between content creators and consumers. As a AI team member noted,

> *The development of short video community is a slowly growing process. Within company, we call it double-side development. The double-side effect will only take effect if there are content creators who continually contribute to contents and consumers who look through those contents. With customized recommendation system, Douyin could rapidly help users to find their favorite contents. It follows a decentralized distribution logic: the system firstly filters contents according to whether their tags match with platform attributes and user targeting. The remaining contents then are distributed into a small user pool and the system will collect data feedback on indexes such as view counts, like, comments, forwards, degree of watching completeness, attention and so on. Those performing better in indexes will be further distributed into a larger user flow, while others will be distributed less. Repeating this process, platform will accumulate a group of high-quality content with excellent data*

feedback, which constitute the recommendation pool. When users open the app, they will be firstly recommended by those contents. In short, the whole process is data-driven: test in a small scale, filter content according to data feedback, recommend in large scale.

Moreover, the strong AI lab team at Douyin applied lots of cutting-edge technologies in deep learning and image recognition domains (e.g. face recognition, body recognition and 3D drawing) to photography function innovation, such as full-view tags, AR tags, 3D hair dry and AR shooting methods. As the general manager pointed out,

While lots of those functions are not exclusive in market, our offerings are better with higher quality (e.g. the special effect is more actual). This is our attitude towards function innovation. In this way, we could provide more surprising user experience than competitors. Some of them even become the standard configuration for short video platforms. It is these details and innovation that help Douyin to be No.1 in App Store at the end of 2017.

Consequently, these re-projection strategies of platform as *entertainment short video community* makes Douyin scale up quickly from May 2017. However, the increasing user overlap, especially with Weibo, and the imitation of Weibo function trigger the warning from Weibo by blocking the API connection with Douyin on Aug 2017. As noted by a consulting analyst,

The competition between Douyin and Weibo becomes more apparent since both platforms tilt to media feature with weak social chain. Comparing with Weibo, the content distribution mechanism at Douyin is more de-centralized in the sense that it is more data-driven rather than concentrated on head content creators. Therefore, Douyin attract lots of ordinary talents, most of them coming from Weibo. They constitute the core resources of Douyin, provide abundant and diverse contents at platform, and attract numerous users to spend time on Douyin. However, they are also the group that Weibo has always tried to develop.

At the same time, as algorithm recommendation system gradually replaces operation team to govern content distribution at Douyin, more content creators abandon their originality and quality judgment but blindly imitate popular short videos that cater to emerging user preference with good watching data. As many head content creators recognized: “the short video mind is about how to make good content acknowledged by Douyin algorithm. We need to keep eyes on fresh user interest. Every day is a new beginning. You always feel overwhelmed since the algorithm mechanism forces you to iterate content without reflection time.” Consequently, this leads to content homogeneity issue on platform from June 2017, where similar vulgar content interaction keeps dominant and deteriorates user experience. This issue was further described by a Douyin operation team member,

> *These content are not deliberate effort driven by Douyin operation team. In fact, we are very nervous on those kinds of content since some of them may impact the original community feature of Douyin, which misleads the experience of users on the standard of good content. The algorithm performs like a black box and you can only draw the outline of algorithmic rule. Sometimes, when I query the algorithm engineer next to me on these inexplicable content, he just shakes his head helplessly.*

While Douyin designers were agonizing over these side-effects of platform re-projection, a favorable turn emerged with a series of unexpected user innovation in Aug 2017 when various dance challenge campaigns were initiated voluntarily by users. By applying the same soundtrack uploaded by initiators, users were engaged in creating new variants which greatly enriched the content genres on platform. As *36kr journal* observed,

> *At the end of August, three talents make a dance short video using music 《Panama》 on Douyin and initiate challenge “C Li C Li Dance” which attracts numerous users to imitate. Similar dance challenges initiated by users during this period highly activate the engagement of users on platform.*

Perceiving the potential of new user interaction on platform, Douyin quickly

adjusted the platform design by completely opening the uploading and sharing function of soundtrack among users. In this way, a new challenge could be easily initiated by users voluntarily and diffused with multiple varieties. Later in Sep 2017, live-streaming function and monetization means for platform users (e.g. information flow advertisement) are launched based on current platform projection to further leverage the creativity and engagement of users. As the general manager of Douyin points out,

> *Instead of competing with other live-streaming platforms, we are still a short video community. The live-streaming function does not influence the identity of Douyin. We are not making a pure and professional live-streaming platform but try to contextualize this function in Douyin (i.e. setting live-streaming function in peripheral entrance rather than home page; replacing usual ranking rule to number of likes supported by fans; designing special effects and tags on live-streaming page) in order for enhancing the interaction between talent content creators and fans. In addition, lots of talents already accumulate large number of fans. They also have monetization demand which is possible at Douyin since our users mainly locate in first and second-tier cities with strong consuming power. As for how many profit live-streaming could bring, we do not make prediction and requirement because live-streaming on Douyin is not for monetization in nature.*

In this way, more users tended to engage in real-time interaction on Douyin besides WeChat and Weibo and platform content also tend to be general in the sense of covering various genres. In the meanwhile, the opening of third-party advertising on platform made Douyin more valuable as vital complementor for Tencent in the sense that the growth of Douyin could back feed other complements created or invested by Tencent in the ecosystem (i.e. Tencent game apps piggyback users from Douyin through advertising), which highly alleviates the growth threat towards the focal platform. As the general manager of Douyin highlighted,

> *We require cooperators to create advertisement that conform to the attributes of Douyin and can be regarded as an independent short video content*

consumed by users. As such, it is high-quality short video content in the first place, and then an advertisement. In this era of information overload, it's very easy to distract users' attention. For advertisers, transferring advertisement to content could catch up users' attention in short time. We got highly superior feedback from users and cooperators on such native information flow advertisement. Some users comment that they watched one advertisement in 20 times. This conforms to our conclusion in prior test.

Observing the more diverse content preference and the favor of real-time interaction on platform, it's easily for Douyin designers to recognize a new promising development path by transferring from short video creation and sharing platform to short video social platform. In this way, the targeting users of Douyin will no longer restrict in short video market but cover everyone with social demand. Further, the reinforcement of social networking as core offering on platform will facilitate Douyin to build higher competition barrier without the dependence on focal platforms. However, the corresponding risk was also on the table in the sense that such independence path will significantly threaten focal platforms in terms of complete user overlap and similar core offerings, leading to the envelopment from WeChat and Weibo.

Struggling with the double edge of growing as an independent platform competing with focal platforms, the opposite road further arose in front of designers as remaining the main content community complementor in social network ecosystem. By doing so, Douyin is able to survival and dominate in short video market with strong support from focal platforms, at the expense of further growth to get out of their control in terms of value creation and capture. As one team member of Douyin pointed out,

Social and community are utterly different from each other. The social tie with content creators is the antecedent for a user to consume content on social platform, while the content quality is the antecedent for a user to follow content creators on content community. Therefore, one key issue for Douyin now is to decide whether we should focus on social or community. Should we do content-driven or social-driven platform? Which one is better? Is it

possible to find a balance point between community and social?

Such decision deadlock was finally broken by carefully considering the status quo of Douyin in terms of users and market condition, and competitive activities of focal platforms. Firstly, although Tencent kept good cooperation with Douyin, Weibo already became an enveloper by building their own independent short video platform in Nov 2017, which forces Douyin to be independent as defense. This urgency is further manifested in the rapid decline of Miaopai during that period due to the decoupling from Weibo, which implies that tight dependence on focal actors is extremely risky for the development of a non-focal actor in the ecosystem. Secondly, as head players in short video market already proved the potential in terms of monetization and envelopment into other platform markets (i.e. 'short video+ live-streaming' mode), short video market is already at rapid growth stage. Consequently, there is no guarantee that Tencent will always regard short video market as complement rather than competitor. As a former strategic analyst at Tencent mentioned,

> *Short video is also a medium. It is information when the contents are news; It is entertainment when the content are editing of varieties and films; It is community when users present their interest and interact with others with similar interest; it is social networking when the interactions are user-centralized (e.g. WeChat, QQ and Weibo).*

Thirdly, as more emergent users tend to revalue Douyin as another social platform, the envelopment risk from focal platforms will be likely under control in the sense that their capability to leverage shared user relationships through offering similar 'social + short video' functionality bundle is relatively limited and insufficient. As a result, Douyin made decision to quickly scale up as an independent platform before focal platforms further react.

4.1.3 Integration or Competition

The further deliberate weakening of entertainment features on platform made explosive user scaling on Douyin with more balanced user portrait (i.e. age, gender, city

distribution, consuming power) between Jan and Feb 2018. This is mainly achieved through two strategic activities. First, by embedding the live-streaming quiz function in platform offerings, Douyin is able to acquire users with very low cost, which further decreased the user threshold at Douyin and expanded the user group in third and fourth-tier cities. As a key investor of Douyin commented,

> *The cost to acquire users for one live-streaming quiz is only less than 1 RMB. The entrance threshold of live-streaming quiz is very low for users. Everyone could participate into this playing method as long as he/she has a smart phone. User could get monetary rewards by sending real-time message and answering questions. As such, it is very attractive for various users with different backgrounds, from the elder to the young, from students in higher education to ordinary workers. Different groups of people join in this live-streaming quiz ceremony. This is indeed the reason why short video platforms combine this functionality into platform after live-streaming.*

Comparing with other independent live-streaming quiz platforms, Douyin contextualized this functionality once again by making smooth linkage with its core value unit—short video creation and sharing—in interface design, which highly increased the user engagement and retention rate at platform. As a technology analyst commented,

> *Live-streaming quiz itself does not have lasting user demand. Although this is a good mode to acquire users rapidly, there is a lack of user engagement. If users could easily choose you, it's also very easy to leave you. Therefore, comparing with independent platforms, the integration of live-streaming quiz as a peripheral function becomes an entrance of the core contents and interactions at Douyin, effectively transforming new users to the engaged ones.*

Similarly, Douyin began to adopt undifferentiated platform connection to reach out as many internet users as possible. As the *Huxu journal* reported,

> *During spring festival, Bytedance increases the marketing budget of Douyin to two billions. Douyin begins to buy user flow from different channels. All top*

apps in IOS store such as game, instrumental app are included in the channel operation of Douyin. The operation manager mentioned: "Currently, there is twenty million budget per day to buy user flow. We try to connect with all channels that we can image."

In addition, a large number of new users were attracted to download Douyin during this period through self-driven promotion of existing users, which highly enhanced the confidence of Douyin designers to be independent of focal platforms in the ecosystem. As the vice president of Bytedance noted,

It is a misunderstanding that user base scaling of Douyin relies on user flows on WeChat. In fact, the natural growth on Douyin is already very high. During spring festival, more than quarter of new users are attracted to come to Douyin through the word of mouth of acquaintances. The social diffusion between acquaintances are the main source of new users. With the large-scale movement of users in geographical locations during spring festival, user base is expanded from first and second-tier cities to third and fourth-tier cities.

Shocked by such user scaling speed (thirty million within one month), Tencent re-launched Weishi short video platform in Feb 2018. Similarly, Weibo launched another new short video platform as defense. Following these successful growth strategies, Douyin officially upgrade its brand as recording good life for everyone (*short video social platform*) in March 2018. As the manager of Douyin explained,

From the perspective of user portrait, the launch of new slogan represents the expansion of user base to other cities. We thought Douyin is a more general product. Currently, users with different ages and gender and in different regions all record good life on Douyin.

Accompany with this new slogan, Douyin also had a very clear idea about how to generalize the content to satisfy diverse user preferences. In March 2018, it launched eight cat face tag at platform for the first time. The operation manager responded: "more targeted special effects and tags according to different scenes will launch later to better help user record good life." He further noted,

We have clear standard of "good" and try to direct users to experience and explore "good life" through product and technology means. Douyin will invest more resources in each vertical field of travel, food, fashion, sport, game, pet and so on, making more users to engage and represent the good life around the world.

At the same time, such reinforcement of life-oriented attribute instead of entertainment facilitated the architecture redesign at platform in developing its own social network. As a team member introduced,

Douyin is targeting at socialization through redesigning the product. After spring festival, Douyin made two rounds of revisions including uploading picture, sending emoji in private letter, multi-user interaction and the information flow mode of attention tab. They all are strategies to encourage interaction and social activities at platform.

This considerable effort to be independent of focal social platforms is further supported by the close connection with remaining platforms owned by Bytedance, including the categories of information flow, Q&A community, middle video, long video and text & picture community. As such, Douyin tried to build a higher competition barrier in user interaction in case of potential revenge from focal actors. As the CTO of Bytedance announced,

Based on current positioning as super content platform, we are going to transfer to intelligent socialization. This mainly manifests in three dimensions: support all types of content creation including picture and text and short video; support one-time distribution on all six platforms of Bytedance; Content published on one platform will be automatically synchronized on other platforms according to the preference of users. In this way, the account system data of content creators on all six platforms will be integrated together, achieving fans increase through different channels and sharing on all platforms. Since there are different target group of users on different platforms, the data integration at different platforms enables content creators to

approach diverse and extensive user groups more effectively. For content consumers, if they are interested in specific creator, they only need to follow him on one platform and it will later synchronize on all other platforms. In this way, content consumers could easily acquire their favorite contents.

With so many and frequent changes in platform strategies, however, the growth ambition of Douyin at that time seems still relatively restrained. As one of the team member recalled,

After spring festival, the daily active users of Douyin grew to forty millions. But Kuaishou was still the leading player at that time with daily active users over one hundred million. No one in our team shouted slogans of being number one short video platform in China. We always think us as a runner-up and keep calm.

Predictably, these decoupling activities from focal platforms trigger intense retaliation including the complete blocking of sharing function of Douyin on focal platforms. At the same time, Tencent began to give Weishi short video platform all available resources (i.e. connecting with and advertising on other platforms owned by Tencent) in order to help it grow rapidly as defense. Similarly, Weibo launched the function "Weibo Story" in March 2018 to further envelop into Douyin's core offerings. As one technology analyst explained,

As Douyin already expanded from a pure content community to 'short video+', it already highly threatens all core businesses of Tencent and Weibo in social and entertainment market. Such threat was further reflected in the increasing use time on short video platforms and decreasing use time in other sub-markets (i.e. reading, game, long video, social). Douyin is no longer a pure platform for content publishing and consuming, but become the new interaction mode for end-users. Although Douyin is still far away from an instant messaging tool, it could go farther in open social relation with the form of short video.

While Douyin already made intensive preparatory work (e.g. multiple rapid scaling

strategies in short term) to withstand the expected counterattacks from focal platforms, they still significantly inhibited its scaling pace, primarily because the cultivation of social network at platform cannot be accomplished at one stroke. As CPO of Bytedance noted,

> *The block of Weibo and WeChat highly influence the user experience at Douyin since they are no longer able to share contents on these platforms. There are more than ten million users sharing on Wechat and Weibo before. So it is really harmful for user experience.*

It was definitely a hard time for Douyin since focal actors are still necessary for its growth during independence process. This was further manifested in Douyin's continuing attempts to re-connect with WeChat and Weibo (e.g. launch mini-program at WeChat and H5 advertisement at Weibo) in subsequent months. Despite every time a new kind of connection would be quickly decoupled by focal platforms in several days, users started to interact in new way through coupling new monetization means. Due to the generalization of content and user portrait on platform, short video actually became the new medium to undertake e-commerce business. By embedding Taobao account in personal home page and creating innovative marketing short video for Taobao commodity from March 2018, more users connect e-commerce platforms with Douyin besides WeChat and Weibo to improve their monetization capability. As *36Kr journal* reported,

> *Douyin already becomes popular marketing place for lots of goods on Taobao and Tmall, which is even not expected by sellers before. There are also lots of similar comments in comment area such as "this is the 99th goods I am recommended and attracted on Douyin."*

Facing the decoupling pressure from focal social platforms and observing emergent coupling with e-commerce platforms, Douyin designers stands at a new development crossroad. As the independence of platform already activated and claimed publicly, there is no way for Douyin to alleviate the envelopment pressure from focal platforms unless fully integrating into Tencent or Weibo as core offering. Although such merging

could help Douyin obtain all available resources (i.e. various complements) in focal platforms without extra effort and cost, the ultimate success in social network market asks for a heavy price to transfer the platform ownership.

Taking into account the cost of platform integration, Douyin turned to think of the possibility to become a new focal platform in social network ecosystem by attracting its own complementors. In this way, Douyin is able to alleviate the side effect of decoupling towards its growth through providing new platform capabilities attractive for participants. Addicted to this vision, designers also have to bear in mind of wipeout as being fully enveloped by Tencent or Weibo since such scaling path directly competes for the complement resources in the ecosystem and challenges the leadership of both platforms as focal actors.

Recognizing the urgency of responding to the retaliation action from focal platforms, Douyin finally take the road of challenging existing focal platforms without more hesitation based on three considerations: First, the user boost and their emergent combination of multiple platforms in diverse markets with Douyin already show its strong capability to empower various platform markets to bloom once more. Combining with the low marginal cost to multi-home in platform context, it is effortless for Douyin to attract sufficient complementors.

Second, until April 2018, Douyin already scaled the user base over 1.8 hundred millions with high user engagement, which realized a sustained network effect and competition barrier that enables Douyin to resist further retaliation from WeChat and Weibo. As a team member of Weishi pointed out,

> *The re-launch of Weishi in March 2018 is more like a strategically defensive product to slow down the pace of Douyin to enter social market. However, although Tencent could provide user flow and resources for Weishi, the nature is still competing competitor with competitor's product logic. As Douyin already generate network effect with abundant and high-quality UGC and community ecosystem, it's less likely to replace a dominant competitor with defensive products.*

Third, as short video market was at boom stage and head players (e.g. Kuaishou) tend to serve same user portrait with similar market positioning, Douyin was forced to build higher competition barrier in order to keep dominant in the market.

As a result, Douyin further strengthens the social functionality at platform as core offering and offers boundary resources to attract complementors at the same time. Specifically, it launched attention tab parallel to short video home page in May 2018. As *Zhoutian Finance journal* observed,

> *As one of the key functions of socialization, Douyin is currently strengthening "attention" system. Lots of product details already began to guide the 'following' behavior between users, such as the function "potential friends you may be familiar". At the same time, there are more recommendation on main feed tab based on attention relationships of users. Previously, users are used to watching main feed tab passively based on recommendation algorithm and spend less time on attention tab. Now, Douyin start to directly recommend new short videos published by followed content creators at home page. After going to the personal page of followed content creators, Douyin will also recommend similar content creators for users to follow. This function is very similar to Instagram. Moreover, Douyin keeps doing closed beta test of information flow mode which is similar to friend circle function at WeChat.*

In the same month, Douyin officially recognized the E-commerce platform connection made by users by introducing Taobao shopping entrance in personal page of users. As *36kr journal* commented,

> *For those content creators with million followers, they have strong monetization demand which is related to their motivation to create and publish contents. If the platform does not satisfy such demand, they will definitely transfer to other platforms. With the standardization of transaction system by officially cooperating with Taobao, Douyin could spend less effort on the governance issue of fake commodity derived from voluntary transaction among users. Users with consuming demand now could directly jump to Taobao*

platform, rather than buy unverified goods through the personal guidance. The purpose is not developing its own e-commerce platform but becoming the entrance of user flow for other e-commerce platforms. In this way, Douyin built vivid ecosystem that enhances the user engagement at platform.

As a response, Tencent and Weibo ceased all business cooperation with Douyin and persisted in launching new short video platforms as counterattack. Yet the effect of these competitive activities on Douyin scaling is very limited. As *Huxu journal* commented,

For weak competitors with low user engagement, block is an effective strategy. However, Bytedance is obviously not such type of competitor, which is continuously reinforcing the network effects through developing its own ecosystem landscape…Building upon the new platform mode of 'short video+', Douyin could further feed back to the incubation of new platforms at Bytedance in various sub-markets. Therefore, although the market share of Bytedance is still smaller than Tencent and Weibo, it is not weak. This determines that the war between them will last for a long term.

With the fiercer competition between Douyin and incumbent focal platforms, more challenges however emerged within the platform itself, especially the capability of Douyin to persistently empower various complements. In July and August 2018, Douyin kept combining and contextualizing the core functions of Weibo (top search list and top video list) into platform offerings. By exhibiting and updating popular topics and relevant videos that are recognized by the algorithm recommendation system at platform, Douyin attempted to provide platform users, especially those long-tail participants, more guidance for content creation in various categories. Accordingly, relevant content created by short video talents and the following imitative contents will be officially recommended and distributed at platform more often. As *36kr journal* commented: "Different from Weibo that focuses on text and picture, Douyin's top list function is based on sounds and videos which could carry more vivid information in terms of news and social topics. It therefore may replace Weibo as the new information distribution center." While this enhanced data-driven platform design persistently

enhances the content distribution efficiency and user participations at Douyin, it is less helpful and even demotivate the participation of complementors since they are very hard to piggyback from the platform. As multiple third-party businesses in E-commerce complained,

> *Such centralized operation towards popular topics and content enhances the media attribute at Douyin. That is, end-users are more loyal to the content and platform itself rather than the people who publish those content. This is an advantage of Douyin but becomes a drawback from the perspective of complementors: you can easily attract users from Weibo but it is very hard to piggyback users from Douyin. In the E-commerce business, this manifests in a low conversion rate of orders when you cooperate with content creators to advertise Taobao goods. Even for a short video talent who have millions of followers, there is only hundreds of final orders converted from his/her short video with six hundred thousand view counts. For some content creators, the conversion rate is even lower than the average level in the industry. In sum, the influence of present Douyin is not proportional to its monetization capability for complementors.*

Such concerns about whether Douyin could successfully support the development of complementors were growing further as Douyin started to spend more effort in preventing the envelopment of focal platforms through decreasing the openness of platform. In particular, more restrictions are placed on users' participation in the monetization at platform in the sense that only those creators who have signed cooperation contract with Douyin are able to obtain more user flows and recommendations at platform. As many content creators complained in that time,

> *The growth of view counts of our short videos will stagnate after a certain level. Such situation already lasted for two months. On the contrary, the top talents who sign contract with Douyin frequently attract investment in recent months. All of these prove that platform is adjusting the distribution structure of user flow which is tilting towards specific creators.*

In this way, Douyin tried to tightly control the key content creators at platform and develop a closed-loop ecosystem. However, these strategies also highly restricted the access of third-party agencies to value co-creation at platform. As the *Deep Web journal* reported,

> *MCN (multi-channel network) agencies play an important role in facilitating the sustainability of a content platform. They provide content creators multiple services such as operation, marketing, monetization, and help them continuously create superior and diverse contents at platform. At present, Douyin does not have such professional skills to cultivate and support so many content creators. One operation team member now has to be responsible for more than 100 short video talents. Without the participation of MCN agencies, Douyin can only focus on a fraction of head creators. The decreasing supply of content from middle- and long-tail users is also against the development of social network at platform since user interactions now are narrowed around several head talents. This strategy is therefore myopic and cannot sustain in the long term.*

Consequently, in August, Douyin experienced a negative growth for the first time in 2018. Once recognizing the potential damage to complementors and other participants at platform, Douyin officially launched Xingtu platform in Sep to facilitate the connection among third-party advertisers, agencies and content creators. The marketing manager at Bytedance explained: “we will provide specific guidance and monetary support for recognized MCN agencies. Talents and third-party organizations can trace their short video data (e.g. user portrait and distribution, video ranking and tags) and manage their content creation automatically.” Two third-party technology analysts commented,

> *Douyin always sways between openness and non-openness. At this time, it finally decides to completely embrace third-party agencies. The launch of Xingtu serves to optimize the content ecosystem at platform. It standardizes the monetization process at platform and enhances the review efficiency. Xingtu*

platform weeds out inferior third-party agencies and leave those who are capable of supporting talents to create high-quality contents. As such, Douyin makes win-win strategy that is beneficial for the value creation and capture of all three parities—platform owners, content creators, and third-party agencies.

Such opening of platform over time further manifests in the launch of top music list which supports the popularity and monetization of original musicians at Douyin and becomes the new place of publication for musicians from other music platforms. In Oct 2018, Douyin further launched mini program which allows various digital platforms (e.g. game, photography tool, e-commerce) to develop and run their mini Apps at Douyin. Combining with new round of social function update (e.g. private message support voice, imitate sharing function of WeChat), Douyin re-motivated the engagement of diverse complementors and end-users in its ecosystem and re-boost the rapid scaling pace again. As one of the senior manager explained,

Nowadays, Douyin is no longer a music short video community, or even a short video platform. Its newest version name has changed from "Douyin Short Video" to "Douyin". It has become a 'monster' with lots of arms such as video, live-streaming, e-commerce, social, local life, and tries to grow more arms in the future. Today's Douyin is out of the expectation of all people, even for those participating from the beginning.

4.1.4 Summary of Findings

In analyzing the growth trajectory of Douyin in the social networking ecosystem, several findings point to the non-linear characteristics of a complementor's scaling process in platform ecosystems.

First, our analysis found that the scaling of Douyin experienced three interdependency dilemma episodes: whether it should remain as performing short video complement in niche market or grow as a main complement in broader entertainment content market; whether it should remain the strong dependency on focal platforms or

grow as an independent short video community in the ecosystem; whether it should still defer the leadership of focal actors in ecosystems or challenge it by developing its own platform complementors. During this process, the position of Douyin keep shifting from a niche complementor to a focal actor in the ecosystem.

Second, it is noted that such growth ambition of Douyin is not a deliberate planning from the launch of the platform. Rather, it is emerging from the dynamic and constant interactions with ecosystem actors over time. On the one hand, it competes for the support from focal actors by demonstrating both distinctiveness and legitimacy in the ecosystem. To this end, platform owners project what it is through specific user targeting, user seeding and platform architecture design strategies. On the other hand, emergent user interactions and multihoming activities at platform keep lighting, warning and shaping what it could be in the future. As such, a complementor continuously confronts crossroads to make choice among multiple possible growth paths. The decision about whether to remain or re-project current growth ambition depends on its judgement on corresponding legitimacy sceneries in the ecosystem.

Third, I show this high-growth trajectory at platform business as a scaling process, manifested in the rapid boost and leverage of its user base in order for creating an ecosystem momentum that tips in favor of its re-projected position in the ecosystem. This requires ecosystem-level economies in the sense that Douyin's value will increase and be established only if there are more affiliated ecosystem actors (e.g. end-users, focal actors and other non-focal actors) to support its development. Further, the constitution of such partner constellations is not constant but varies according to its position in the ecosystem. While focal actors are important supporters and cooperators when the platform was still a non-focal complementor in the ecosystem, they become threatening competitors and envelopers when the platform attempts to develop its own leadership in the ecosystem. Similarly, a potential non-focal competitor at initial stage in the niche market may become a crucial complementor for the platform scaling later. It is therefore such fast-changing coopetition tensions among numerous and diverse ecosystem actors over time that requires a platform business to rapidly scale up in order

to pursue and establish its re-projected position in the ecosystem.

Having analyzed the case of rapid scaling of non-focal platform at Douyin in the social networking ecosystem, I now move on to discuss these analytical findings in order to build a process model of complementor growth in digital ecosystems. In particular, I will reveal out how platform identity plays a role in navigating this rapid scaling process and its implication for complementarity in digital ecosystems.

4.2. Theory Building

This section presents the mechanisms that drive the rapid scaling process of Douyin from a non-focal complementor to a new focal actor in the social networking ecosystem. The emerging three mechanisms are then synthesized to a tentative formal process model based on CMO framework.

Specifically, at the core of this scaling trajectory, the tentative model in this section aims to identify and understand how the platform business in this case, Douyin, navigates its complementor's dilemma process in the following aspects: 1) how does it pursue the projected platform position in the ecosystem? 2) what drives the platform position shift in the ecosystem? 3) how does it make the trade-off among multiple promising platform positions in the ecosystem?

The theory is built in three steps. First, it explicates the nature of complementor scaling process at Douyin. The purpose is to abstract the empirical findings to the complementor's dilemma process-that is, the continuing (re)balance between growth ambitions and the dependency on focal actors in the ecosystem. In this sense, digital platform scaling is framed as a position shift process in digital ecosystems which serves as the foundation for further theory building. It then moves on to identify the generative mechanisms that drive my empirical findings. In particular, I figure out that platform identity plays a leading role in navigating this dilemma process. Finally, a complete process model of platform scaling combining contextual conditions at the ecosystem level, generative mechanisms of the complementor's dilemma process and scaling outcome is presented.

4.2.1 Platform Scaling as Position Shift in Digital Ecosystems

The case of Douyin demonstrate its unprecedented scaling capability as a platform business, manifested in the rapid growth rate in terms of monthly user base and monthly average use time. However, what does the term 'scaling' really mean? In this case, we observed that scaling should be understood more appropriately as a nonlinear process co-shaped by diverse ecosystem actors over time rather than a particular resulting state projected by the platform owners. As the team members at Douyin explained, their growth ambition is not set once for all but keeps adjusted over time. Initially, they just wanted to build a music short video community for the young. Even until the active user base grew over forty millions in Feb 2018, it still did not aim at pursuing No.1 short video platform in China. Those growth opportunities emerge from the participation of diverse users in the social networking ecosystem such as the voluntary forward activity of Weibo users, various dance challenge campaigns initiated by content creators at platform and self-driven connection with E-commerce platforms. As such, "Today's Douyin is out of the expectation of all people, even for those participating from the beginning." Commented by a senior manager at Douyin.

At the same time, we have seen that such scaling process keeps shaping its interdependency with other platform businesses in the social networking ecosystem, which particularly manifests in its dynamic coopetition tensions with focal and other non-focal actors in the ecosystem. On the one hand, Douyin's scaling cannot materialize without the support from focal platforms. It has to draw upon their infrastructure resources (e.g. API connection, social functionality) to piggyback users and develop competitive platform offerings in the ecosystem. Even until Douyin grew as an independent short video social platform in March 2018, it is still reluctant to completely decouple with WeChat and Weibo. Consequently, it must add value to their infrastructure resources (e.g. open third-party advertisement for WeChat) in order to gain the legitimacy in the ecosystem-that is, the focal actors' belief or feeling that it is indeed competent, appropriate, proper and desirable within the ecosystem. Similarly, Douyin has to gain the support from other non-focal businesses, especially when it tries

to build its own complementor partners in the ecosystem. This is presented in the diverse openness strategies from May 2018 such as the launch of Xingtu platform and mini program.

On the other hand, Douyin's scaling will increasingly threaten the leadership of focal actors in the ecosystem and/or the dominance of ecosystem actors in sub-markets. This is shown in the on-going user outflow or user engagement decrease at focal and other short video platforms with the scaling of Douyin. As such, today's cooperators may become the tomorrow's competitors. This is presented in the attitude change of WeChat and Weibo towards Douyin from acquiescent support to complete block. In this situation, Douyin confronts a continuing dilemma to balance its growth ambitions and dependency on focal actors in the ecosystem, which determines whether a complementary platform can successfully scale up and further to what extent it will scale up.

It is further noted that the essence of this dilemma process is in fact an issue related to Douyin's position shift in the ecosystem. Starting as a small player in the short video niche market, Douyin's core offerings and activities ever limited to complement existing social networking service around text and picture. With a series of emergent growth opportunities, Douyin evolves from a non-focal actor who defers to and builds upon the leadership of WeChat and Weibo platforms to a focal actor who becomes a new innovation and network hub in the ecosystem. During this position shift process, Douyin is shaped by existing ecosystem structure in the sense that current alignment among ecosystem members regarding their positions and configuration of activities impose the legitimacy pressure on Douyin for its growth. At the same time, Douyin's position shift also shapes the existing ecosystem structure in the sense that the growth of Douyin will increasingly shake and threaten ecosystem members' positions and activity flows among them, especially the leadership of focal actors. Therefore, at the core of platform scaling process, we have to understand how it solves the complementor's dilemma over time, more specifically, how to navigate the position shift process co-shaped by diverse ecosystem actors over time.

4.2.2 Three Mechanisms to Drive the Complementor's Dilemma Process

The case narrative manifests a distinct capability of Douyin to project and re-project its identity to balance its growth ambitions and dependence on the focal actors in China's social networking ecosystem, WeChat and Weibo. In what follows, I outline the main mechanisms that underpin this process and the process model generated in this research.

Creative proposition. Launching and developing in the social networking ecosystem, Douyin confronted an intricate competitive environment where diverse players in the short video market raised multifarious value propositions (i.e. target user, product design, core practice) under the governance of focal social platforms, WeChat and Weibo. To keep pursuing growth ambitions under these circumstances, Douyin had to not only develop the competitive advantage that differentiate itself from others at same position, but also properly deal with the dependency on focal platforms for their support over time. In this regard, Douyin defined its complementarity in the social networking ecosystem. To do this, Douyin conceives and defines the essential features central to its character creatively, including platform participants (e.g. the young and fashion), core value units (e.g. data-driven short video sharing), and architecture frontier (e.g. functionality and capability depending on focal or other non-focal actors). I refer to this mechanism as creative proposition (see Figure 9).

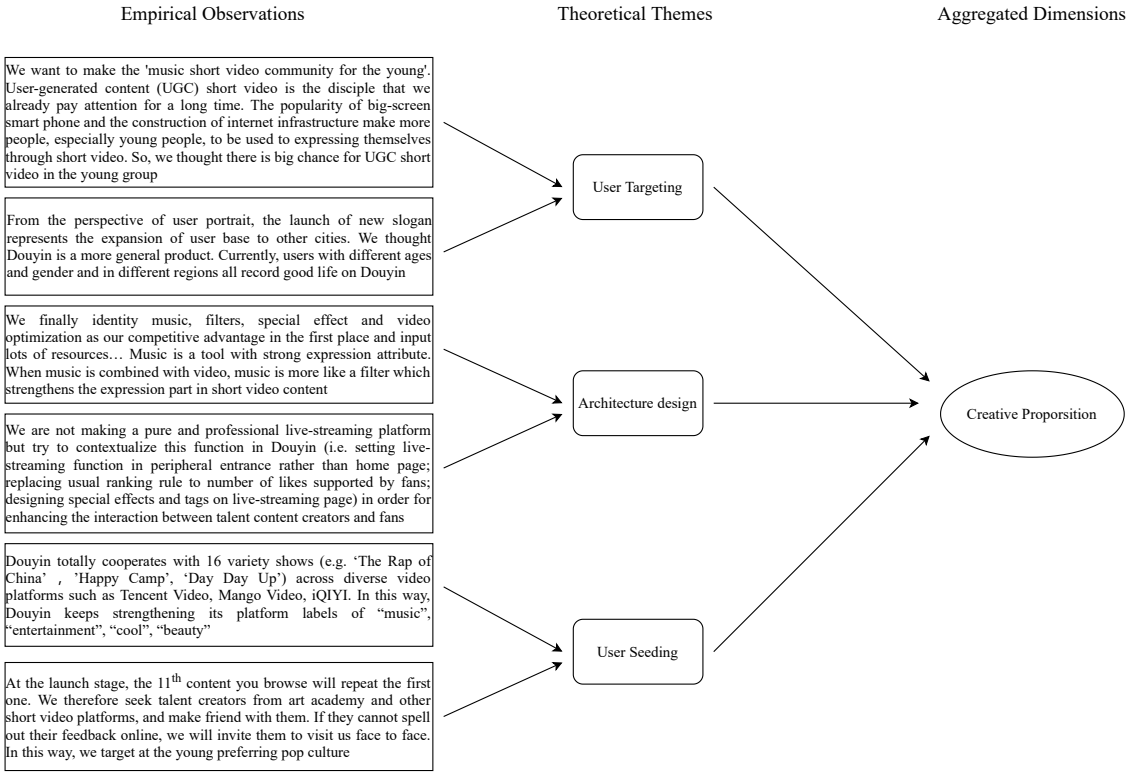


Figure 9. The Mechanism of Creative Proposition

A non-focal actor's creative proposition should be seen as an attempt to imagine who it is and what it is good at during growth. Keeping a close watch on the interdependency dynamics and technology change in the ecosystem, the non-focal actor pursues an desired ecosystem position through three activities. First, *user targeting* helps a non-focal actor to locate the market scope and unmet demands that it can leverage for the target position. Second, *user seeding* involves activities by which a non-focal actor steers the interaction that it wants users to engage in repeatedly. Both activities facilitate a non-focal actor to envision a distinctive growth ambition and competitive domain in a platform ecosystem. For instance, by defining as a music short video community for the young in 2016, Douyin anchored an emerging, unique market which makes itself stand out from the numerous complementors in the social networking ecosystem.

Third, a non-focal actor is able to further identify and design a series of viable and novel technological components through which the core competence at platform is leveraged to realize and solidify the expected position in an ecosystem, so called *platform architecture design*. As an example, when Douyin added live-streaming feature

in Sep 2017, it did not simply copy the usual functionality done by other live-streaming platforms, but contextualized it in a way to facilitate real-time interaction in entertainment short video community. Similarly, when Douyin initially launched in Sep 2016, it designed a series of specific beauty effect and film editing tools by combining its strong AI capability, which quickly differentiated itself from other short video apps in the ecosystem. In addition, the re-definition as entertainment short video community directed Douyin to open third-party advertising mode at platform which maintains the support from WeChat during growth.

Emergent deviation. My data analysis also revealed the key role of users in shaping the growth trajectory of Douyin. While platform owners have close engagement with Douyin in its design and governance dimensions, users (e.g. content creators and consumers) get more direct engagement with the platform in use. By actively selecting resources of an offering and recombining them with other resources (Henfridsson et al. 2018), latent and evolving end-users give new sense to existing offerings and further bring forth fresh growth opportunity that deviates from current identity proposition. I refer this mechanism as emergent deviation (see Figure 10). Consider the voluntary forward activities of key sharers on Weibo triggers off a short-term expansion of user groups and the popularity of entertainment-oriented content at Douyin in March 2017, the deviation from the projected user group (i.e. young and female) and core interaction (i.e. creating and sharing performing short video) implicates an emergent growth path for Douyin with high uncertainty.

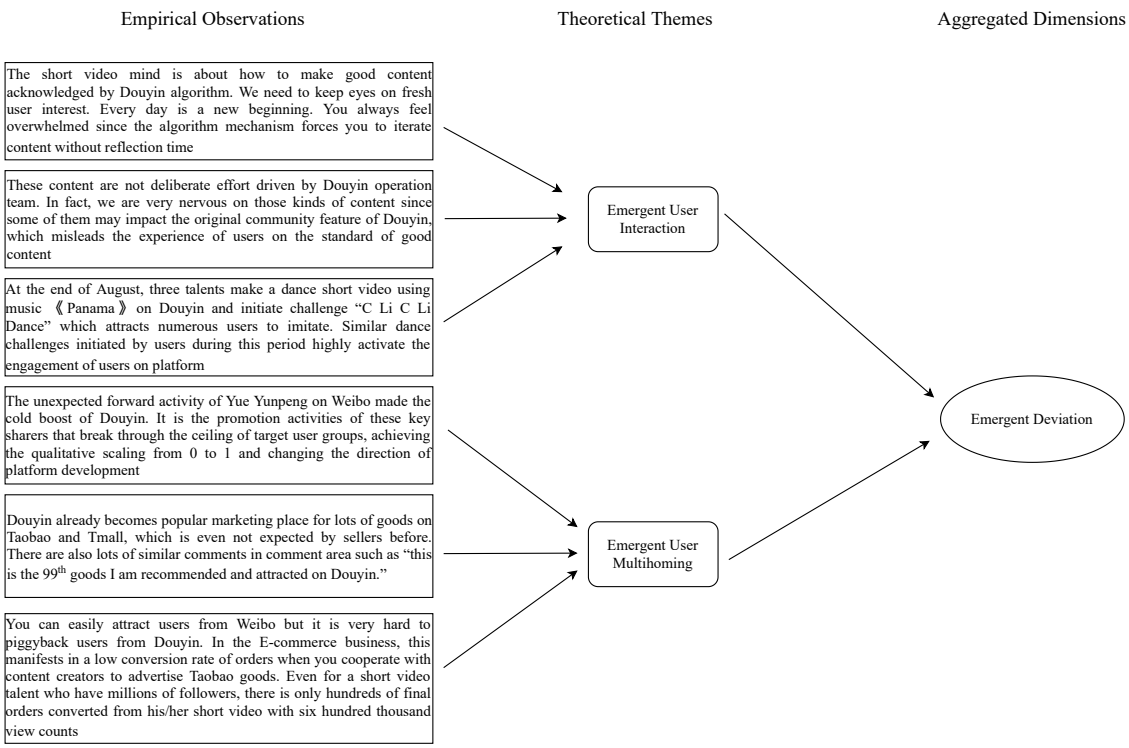


Figure 10. The Mechanism of Emergent Deviation

I found such growth opportunities mainly derives from two activities done by users. First, instead of engaging in the activities designed and expected by platform owners, end-users may generate *emergent user interaction* by actively recombining the digital resources offered on platform. As an idiographic user interaction is taken up by others, the core interaction of a platform will be under change. My data analysis shows that this changing process is extremely fast and ubiquitous on data-driven platforms as machine algorithm accelerates the recognition and spread of individual interaction that is preferred by platform users. For instance, when new dance challenge campaigns were just initiated on Douyin in Aug 2017, the content recommendation algorithm system promptly captured this emergent trend according to users' watching behavior (e.g. more click rate and like rate for such content), which opens up new growth opportunities on platform. It should be further noticed that algorithm may also zoom up unfavorable individual value paths that deteriorate platform growth (e.g. content homogeneity issue on June 2017) since algorithm does not have value judgement but only learns user behavior. As a result, complementors have to trace user activities persistently and cautiously in case of unexpected interactions on platforms.

Second, end-users may shape the position of Douyin relative to focal platforms through *emergent user multihoming*. As users are able to cherry-pick digital resources across different platforms over time in the moment of use, a particular value path offered on focal platforms may be adopted in part and further combined with other digital resources in many cases (Henfridsson et al. 2018). In this multihoming process, end-users re-configure the value from using complementary and focal platforms, which shifts their existing asymmetric interdependency in ecosystems. In the case of Douyin, we saw a progressive multihoming process where more users from Weibo and WeChat adopted Douyin as an emerging platform to share entertainment contents, do real-time social interaction and connect existing complementors in ecosystems at the end. Consequently, an increasing number of core offerings on focal platforms is no longer exclusive but partially picked-and-shared with Douyin by end-users, which gradually decreases the asymmetric power of Weibo and WeChat towards Douyin.

As such, emergent innovation in different user communities constantly assign new functions to a given digital platform based on their individual purposes in diverse contexts. These unexpected user activities keep lighting new identity inspiration in terms of "what an organization could be in the future", leading to "aha" moments for platform owners to re-think about the platform in a novel way. The resulting discrepancy between "what a platform is now" and "what it could be later" therefore demonstrates that platform identity is not an enduring concept in the long term, which is continually co-shaped by diverse actors in the ecosystem.

Strategic Reflexivity. While creative proposition helps Douyin define what it is in the present, the emergent growth opportunities derived from user activities urges for a deliberate reflection on what it wants to be in the future. In particular, due to the prominent power asymmetry relative to focal platforms, a non-focal actor has to weigh multiple interdependence scenarios implied in emergent growth opportunities in a first-mover fashion, which would be seized by competitors otherwise. I refer to this mechanism as strategic reflexivity (see Figure 11).

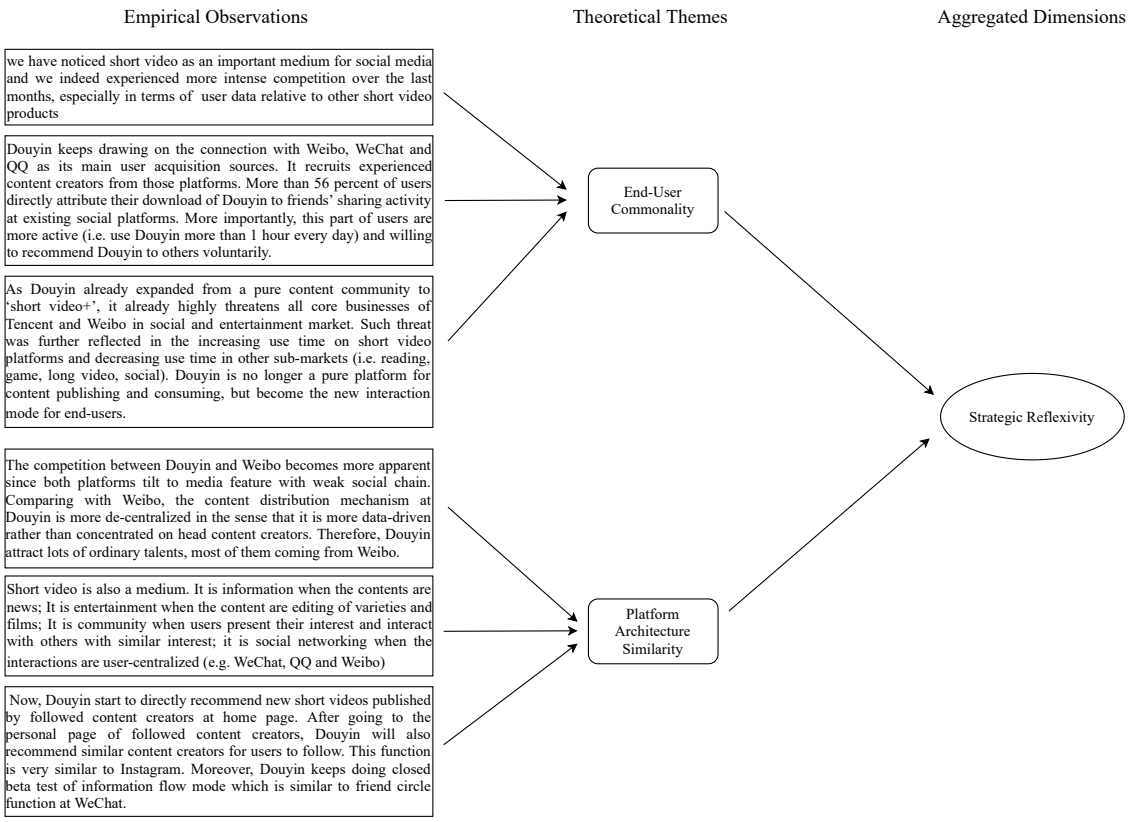


Figure 11. The Mechanism of Strategic Reflexivity

At the core of this mechanism, a complementary platform predicts the coopetitive activities of focal platforms by evaluating their platform architecture similarity and end-user overlap for different growth paths. First, *platform architecture* refers to the structure of a platform business, including technological capability of a platform and the way platform technological components function and connect participants. With higher platform architecture similarity (i.e. the degree the technological architectures of the two platforms share same functionalities, capabilities and technological attributes), Douyin transforms from an innovation node to innovation hub in ecosystem by enabling similar value creation on platform. Second, *end-user profile* represents the market that a platform serves, which defines the relevant actor communities in the ecosystem who are expected to be matter for the platform identity. With higher end-user overlap (i.e. the ratio of the end-users at a focal platform who also participate in the complementary platform) , it is more promising for Douyin to challenge the network center (i.e. WeChat and Weibo) by leveraging the shared user relationship to generate similar network effects.

As a result, by analyzing and comparing the platform architecture similarity and end-user overlap under the projected and emergent platform identities, Douyin is able to figure out the degree of deviation from present legitimacy scenario vis-à-vis focal platforms and further their potential reaction. As an example, when Douyin initially projected as music short video community for the young, it has low user commonality with WeChat and Weibo due to its niche targeting user group in young and female users. Similarly, they got relatively low platform architecture similarity in the sense that focal platforms focus on mainstream social interaction mode based on text and picture but Douyin focus on content creation and sharing based on short video. At this stage, Douyin is more likely to be regarded as a beneficial complementor by reaching out users and developing value outside the ecosystem boundary, leading to strong endorsement from focal actors. However, if it re-projects as entertainment short video community, the platform will envelop into and therefore threaten Weibo's identity domain by leveraging the similar user network and platform functionality/capability, leading to decreasing support from Weibo. Similarly, when Douyin confronts the growth opportunity to be an independent social platform, the foreseeable increase in platform architecture similarity and end-user overlap will highly threat the focal position of WeChat with intense retaliation such as connection blocking. As such, Douyin is able to expect how its legitimacy may change and why it changes in the ecosystem.

Strategic reflexivity therefore brings clarity to the co-opetition condition of a particular growth path, which further helps Douyin to take preemptive strategies/activities in new legitimacy sceneries. Specifically, for a legitimacy scenario that is still possible to gain necessary support from focal actors, the platform business could deliberately navigate its identity proposition to alleviate the potential tension with focal actors during growth. For instance, while re-projecting as entertainment short video community will inevitably deteriorate the relationship with Weibo, it is not consequent via-a-via WeChat. By explicitly specifying the target users as those who prefer entertainment content and opening third-party advertising mode at platform,

Douyin took more effort in exploiting distinctive market and technological capabilities that complement to WeChat's focal value. In this way, Douyin secured its support from WeChat in the new legitimacy scenario.

On the contrary, for a legitimacy scenario within which legitimacy and the endorsement from focal platforms are unlikely to gain, the platform business has to either give up this growth path or bypass the dependency on focal platforms through aggressive "get-big-fast' strategies in order to obtain sufficient resources within and outside the ecosystem in that legitimacy scenario. As an example, when Douyin attempted to re-project as independent short video social platform, it will be inevitable to lose the legitimacy from both WeChat and Weibo since their interactions will completely escalate into winner-take-all battles by competing for same platform capabilities and participants. In this situation, the only way to materialize this identity is to develop strong enough network effects and tip the ecosystem to its favor before focal actors' reaction. As such, Douyin could build mutual forbearance with WeChat and Weibo, which forces them to recognize its legitimacy in new identity domain. This directs the aggressive platform connection and operation strategies across ecosystems in Jan and Feb 2018, which becomes the foundation for the successful re-projection of Douyin identity from March 2018.

4.2.3 A Process Model of Complementor Growth in Platform Ecosystems

I propose a process model (See Figure 12) that encapsulates (a) the *ecosystem contexts* that sensitize a complementor to the interdependency dilemma period, (b) the *interaction between identity projecting mechanisms* that help the complementor navigate the interdependency dilemma period in platform ecosystems, and (c) its *outcomes* in terms of user base scaling and user engagement growth.

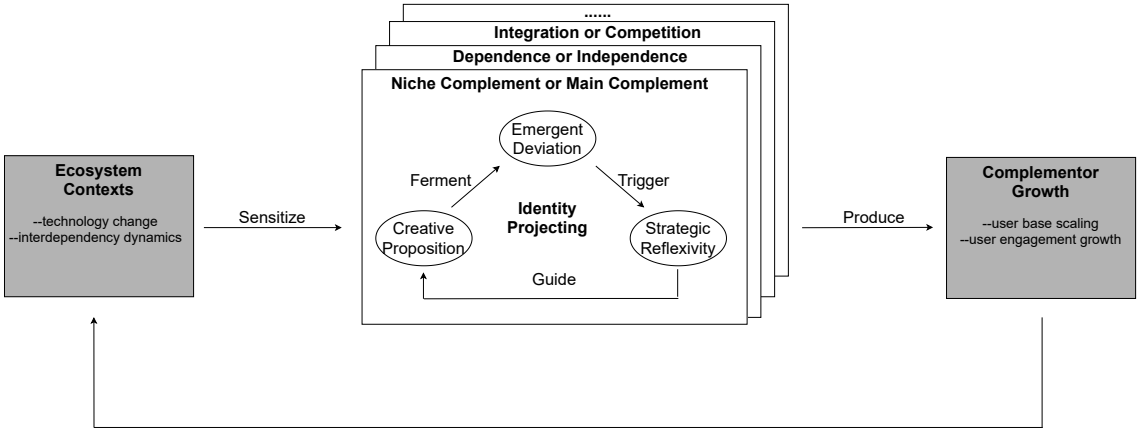


Figure 12. A process Model of Platform Identity Projecting

Ecosystem Contexts. Complementors become sensitive to the interdependency dilemma due to the changing ecosystem conditions over time. First, the change in the underlying digital infrastructure of whole ecosystem paves the way for new growth opportunities (Constantinides et al. 2018; Henfridsson 2020). The widespread availability of digital technologies (e.g. 4G and full-screen smart phone) enabled and facilitated new computed human experience (Baskerville et al. 2020; Yoo 2010), which were increasingly perceived and materialized as the new growth point by ecosystem actors. Second, interdependency dynamics portray the competition and complementarity among focal platforms and complementors in platform ecosystems over time. As digital innovation boundaries become more porous and fluid with less predefined agency (Lusch and Nambisan 2015; Nambisan et al. 2017), platform ecosystem actors are forced to constantly reflect on their activities and positioning in order for competitive advantage. Further, the more intricate and unpredictable innovation landscape in platform ecosystems (Boland et al. 2007; Yoo et al. 2012) makes the power asymmetric between focal platforms and complementors less invincible over time, which unfreezes their relative positions but also change the support attitude of focal platforms toward complementor growth. Consequently, it is more urgent for an embedded complementor in platform ecosystems to consider how to balance its growth ambitions and the dependency on focal platforms as it is growing.

Interaction between Identity Projecting Mechanisms. At the crux of this complementor's dilemmas, a growing complementor needs to be aggressive while, at

the same time, gaining endorsement from focal actors. To this end, the complementor must periodically reflects on its platform identity in terms of who it is and what it wants to be in the future, through which it seeks to convey and establish a desirable, appropriate, competent, but also distinctive position in platform ecosystems. Co-shaped by diverse ecosystem actors together, such platform identity projecting at complementors is driven by the iteration of three mechanisms as outlined below.

*Strategic reflexivity **guides** creative proposition.* To pursue growth ambitions in intricate competitive ecosystems governed by focal platforms, a complementor must be sensitive to its position shift in ecosystems, in other words, what it is relative to focal actors in the ecosystem. Given the necessity of focal platform endorsement towards complementor growth, strategic reflexivity provides the cues of whether or not to pursue a particular growth path in current ecosystem context. Depending on the possibilities to secure or bypass the existing dependency on focal platforms, strategic reflexivity serves as a filter to guide the search and design of viable, novel identity proposition in a manner that matches with the competitive domain and core competence of the complementor (Santos and Eisenhardt 2005; Tripsas 2009). As such, the conceived position realizes and solidifies over time, which portrays a new interdependency scenario with other actors in platform ecosystems.

*Creative proposition **ferments** emergent deviation.* Since users are reflective agents who situate themselves in platform ecosystems (Garud and Karnøe 2001; Henfridsson and Yoo 2014), they also generate individual value paths by recombining complementor offerings in ecosystems, or even rethinking their usages and purposes, which deviate from the existing identity proposition made by complementors themselves. When such idiographic user activities tend to generalize on platform powered by algorithm, new promising growth paths are fermented in front of a complementor. Accordingly, unexpected identity deviation fermented from present identity proposition inspires new growth ambition and ecosystem position available for a complementor, but also potentially breaks the established interdependency with focal actors, leading to an interdependency dilemma concern from the complementor.

*Emergent deviation **triggers** strategic reflexivity*. Promising growth paths brought by emergent identity deviation also represent new interdependence scenarios for a complementor, which are coveted by numerous, heterogeneous competitors in platform ecosystems. In particular, due to the power asymmetry with focal actors (Hurni et al. 2021), the emergent identity deviation propels the complementor to assess and weigh their potential reactions among multiple promising growth paths strategically in order to pursue the optimal one in a first-mover fashion. Specifically, through reflecting on the end-user overlap and platform architecture similarity with focal platforms, a complementor is able to appreciate and imagine its future position in a platform ecosystem in view of the current one (Cennamo 2021), which facilitates the evaluation of forthcoming tensions with focal actors in different growth paths. Accordingly, the complementor is capable of making decision to refresh its growth ambitions and corresponding ecosystem position through subsequent identity proposition.

Complementor Growth. As complementors re-project their identity, the complementor's dilemma is shaped through balancing the growth ambitions and focal platforms interdependency temporarily, which produces rapid growth of complementary platforms in terms of user base and user engagement. Further, the active shift of positions in platform ecosystems during growth makes the complementors' dilemma process more apparent and breathtaking due to its higher sensitivity to the context conditions. For instance, considering the first dilemma process that only requires to make decision between niche complementor and main complementor. In this situation, the complementor's dilemma is not a serious issue since new growth ambition does not apparently influence existing ecosystem structure and further its legitimacy in the ecosystem. However, with rapid growth of Douyin and more intense coopetition tension with focal actors later, the dilemma processes (e.g. dependence vs independence) ask for more deliberate and urgent consideration as emerging growth paths will increasingly disrupt its legitimacy in the ecosystem. In this situation, wrong judgment and response towards emergent identity discrepancy are more likely to harm and even destroy the complementary platform, making the complementor's dilemma process more relevant

and vital for platform scaling in digital ecosystems.

4.3 Summary of the Empirical Study One

This chapter develops the mechanisms that drive the complementor's dilemma process at Douyin and further build a process model of complementor growth in digital ecosystems.

At the foundation of Douyin's evolution trajectory, I frame the platform scaling as position shift in digital ecosystms. In particular, Douyin's growth is not a target state set by platform owners once for all, but a continuous changing process based on ecosystem-level economies co-shaped by diverse actors over time. During this process, the platform's position shift from a complementor who highly draw upon existing focal actors' infrastructure resources to be independent and even parallel with incumbent focal platforms through building its own complementor network, leading to complicated and changeable coopetition tensions among ecosystem actors.

In order to ravel out this position shift challenge during scaling, a platform business has to apply platform identity to balance its growth ambitions and the dependency on focal actors in ecosystems. Specifically, three mechanisms are figured out in this case as identity projection, identity deviation and identity evaluation. By deliberately projecting what it is now, a platform business can be both competitive/distinctive within like organizations by searching and designing viable and novel growth strategies and legitimate by defining its membership in a broad group of like organizations. However, latent and evolving end-users will keep giving new sense to existing offerings and further bringing forth fresh growth opportunity that deviates from current identity projection, which requires a series of careful trade-off among multiple legitimacy sceneries. Through such identity evaluation, a platform business makes sense of what it wants to be in the future and reshapes its interdependency with other actors in the ecosystem. The process model of complementor growth therefore highlights that platform identity is an important prescription to help platform business "get big fast".

The theory building is not without limitation. First, I am exclusively relying on an extreme case of Douyin in social network ecosystem. While Douyin serves as a great

example of complementor growth, I recognize that the interdependency structure in this ecosystem is more relaxed than a classic platform ecosystem such as IOS and Android ecosystem where single actor takes an incontestable focal position which is almost impossible to be shook by other ecosystem participants. Future research could consider other ecosystem contexts which helps to understand the conditions and degrees that a complementor may confront the interdependency dilemmas during growth. Second, this research did not specifically study the process by which a particular user activity, originally idiographic, are taken up by other users and generalized on platforms. Future research can extend my study by including more granular user data at individual level to show how the dynamic interaction between users and platform owners in digital resource recombination shape platform growth in ecosystems. Third, this study did not go deep into the tensions within the platform business, particularly the potential resistance and conflict in different departments during identity re-projection process. Since prior literature emphasizes the enduring nature of identity within organizations (Albert and Whetten, 1985; Whetten 2006), it is interesting to explore whether the employees at platform businesses hold similar belief and how platform owners reconcile such tensions when identity re-projection becomes necessary for continuing growth in digital markets.

The following chapter partially respond to the above-mentioned limitations by moving on to test and generalize the findings into the broader social networking ecosystem context at iOS store, particularly the association between identity projection and the survival of platform businesses.

5. THE EMPIRICAL STUDY TWO: IDENTITY PROJECTION STRATEGIES IN THE SCOIAL NETWORKING ECOSYSTEM

Non-focal actors in platform ecosystems have to be both competitive among and backed by ecosystem participants. Building upon the literature and causal mechanisms derived from process-tracing in preceding chapters, this chapter further explored and tested potential identity projection strategies that a non-focal actor can use to navigate its survival in digital markets. To this end, research hypotheses tailored for the research question were developed. I will show that the preceding theory development process not only facilitates our methodological innovation in the study of platform identity in IS discipline (e.g. a computational approach), but also enhances our understanding of platform business survival in specific ecosystem contexts (e.g. boundary conditions).

5.1 Hypothesis Development

As discussed in literature review chapter, extant research suggests a strong association between identity projection and non-focal actor development in platform ecosystem context. In particular, during the pursuit of new position in an ecosystem, a non-focal actor (e.g. complementor) has to keep evaluating and adjusting its identity proposition with respect to the endorsement of end-users, other non-focal actors and focal actors, manifested in the three mechanisms in the process model (See Figure 12). I therefore propose following five hypotheses to test the effect of different identity projection strategies on solving the complementor's dilemma, manifested in the survival duration in digital ecosystems.

5.1.1 Identity Conformity

As one of the key strategies to gain legitimacy, a non-focal platform is able to align itself with the taken-for-granted, already-legitimated structure and practices which mirror actors' expectations about its "appropriate" and "inappropriate" positions and activities in the ecosystem (Anthony and Tripsas 2016; Zimmerman and Zeitz 2002; Zuckerman 2004, 2000). As such, legitimacy is achieved through *identity conformity* which demonstrates its consistency or conformity to the institutionalized preferences

(Ansari et al. 2015; Deephouse 1996). In platform ecosystems, it enacts in the defined common interest and aligned inter-linkage (e.g. focal and non-focal position) among ecosystem actors. In this regard, there are at least two specific strategies that a non-focal actor can adopt to achieve such conformity.

First, connecting with boundary resources (e.g. API) provided at focal platforms, a non-focal actor can not only access to superior innovation capability and network resources (Ghazawneh and Henfridsson 2013; Parker et al. 2016), but also communicate its non-focal position in the ecosystem with increasing dependency on focal platforms. As such, boundary resource connection activities help the actor to gain the legitimacy from focal platform owners with regard to its competence in contributing to the ecosystem and appropriateness in deferring to the leader positions of focal platforms. Consequently, I derive the following hypothesis:

H1(a): Boundary resource connection is positively associated with the likelihood of the survival of non-focal app in digital ecosystems.

Second, at the same time, a newly joined actor of a digital ecosystem can share similar strategic group gene through developing platform architecture similar to other ecosystem members (Kazan et al. 2017). While such an architecture assimilating process helps the actor to commit to a membership of broad groups of like organizations in the ecosystem, it increasingly blurs the actor's characteristics comparing with incumbent non-focal members, leading to a less competitive position when rivaling for the attention of focal platform owners and end-users. This is especially salient in mature markets within which most consumer demands are served by incumbent non-focal actors who have established their position in the particular ecosystem. As such, the contribution of architecture assimilating to actor development is expected to be limited in digital ecosystems. I therefore formulate the following hypothesis:

H1(b): Architecture assimilation does not significantly increase the likelihood of the survival of non-focal platforms in digital ecosystems.

5.1.2 Identity Differentiation

At the same time, by projecting the identity different enough from the exemplars (or

prototypes) in the ecosystem, a non-focal platform can convey its novelty or distinction with respect to the competence of making unique contribution towards the innovation potential or network effects in the ecosystem. As such, legitimacy is achieved through *identity differentiation* which demonstrates its distinctiveness which are preferred by external stakeholders (Navis and Glynn 2011) and make it more likely to win the competition for the focal platforms' attention. However, such nonconformity has to be perceived as "good risk" by focal platforms in the sense that it is not threating their focal position in the ecosystem. To this end, the non-focal actor has to differentiate itself from other similar actors within the ecosystem and sticks to its non-focal positioning at the same time. There are at least two specific strategic activities to achieve this purpose.

First, through successively dissimilating the platform architecture from others affiliating in same membership, the non-focal actor is able to build an asymmetric identity domain when competing with other incumbent non-focal members. It is not only attractive for the end-users at focal platforms, but also helpful for gaining legitimacy from focal platforms given their dissimilar architecture through leveraging different and unique platform capabilities. In particular, since focal platforms will only react to others' action in a particularly salient "competitive arena that best demonstrates and reinforces their identity in the marketplace" (Livengood and Reger 2010, pp. 48), their endorsement is more likely to sustain as long as the actor keeps asymmetric identity domain. Consequently, I propose:

H2(a): Architecture dissimilation is positively associated with the likelihood of the survival of non-focal platforms in digital ecosystems.

Second, actors can materialize the identity differentiation by directly adjusting its membership affiliation and corresponding user group in the ecosystem. While such membership shift helps to revitalize existing platform offerings in new market scope, it may highly confuse and decrease the identity recognition from existing ecosystem members (e.g. on-board app users, app cooperators) in terms of who it is and what it does, leading to negative feedback from relevant stakeholders (Gioia et al. 2000) and

less effectiveness of growth strategies at the non-focal platform (Hannan et al. 2006; Hsu and Hannan 2005). For those reasons, I formulate:

H2(b): Membership shift does not significantly increase the likelihood of the survival of non-focal platforms in digital ecosystems.

5.1.3 Identity Refinement

Lastly, developing a legitimately distinctive identity through identity conformity and identity differentiation does not necessarily signify that it can be maintained by the non-focal platform in the long term. This uncertainty and pressure of sustaining projected identity are particularly salient in digital markets, where legitimacy is highly contested by platform actors who are aggressively competing to institute their offerings, market, and position (Drori et al. 2009; Zook 2005), and establishing their credibility and authority in ecosystems (Nambisan et al. 2017; Parker et al. 2016) due to the winner-take-all logic (Eisenmann et al. 2006). As a result, a non-focal platform has to prevent from losing its established legitimacy in the face of emerging ecosystem participants through *identity refinement* which refers to the reinforcement and clarification of projected identity without major revision or reformulation (Cloutier and Ravasi 2020; Ravasi et al. 2020). In mobile app markets, this can be achieved by on-going optimization of existing platform architecture and API connection which defines its current membership and competence (Cennamo 2021), Thus, I formulate:

H3: Architecture maintenance is positively associated with the likelihood of the survival of non-focal platforms in digital ecosystems.

I summary the econometric model in Figure 13 as following.

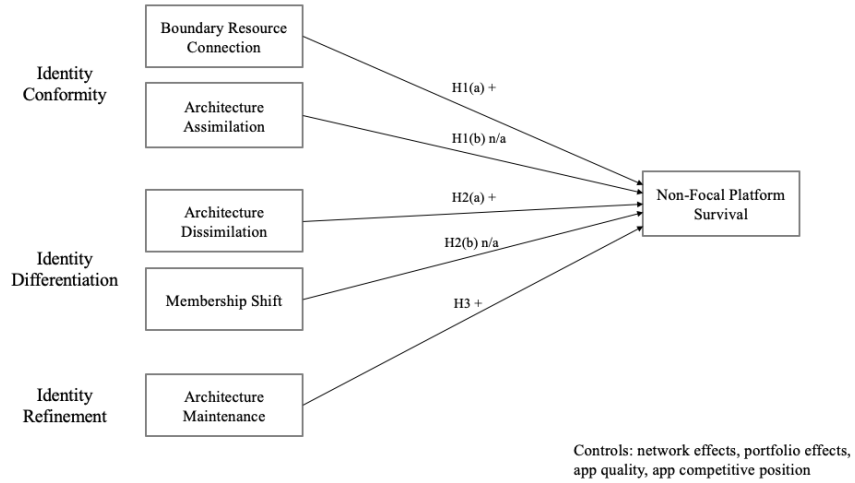


Figure 13. Econometric Model Based on Proposed Hypotheses

5.2 Regression Result

Building upon the three models explained in methodology part, I presented the consistent result in Table 13.

Table 13. app Survival Estimation Result

Parameter	(1) Cox with gamma frailty	(2) Weibull with gamma frailty	(3) Discrete-time logic random effect hazard
C	0.92** (.027)	0.92** (.027)	0.94* (.027)
S	1.01 (.008)	1.01 (.008)	1.00 (.008)
NS	0.98** (.008)	0.98** (.008)	0.98* (.009)
CC	1.09 (.070)	1.09 (.070)	1.06 (.070)
M	0.96***(.005)	0.96***(.005)	0.98** (.006)
U	0.80***(.034)	0.80***(.034)	0.83***(.036)
T	0.83***(.031)	0.83***(.031)	0.84***(.030)
ASC	0.91***(.020)	0.91***(.020)	0.90***(.020)
ADC	1.01 (.003)	1.01 (.003)	1.01 (.003)
AR	1.18***(.048)	1.18***(.048)	1.09** (.044)
UC	0.99 (.000)	0.99 (.000)	1.00 (.000)
UR	1.30** (.000)	1.30** (.000)	1.26***(.071)

OR	0.87 (.135)	0.87 (.135)	0.96 (.168)
UBO	0.98 (.012)	0.98 (.012)	0.99 (.013)
Frailty	0.11***(.055)	0.11***(.055)	0.10***(.051)
LL^	-4039	-1253	-3062

*p<0.05, **p<0.01, ***p<0.001; n=1917; report in hazard ratio

^ Hazard models are estimated using log likelihood (LL) functions and LL indicates the fit of the model, with lower absolute values indicating a better fit.

API connection: Connecting API of focal platforms is associated with significant decrease in the hazard ratio of removing from the iOS store. In particular, change in API connection update is estimated to increase survival time by appropriately 8.04%, supporting H1.

Architecture assimilation: Making social functionality update has no significant effect on the survival duration of an app at iOS store. In other words, developing similar technological capabilities (e.g. enhancing social interaction among users) relative to other actors in the social networking ecosystem does not contribute to the app survival. The estimate allows me to rule out even a pretty small effect of 0.5% change in survival time. Hence, H2 is supported. This result is especially interesting and counterintuitive given the fact that more existing and emerging apps across different categories tend to combine social computing technologies as a strategy to build new competitive advantage.

Architecture dissimilation: As expected, by differentiating the technological capabilities from other similar apps in the social networking ecosystem through innovating non-social functionality (e.g. e-commerce, map, music, game) is strongly associated with the survival duration of an app at iOS store. Specifically, apps with one more update of non-social function tend to survive 2.4% longer at iOS store (P=0.005). These findings support H3.

Membership shift: I also find no evidence that frequent change of app membership across different categories (e.g. social, music, book, travel, health) defined at iOS store

will be association with an app's survival duration, indicating the potential cancelling effect between the advantages and drawbacks brought by membership shift. Hence, H4 is supported.

Architecture maintenance: As expected, I also find that reinforcing existing projected identity through functionality optimization is associated with a strong positive effect on the survival time of an app at iOS store. In particular, apps with one more update of function maintenance are estimated to survival approximately 4.6% more months at iOS store. Hence, H5 is clearly supported.

Control variables: Network effect is positively associated with the survival time of an app, both from user base and user engagement. Number of sister apps produced in same category positively contribute to the survival duration, indicating the potential knowledge and resource sharing among similar apps produced by the same developer. In addition, more controversial apps with relatively lower rating seems survival longer in the matured digital market, which indicate more extensive app engagement from different user groups with diverse usage preferences. App developers then have more chance to attempt different growth paths based on different user feedback. With regard to the competitive position, competitive apps are positively associated with survival duration. In particular, only the ranking in the category that the app affiliates is significant comparing with its overall ranking across categories, showing the importance of within-membership competition for app survival in matured ecosystems.

5.3 Robustness Checks

Although the preceding econometrics analysis shows an overall positive and statistically significant association between platform identity projection strategies and app survival duration at iOS store, the nature of observation data raises concern about the causal interpretation of the findings. Specially, through the exogenous sampling selection based on explanatory variables (e.g. filter apps with stable user base over the life cycle), I control for the bias from missing data. However, I did not control for the bias from self-selection. That is, since I did not randomly assign app developers to identity projection (treatment group), I was not able to control for unobservable

variables that drive app developers to self-select themselves into a treatment group (e.g. whether to do identity projection or not). It is easy to think of variables that are likely to influence developers' identity projection decision and simultaneously their time to removal from iOS store, hence leading to a self-selection bias.

To solve this self-selection issue, I adopted two approaches as following. First, a *Heckman two-step test* was conducted (Wooldridge 2009). Given the sample selection binary variable *identity projection* (in this case, whether an app has ever made function update or not over the lifecycle), the original econometric model can be rewritten to show that it is jointly determined by two latent models:

$$\text{IdentityProjection} = \sum_{n=1}^{N} \nu_{in} X_n + \epsilon_i \ ;$$

$$H_i(t)=H_0(t)\exp\begin{pmatrix} \alpha_0 + \sum_{j=1}^{J} \beta_{ij} IdentityConformity_i \\ + \sum_{k=1}^{K} \gamma_{ik} IdentityDifferentiation_i \\ + \sum_{l=1}^{L} \delta_{il} IdentityRefinement_i \\ + \sum_{m=1}^{M} \theta_{im} ControlVariable_i \end{pmatrix} \quad \text{if IdentityProjection}>0 \ (1)$$

$$\text{and} \quad H_i(t)=H_0(t)\exp\left(\alpha_0 + \sum_{m=1}^{M} \theta_{im} ControlVariable_i\right) \ \text{if IdentityProjection} \leqslant 0 \ (2)$$

The solution is therefore to predict the likelihood of participation in identity projection at first stage using a probit model based on following observed variables:

PreviousUpdate, which indicates the number of function update of an app before 2014;

SocialApp, which equal to 1 if an app belongs to the social category at iOS store when it launched;

CatAppNum, which indicates the average number of apps in the category that an app belongs to;

SisterApp, which indicates the average number of sister apps that a same app developer made;

AppAge, which indicates the launch months before 2014;

After calculating the predicted inverse Mills ratio ($\hat{\lambda}$) for each observation, I use it as a predictor of the survival model in the second step. Since the coefficient on IMR ($\hat{\lambda}$) is statistically equal to zero, there is no apparent evidence of self-selection issue

and the survival analysis results are consistent (See Table 14).

Table 14. app Survival Estimation Result with Heckman Test

Parameter	Cox with gamma frailty
C	0.92* (.031)
S	1.01 (.009)
NS	0.97** (.010)
CC	1.09 (.070)
M	0.96***(.006)
U	0.80***(.034)
T	0.83***(.035)
ASC	0.97*(.012)
ADC	1.01 (.003)
UR	1.18***(.048)
UC	0.99 (.000)
CR	1.30** (.000)
OR	0.99 (.135)
IMR	4.03 (.008)
Frailty	0.09***(.050)
LL^	-3246

*p<0.05, **p<0.01, ***p<0.001; n=1917; report in hazard ratio

Second, a *proportional score matching* approach (Oestreicher-Singer and Zalmanson 2013) is conducted to corroborate the result from Heckman test. Following a different logic, a proportional score matching matches dataset with similar observable variables (e.g. *PreviousUpdate, SocialApp, CatAppNumber, SisterApp, AppAge*) that may influence the identity projection decision at an app. Those apps with similar variable values will have similar propensity to project their platform identity. As such, I match the sample data into treatment group (app that projects identity) and untreated group (apps that do not project identity). Since exact matching is often untenable with very few matches, I do it not according to the exact attributes of apps but according to their propensity scores which easily accommodate a large number of control variables (Rosenbaum and Rubin 1983).

To implement this approach in my case, I grouped identity projection activities at an app into three distinct binary treatments:

IdentityConfomity, which is equal to 1 if an app has ever made boundary resource connection or architecture assimilation

IdentityDifferentiation, which is equal to 1 if an app has ever made architecture dissimilation or membership shift

IdentityRefinement, which is equal to 1 if an app has ever made architecture maintenance

As for the matching algorithm of propensity score, I apply the Mahalanobis matching technique for the *IdentityPorjection* variable similar to Oestreicher-Singer and Zalmanson (2013). Using this method, I estimate a different propensity score for each treatment included in the *IdentityProjection* variable as mentioned before, and apps are then matched on the basis of these multiple scores.

The result for the treatment is presented in Table 15. With all data matched in treated or untreated group, the survival duration difference between treated and untreated group is statistically significant ($P<0.001$). In average, controlling for the observed differences between the groups, apps that do identity projection are more likely to survive longer for about 8 months. This difference emphasizes the effect of identity projection on the propensity to survive longer at iOS store, and it strengthens the findings of the hazard survival model.

Table 15. Propensity Score Matching

Treatment	Identity Projection Activity
Diff Mean	8.2
t-test (Diff Mean>0)	4.26^{***}
Diff Mean (Std. Err.)	1.923
Rosenbaum upper bounds significant for Gamma (Γ)	2

One limitation of propensity-score matching is its strong assumption that observable characteristics fully account for the selection of apps into the treatment and control

conditions. However, unobserved characteristics may still take effect in the selection bias. Accordingly, I further conducted sensitivity analysis by estimating Rosenbaum bounds (Rosenbaum 2002) which measure "how strongly an unobservable must influence the selection process in order to completely nullify the causal effects identified in the propensity-score analysis" (Oestreicher-Singer and Zalmanson 2013, pp.608) — in this case, the causal relationship between identity projection and survival duration. I presented the result of Rosenbaum bounds analysis in the bottom row of Table 18. I reported the critical value Γ at which the identity projection effect on app survival duration becomes insignificant due to the unobservable factors. In other words, an unobservable variable would have to change the odds of selection into the treatment group by at least 100 percent to nullify the identified effect of identity projection activity on app survival duration. This threshold is a very large value, similar to the findings of Oestreicher-Singer and Zalmanson (2013) and Sun and Zhu (2012). The result therefore suggests that unobserved selection is unlikely to nullify the causal effects.

5.4 Theory Generalization

This paper contributes to the platform literature, especially platform identity, by conceptualizing three identity projection strategies, namely identity conformity, identity differentiation and identity refinement. Based on the further testing of their relationship with non-focal platform survival in digital ecosystems, I discuss each of them as following.

First, identity conformity refers to the commitment to the identity-related expectations from ecosystem members about "appropriate" and "inappropriate" activities and positions in the ecosystem. Prior study emphasized the conformity towards the membership of broad groups of like organizations, mainly because such category-based expectation constructs the taken-for-granted practices and logics which are the key sources of legitimacy (Anthony and Tripsas 2016; Navis and Glynn 2011). However, the results reveal that non-focal actors are more sensitive to focal platforms' expectations in digital ecosystem context, manifested in the significant effect of API

connection on app survival. At the core of this difference, focal actors set and enforce the governance rules, alignment structure and reap the lion's share of gains in a platform ecosystem (Adner 2017; Tiwana 2013). In this regard, the endorsement from focal actors become more vital for firm survival than other similar non-focal actors in the ecosystem. Moreover, the insignificant association between architecture assimilation and app survival indicates the unbounded innovation space (Henfridsson et al. 2018; Nambisan et al., 2017) in platform ecosystem context, where actors are more inclusive for uncertainty and ambiguity due to the fluid and evolving scope, feature, and value of digital offerings (Yoo et al. 2010). As such, "the liability of newness" (Stinchcombe 1965) highlighted in industrial context is no longer an issue for platform businesses to gain legitimacy, which do not need to bound themselves within a particular membership.

Second, identity differentiation refers to differentiating the platform identity from other similar actors within an ecosystem. Extant research has suggested that external stakeholders accept some degree of variation in conformity to their expectations (Glynn and Navis 2013) as long as the organization is believed to be "focused enough" (Vergne and Wry 2014, pp. 69). In platform ecosystem context, this degree of freedom to project and enact identity discretionarily becomes higher and weighted more importantly for firm development, manifested in the significant relationship between architecture dissimilation and app survival. Since digital ecosystems are open-ended with low cost to participate (Svahn 2012; Yoo et al. 2010), an ecosystem actor will confront less predefined competitors with diverse goals, motives and capabilities. In this condition, focal actors benefit from attracting heterogeneous innovation agency (Boland et al. 2007), leading to escalating rivalry among non-focal actors. As such, platform ecosystem members value more on novelty and distinctiveness than conformity. At the same time, this study also indicates the necessity to build distinctiveness upon the focused core interaction (cf. Parker et al. 2016) in platform context. Since the core interaction defines the fundamental value to participants and attracts most users to the platform in the first place, arbitrary shift of platform membership characterized by

similar core interaction propositions will counteract the potential novelty it may bring, leading to insignificant effect on app survival in the results. In the end, I support to mirror the layered platform architecture design when projecting platform identity—that is, developing architecture dissimilation on top of core membership.

Third, identity refinement refers to reinforcing existing projected identity without major change. While organization identity literature tends to discuss the "enduring" or "continuity" ends underlying such refinement strategy which help to yield enhanced legitimacy and higher survival chances (Albert and Whetten 1985; Drori et al. 2009; Whetten 2006), it starts with a totally different logic in platform ecosystem context, namely "winner-take-all" (Eisenmann et al. 2006) and "get-big-fast" (Cennamo 2021). As such, platform actors are forced to refine their identity in case of losing position when confronting fierce competition from emerging actors. In this regard, refinement strategy rather implies a volatile nature of identity in platform ecosystems, which has to be elaborately defended in order to maintain the established legitimacy. Accordingly, successful refinement of platform identity will highly increase the chances of survival which is shown in the effect of architecture maintenance on app survival.

Combining the three identity projection strategies together, platform identity seems to be characterized by dynamics which involves periods of ongoing change punctuated by episodes of perceived stability. In Huang et al. 's (2017) work, it is marked as a continuous shift process through "recurring definition of what they do and who they are" (pp. 9). Ultimately, non-focal actors in platform ecosystems may "defend" or "betray" their existing identity in order to cater to competing market imperatives-that is, the expectation of what an organization should be in order to be competitive with other actors (Gioia et al. 2013a). To fully unpack this dynamic nature of platform identity, I ask further investigation to reinvent organizational identity research in a digital world. Moreover, while extant platform research tends to account for architecture innovation at Apps as a sequence of homogenous activities integrated in crude version update metrics (e.g. Boudreau 2012; Claussen et al. 2013; Foerderer et al. 2018), this study demonstrate that it can become vital leverage point for platform business to materialize

different identity projection strategies in digital ecosystems.

In addition, I contribute to the understanding of platform competition in an increasingly prevalent scenario—mature digital markets. With the stabilization of various digital markets dominated by early platform giants (e.g. Google, apple, Amazon), firms are more frequently forced to engage in multiple established ecosystems in order to seek for new growth opportunities. As such, even those focal actors in the native ecosystems may descend to be non-focal during the cross-ecosystem participation. Identity recognition in an ecosystem thus become more vital than ever before. Specifically, non-focal firms have to deliberate on the specific competition condition in such market when taking identity projection strategies. As the results show, some tactics (e.g. architecture assimilating, membership shift) may lose their positions due to the escalating rivalry within rigid markets. In this regard, non-focal firms are expected to keep leveraging their distinctive capabilities based on a stable membership affiliation in the ecosystem. This study therefore provides practical implication for those emerging and incumbent firms who attempt to participate across different digital ecosystems in the digital age.

Despite valuable contributions, this study has some limitations which provide opportunities for future studies. First, I focus only on the social networking ecosystem at iOS store. Since this is a pure digital space, we may expect different identity projection patterns and impact on platform development in other contexts (e.g. platforms crossing digital and physical space like Uber and Airbnb). I therefore call for future studies to replicate the findings in different contexts to confirm generalizability. Second, this study limits the measurement and analysis of identity projection tactics in Apps' update activities. Future studies may extend this paper by identifying further types of identity projection from different sources (e.g. platform statement, language used by platform owners, governance rule at platform). Finally, I locate the study in saturated markets. However, it does not exhaust the need to understand platform identity in emerging and rapid-growing contexts, especially its role in facilitating digital transformation process in numerous industrial markets. I therefore encourage scholars in

IS to explore this exciting domain in future studies.

5.5 Summary of the Empirical Study Two

This chapter generalizes the process-tracing findings related to platform identity in the empirical study one to all non-focal apps in the social networking ecosystem in China through a computational approach. While process-tracing method is highly suitable for theory development, a computational approach can be followed for theory testing. Specifically, given the vital role of ecosystem endorsement to complementor growth manifested in the process model in chapter four (e.g. identity deviation, identity evaluation), I explored potential identity projection strategies that can facilitate non-focal actors to gain legitimacy from ecosystem members (e.g. end-users, focal platforms) in this chapter. Further, building upon the identity projection mechanism (e.g. platform architecture design and platform scope targeting) generated in the process model, I conceptualize three identity projection strategies (identity conformity, identity differentiation, identity refinement) for non-focal platform development in digital ecosystems. The corresponding hypotheses tests based on large-sample econometric analysis revealed that beyond facilitating continuous growth in user base and user engagement since start-up, platform identity also plays a key role in entrenching non-focal actor survival when acquiring new positions in early matured digital market. As such, I extend platform identity theories developed from single case study to the whole life cycle of different non-focal actors in digital ecosystems.

My theory generation is not without limitations. First, to fit the developed theory with wide context, I restrict my theory generalization in the social networking ecosystem within which the non-focal actors share similar ecosystem structures with Douyin. While such data sampling increases the confidence interval of hypothesis test, my theory generalization is still limited without considering other platform ecosystem contexts. Future study therefore could test the platform identity theories developed from this study. Second, my theory generalization mainly focuses on one mechanism developed in the process model—identity projection. In this regard, I am still concentrated on platform owners' perspective, especially the potential strategies they

can use to facilitate platform business development. Future studies could further generalise the other two mechanisms respectively from the perspective of end-users and focal actors. Specifically, the crucial role of end-users in co-shaping platform identity and further platform growth will not exist only in the Douyin case (e.g. Lusch and Nambisan 2015; Lyytinen et al. 2016; Nambisan et al. 2017). Scholars could measure the design-use value path overlaps (Henfridsson et al. 2018) at a non-focal platform and explore to what extent that a new value path created by use recombination is able to lighten new platform identity and further the promising growth opportunities after it is recognized and adopted by platform owners in design recombination.

Moreover, scholars should consider the wider competitive environment (e.g. other non-focal actors, focal actors) when studying the role of platform identity in navigating non-focal platform growth. In particular, I suggest the red queen competition theory (Derfus et al. 2008; Giachetti et al. 2017) is highly valuable to understand how the effectiveness of identity projection strategies on platform survival/growth may be influenced by the competition dynamics in digital ecosystems. For instance, red queen theory indicates that the escalating competition from focal actors will be contingent on levels of product variety and technology heterogeneity in the ecosystem. Similarly, focal platforms' decisions on imitation scope and speed of new product innovation introduced in the ecosystem will also influence non-focal actor performance. As such, future studies are able to test the moderation effect of competition intensity in the ecosystem on the relationship between identity projection strategies and non-focal platform survival or growth.

Lastly, I recognize the huge potential of computational approaches in facilitating theory building and testing in the IS discipline. However, I only apply econometrics and natural language processing methods in this study. I therefore encourage the methodological pluralism in the research of platform identity such as sequence analysis (Gaskin et al. 2014), system dynamic modeling (Fang et al. 2018) and network visualization (Miranda et al. 2015).

The following chapter move on to discuss the theoretical, practical and

methodological implications of this study, particularly the contribution to digital platform scaling research in IS discipline.

6. DISCUSSION AND IMPLICATIONS

This chapter links the findings in the theory building and theory generalisation chapters with extant literature, especially their implication for current studies in complementor's dilemma, platform identity, digital complementarity, and platform scaling. As the world becomes increasingly networked in the digital age, this research also provides practical insights for the scaling of platform businesses. The chapter closes with discussion of the methodological implications for studying contemporary digital phenomena in the IS discipline.

6.1 Theoretical Contribution

The crucial role of platform identity in navigating non-focal actor growth in the Douyin case and broader social networking apps refreshes our understanding of the complementor position in digital ecosystems, organisational identity in platform contexts, and complementarity in the digital age. Combining these three theoretical implications, this study echoes with the overarching theme of platform business scaling in the digital age. I now discuss each of them in the following.

6.1.1 Contribution to Literature on Complementor's Dilemma

The process model proposes that the non-focal role of complementors should not be taken for granted. As unexpected user activities and changing ecosystem conditions keep illuminating alternative growth paths, complementors may confront interdependency dilemmas during growth. I explicate three such "complementor dilemmas": in this case, as niche complement or main complement, dependence or independence, integration or competition — where decisions change a complementor's position in a digital ecosystem over time. Since complementors start as the innovation and network peripheral whose growth draws upon focal actors' technological, monetisation, and distribution resources, prior studies tended to focus their effort on the focal platforms which determine and navigate the survival and development of the ecosystem. For instance, Tiwana et al. (2010) provided a governance framework to

cultivate and control external contribution in platform ecosystems. Later research further examines diverse governance mechanisms and strategies in different empirical settings, such as the openness management at Apple's iOS platform and Google's Android platform through boundary resources (Eaton et al. 2015; Ghazawneh and Henfridsson 2013; Karhu et al. 2018); curation and screening strategies to ensure matching quality among platform participants at OKCupid and eHarmony (Cennamo 2021; Parker et al. 2016); and complementor quality management at Facebook and Phillips Hue (Claussen et al. 2013; Hilbolling et al. 2020b). Looking closer at this platform governance literature, complementors are always pre-assumed as "freelances" who are able to access, quit, multi-home, and switch among different open-source platform ecosystems smoothly. This perspective is further assumed in the original definition of non-focal actors, whose "survivals are typically not dependent on the specific ecosystem" (Selander et al. 2013, pp. 184).

However, I argue that the fact that complementors are free from any specific ecosystem does not mean there is no friction when they participate in an ecosystem. As complementors in platform ecosystems can continuously search and redeem external capabilities across different innovation layers — including devices, networks, services, and contents (Cennamo et al. 2018; Salender et al. 2013; Yoo et al. 2010) — their growth is not bounded in any specific scale compared with industrial enterprises. In this regard, their non-focal roles are not fixed but changeable, which increasingly threatens focal actors' position in the ecosystem — manifested in the decreasing support from Weibo and WeChat in Douyin's dilemma process. In extreme cases, a complementor can even develop as a new focal actor in the ecosystem, leading to intense competition with incumbent focal giants. Hence, with the introduction of time, the co-evolution of ecosystem actors is about more than just horizontal rivalry in the same positions (i.e., some complementors become more salient at different points in time) (Teece 2018) but may affect the structural alignment of multilateral positions (i.e., complementors replace the focal position of incumbent platforms). Scholars therefore must be sensitised to the on-going complementors' interdependency dilemmas as a result of their growth

ambitions. As such, this thesis contributes to understanding the challenges and risks that these non-focal actors will confront from the strategic use of existing digital platforms and infrastructures (Smolander et al. 2020).

6.1.2 Contribution to Literature on Platform Identity

The process model suggests that platform identity helps navigate position coordination in digital ecosystems. A platform can convey a desired position that it would like ecosystem actors to see and achieve together through identity projection. However, it has to evaluate ecosystem actors' potential reactions toward a particular position through identity evaluation for it to materialise. Past research in management defines identity as a collective understanding of who they are in the eye of an organisation's members (Albert and Whetten 1985; Whetten 2006). In this regard, the framing of identity is a highly bounded process within an organisation which tends to be enduring in the long run. Platform business, however, is not designed by a single organisation and can only function with the participation of heterogeneous actors (Nambisan et al. 2017; Parker et al. 2016). Consequently, the identity forming process in digital ecosystems is far beyond an endogenous effort of inner platform designers and contingent on diverse ecosystem members. As such, tensions among those less-predefined ecosystem participants always exist, which are impossible to align once for all. Identity constructing at platform businesses then becomes more dynamic, manifested in an on-going re-projection process (e.g., identity conformity and identity differentiation strategies) punctuated by episodes of perceived stability (e.g., identity refinement strategy) as examined in in chapter five. As a result, adopting the identity lens in the platform context reveals a large difference between platform businesses and traditional organisations, which supports and answers the call to understand platforms as a qualitatively different form of organisation in the digital age (Gawer 2014; Henfridsson 2020; Huang et al. 2017).

While extant research conceptualised platform identity in terms of distinctive platform architecture and platform scope (Cennamo 2021), this study adds the

dimension of conformity that platform identity helps non-focal platforms acquire in digital ecosystems. This is based on the fact that beyond competing for the value source from the demand side (e.g., complementors and end-users) (Lusch and Nambisan 2015; Parker et al. 2016), non-focal platforms must gain supply-side support from focal actors due to their asymmetric interdependency in the ecosystem. As such, the framing of platform identity should extend from being purely distinctive (Cennamo 2021) to being legitimately distinctive (Navis and Glynn 2011) in digital markets. Such legitimately distinctive identity is further supported by the result in chapter five, which shows a significant impact of both identity conformity and identity differentiation on non-focal platform survival in digital ecosystems. In this regard, both identity components — platform architecture and platform scope — determine the value of a platform business, including its market orientation, overall user experience, and how various ecosystem actors connect to and perceive the platform (Cennamo 2018; Cennamo and Santalo 2013; Eisenmann et al. 2011). Hence, it is revealed that platform identity portrays the interdependency of a non-focal actor in digital ecosystems and heeds the recent call for more studies in "understanding the creation of novel solutions for non-focal actors that must be able to identify the risks and opportunities related to digital platforms and infrastructures and prepare for technology and business changes in the future" (Smolander et al. 2020, pp.5954).

Moreover, our research highlights the key role of end-users in co-shaping the identity projection process at non-focal platforms. Instead of passively accepting platform offerings and scope designed by platform owners, end-users voluntarily generate their own value in use through a pick-and-choose fashion (Selander et al. 2013), or even rethink the usage and purpose of given resources (Henfridsson et al. 2018). As such, end-users are highly autonomous with diverse capabilities, motives, and preferences that are outside of the platform owner's knowledge and control. In this situation, end-users' innovation activities create more uncertainty for the identity forming process. While some use recombination (Henfridsson et al. 2018) illuminates new promising growth paths for a non-focal platform, others may deteriorate its existing

competitive position in the ecosystem (e.g., the content homogeneity issue in Douyin's case). Platform owners therefore must carefully screen different deviated paths triggered by user activities to sustain the legitimately distinctive projection of identity. This conforms to the screening mechanism (Parker et al. 2016; Wareham et al. 2014) proposed in platform governance, in the sense that not every user innovation counts equally for platform growth. Platform owners must certify the quality of user innovations, and accordingly limit and filter participation in the identity forming process for those not contributing to acquiring legitimacy in the ecosystem.

6.1.3 Contribution to Literature on Digital Complementarity

This study extends existing understanding of digital complementarity in platform ecosystems. As digital objects are created first in platform ecosystems (Baskerville et al. 2020), the theories of Edgeworth complementarity (Edgeworth 1897) and unique complementarity (Teece 1986) initiated in the industrial age must be refreshed. Prior research responds to this call and proposes the concept of digital complementary assets (Rosemann et al. 2011) by highlighting the non-excludable and non-rival features of digital artifacts among consumers. In other words, digital artifacts are linked in networks which are accessible and open for discretionary recombination for everyone without asset specification. We add to this by further pointing out the self-referential (Yoo et al. 2010) attribute of digital artifacts. That is, the value of digital artifacts is agnostic in nature (Henfridsson et al. 2018), in the sense that their meaning is largely defined by their relationships to other artifacts in the use situation rather than self-contained with fixed function. For example, in the study on Douyin it was shown that platform designers, users, and focal platforms rarely share the same understanding regarding identity in the social networking ecosystem. Hence, a successful position shift is highly contingent on support from diverse ecosystem actors over time. As a result, the complementarity in the platform ecosystem context is qualitatively different from existing complementarity types, in the sense that the value of A has to be confirmed with B. While Edgeworth and unique complementarity are concerned with the amount

of value (e.g., A becomes more valuable with B) and existence of value (e.g., A only has value with B) respectively, digital complementarity focuses on contingent relational value (e.g., what the value of A is given/relative to B) given the fact that the value of an ecosystem actor is no longer binding within a particular relationship but referential to others over time.

Digital complementarity is always two-way, in the sense that the value of A has to be confirmed with B, and vice versa. It is not influenced by the power asymmetry among different ecosystem members. For instance, although focal actors propose and enforce the focal value propositions in an ecosystem, the ultimate instantiation must be confirmed with ecosystem participants who define their own ecosystem strategy in terms of a view on ecosystem structure, roles, and risks. There is no requirement of consistency in ecosystem strategy among the relevant actors. While greater consistency can result in higher action convergence towards the focal value propositions, focal actors have no way to command or control their activities like the governance in industrial organisations (Tiwana 2013). In the case of Michelin's PAX tire ecosystem, the introduction of a new value proposition took years to be fully recognised by other non-focal actors (e.g., garages and tire manufacturers) through equipping with the new PAX repair equipment, mainly because ecosystem partners pursue different end goals with different motivations (Adner 2017). Failure to do so would keep the focal value proposition consistent with the traditional tier ecosystem that lasted for a decade.

Similarly, while the value propositions at non-focal platforms are shaped by user innovation, users' action potential is also afforded and constrained by the digital technologies offered at platforms. It is such technology affordances and constraints (Gibson 1979; Leonardi 2011; Majchrzak and Markus 2013) that determine how and why a platform offering can be recombined and even repurposed by different users in different contexts (Nambisan et al. 2017). For example, the open USB and Bluetooth ports pre-set in Amazon Echo enable users to generate a specific individual value path by combining it with other music libraries such as Google Play music and Apple iTunes music (Henfridsson et al. 2018). As such, the individual value paths created by platform

users must be confirmed with the platform offerings, in the sense that users' goals and innovation capabilities are related to the inherent potential offered by the features of a technology. This is not an issue of whether a user can create individual value paths, since value only occurs when the digital offerings are useful to customers (value-in-use) (Lusch and Nambisan 2015). Rather, it is about what kind of value paths the user can generate by building upon and adding to existing digital offerings.

6.1.4 Contribution to Literature on Platform Scaling

Combining the three theoretical implications listed before, this study contributes to the overarching theme of this thesis — platform scaling — in terms of three dimensions. First, the project as a whole reveals and highlights the new meaning of scaling for complementors in platform ecosystems—that is, *a process by which the operational efficiency in innovation and interaction increases as it boosts its user base.* Essential to this definition is a shift of the driver of growth from internal economies in Penrose's (1959) work to ecosystem-level economies in the digital age. In particular, as digital resources become more versatile in their combinative potential, new productive opportunities cannot be fully unpacked and actualized by solely leveraging the ventures' own capability. This is embedded in the complementarity nature of digital platforms (Teece 2018), where multiple complement providers and users are required to co-create value in the open-ended landscape of digital innovation. As such, while Penrose sharply pointed out scaling as a 'continuous on-going process of development' (p. 1) of businesses, the underlying traction of this process has changed to demand-side orchestration driven by the positive network effects in platform context.

Second, corresponding to this view of scaling is a qualitatively different measure of platform growth in user base (Huang et al. 2017), which hits the new fact that a platform with the largest active user base will generate the highest value for each participant, endowing the business with unparalleled competitive advantage in markets (Eisenmann et al. 2006; Parker et al. 2016). Given the seemingly straightforward relation between user base scaling and positive network effects, the dominant sentiment

among platform businesses is a sense of urgency to grow on steroids rapidly. For example, the big-bang adoption strategy (Parker et al. 2016) tends to highlight the role of acquiring large amounts of attention to a platform in triggering positive network effects. Similarly, platform envelopment (Eisenmann et al. 2011) and path channelling (Henfridsson et al. 2018) are explained as successful scaling strategies, in terms of their role in exploring and leveraging overlapping user bases between platforms (Bharadwaj et al. 2013; Constantinides et al. 2018).

However, my study shows that even though a scalable user base is the fundamental condition for positive network effects, there is no guarantee that it will come with strong positive network effects. What really matters here is active users and their activities — the number of users who interact and engage on a platform (Parker et al. 2016). In other words, user engagement must come together with user acquisition for platform scaling. As an example, while Douyin rapidly expanded its user base from a niche young female group to a broader entertainment community since June 2017, the decreasing user engagement due to the content homogeneity issue highly constrained its scaling pace afterwards. A similar scenario occurred in April 2018, when complete blocking from focal platforms strongly influenced the user experience at Douyin and led to user outflow. In chapter five, it is demonstrated that both user base and user engagement are significant for platform survival in digital ecosystems. Higher user engagement not only produces an immediate effect on user base, but also facilitates the long-term growth of platforms by illuminating more promising growth paths and competitive identity projection. As a result, it is not enough for a metric to only measure the number of users (Huang et al. 2017) when navigating platform scaling. Otherwise, a platform business with rapid scaling will also implode quickly at the end. A typical example is BranchOut, which both scales and collapses quickly within one year due to using the wrong metric measurement on its membership list. As such, my definition of scaling tunes the focus of extant platform scaling literature from over-tilting user base scaling to a more balanced view between user acquisition and user engagement. It therefore contributes to theorising and advocating for a change in the understanding of "user" in the platform

context to one that is active and creates value for the rest of the platform.

It is further noted that while user acquisition and user engagement are not contrary to each other, there is a risk to focusing too much on one dimension at the expense of the other during the complementor's dilemma process. For example, while the early strategic emphasis on user channelling from focal actors enabled Douyin to rapidly scale up its user base, it also means higher dependency on focal actors' core offerings. As such, Douyin is not able to redeem the user engagement derived from these offerings (e.g., through integrating the offerings in its own platform architecture) due to its non-focal positioning in the ecosystem. As we can see, the effect of such risk on user engagement comes out when WeChat and Weibo blocked the channelling with Douyin. Similarly, while Douyin's decision to maintain its identity projection in April 2017 helped to preserve existing community attribute and preference, the consequent increased user engagement was at the expense of user outflow piggybacked from the Weibo platform. In both instances, the unbalanced risk of user base and user engagement is not randomly characterised by managerial blindness (i.e., deliberately ignore one beside the other). Rather, it is a particular or inevitable outcome of the dilemma process during which complementors are bounded in a specific time and a specific ecosystem context. In this situation, a strategic decision must be made between alternatives that will all have undesirable results for the complementor. One can therefore think of this unbalancing risk as a by-product of the complementor's dilemma process.

Third, my study creatively offers a complementor lens of platform scaling in digital ecosystems. While recent work starts to pay attention to non-focal actors' participation within and across platform ecosystems (e.g. Hurni et al. 2021; Huber et al. 2017; Salender et al. 2013), few of them recognize that complementors have their own ambitions to scale up in digital markets. In particular, two challenges are profound for the scaling process of complementor comparing with focal platforms.

First, while positive network effects posit that users will converge on fewer platforms which create the most value for each participator and hence lead to winner-

take-all at the end, it operates strongly only when the number of active platform users is high. In this regard, positive network effects cannot explain the initial scaling when there is no network on platform. As a result, one key challenge for complementor scaling is to build and activate an initial user base to trigger positive network effects.

Specifically, this scaling process from 0 to 1 cannot be achieved through attracting and cultivating new users independently, but usually draws upon the existing user base in an ecosystem due to their power asymmetry (e.g., limited resources and capabilities) at the launching stage. As such, the key to solving the chicken-or-egg issue (Parker et al. 2016) is to gain recognition and support in a newly joined ecosystem. In Douyin's case, this legitimacy is achieved through deliberate identity projection strategies. By taking advantage of present ecosystem conditions in terms of technology change and interdependency dynamics, the emerging platform can differentiate from rivals in platform scope and architecture design, which make it more competitive when piggybacking existing users from focal actors. This contributes to the platform scaling literature by noting the new way of thinking to beat the chicken-or-egg dilemma through identity projection. This insight is further elaborated in chapter five by conceptualising and testing three identity projection strategies for non-focal platforms that participate across different digital ecosystems. Consequently, I argue that identity projection strategies are crucial not only for triggering off network effects of complementors, but also for rebooting their network effects in early matured markets.

Second, the continuous identity re-projection process at Douyin represents a dynamic perspective towards complementor scaling. Empowered by digital technology, the feature, scope, and value of digital products are open to new meanings and continually evolve even after design and launch, leading to an uncompleted and unstable status for digital designs (Henfridsson et al. 2014; Lyytinen et al. 2016). Manifesting in the layered modular architecture (Yoo et al. 2010) at platform businesses, the relationship between core components and modules is only contingently obligatory and can be dynamically framed as different offerings through recombination at or across different layers (Delanda 2006; Um 2016). While this fluid and dynamic

innovation space enables complementor scaling by overstepping the market boundary, it creates extra burden for a complementor to maintain the legitimacy and further the focal platforms' endorsement during scaling. As such, complementor scaling is extremely fragile due to the on-going dependency of network effects on focal platforms in digital ecosystems. My study contributes to this statement by unpacking how a complementor can navigate this hazardous scaling trajectory through identity re-projections. In particular, the sustaining scaling outcomes are driven by the settlement of a series of emerging complementor's dilemmas during growth. A complementor must keep re-balancing its growth ambitions and dependency on focal actors through re-projecting its platform scope and architecture design. This finding is further supported in chapter five, in the sense that identity refinement strategies must be jointly applied with identity conformity and identity differentiation strategies to be competitive in digital ecosystems. In summary, the swift identity shift suggests a qualitative difference in scaling pace between complementors and focal platforms, which breaks new ground in the study of platform scaling in digital ecosystems.

6.2 Practical Implications

During the last decade, the rapid and pervasive digitalisation of business infrastructures has fundamentally transformed products and services, firm capabilities, and inter-firm relationships in extended business networks. It unleashed the concept of digital business strategy, defined as "organizational strategy formulated and executed by leveraging digital resources to create different value" (Bharadwaj et al. 2013, pp. 472). Different from traditional business strategy, digital business strategy reshapes the business process as cross-functional, modular, distributed, and swift, which enables work to be carried out across boundaries of artifacts, place, actors, and time (e.g., Banker et al. 2006; Baskerville et al. 2020; Nambisan et al. 2017). Accordingly, this thesis contributes to the management practice by offering specific metrics of firm performance from the four dimensions of digital business strategy.

First, digital technologies have fundamentally changed the scope of business strategies, which defines the portfolio of products, businesses, and activities that are

conducted within the firm's direct control and ownership. While industrial enterprises can only focus on single or a limited line of products and services (e.g., Coca-Cola and General Motors), digital businesses take advantage of digital frontiers across device, network, service, and content layers (Henfridsson et al. 2018; Yoo et al. 2010). For instance, Nike developed connected wearable technology devices and sports apps (Nike +) to complement its shoe products. Similarly, Amazon explored new technology extensions in the areas of hardware (Kindle) and web services (AWS). As a result, the metrics to measure firm scope must be updated in the digital age. In the case of Douyin and broader social networking apps, I propose to trace the platform architecture (re)design which deliberates the core and peripheral interactions offered at the platform. Since firms are increasingly intertwined based on layered modular platform architecture, no business can grow in vacuum. As such, digital business strategies must be conceived, beyond tight supply chains with partners in the industrial age to loosely coupled ecosystems that are constituted of heterogeneous focal and non-focal participants with dynamic cooptative tensions. There is good reason to believe that the interdependency dilemma will become a common issue confronted by digital businesses during growth. In particular, a sound growth strategy has to go beyond the horizontal competition landscape and consider the overall interdependency structure across ecosystems. To this end, the firm must constantly reflect on its identity in terms of what it is and what it wants to be to respond to the rapidly changing ecosystem conditions. This opens an entirely new direction to analyse and navigate the growth process for digital businesses.

Second, digital technologies fundamentally shape the scale of digital business strategies. Recall that scale brings the benefit of increased operational efficiency. Traditional management practice mainly thought of scale in terms of physical factors of production, distribution, or geographic coverage. In other words, the source of scaling is adding and integration of new operating units in organisations such as procurement, operations, marketing, logistics, or others, which are bounded in optimal size. However, as physical infrastructures become increasingly connected with digital resources,

through which reproduction is “comparably inexpensive to scale” (Henfridsson et al. 2014, pp. 30), the limit of scale is unleashed and transcends traditional operation units and land in ecosystem-level economies. Specifically, network effects have become the key differentiator and driver of value creation, which stimulate either supply-side scope of innovation (e.g., Apple and Google) or demand-side scale of interaction (e.g., Facebook and Twitter). As we already see in the case of Douyin, the more intensive value co-creation with focal firms, non-focal firms, and end-users facilitates the platform to explore external resources and capabilities across different traditional industrial boundaries, leading to rapid scaling over time. This calls for changing the metrics of scaling strategy from traditional statistical proxies (e.g., market share, profitability, or fixed cost) to user base and user engagement, both of which reflect the nature of scaling through partnerships and alliances among ecosystem members.

Third, while time is recognised as the driver of competitive advantage at industrial enterprises, it takes a more central role in digital business strategy. Considering the winner-take-all phenomenon in digital markets, businesses taking the first-mover advantage can easily leverage network effects and dominate in the market in a short time period. As a result, digital business strategy requires fast product launches. At the same time, since digital products are characterised by design flexibility (Henfridsson et al. 2014) with low adjustment cost, their speed of launch is further accelerated by taking advantage of on-going improvements across device, network, service, and content layers. We saw this in WeCash’s instant release mechanism (Huang et al. 2017) and the continual architecture re-design pioneered by Douyin, for example, in AI-driven recommendation systems and live streaming functionality combinations over six years to be competitive in their social networking ecosystem. Looking closely at this platform evolution process, the digital business context requires the coordination of product launches among ecosystem members. It is only after the emergence of 5G infrastructures that social interaction through short videos becomes possible. Similarly, without the complementary products and services (e.g., photography, music, e-commerce) in the social networking ecosystem, Douyin would not be able to grow as a

new platform giant. This is distinct from traditional business strategy, the speed of which is largely under the control of a single enterprise with autonomous, standalone product launches.

Along with a high speed of product launches, digital businesses must speed up their decision-making process. Considering the three swift shifts of identity projection at Douyin, non-focal actors are left with a very short time period to make decisions on their emerging interdependency dilemma. Continuing hesitation not only impedes user scaling, but also weakens their legitimacy in the ecosystem, primarily because of the high envelopment risk from potential competitors and focal actors. This is further confirmed by the app developers in the iOS store, who can easily access, align, realign, and cancel different memberships and further ecosystems. Digital businesses are therefore required to increase their capability to sense and respond to dynamic ecosystem conditions faster than ever before. Sample practices include the data-operation at WeCash (Huang et al. 2017), social media centre at Dell (Bharadwaj et al. 2013) and cloud data warehouse at Volvo (Svahn et al. 2017). They all facilitate collecting, analysing, and evaluating a significant volume of data within and outside the company in real-time.

Combining the three dimensions together, we see the large change in value creation and capture in digital businesses. While traditional management practice focuses on leveraging tangible physical resources, the key value sources for digital business strategy are digital resources (Henfridsson et al. 2018) which are product-agonistic with design scalability. Since they have the potential to belong to multiple value paths simultaneously, digital businesses must rely on a multi-layered business model for value co-creation. For instance, Douyin gave away content creation and sharing free for users and monetised it at the service layer through launching live streaming functionality. Similarly, Google gave away the software (Android) to third-party developers and captured value from advertising. In such settings, both value creation and value capture from digital innovation intersect and interoperate across different ecosystem members, which mirrors the interdependency structure of digital ecosystems. Management

practice therefore requires richer metrics such as value intensity, value scope, and design-use value path overlap (Henfridsson et al. 2018) to assess the outcome of digital business strategy in the open-ended value landscape of digital innovation. It is further noted that unlike the traditional industrial context, the key strategy to dominate in a digital ecosystem is based on the control of ecosystem structure. As this process model shows, the consequent increase of market share is not the driver of ecosystem position shift from non-focal to focal actors. Rather, it is materialised through building an independent platform around a new social interaction medium (short video) which reshapes the existing ecosystem structure defined by WeChat and Weibo. As such, a digital business can generate "architectural advantage" (Jacobides et al. 2006) in terms of a high level of value appropriation without the need to engage in vertical integration or market share competition.

6.3 Methodological Implications

Information systems is well-recognised as a practice-based research discipline which contains both natural science and social science (Carlsson 2005; Mingers 2004; Venkatesh et al. 2013). In this regard, the adoption of critical realism (CR) in the thesis resonates with this argument by providing a middle way between empiricism/positivism and interpretivism/anti-naturalism. As such, it embraces various methodological approaches grounded on a different philosophical position — that is, adopting "a critical stance towards the necessity and validity of current social arrangements" without following "the extant paradigms' assumption at face value" (Mingers 2001, pp.248). Developing on the recent work of CR-based study in IS (e.g., Henfridsson et al. 2013; Mingers 2004; Zachariadis et al. 2013), I discuss its methodological implications for contemporary digital phenomena in this part. The following paragraphs first highlight the importance of rethinking scaled digital phenomena as enacted in process. To this end, I then suggest leveraging the power of digital traced data and develop a mixed method, specifically the combination of process-tracing and computational approaches, in research methodology.

6.3.1 Develop A Process Lens to Considering Contemporary Digital Phenomena

Contemporary digital phenomena are filled with machine learning algorithms, multiple sensors, distributed platforms, and big data. As such, they are increasingly becoming more complex, dynamic, open-ended, large, and widespread. However, established methods to engage with these matters of scale at cross-sectional, cross-platform, or cross-ecosystem levels are still relatively limited to a macro focus — that is, building "models and theories to explain phenomena at scale by aggregating and abstracting from specific conditions and experiences on the ground" (Barrett and Orlikowski 2020, pp. 19). In this regard, studying phenomena at scale does not help us understand phenomena with scale, since this treatment of scale cannot capture the lived experience of scale — the process of how it is produced, stabilised, and sustained in empirical digital events and activities. For instance, while the complementor's interdependency dilemma is a widespread phenomenon across different digital ecosystems, straightforward macro-level studies across time, space, artifact, and actor boundaries decrease the granularity by which the underlying mechanisms driving the emergence, shift, and repetition of interdependency dilemmas can be studied and captured in IS. Instead, such a dilemma process is (re)produced in the ongoing interaction among specific ecosystem members, locally situated in specific times and places, manifested in specific digital technologies and ecosystem architectures, and grounded in emergent gaps, tensions, disruptions, and contradictions that generate both problematic and constructive outcomes. A process lens therefore asks for considering digital phenomena with scale empirically, which are recursively (re)produced and transformed through the choices, negotiations, interactions, experiments, and struggles of human and material agencies over time. Accordingly, more process-based studies are needed to understand how a digital phenomenon is entangled with scale through specific digital configurations that condition the possibilities of materialising that phenomenon.

At the same time, a process lens also conforms to the practical adequacy of CR-based study. While a process lens has the capability to explain and direct the realised

activities/events through tracing back and forth causal chains in cases, it acknowledges that an empirically valid knowledge is frequently situated, contingent, and may not work in every situation. As a result, it does not force the generating of a generalised theory or model emphasised in most quantitative research. Instead, it is more important to iteratively sharpen and revise the developed knowledge, based on different aspects of the reality. This again resonates with the recent appeal in the study of contemporary digital phenomena, in the sense that the differentiated and multifaceted digital world has to be approached, captured, and understood pluralistically through a wide range of research methods (Minger et al. 2013; Zachariadis et al. 2013).

6.3.2 Leverage the Power of Digital Trace Data in Contemporary Digital Phenomena

Despite the advantages of a process approach in digital phenomena, it cannot be materialised without difficulty. Considering that phenomena enact in/over time and place, researchers need to trace and collect multiple distributed longitudinal data in empirical studies. Similarly, since phenomena are continually produced, reproduced, and transformed over time, data collection must ensure sufficient granularity by which researchers can capture the interaction detail among nonmaterial and material agents. As such, a commitment to a process lens is frequently recognized as a time-consuming and intellectually challenging task in traditional organisational and management research (George and Bennett 2005). However, with the abundant and ever-increasing digital trace data now widely available, I argue that the extant shackles on process-based research can be liberated through leveraging their power in data collection and analysis.

Recall that digital trace data refer to the digital records of activities and events that contain digital technologies (Howison et al. 2011). They are particularly attractive for process-based research for three reasons. First, digital trace data are by-products of actual activities of actors rather than produced data following a specific research instrument (e.g., interview, survey). Given the wide adoption of digital technologies (e.g., ERP, management systems, mobile devices) in organisations and societies, virtually every phenomenon now leaves digital traces. This allows researchers to access

large-scale found data among diverse actors across time and space without barriers, which are unavailable for traditional social science, where “up to now, access to collective phenomena has always been both incomplete and expensive” (Venturini and Latour 2010, pp. 90).

Second, digital trace data are event-based records of activities and interactions. They track abundant socio-material dimensions of practices including conditions, properties, and movements of digital configurations (Yoo et al. 2010). Therefore, digital trace data provide rich and precise accounts of micro-level events that constitute the emergence, stabilisation, and evolution of scaled digital phenomena. In the case of Douyin, they manifest in both the strategic activity journey of all related parties and the dynamics of ecosystem conditions. Moreover, digital trace data are by nature relational. As digital technologies are self-referential (Yoo et al. 2010), the trace data they support will naturally encompass the information of how different digital configurations adapt, interact, and shape with each other over time through social practices (Henfridsson et al. 2009). In the case of Douyin, such interdependency underlying platform ecosystem architecture represents the on-going coopetition tensions among ecosystem members, which help to capture the underlying mechanisms driving platform scaling phenomenon. As a result, digital trace data are significantly helpful to understand phenomena with scale by revealing how they entangle with digital configurations in empirical micro-processes.

Third, digital trace data are longitudinal data with the form of time-stamped sequences of activities. As such, researchers can gain significant insights about the contingent antecedents and consequences of digital phenomena, both intended and unintended. Such causal chains make it possible to capture and analyse the tensions, gaps, disruptions, and contradictions that overflow from the empirical activities and events. Digital trace data therefore increase the number and variety of questions and phenomena that IS scholars can investigate (Agarwal et al. 2008; Berente et al. 2019; W. J. Orlikowski 2007). At the same time, digital trace data open the movement of research paradigms to the next generation of research methods. On the one hand, the abundant

quantitative digital traces allow for more computational-intensive variance research in IS (Berente et al. 2019). On the other hand, the unprecedented scale and level of detail of qualitative digital traces open a shift in process research (Langley 2007). Combining them together, I next discuss the advantages and implications of this data-driven mixed method in IS research.

6.3.3 Building Mixed-Method Research for Contemporary Digital Phenomena

Critical realism supports mixed research methods since they overcome the issues within the underlying philosophy of science of both quantitative methods (empiricism) and qualitative methods (interpretivism) — reducing statements of being to ones about experience of being or human knowledge of being. While those different paradigmatic premises have enriched our understanding of an overall phenomenon from different facets, they may also produce confusion and bias about how to conduct, measure, and conceptualise the phenomenon — in Brown's words, "there is little evidence that authors are becoming sufficiently broadminded to see beyond their own narrow paradigmatic assumptions" (Brown 2009, pp. 187). This especially happened in the research domain of organisational identity.

One mainstream of organisational identity research in management and organisation adopted survey-based quantitative methods (e.g., Bartel 2001; Dukerich et al. 2002; Foreman and Whetten 2002; Gioia and Thomas 1996). In their perspective, organisational identity is mainly conceived as individual member's perception of central and distinctive traits of the organisation. These perceptions and observations are simply providing a mirror on nature, which is objective, knowable, and can be accurately captured through deliberate quantitative measurement. Through describing the correlation or constant conjunctions of events (e.g., identity and organisational behaviour), they assume that they can further reveal underlying general laws and predict particular outcomes from the laws. As such they adopt empiricism, which sees science as explaining phenomena that can be empirically experienced. However, by reducing existence to what we can experience directly, it fails to capture the identity dimensions

that are outside of the awareness of people — such as the constructing, negotiating, and shifting process of identity before it is identifiable (Ravasi and Canato 2013). Similarly, it fails to recognise that our access to social phenomena is limited and localised in space, time, actor, and activities. In other words, there is no objective knowledge that operates universally according to general regularities. Moreover, even for those scholars who attempted to face this problem by developing organisation-specific or field-specific identity measures (e.g., Foreman and Whetten 2002; Voss et al. 2006), they confront great challenges in the ensuring validity and quality of inferences through collecting numerous, relevant, and tractable samples to the focal settings.

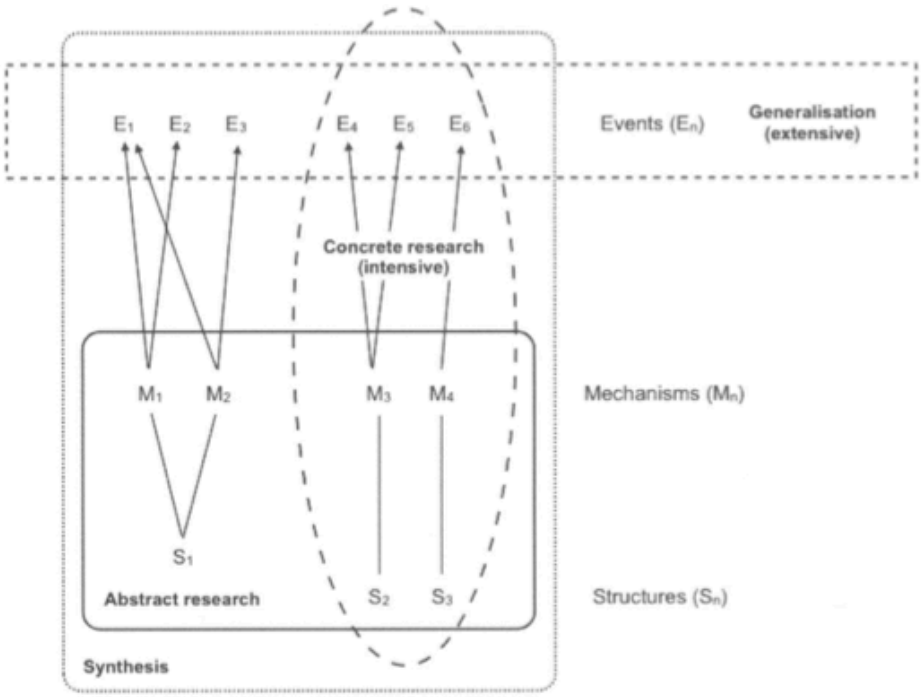
Recent waves of research adopted various qualitative methods, such as ethnography (e.g., Humphreys and Brown 2002; Ybema 2010) and narrative analysis (e.g., Chreim 2005; Sillince and Brown 2009) on this concept. Organisational identity then is represented by the "claims/self-referential statements" of what an organisation is and stands for (e.g., Glynn 2000; Kjærgaard et al. 2011) and "narratives" that are woven and crafted in and around organisations (e.g., Brown and Coupland 2004). From this perspective, social phenomena cannot be independent from human perception, conceptualisation, and judgment. Organisational identity is not an impersonal existence but purposefully constructed and used by organisational members to communicate their social reality with inside and outside stakeholders. As such, data collection and analysis focus on informants' interpretation of how different representations of an organisation is constructed, enacted, negotiated, challenged, and constituted through discursive practices (e.g., language, conversation, strategy, policy) and artefacts. Scholars aim at capturing and theorising socially accepted truth within a particular community rather than an external, human-independent reality. While such interpretivism based on traditional qualitative methods denies the objective, unmediated observation of empirical facts, it falls into another trap — that the ontological domain of existence is reduced to the epistemological domain of knowledge. As such, different knowledge can exist at the same time and are assumed to be equally valid since every paradigm is created to reflect local social realities with different subjective standards.

Summarising both traditional research methods in organisational identity, we can find their issues as either restricting the study of identity to the empirically observed and measured ones or to human knowledge of it. The consequent proliferation of definitions based on the same label therefore asks for a more integrated methodology and theory to reconcile different conceptualisations of identity-related phenomena in organisations (e.g., Brown et al. 2006; Gioia et al. 2000). As some scholars acknowledged recently, "this proliferation of definitions ... masks several more profound issues, including the contradictions between the ontological and epistemological assumptions underlying each conceptualization" (Corley et al. 2006, pp. 86). To solve this issue, I argue that the research methods based on critical realism are particularly attractive. Specifically, by drawing upon a structured methodological toolkit borrowed from the positivist paradigm to produce more convincing interpretive accounts of identity processes, the CR-based research methods take a middle ground between empirical realism and social interpretivism. In this regard, organisational identity is conceived as having a real existence independent of human perception and knowledge, since it produces effects on behaviour (e.g., strategy making, social interaction, firm scaling) that can be transferred across the boundaries of research setting (Gioia et al. 2013b; Rodrigues and Child 2008). As such, similar methodological language and tools which reflect positivistic concerns of validity, replicability, and generalisability should also be applied in identity-related phenomena. At the same time, the engagement with or sense-making process of their underlying causal mechanisms is always conceptually mediated by our cognitive resources. In this condition, the only way to approach and unfold the phenomena is through knowledgeable informants (Fleetwood 2005; Gioia et al. 2013b). The researcher's task then is "to facilitate informants' articulation of their — often tacit — knowledge to produce new concepts and refine existing ones, in an ongoing attempt to improve our theorization of the mechanisms that underlie social reality" (Ravasi and Canto 2013, pp. 191). As such, similar methodological approaches through the use of textual data to capture informants' interpretation and interpretive work should be applied in identity-related phenomena.

The research stream of this paradigm in organisational identity is attempted through grounded-theory-building method (e.g., Clark et al. 2010; Ravasi and Schultz 2006; Nag et al. 2007), which develops more robust and generalised theories from systematic qualitative data collection and analysis. In the empirical study one, I introduce the process-tracing method that follows a similar systematic research process by combining both quantitative and qualitative data sources. The former one provides descriptive evidence of the interested phenomenon, which guide the further qualitative research in a manner that becomes more capable of uncovering the underlying causal mechanisms from informants' experience of the focal phenomenon. Beyond that, I argue that the superiority of combining quantitative and qualitative data in IS study can be further leveraged by developing mixed methods (Venkastesh et al. 2013) (e.g., combining qualitative and quantitative research methods in this thesis), mainly due to three reasons.

First, since digital phenomena are contextually defined (i.e., subject to different mechanisms and causal powers in a specific system) and further the underlying mechanisms may not always actualise empirically due to the complex interaction with other mechanisms, scholars have to rely on different research methods to convey different and complementary kinds of knowledge about these mechanisms. Specifically, intensive qualitative research is profound in uncovering contingent mechanisms and structured interactions between them (Zachariadis et al. 2013). Extensive quantitative research is helpful to identify, quantify, and describe certain characteristics of a structure or object (Sayer 1992), develop propositions of existing casual mechanisms that occasionally actualise in the partial event patterns over a definite region of time and space (Bache 2003), and assess and revise the results of qualitative work (Zachariadis et al. 2013) (See Figure 14). As such, different methods can be synthesised in the mixed method which obtains different levels of abstraction of the multi-layered world, ensures a complete picture of the interested phenomena, compensates the weakness of single method, and inspires further research through iterative corroboration. In this thesis, this mixed-method manifests in the use of process-tracing analysis to uncover underlying

mechanisms of platform scaling, which further guides the building of a quasi-closure econometric model as a way to test the inferential validity from qualitative work at the empirical level. Later studies could generally apply this method in two different tracks: 1) the patterns (e.g. correlations, regressions, decision trees) generated through quantitative analysis constitute pre-theoretic understanding that serve as a foundation for the theory building through qualitative analysis; 2) the theories constructed through qualitative analysis constitute the lexicons (Berente et al. 2019) as pre-theoretic references that serve as a foundation for the theory to test in empirical settings through quantitative analysis.



adapted from Sayer (1992)

Figure 14. Synthesis of different research methods

Second, CR-based mixed method can leverage the power of digital trace data to the greatest extent. Recall that the IS discipline is "devoted to investigating complex sociotechnical settings that require us to make sense of large amounts of digital trace data that pertain to the interaction of the social and the technical" (Berente et al. 2019, pp.62). Consider the intensive, manual process in qualitative research based on trace data such as trace ethnographies (Geiger and Ribes 2011) and discourse achieves

(Levina and Vaast 2016). While they are legitimised in empirical analysis and grounding novel theory (e.g., Bryant and Charmaz, 2007; Eisenhardt 1989; Glaser and Strauss 1967), the increasing abundance and forms of trace data today make them less capable of identifying patterns in data (e.g., sample, code, match data) and further generating theory inductively. At the same time, although automated, computational processes in quantitative research such as econometrics (Li and Agarwal 2017) and machine learning (Gopal et al. 2011) facilitate fishing and mining the patterns of association in digital trace data, they do not move forward the sense-making of the phenomenon. As a result, a combination of both qualitative and quantitative research methods is necessary to develop more robust theories from digital trace data. It recognises the chance afforded by the widespread pregnancy of trace data in the interplay process of manual and computational techniques, which opens novel theorising through a variety of computationally intensive inductive analyses (Berente et al. 2019). I therefore call for further work in this emerging paradigm to expand it within the IS discipline.

Lastly, CR-based mixed method can embrace a process lens in IS. By adopting qualitative techniques in empirical settings, a mixed method ensures that scholars can capture the live trajectory of digital phenomena in an ongoing fashion. For instance, identity-related narratives feature prominently in actors' discursive activities, such as organisational polices and strategic investments (e.g., Chreim 2005; Ravasi and Phillips 2011; Whetten 2006). Similarly, a cognitive dissonance experienced by some members due to an identity-strategy discrepancy can be captured and highlighted in interview analysis (e.g., Corley and Gioia 2004; Kjærgaard et al. 2011; Ravasi et al. 2020). Further, by adopting quantitative techniques, a mixed method ensures practical adequacy in judging various developed process theories based on their capability to explain and direct the realised practices in specific contexts. For instance, the econometric model developed based on the Douyin case study helps us examine and expand our understanding of platform business scaling obtained in the process model in the social networking ecosystem in China. Specific identity projection strategies are

further conceptualised during this process. I therefore encourage future studies to push forward such a process-oriented mixed method. At the same time, scholars should be alerted to overstate on the "performativity" of this method (Callon 1998; MacKenzie and Millo 2003). In identity study, it means that the influence of developed identity-related constructs/concepts on organisation evolution may not be as significant as researchers expect, which induces actors to engage more in identity-sensitive thinking and action than they would otherwise.

6.4 Summary of Discussion and Implications

This chapter outlines key implications of the research findings on analysing the platform scaling process in the social networking ecosystem in China. They stretch across theoretical, practical, and methodological dimensions to provide prospective insights for future studies.

From the theoretical perspective, this thesis contributes to the understanding of the platform scaling process in the digital age. Platform business scaling is qualitatively different from industrial enterprise scaling in terms of three aspects. First, platform survival and scaling significantly depend on the support and engagement from ecosystem actors due to network effects. As platforms keep envisioning their growth ambitions, the scaling implies a dynamic position shift in the ecosystem beyond a simple increase in traditional statistical proxies. As such, digital ecosystem participation is not without frictions but encounters ongoing interdependency dilemmas for every platform business, which may lead to the imbalance between user acquisition and user engagement at platform. Second, at the core of navigating this scaling challenge, platform identity takes the key role of acquiring both demand-side (e.g., end-users, complementors) and supply-side (e.g., focal actors) supports through being distinctively legitimate. While traditional organisational identity is internally defined and enduring, platform identity is more dynamic and co-shaped by diverse ecosystem participants. Specifically, to trigger, reboot, or sustain network effects at platforms, identity projection in terms of what it is and what it does is not once for all but requires constant re-evaluation and adjustment in the open-ended value landscape of digital innovation.

Third, informed by the interdependency dilemma and identity re-projection process, platform scaling implicates a new type of complementarity in the digital age in the sense that the value of a platform business is no longer binding with a particular relationship but referential to other ecosystem members over time.

From the practical perspective, this thesis contributes to the design of digital business strategies. In particular, digital technologies transform traditional business strategies in three aspects. First, the scope of business strategies has been redefined from a single or limited line of products and services to unbounded digital frontiers across device, network, service, and content architecture layers. As such, the spectrum of digital business strategies goes beyond tight supply chains in the industrial age to loosely coupled ecosystems in the platform context. Second, the limit to the scale of digital business strategies is radically unleashed to transcend traditional operation units and land at the ecosystem-level economies, which requires the updating of the criteria of scaling strategy from traditional statistical proxies (e.g., market share, profitability, fixed cost) to user base and user engagement. Third, the speed of business strategies become more crucial for gaining competitive advantage in the digital age, which requires faster product launches and decision-making processes through collaboration with ecosystem members. All in all, the sources of value creation and value capture for digital businesses have been changed to versatile digital resources and the control of ecosystem architecture, which require richer metrics to measure the outcome of digital business strategies.

From the methodological perspective, this thesis encourages a CR-based mixed method in platform identity research to leverage digital trace data in a process-orientated research fashion. Specifically, by drawing upon a structured methodological toolkit in the positivist paradigm to produce more convincing interpretive accounts of contextually defined, ongoing identity-related phenomena, the CR-based mixed methods take a middle ground to overcome the issue of both empirical realism and social interpretivism. As such, the mixed method turns the focus of IS research from macro-level phenomena at scale to the live trajectory of digital phenomena with scale in

situated processes. Meanwhile, it ensures practical adequacy by providing a means to judge generated theories based on their capability to explain and direct the realised activities in specific contexts. Further, through combining automated quantitative techniques with manual qualitative techniques, the computational-intensive mixed method reinforces conventional and linear approaches to IS research through mining patterns of association and making sense of patterns iteratively from the abundant and ever-increasing digital trace data.

7. CONCLUSIONS

The final chapter concludes the thesis. It firstly provides an overview of the thesis before presenting the findings to the research questions. It then summarizes the derived contribution to theory, practice and methods. After moving to the discussion of validity and limitations of this research, I close with consideration of future research paths and final marks.

7.1 Overview of Thesis and Summary of Findings

The disruptive power of digital technologies is transforming the landscape of business in ways that would have been impossible a few decades ago. We have seen a series of improbable upheavals in one industry after another that shares a similar DNA: digital upstarts invade a major business segment and earn their positions in a matter of months, let alone market dominance. Yet, extant research of such scaling of digital enterprises is still at twilight zone with limited insights, which is the ends for this thesis to address.

Looking close to earlier evidence, digital enterprise scaling was supposed to be qualitatively different from industrial enterprise scaling. While the later one focuses on high-growth firm size as the consequence of internal economies, the former one concerns more on the growing process to ecosystem-level economies as they leverage from the digital infrastructure in place. Specifically, start-up as a non-focal actor in platform ecosystems, digital enterprise has to grow upon and gain endorsement from other ecosystem members such as focal platforms and end-users over its lifecycle. Yet, in seeking growth, inevitable tensions will be raised among them due to the changing ecosystem position relative to each other. This thesis therefore attempts to advance our understanding of such scaling process for non-focal digital businesses: ***how to balance growth ambitions and the interdependency with other ecosystem actors over time?*** To answer this overarching question, it is further deconstructed into three sub-questions to direct my research design.

In the first place, a comprehensive understanding of *what the scaling challenge is*

for non-focal digital businesses has to be developed before answering 'how' questions. To this end, I conducted an in-depth embedded case study of Chinese short video platform, Douyin, from its inception as a complement in 2016, through its spectacular growth, to its establishment as focal actor in 2018. Over this scaling journey, I found that Douyin confronted a series of trade-off between remaining and changing its complementor's position in the social networking ecosystem, including niche complement or main complement, dependence or independence, integration or competition. On the one hand, the attraction and pressure of winner-take-all phenomenon in digital markets keep pushing a non-focal business's growth ambitions that must build upon other ecosystem members. On the other hand, the growth-seeking process will inevitably come across the tensions in its relationship with other ecosystem members due to the increasingly threats to their ecosystem positions. Consequently, the empirical finding demonstrated that non-focal digital businesses are subject to specific scaling challenge—that is, interdependency dilemmas in platform ecosystems.

Following the answer of first sub-question, I then came up with the second sub-question: *how to navigate the interdependency dilemma?* Developing on the in-depth case study of Douyin, I found that platform identity plays a key role in this process. Specifically, the interdependency dilemma, in nature, should be deemed as a legitimacy issue in digital ecosystem, which requires the non-focal business to carefully project who they are and what they do in platform ecosystems. By doing so, it communicates with other ecosystem members in terms of its desirability, appropriateness, competence and distinctiveness. It was further noted that this identity-constructing process is not an independent effort of internal members at Douyin, but continuously shaped by external ecosystem actors. Through on-going evaluation on prospective reactions from focal platforms in regard to the identity schemes emerging from user innovation, non-focal businesses are able to (re)project a legitimately distinctive identity as they are growing. To further understand how such identity projection works, I extended the exploration to all non-focal apps in the social networking ecosystem in China between 2014 and 2019. The result from econometric survival analysis revealed three identity projection

strategies that will enhance their survival and growth prospect in digital ecosystems.

Following this question, the final sub-question addressed the nature of scaling in the digital age, formulated as: *how to scale up business in the digital age?* In the case of Douyin, it first manifested in different growth metrics, namely user base and user engagement. Specifically, although both terms are equally important for digital business growth and scaling, they are not easily harmonized together in practice, as shown in the nonlinear scaling journey at Douyin and other similar apps in the social networking ecosystem. Second, the persistent interdependency dilemma and identity projection process demonstrated that scaling in the digital age is beyond any single actor's grasp, but co-shaped by evolving ecosystem actors over time with diverse motives, capabilities and goals. In particular, the autonomous innovation activities from end users are crucial for both triggering off and sustaining rapid scaling at digital businesses.

After elaborating the empirical findings to the research questions, the following section presents in greater detail of the theoretical, practical and methodological contributions from the thesis.

7.2 Research Implications

The theory building and theory generalization chapters (chapter 4, 5) recast the empirical findings as a tentative process model of non-focal business scaling in digital ecosystems before applying this model to conceptualize three identity projection strategies in the econometrics study. Accordingly, three theoretical contribution tracks are developed to respond to the research questions.

First, by theorizing on the complementor's dilemma, this study sensitizes scholars to dynamics associated with the interdependency structure between complementors and focal actors over time, and the potential coopetitive tensions that a non-focal business must navigate during growth. This offers a contribution to existing platform research which usually bounds the attention to focal platforms in digital ecosystems. While non-focal actors have significant frictions in ecosystem participation, it does not mean their non-focal position is taken-for-granted. Underlying this position shift process, the concept of complementarity has been largely redefined as the contingent, relational

value among ecosystem actors in the sense that the value of A has to be confirmed with B. As such, a growing non-focal business's position is established only if its value is uncontested among key ecosystem stakeholders, making the interdependency dilemma tricky and imperative.

Second, by theorizing on the platform identity, this study points out some unique features of identity in digital context comparing with extant organization and strategy literature. While platform identity shares similar gene with organizational identity and technical identity in building legitimacy and distinctiveness in the living environment, it is neither a purely endogenous effort inside the digital business nor a purely exogenous effort from outside ecosystems. Specifically, although the platform architecture is designed by business owners, the value creation at platform is open for and co-determined by wider ecosystem participants. As such, the boundary between insider and outsider at digital businesses become blurrier since traditional outsiders no longer passively perceive and respond to a firm's identity, but actively engage in its constructing and shaping process in terms of key values, practices and activities. Consequently, identity becomes a more dynamic concept co-shaped by both 'insider' and 'outsider' defined in traditional identity context. By analogy, new metrics are required to capture this identity shift process, namely platform architecture design and platform scope. Developing on the initial conceptualization by Cennamo (2021), this study further uncovers their role in acquiring both supply-side and demand-side endorsement in digital context.

Lastly, by theorizing on digital business scaling, this study support two new metrics relevant to scaling in the digital age, namely user base and user engagement. While both terms are not contrary to each other by nature, they may be unbalanced as a particular or inevitable outcome of the dilemma process, during which the non-focal business is bounded in a specific time period and a specific ecosystem context. As such, scaling is not same as the underpinning assumptions of network effects theory which views it as an exogenous process. Rather, the endogenous forces are in play as the digital venture navigates its interdependency dilemma process through identity projections. Serving as

"elastic filters," platform identities not only support the identification and selection of viable scaling strategies related to user acquisition and user engagement, but also allows for developing corresponding dynamic capabilities that facilitate the venture's coping with an open-ended digital innovation space, especially in guiding and screening spontaneous user innovation as it is growing. This research therefore complements extant entrepreneurial scaling literature with more focus on 'how' beyond 'how much' to scale in the digital age.

The second area of contribution is related to the practice. The social networking ecosystem in China has been controlled by incumbent companies for a long term. Douyin's striking success in shaking the focal position of WeChat and Weibo therefore has encouraged many digital enterprises to emulate. While emergent user activities always open up new growth opportunities for Douyin, it is the deliberate projections of platform identity in terms of who it is and what it wants to be that serves as a vital role to navigate the complementor's dilemma process. In this regard, I support platform identity projection as one of the vital digital business strategies (Bharadwaj et al. 2013), which reinvent the scope, scale, speed and value source of business strategies through leveraging digital resources. Specifically, digital businesses strategies have transcended beyond traditional tight supply chain with stable partners to loosely coupled ecosystems with evolving participants. The scale of digital business strategies also transformed from internal economies by leveraging physical production factors to ecosystem-level economies through alliances and partnerships across different digital ecosystems. To be competitive in such winner-take-all markets, digital businesses have to shorten the time window of product/service launch and decision-making process, both of which are shaped by broader ecosystem participants. To cope with these challenges, digital businesses must rethink the source of value creation and capture in in the open-ended value landscape of digital innovation (Henfridsson et al. 2018).

The third and final area of contribution is to research methods for studying contemporary digital phenomena, especially identity-related phenomena. Since information systems is a practice-based research discipline which encompasses both

natural science and social science, it is particularly well-positioned to embrace a methodological revolution in computational-intensive social research (Agarwal and Dhar 2014). Adopting a CR-based mixed method, this study recognizes that spectacular digital phenomena are always (re)enacted in the ongoing interaction among specific agencies, locally situated in specific times and places, manifested in specific digital technologies and architectures, and grounded in emergent gaps, tensions, disruptions, and contradictions that generate problematic as well as constructive outcomes. As such, the study of complex sociotechnical phenomena at scale has to start with their pervasive digital activities in processes which could be only captured by leveraging CR's methodological pluralism strategy (Mingers 2001). Further, grounding in the opportunities afforded by the widespread abundant trace data pertaining to the interaction of 'the social' and 'the technical', there is a very real need to combine both intensive and computational activities in order for developing novel and accurate theory. By doing so, it is promising to develop an integrated theory of identity-related phenomena in digital context, which makes it possible to reconcile different ontological and epistemological assumptions underlying each conceptualization in extant literature.

7.3 Validity and Research Limitations

In order to make sure the validity and quality of research in the sense that the conclusions and claims in the thesis are truthful, the research process and evidence must can be reviewable and accountable to agreed standards (Bauer and Gaskell 2000). However, as the research presented in this thesis adopted a CR-based mixed method, it cannot directly translate into the quality criteria of established quantitative or qualitative research framework. Specifically, while three commonly used validity types (Venkatesh et al. 2013) are also applied in CR-based mixed method, they represent different meanings as following.

First, instead of concerning whether correlated empirical phenomena are causally linked, internal validity in the view of a critical realist focuses on establishing whether the generative mechanisms manifest in the observed events in the field (Zachariadis et al. 2013). In the thesis, such internal validity is assured through three sequential

activities. The first was go deep into iterative, systematic coding of the casual chain evidence in cases. As such, the process-tracing analysis is not about recording constant conjunctions of events in positivism, but about the underlying generative mechanisms in terms of "to what extent and how possible outcomes of a case were restricted by the choices made at decision points along the way in particular context" (George and Bennett 2005, pp. 252). To ensure that the identified mechanisms are truly the ones causing the events, I then developed new facts and observations within the same case to test against each other. As such, the corroboration from other observations within the same case can offer a strong internal causal inference for the generative mechanisms. Lastly, the developed causal relationships were further tested through a computational approach in the empirical study two. The resulting robustness analysis demonstrates an integrative inference efficacy for my research inquiry (Venkastesh et al. 2013).

Second, while construct validity for an empiricist describes whether the variables used in empirical domain capture what they intend to measure, it addresses whether empirically available data give valid knowledge about the actual events caused by the generative mechanisms (Johnston and Smith 2010). Given the fact that actualized events may be observed or not in specific context and further appear in different empirical traces, this thesis leverages the power of digital trace data in order to capture as many information as possible. Specifically, abundant quantitative and qualitative evidence from diverse sources are collected at daily basis. Perspectives from different related parties (e.g. Douyin developer, focal platforms, end-users, investors, third-party analysts) are documented and cross-checked with each other. Such high precision and granularity of data guarantee that I can capture relevant events of interest in the following process-tracing and computational analysis.

Finally, external validity for CR concerns with the likelihood that similar or related events occurring (or might occurring) in other settings are caused by the same generative mechanisms (Johnston and Smith 2010). Although this external validity in the real domain is different from conventional interpretation in the empirical domain in the sense that the presumed causal-effect relationship between observable events will

apply across different contexts, it can be tested in the empirical domain to some extent. In this thesis, by applying the findings in Douyin to all apps in the social networking ecosystem, I tested the developed theory in a quasi-closure system that shares similar contextual factors (e.g. spatial and temporal) with original settings. As such, same generative mechanisms are highly likely to manifest in the same relationship between similar empirical events. Therefore, the theory generalization based on quantitative methods in chapter 5 provides a solid evidence to prove the external validity of the first single case study.

This research is not without limitation. Due to the nature of the research context and the theory I generate, this thesis only applies several specific mixed-method techniques such as process-tracing, natural language processing and econometrics. I therefore encourage researchers to attempt more existing and novel techniques to flesh this method out. Similarly, the theory building and generalization in this thesis are limited in specific social networking ecosystem in China. As digital phenomena always enact locally, more studies are needed to explore identity-related phenomena in different contexts. Lastly, while platform businesses are the exemplars of digital business, there are other enterprise forms that are not platform-based but leverage digital infrastructures in current age. In response to this point, vast research space is available for research in digital business scaling, especially the test and expansion of current conclusion in this thesis.

7.4 Future Research

Scaling has been the essential driver of value creation in the industrial age. In view of the increasingly pervasive digital technologies in the contemporary age, there is an increased need to review the role and nature of scaling for digital enterprises. Developing on this thesis, I belabor the research challenges and present sample research questions for future study as following.

First, recognizing ecosystem-level economies of complementarity as the general driver of digital business scaling, this research further points out that this scaling is not exclusive for the focal actors in ecosystems. For instance, a non-focal actor, such as

complementor, can also draw on, benefit from and leverage existing network effects in ecosystems to rapidly grow as a focal platform at the end. Accordingly, IS scholars have to question and complement their received theory and model related to platform scaling, i.e. network effects theory (Eisenmann et al. 2006), platform governance framework (Tiwana et al. 2010), and boundary resource model (Ghazawneh and Henfridsson 2013), that bound the scaling object in focal actors who only concern demand-side (e.g. third-party developers, end-users) interdependency management in ecosystems. Instead, IS scholars must imagine new theoretical framework to capture scaling of non-focal actors who are struggling with both demand-side and supply-side (e.g. focal platforms) interdependency management in ecosystems. We need to articulate such ecosystem dynamics triggered by the growth ambitions of non-focal actors, asking: *Does scaling limit to certain types of firms in digital age? How to understand scaling of non-focal actors in digital ecosystems? What risks and opportunities come with rapid scaling for non-focal actors in digital ecosystems? How does digital business scaling shape our understanding of platform ecosystems in a more dynamic view?*

Second, recognizing the two new metrics of scaling—user base and user engagement—in the digital age, the understanding of their interaction and subsequent consequence to digital business scaling is still at early stage. Specifically, the assumption that only user base matters for scaling in extant platform scaling strategies (e.g. Eisenmann et al. 2011; Parker et al. 2016; Huang et al. 2017) has to be revisited for new theorization. Important research questions include: *What are the implications of unbalanced risk between user base and user engagement for digital business scaling? How to balance both metrics during digital business scaling? Are both metrics always equally important for digital business scaling over its lifecycle? Which digital technologies and their affordance are more likely to drive digital business scaling in both metrics? How? Why?*

Lastly, as we have seen, platform identity plays a key role in navigating non-focal business scaling in ecosystems. Dissecting the components of platform identity, I noted that the distinction of non-focal actor (i.e. complementor) from focal actors in digital

ecosystems does not necessarily lie in their 'technical' elements (e.g. whether it is platform architecture-based or not). Rather, this complementarity draws much more on their 'social' positioning in the ecosystem (e.g. user overlap and architecture similarity vis-à-vis others). Specifically, as diverse and distinct digital innovation are created by multiple, heterogeneous actors over their growth trajectories, these wakes of innovation (Boland et al. 2007) will keep overlapping on, intruding on, and interacting with each other in ways that form a complex, turbulent, undulating coopetition landscape within or across different ecosystems. Accordingly, a growing digital business has to continually reflect on its identity as 'non-focal' or 'focal' in order to be competitive in ecosystems. This demands us to reexamine traditional theoretical lens of organizational identity and technical identity as studying identity-scaling nexus. Therefore, critical research questions include: *How to understand complementarity in digital ecosystems? What agencies may influence the scaling process of digital businesses? How do digital businesses leverage economies of complementarity in ecosystems through identity projection? How do user innovations play a role in shaping identity-seeking process during scaling?*

In summary, this study opens up at least three different, yet inter-linked, streams of future research in digital business scaling, including more in-depth empirical analysis on the scaling process of non-focal actors in digital ecosystems, the relevant metrics, new conceptualization of complementarity and identity in digital context, and their implication for facilitating digital business scaling.

7.5 Final Summary

As this thesis comes to the end, it is the time to summarize the research presented in the preceding seven chapters. This thesis opened with the description of my motivation to pursue academic career, especially the domain of digital innovation, entrepreneurship and transformation as my PHD journey.

Within this general interested domain, the introduction presented the specific research motivation for the phenomena of digital business scaling which leaded to the formulation of the overarching question: What is the process by which growing

businesses navigate the interdependence with other actors in digital ecosystems through identity projection? It then specified the research objective, approach and contribution target before presenting the structure of this thesis.

The literature review first presented the overarching theme of digital business scaling. Drawing on the platform-based architecture design, digital business scaling is qualitatively different from industrial enterprises, characterized by complex and dynamic interdependencies in digital ecosystems. From this vantage point, it reviewed the concept of complementarity, complementor's dilemma, and finally conceptualized platform identity as the theoretical lens for this thesis.

The Methodology chapter then introduced the critical realism (CR) in information systems research before being applied to construct a CR-based mixed-methods research design. Specifically, chapter 4 developed a four-step, iterative process-tracing approach to build theory in single case study, which was further complemented by a data-driven computational approach for theory generalization in chapter 5. Together, they made it possible to study contemporary digital phenomena with scale by leveraging digital trace data in a process-orientated fashion.

Following the sequential empirical analyses of Douyin case and the broader social networking ecosystem in China, I developed an integrated process model of platform identity projecting in response to interdependency dilemmas in platform ecosystems. In particular, three identity projection strategies were conceptualized to facilitate platform business scaling in the digital epoch.

Following from this, the discussion and implication chapter presented the theoretical contribution to literature on complementor's dilemma, platform identity, complementarity and digital business scaling in general. Similarly, practical implications for digital business strategy and methodological implications for studying contemporary digital phenomena were then discussed in detail.

Finally, this concluding chapter provided an overview of this thesis before evaluating its validity and limitations. Future promising research paths emerging from the work were discussed at the end.

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APPENDIX 1: PAPER ABSTRACTS

This appendix contains abstracts of research papers generated on the basis of the research presented in this thesis.

Appendix 1.1. MIS Quarterly

Liu, S., Henfridsson, O., Nandhakumar, J. and Hummel, J. The complementor's dilemma: Balancing growth ambitions and the dependency on focal actors in platform ecosystems. Manuscript under review at MIS Quarterly.

Abstract

In the platform ecosystem literature, there is little recognition that non-focal actors (i.e., complementors) typically pursue their own growth ambitions. If successful, the growth ambitions may even shift the complement's position as a non-focal to a focal actor in the platform ecosystem. While such a position shift opens up new possibilities for the complementor, it also challenges its relations with focal platforms in the ecosystem on which it depends. This is what we refer to as the complementor's dilemma: how can a non-focal actor pursue growth ambitions while maintaining favorable relationships with the focal platforms they grow upon?

To address this research problem, we conducted an in-depth embedded case study of a Chinese short video platform, Douyin (known as TikTok outside of China) from its inception as a complement in 2016, throughout its spectacular growth, to its establishment as focal actor in 2018. We zoom in on the shifts of Douyin's projected identity and the ways the short video platform successfully redefined its complementarity to focal platforms such as Weibo and WeChat in China's platform ecosystem of social networking. We use the notion of platform identity to understand how the complementary platform locates who it is in the moment and the trade-off of two, or multiple, future scenarios of its relationship with focal platforms. Our research contributes to the platform literature by offering a process model of complementors' identity projection as they grow in platform ecosystems. The model offers important implications for our understanding of complementarity as a dynamic process involving purposeful identity reprojection, as complementors attempt to navigate tensions with focal actors in platform ecosystems during growth.

Appendix 1.2. AOM 2020

Liu, S., Henfridsson, O. and Nandhakumar, J. (2020) Identity projection for growing

digital venture: An in-depth study of a Chinese short video venture. In proceedings of 80th Annual Meeting of the Academy of Management, Vancouver, Canada.

Abstract

Identity, a holistic organization definition of what they do and who they are, is pivotal to help make sense and explain actions in organizational practices. In digital venture context, identity presents unique features of continuous and rapid change which deeply resonates with growth strategies of organization. However, the role of identity shift in facilitating digital venture growth remains relatively unexplored. We report on a longitudinal study of a Chinese short video venture called Douyin, and we focus on how four times of identity re-projecting are shaped to facilitate venturing growth in terms of user acquisition and user activation over two years. Drawing upon von Hippel and von Krogh's (2015) and Gioia et al.'s (2017) conceptualization of dynamic need-solution design pairing, we develop understanding of digital venture identity as a both purposeful and emergent process that is co-shaped by reflective and evolving innovation actors over time. Dynamically re-projected identities serve as an "elastic filter" that on one hand guides to identify and select viable growth strategies related to user acquisition (value intensity increase and user channeling) and user activation (value scope expansion and user seeding) in a patterned way, and on the other hand allows for developing corresponding dynamic capabilities to cope with a fluid and open-ended digital innovation space.

Appendix 1.3. HICSS 2022

Liu, S., Henfridsson, O. and Nandhakumar, J. (2021) Identity projection strategies for non-focal actors in digital ecosystems. In Proceedings of the 55th Annual Hawaii International Conference on System Sciences.

Abstract

In digital ecosystems, non-focal actors cannot survive without working on the identity of their apps. The identity expresses what the app is about to customers. However, it also projects an image of the role of the non-focal actor in the larger ecosystem. Such identity projection is relevant for managing the relationship with focal actors of the digital ecosystem. We outline and test three strategies for identity projection (identity conformity, identity differentiation, and identity refinement). Using panel data of social networking applications in the iOS appStore in China between 2014 and 2019, we investigate the influence of non-focal actors' identity projection on their survival in digital ecosystems.

Our result shows significantly increased app survival for those who actively pursue the identity projection strategies in three directions. Thus, we shed light on the role of platform identity in navigating platform competition in the digital age when participation across ecosystems becomes compulsory for every digital business.

Appendix 1.4. ECIS 2019

Liu, S., Nandhakumar, J. and Henfridsson, O. (2019) Balancing user base and user stickiness in platform scaling. In Proceedings of 27th European Conference on Information Systems, Stockholm, Sweden.

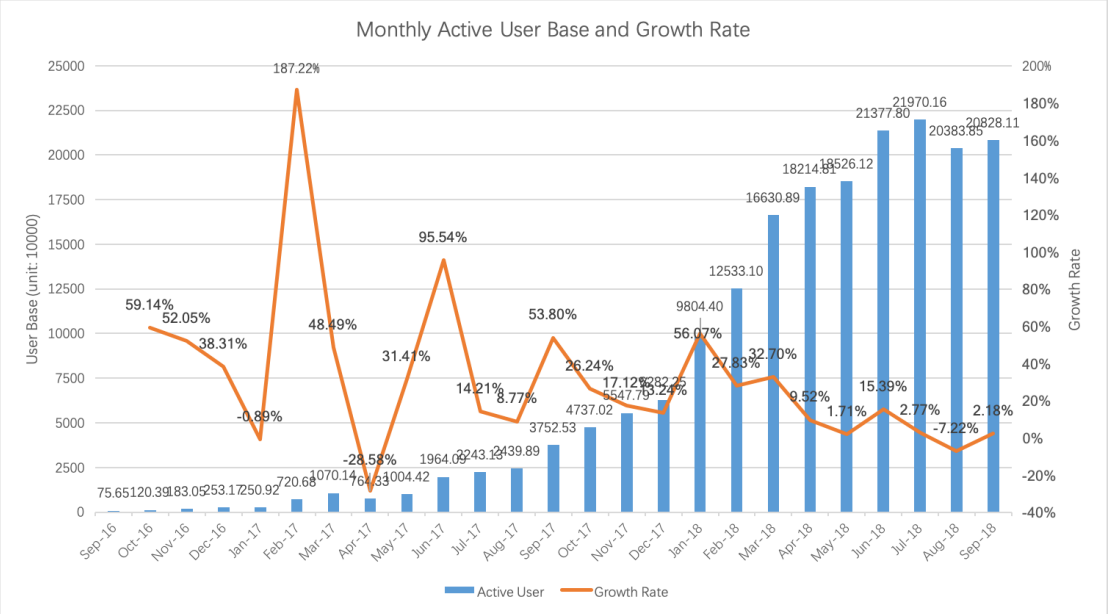
Abstract

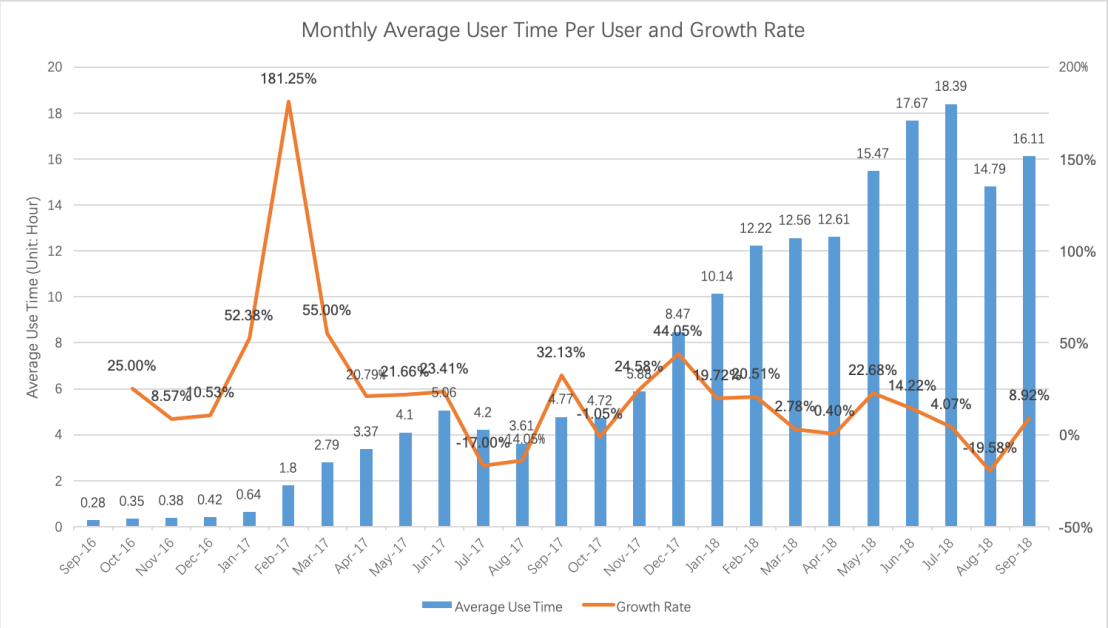
Rapid user base scaling is imperative for a nascent platform venture to generate value and stand out from its competitors. However, even with rapid growth of the user base, there is no guarantee that it will come with user stickiness, that is, a capacity to stimulate extended user interactions and engagement on the platform. We refer to the risk to focus too much on the user scaling at the expense of the user stickiness as the platform scaling trap. To understand how a nascent platform business can overcome the platform scaling trap, we conducted a longitudinal multiple-case study on five short video platforms in China. In this paper, we present our research-in-progress and our anticipated contributions. Our initial findings show that the way that platforms combine digital resources impacts both the growth of the user base and user stickiness. Upon the completion of the research, this study is expected to make a contribution to the platform literature by unpacking the mechanisms of platform scaling through examining digital resource recombination strategies.

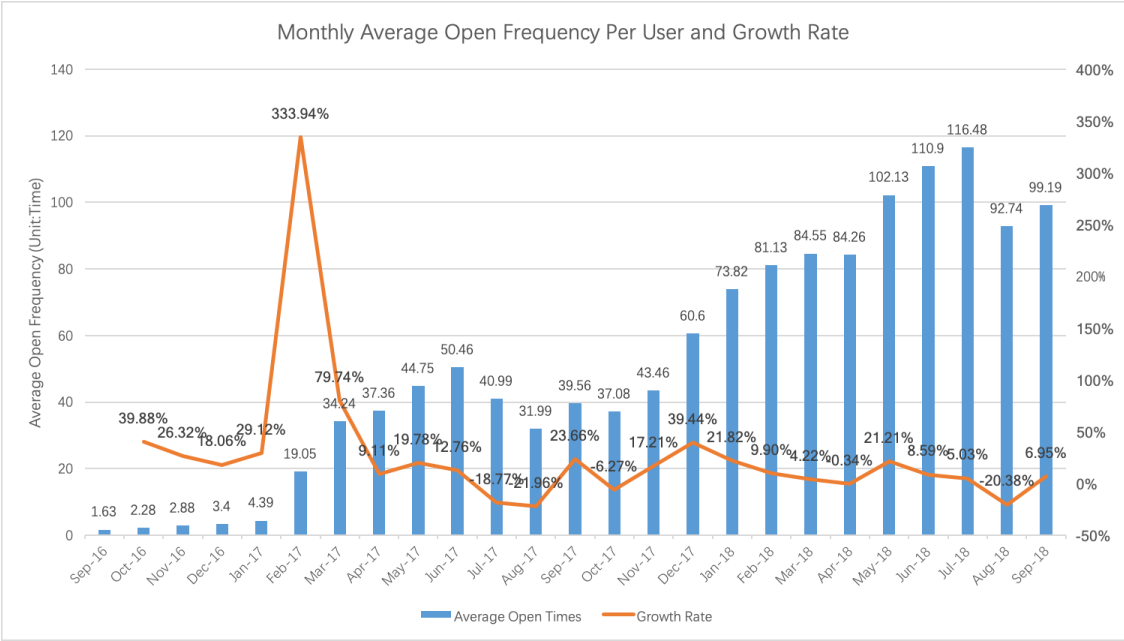
APPENDIX 2: DATA CODING AND VISUALIZATION FOR THE EMPIRICAL STUDY ONE

This appendix contains main data coding and visualization results from the empirical study one.

Appendix 2.1. Douyin Growth Trajectory






Monthly Average Open Frequency Per User and Growth Rate
Average Open Frequency (Unit:Time)
140
120
100
80
60
40
20
0
400%
350%
300%
250%
200%
150%
100%
50%
0%
-50%
1.63
2.28
2.88
3.4
4.39
19.05
34.24
37.36
44.75
50.46
40.99
31.99
39.56
37.08
43.46
60.6
73.82
81.13
84.55
84.26
102.13
110.9
116.48
92.74
99.19
39.88%
26.32%
18.06%
29.12%
333.94%
79.74%
9.11%
19.78%
12.76%
-18.77%
-21.96%
23.66%
-6.27%
17.21%
39.44%
21.82%
9.90%
4.22%
0.34%
21.21%
8.59%
5.03%
-20.38%
6.95%
Sep-16
Oct-16
Nov-16
Dec-16
Jan-17
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
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Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Average Open Times
Growth Rate

Appendix 2.2. Key Activities and Events During Douyin Growth

Month	Focal Platforms (WeChat and Weibo)	Douyin Designer	Douyin User
Complementor Dilemma 1: Niche Complement or Main Complement			
Sep 2013	Tencent launched Weishi App in short-form video market, supported by WeChat and QQ Weibo integrated Miaopai short-form video App at Weibo platform		
Oct 2014	Tencent launched short-form video function at WeChat		
Dec 2015	Weibo further invested in Miaopai and 90% of Miaopai users came from Weibo platform	ByteDance company invested one billion RMB in subsidizing short-form video creators at Toutiao platform	The daily view counts of short-form video were more than one billion times at Toutiao information flow platform
Sep 2016	Both platforms acquiesced in the API connection from A.ME	1. ByteDance launched short-form video app called A.ME which was officially introduced as a photography tool emphasizing female users 2. Core functions as full-screen play, short-form video shooting with music, film editing technique, beauty and filter effects, algorithm recommendation system	Users could log-in with WeChat and Weibo account, and invite friends from WeChat and Weibo platform

		3. API connection with WeChat and Weibo	
Nov 2016	Both platforms acquiesced in A.ME's marketing activities at WeChat and Weibo	1. Invited and trained seed users at platform; Guide content creation through performance campaign themes and specific playing methods (e.g. camera work) 2. Platform recommendation system preferred content created by the talents invited by the operation team at A.ME 3. Marketing on WeChat and Weibo by creating official account	73% active users were under 24 and 86% active users were female
Dec 2016	Tencent launched video uploading functions at WeChat	1. A.ME was renamed as Douyin with new icon and slogan 'short-form performance video community for the young', targeting at the young and fashionable users 2. Interface redesign to strengthen short video creation and sharing activities at platform (e.g. hottest challenges and music are marked at home page)	Female users and those under 24 remained as the majority at the platform
Jan 2017	Tencent acquiesced in Douyin users' video sharing activities at WeChat	1. Launched social functions (@friend) built on short-form video interaction 2. Connected video sharing function of WeChat	Users were able to upload and share short-form video from Douyin to WeChat

Feb 2017	Tencent acquiesced in the Douyin watermark attached in users' shared videos at WeChat	1. Added social function (i.e. constellation and city information of users) built on short-form video interaction 2. Attached Douyin's watermark and user nickname for those short-form videos shared to WeChat and Weibo	1. 56% users downloaded Douyin after watching the short-form video shared at WeChat and Weibo 2. The proportion of users under 24 and female decreased for the first time at Douyin
March 2017	Weibo acquiesced in the short-form video sharing activity from other platforms	1. Function optimization and launched more face tags 2. Challenging campaigns could directly be shared to WeChat and Weibo	One comedy star on Weibo actively forwarded Douyin short-form video at Weibo, creating first-round user growth at Douyin
April 2017	1. Weibo launched story mode that focuses on 15s Vlog 2. Weishi App ceased operating due to unclear product positioning and market prospect	1. Strengthened proprietary user account system by allocating exclusive ID number for those who log-in with WeChat and Weibo account 2. Highlighted platform feature by adding 3D shaking watermark effect for those videos shared to WeChat and Weibo	User outflow at Douyin with more diverse user portrait (proportion of user under 24 decrease to 61% and female users decrease to 78%)
Complementor Dilemma 2: Dependence or Independence			
May 2017	Tencent acquiesced in Douyin's marketing activities at its long-form video platform	1. Big-bang marketing at diverse long-form video platforms, including Tencent video platform owned by WeChat company	1. More users were multihoming from Weibo and Tencent video platform to Douyin (user overlap increases to 57% and 51% respectively)

		2. Highlighted entertainment feature of Douyin during marketing activities 3. Content operation at platform changed to entertainment-oriented fashion	2. The proportion of users under 24 decreased to 52%
June 2017	Both platforms acquiesced in piggyback activities of Douyin on their existing user bases	1. Weakened manual operation and strengthen algorithm content distribution which is inclined to push popular content 2. Launched new 3D tag and music special effect 3. Invited more entertainment stars to create short video at platform 4. Interface redesign to enhance content distribution based on user location (nearby content)	1. Content creators were motivated to imitate popular content in order to be recommended by algorithm system 2. Only 9.5% users frequently watched nearby content
July 2017	1. Both platforms acquiesced in piggyback activities of Douyin 2. Weibo user overlap with Douyin increased to 4%; WeChat user overlap with Douyin increased to 2%	1. Interface redesign through imitating story mode of Weibo, through which users could create and share daily-life video within 24 hours 2. Showing users' Weibo account at their personal homepage at Douyin	1. Decreasing user engagement and user growth due to homogeneous content distribution at Douyin 2. User overlap with Weibo increased to 64%, user overlap with WeChat increased to 88%

Aug 2017	1. Weibo blocked API connection from Douyin and banned the official account of Douyin at Weibo platform 2. Weibo user overlap with Douyin kept 4%; WeChat user overlap with Douyin kept 2%	Further enhancing entertainment feature by changing slogan as 'the official recommendation by The Rap of China'	1. Users could no longer invite users from Weibo directly 2. Users actively launched a dance challenge campaign which quickly became pop on platform 3. User overlap with Weibo decreased to 63%, user overlap with WeChat increased to 89%
Sep 2017	1. Tencent started to do business cooperation with Douyin (e.g. marketing on Douyin and made commercial procurement) 2. Weibo user overlap with Douyin increased to 6%; WeChat user overlap with Douyin increased to 4%	1. Motivated more innovative content creation by enabling the user-generated soundtrack to be shared among each other 2. Launched new 360° panoramic video and AR camera 3. Launched information flow advertisement business which enables third-party platforms to marketing at Douyin	1. Content homogeneity was highly alleviated with more innovative content creation 2. User overlap with Weibo kept 63%, user overlap with WeChat increased to 91%
Nov 2017	1. Tencent acquiesced in the growth of Douyin 2. Weibo built its own short-form video platform Kuran	1. Launched live-streaming function 2. Strengthened location-based content distribution by adding location information for published short-form video	1. Users became more engaged with new monetization means and real-time interaction mode

	3. Weibo user overlap with Douyin increased to 9%; WeChat user overlap with Douyin increased to 6%	2. Targeted marketing on three specific variety shows and Mango TV platform	2. User overlap with Weibo decreased to 60%, user overlap with WeChat increased to 93%
Dec 2017	1. Tencent acquiesced in the growth of Douyin 2. Weibo invested three billion in online video business 3. Weibo user overlap with Douyin increased to 10%; WeChat user overlap with Douyin increased to 7%	1. Launched motion sensing playing method supported by AI technology 2. Targeted marketing on four specific variety shows	1. The proportion of users under 24 decrease to 29% and female users decreased to 63% 2. User overlap with Weibo decreased to 57%, user overlap with WeChat increased to 95%
Complementor Dilemma 3: Integration or Competition			
Jan 2018	1. Tencent acquiesced in the growth of Douyin 2. Weibo launched independent short-form video App 3. Weibo user overlap with Douyin increased to 13%; WeChat user overlap with Douyin increased to 10%	1. Launched live-streaming quiz playing method with cash reward 2. Launched musician plan to support and train original musician 3. Imitated private letter function of Weibo 4. Marketing activities changed to cover undifferentiated users	1. High-speed growth of users (thirty million within one month) and their engagement 2. User preferred to real-time interaction around short video content (i.e. 51.8% for comment function, 51.5% for like function) 3. User overlap with Weibo decreased to 55%, user overlap with WeChat increased to 96%

Feb 2018	1. Weishi re-launched in IOS store 2. Weibo user overlap with Douyin increased to 17%; WeChat user overlap with Douyin increased to 13%	1. Launched red package playing method for spring festival with cash reward 2. Spent 4 million RMB every day to acquire users from all possible platforms, including all top Apps in IOS store	1. User in third-tier and four-tier cities highly increased; user portrait became more balanced 2. Content creators voluntarily embedded Weibo and WeChat advertisement and Taobao account at personal home page 3. User overlap with Weibo decreased to 52%, user overlap with WeChat kept 96% 4. Active users grew over one hundred million with higher user engagement comparing with Weibo platform
March 2018	1. Douyin link shared to Weibo became unobservable; WeChat restricted users' sharing activities from Douyin 2. Tencent invested three billion in Weishi 2. Weibo user overlap with Douyin increased to 21%; WeChat user overlap with Douyin increased to 18%	1. Launched social networking function (i.e. sharing photos in community) 2. Brand upgrade by changing slogan as 'Record Your Beautiful Life' 3. Generalized content categories to cover all aspects of life (i.e. food, cloth, dance, travel and pet) 4. Adjusted algorithm recommendation system to fit with content generalization 5. Account system of all platforms owned by ByteDance was integrated completely	1. User overlap with Taobao increased to 78% 2. More Taobao commodity became saleable due to the voluntary marketing short video made by Douyin users

April 2018	1. WeChat and QQ further restricted users' sharing activities from Douyin 2. Weishi connected with QQ and QQ Music platform 3. Tencent announced that Weishi would connect with all platform resources owned by Tencent	1. Further improved social networking function (i.e. text and photo sharing, multi-user interaction) 2. Opened Taobao API connection for head users 3. Suspended and rectified live-streaming function	Fake commodity short video increased at Douyin
May 2018	1. Weibo restricted Douyin's operation and marketing activities at Weibo platform 2. Tencent removed Douyin's H5 marketing activities at WeChat platform	1. E-commerce store function connected with Taobao started to open for all users 2. Interface redesign to strengthen social interaction mode (i.e. attention tab becomes parallel with short video home page) 3. Private message supported to send emoji	Increasing user engagement
Jun 2018	1. Tencent stopped all business operation with Douyin (i.e. marketing on Douyin and commercial procurement) 2. Weishi supported sharing function to WeChat 3. Weibo launched another independent short-form video App	1. Reopened live-streaming function and test advertisement system 2. Enhanced platform monetization by supporting business accounts with new function	Increasing user engagement

July 2018	Tencent removed Douyin's mini program at WeChat	1. Imitated top search list of Weibo to motivate and direct content creation 2. Imitated Weibo's content distribution system which tended to be centralized to head users with most followers	Demotivation and outflow of long-tail users
Aug 2018	Tencent launched one independent short-form video platform and acquired one short-form video platform	1. Launched top music list; top search list added video list; private message supported voice function 2. Launched new playing method to enhance user interaction experience	Demotivation and outflow of long-tail users
Sep 2018	1. Tencent tested the integration of Weishi at WeChat 2. Weibo integrated live-streaming App	1. Launched Xingtu platform to support the cooperation between content creators and third-party businesses 2.Imitated WeChat sharing function within the platform 3. Launched game tag and new playing methods 4. Simplified friend invitation from WeChat and Weibo by launching new QR code	Recovery of user engagement
Oct 2018	Tencent launched one independent short-form video platform	Launched mini program to attract third-party complementors (e.g. game, photography tool, e-commerce)	User base and user engagement kept growing

Appendix 2.3. Douyin Evolution Process Flowchart

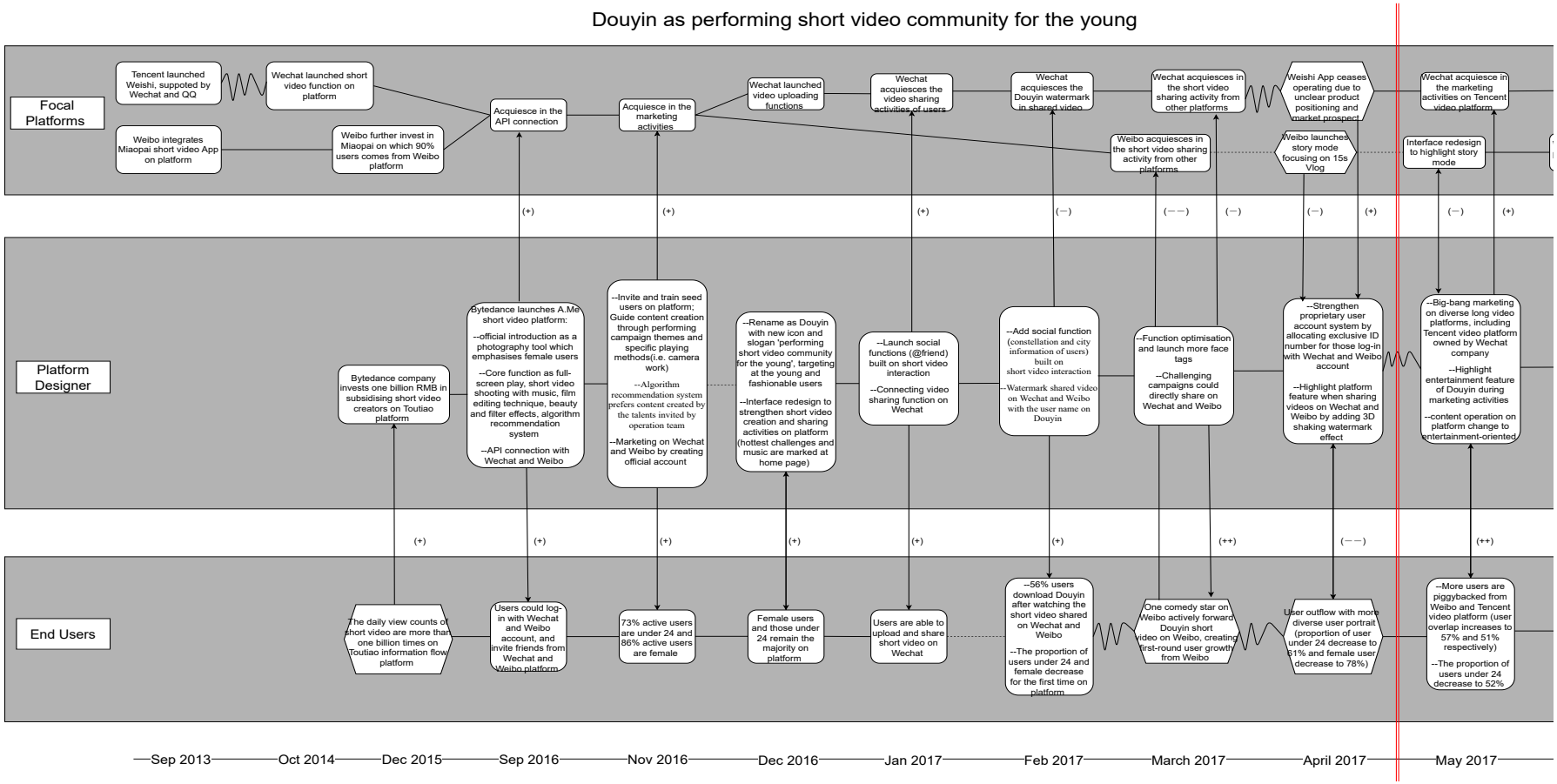
Explanation of Graph: 【Following the Visual Mapping Strategy (Langley 1999)】

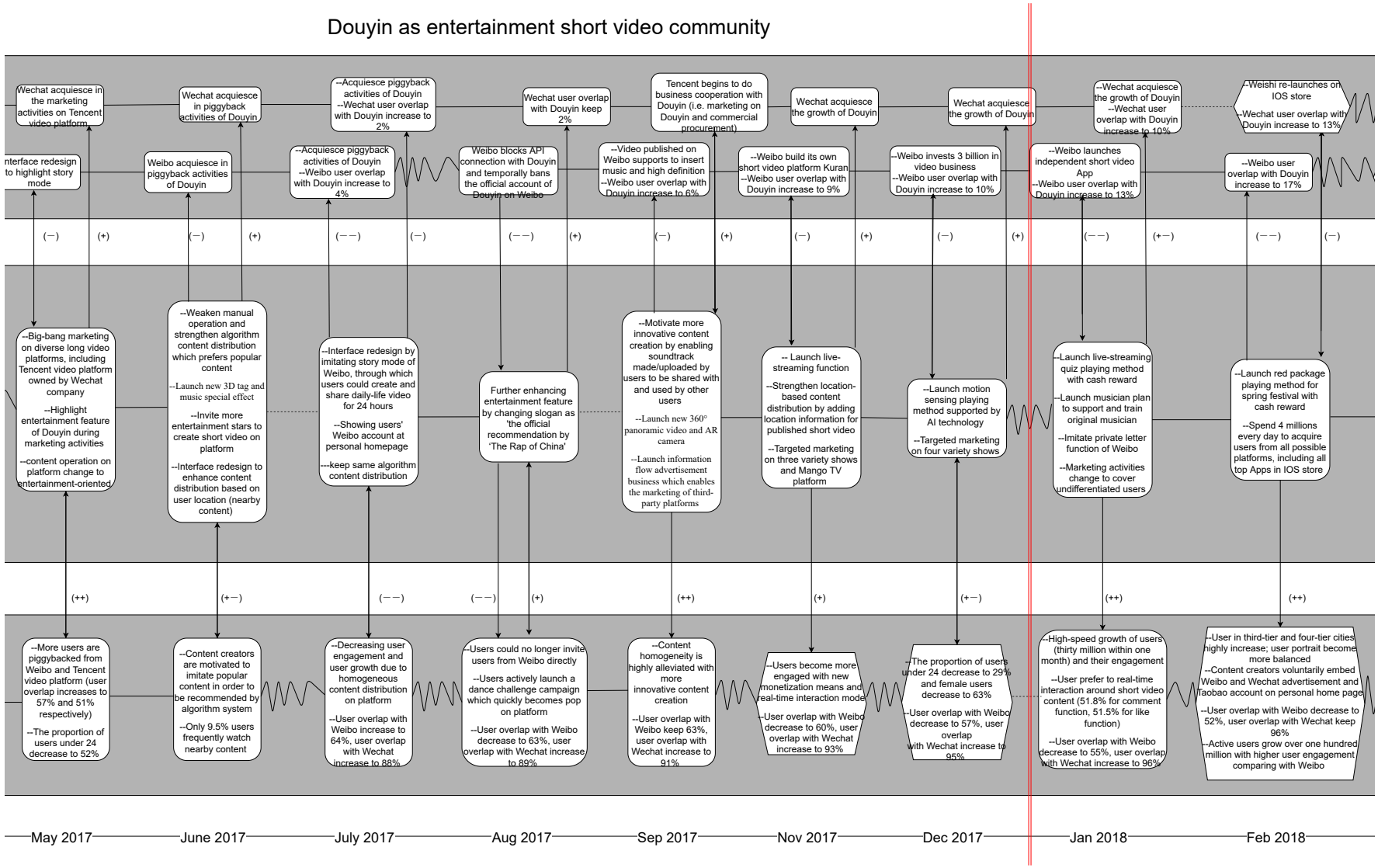
1. Round-cornered rectangles represent an activity/event that happened in specific month; Hexagon represents the tipping point event/actions that drive the re-projection of platform growth.

2. The line between two boxes represents the continuity among linked event (full line represents strong continuity, dotted line represents some continuity, break line represents significant change with little continuity.

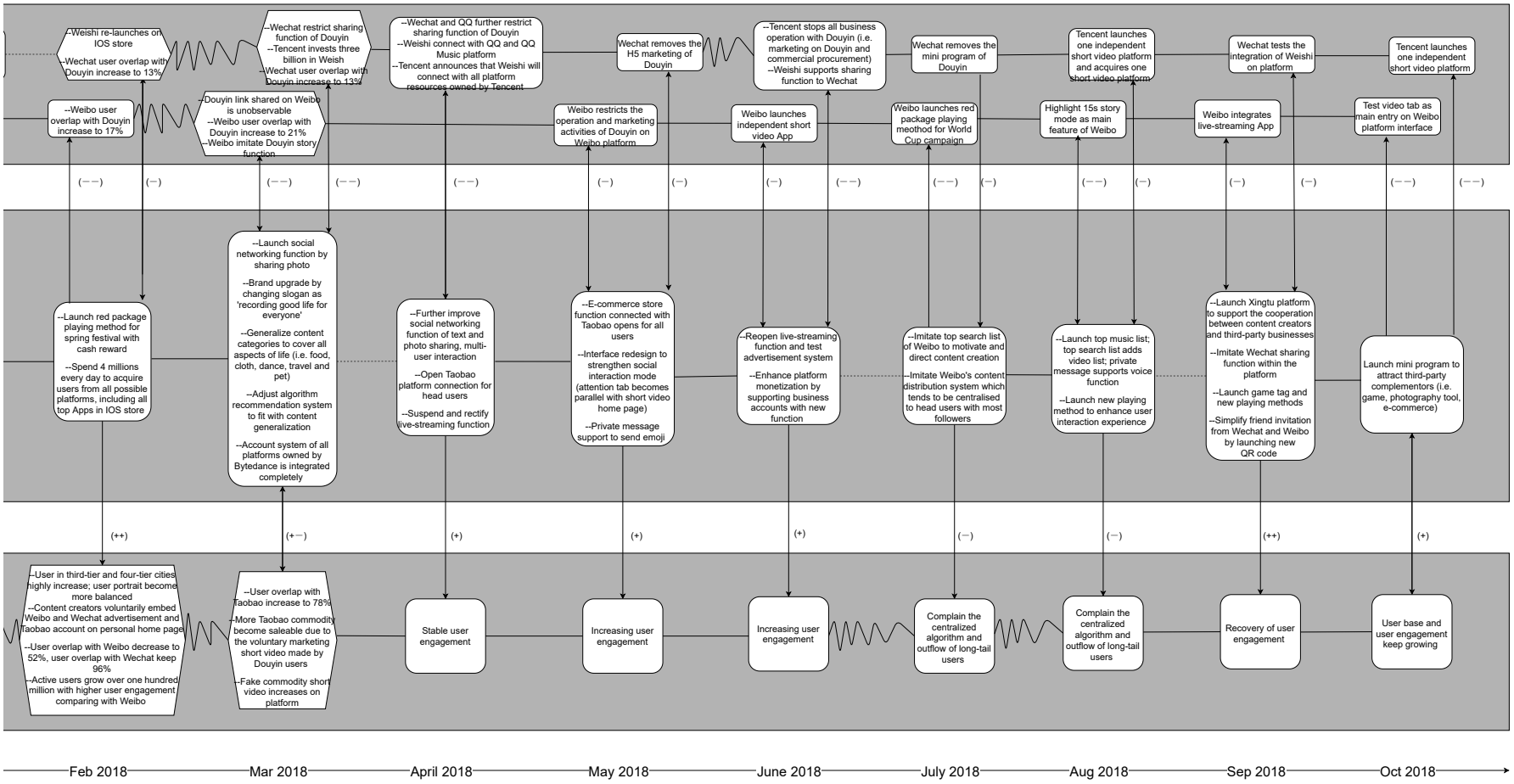
3. The arrow among three bands indicates the effect between event/action of different bands in a specific month (+, ++, -, -- represent the degree of effect).

4. The time scale along the bottom of the charts is distorted in order to keep the size of the charts to a minimum while representation of episodes involving a higher intensity of activity.


Douyin as performing short video community for the young
Focal Platforms
Platform Designer
End Users
Tencent launched Weishi, suppoted by Wechat and QQ
Wechat launched short video function on platform
Weibo integrates Miaopai short video App on platform
Weibo further invest in Miaopai on which 90% users comes from Weibo platform
Acquiesce in the API connection
Acquiesce in the marketing activities
Wechat launched video uploading functions
Wechat acquiesces the video sharing activities of users
Wechat acquiesces the Douyin watermark in shared video
Wechat acquiesces in the short video sharing activity from other platforms
Weishi App ceases operating due to unclear product positioning and market prospect
Wechat acquiesce in the marketing activities on Tencent video platform
Weibo acquiesces in the short video sharing activity from other platforms
Weibo launches story mode focusing on 15s Vlog
Interface redesign to highlight story mode
Bytedance company invests one billion RMB in subsidising short video creators on Toutiao platform
Bytedance launches A.Me short video platform:
--official introduction as a photography tool which emphasises female users
--Core function as full-screen play, short video shooting with music, film editing technique, beauty and filter effects, algorithm recommendation system
--API connection with Wechat and Weibo
--Invite and train seed users on platform; Guide content creation through performing campaign themes and specific playing methods(i.e. camera work)
--Algorithm recommendation system prefers content created by the talents invited by operation team
--Marketing on Wechat and Weibo by creating official account
--Rename as Douyin with new icon and slogan 'performing short video community for the young', targeting at the young and fashionable users
--Interface redesign to strengthen short video creation and sharing activities on platform (hottest challenges and music are marked at home page)
--Launch social functions (@friend) built on short video interaction
--Connecting video sharing function on Wechat
--Add social function (constellation and city information of users) built on short video interaction
--Watermark shared video on Wechat and Weibo with the user name on Douyin
--Function optimisation and launch more face tags
--Challenging campaigns could directly share on Wechat and Weibo
--Strengthen proprietary user account system by allocating exclusive ID number for those log-in with Wechat and Weibo account
--Highlight platform feature when sharing videos on Wechat and Weibo by adding 3D shaking watermark effect
--Big-bang marketing on diverse long video platforms, including Tencent video platform owned by Wechat company
--Highlight entertainment feature of Douyin during marketing activities
--content operation on platform change to entertainment-oriented
The daily view counts of short video are more than one billion times on Toutiao information flow platform
Users could log-in with Wechat and Weibo account, and invite friends from Wechat and Weibo platform
73% active users are under 24 and 86% active users are female
Female users and those under 24 remain the majority on platform
Users are able to upload and share short video on Wechat
--56% users download Douyin after watching the short video shared on Wechat and Weibo
--The proportion of users under 24 and female decrease for the first time on platform
One comedy star on Weibo actively forward Douyin short video on Weibo, creating first-round user growth from Weibo
User outflow with more diverse user portrait (proportion of user under 24 decrease to 61% and female user decrease to 78%)
--More users are piggybacked from Weibo and Tencent video platform (user overlap increases to 57% and 51% respectively)
--The proportion of users under 24 decrease to 52%
(+)
(−)
(−−)
(++)
Sep 2013
Oct 2014
Dec 2015
Sep 2016
Nov 2016
Dec 2016
Jan 2017
Feb 2017
March 2017
April 2017
May 2017


Douyin as entertainment short video community
Wechat acquiesce in the marketing activities on Tencent video platform
Wechat acquiesce in piggyback activities of Douyin
--Acquiesce piggyback activities of Douyin --Wechat user overlap with Douyin increase to 2%
Wechat user overlap with Douyin keep 2%
Tencent begins to do business cooperation with Douyin (i.e. marketing on Douyin and commercial procurement)
Wechat acquiesce the growth of Douyin
Wechat acquiesce the growth of Douyin
--Wechat acquiesce the growth of Douyin --Wechat user overlap with Douyin increase to 10%
--Weishi re-launches on IOS store --Wechat user overlap with Douyin increase to 13%
nterface redesign to highlight story mode
Weibo acquiesce in piggyback activities of Douyin
--Acquiesce piggyback activities of Douyin --Weibo user overlap with Douyin increase to 4%
Weibo blocks API connection with Douyin and temporally bans the official account of Douyin on Weibo
--Video published on Weibo supports to insert music and high definition --Weibo user overlap with Douyin increase to 6%
--Weibo build its own short video platform Kuran --Weibo user overlap with Douyin increase to 9%
--Weibo invests 3 billion in video business --Weibo user overlap with Douyin increase to 10%
--Weibo launches independent short video App --Weibo user overlap with Douyin increase to 13%
--Weibo user overlap with Douyin increase to 17%
(−) (+) (−) (+) (−−) (−) (−−) (+) (−) (+) (−) (+) (−) (+) (−−) (+−) (−−) (−)
--Big-bang marketing on diverse long video platforms, including Tencent video platform owned by Wechat company
--Highlight entertainment feature of Douyin during marketing activities
--content operation on platform change to entertainment-oriented
--Weaken manual operation and strengthen algorithm content distribution which prefers popular content
--Launch new 3D tag and music special effect
--Invite more entertainment stars to create short video on platform
--Interface redesign to enhance content distribution based on user location (nearby content)
--Interface redesign by imitating story mode of Weibo, through which users could create and share daily-life video for 24 hours
--Showing users' Weibo account at personal homepage
---keep same algorithm content distribution
Further enhancing entertainment feature by changing slogan as 'the official recommendation by 'The Rap of China'
--Motivate more innovative content creation by enabling soundtrack made/uploaded by users to be shared with and used by other users
--Launch new 360° panoramic video and AR camera
--Launch information flow advertisement business which enables the marketing of third-party platforms
-- Launch live-streaming function
--Strengthen location-based content distribution by adding location information for published short video
--Targeted marketing on three variety shows and Mango TV platform
--Launch motion sensing playing method supported by AI technology
--Targeted marketing on four variety shows
--Launch live-streaming quiz playing method with cash reward
--Launch musician plan to support and train original musician
--Imitate private letter function of Weibo
--Marketing activities change to cover undifferentiated users
--Launch red package playing method for spring festival with cash reward
--Spend 4 millions every day to acquire users from all possible platforms, including all top Apps in IOS store
(++) (+−) (−−) (−−) (+) (++) (+) (+−) (++) (++)
--More users are piggybacked from Weibo and Tencent video platform (user overlap increases to 57% and 51% respectively)
--The proportion of users under 24 decrease to 52%
--Content creators are motivated to imitate popular content in order to be recommended by algorithm system
--Only 9.5% users frequently watch nearby content
--Decreasing user engagement and user growth due to homogeneous content distribution on platform
--User overlap with Weibo increase to 64%, user overlap with Wechat increase to 88%
--Users could no longer invite users from Weibo directly
--Users actively launch a dance challenge campaign which quickly becomes pop on platform
--User overlap with Weibo decrease to 63%, user overlap with Wechat increase to 89%
--Content homogeneity is highly alleviated with more innovative content creation
--User overlap with Weibo keep 63%, user overlap with Wechat increase to 91%
--Users become more engaged with new monetization means and real-time interaction mode
--User overlap with Weibo decrease to 60%, user overlap with Wechat increase to 93%
--The proportion of users under 24 decrease to 29% and female users decrease to 63%
--User overlap with Weibo decrease to 57%, user overlap with Wechat increase to 95%
--High-speed growth of users (thirty million within one month) and their engagement
--User prefer to real-time interaction around short video content (51.8% for comment function, 51.5% for like function)
--User overlap with Weibo decrease to 55%, user overlap with Wechat increase to 96%
--User in third-tier and four-tier cities highly increase; user portrait become more balanced
--Content creators voluntarily embed Weibo and Wechat advertisement and Taobao account on personal home page
--User overlap with Weibo decrease to 52%, user overlap with Wechat keep 96%
--Active users grow over one hundred million with higher user engagement comparing with Weibo
May 2017
June 2017
July 2017
Aug 2017
Sep 2017
Nov 2017
Dec 2017
Jan 2018
Feb 2018

Douyin as short video social platform



APPENDIX 3: ANALYTICAL SCRIPTS FOR THE EMPIRICAL STUDY TWO

In order to ensure maximum transparency and rigor of various digital trace data analysis conducted as part of this thesis, this appendix encompasses the main analytical scripts used in the course of empirical study two.

Appendix 3.1. Sample Data storing Codes by SQL

```
#data integration in Mysql

#1. create new table to integrate with 'socialapp' database
CREATE TABLE health_integrated_content
(SELECT s.app_id, s.app_version, s.`update_date`, s.`update_content`
FROM `health_app` s
LEFT JOIN `iai_social_others` i
ON s.`app_id`=i.`app_id` AND s.`app_version`=i.`app_version`)
UNION
(SELECT i.app_id, i.app_version, i.`update_date`, i.`update_content`
FROM `health_app` s
RIGHT JOIN `iai_social_others` i
ON s.`app_id`=i.`app_id` AND s.`app_version`=i.`app_version`
WHERE s.app_version IS NULL)
ORDER BY app_id, app_version;

#2. check data format after integration
SELECT `app_id`,`app_version`,`update_date`,`update_content`
FROM `integrated_contents`
ORDER BY app_id, app_version;

#3. update new table data, complement column 'update_content' in socialapp
database
UPDATE `health_integrated_content` c
INNER JOIN `iai_social_others` i
ON c.`app_id`=i.`app_id` AND c.`app_version`=i.`app_version`
```

```
SET c.`update_content`= i.`update_content`
WHERE c.`update_content`='';

#4. take words “预定”in tabe app_version to N/A, just remain version number
UPDATE `health_integrated_content` SET app_version=REPLACE(app_version,'预订','');

#5. cancel content rows that repeated in both table 'integtated_content' and 'iai_socialapp'
#(1).find the repetition line based on column 'app_id' and 'app_version'
SELECT app_id, app_version,update_date
FROM `integrated_contents`
GROUP BY app_id, app_version
HAVING
(COUNT(app_id))>1 AND
(COUNT(app_version))>1

# (2).recombine repeated data raws with original table
SELECT i1.*
FROM `anime_integrated_content` i1
JOIN
(SELECT app_id, app_version
FROM `anime_integrated_content`
GROUP BY app_id, app_version
HAVING
(COUNT(app_id)>1) AND
(COUNT(app_version)>1)) i2
ON
i1.app_id=i2.app_id AND
i1.app_version=i2.app_version
WHERE update_date='1000-01-01'
ORDER BY app_id,app_version
```

```
#(3).delete repeated data
DELETE i.*
FROM health_integrated_content i,
(
SELECT i1.*
FROM `health_integrated_content` i1
JOIN
(SELECT app_id, app_version
FROM `health_integrated_content`
GROUP BY app_id, app_version
HAVING
(COUNT(app_id)>1) AND
(COUNT(app_version)>1)) i2
ON
i1.app_id=i2.app_id AND
i1.app_version=i2.app_version
WHERE update_date='1000-01-01'
ORDER BY app_id,app_version
) i3
WHERE i.app_id=i3.app_id AND
i.app_version=i3.app_version AND
i.update_date=i3.update_date AND
i.update_content=i3.update_content

#(4).check data rows with blank value in column 'update_content', check
whether already deleting the repeated rows completely
SELECT app_id FROM `health_integrated_content`
GROUP BY `app_id`,`app_version`
HAVING COUNT(*)>1
```

Appendix 3.2. Sample Data Analysis Codes by Python

```
#1. import data of app user review from Mysql database
eng=
```

```
create_engine('mysql+pymysql://root:lsy3718056@localhost:3306/appdata?charset=utf8')
sql = "SELECT app_id,comment_date,existed_number,deleted_number FROM app_comment ORDER BY app_id, comment_date"
app_comment = pd.read_sql(sql,con=eng)
appid=app_comment['app_id']
id_list=appid.unique().tolist()
for ids in id_list:
    df1=app_comment.loc[app_comment.app_id == str(ids)]
    df1=df1.set_index('comment_date',drop=True)
    df1.existed_number=df1.loc[:,'existed_number'].apply(pd.to_numeric)
    df1.deleted_number=df1.loc[:,'deleted_number'].apply(pd.to_numeric)
    df1 = df1.loc[:, ~df1.columns.str.contains("^Unnamed")]
    df1.index = pd.DatetimeIndex(df1.index)
    df1.drop(columns=['app_id'], inplace=True)
    month_mean=df1.resample('M').sum()
    month_mean.reset_index(inplace=True)
    month_mean.insert(0,'app_id',ids)
    with open('social+comment.csv', 'a', newline='', encoding="utf8") as file_object:
        month_mean.to_csv(file_object, mode='a+', index=False, header=False)

#2. get 'monthly review number','accumulated review number', 'monthly review difference'
import pandas as pd
import numpy as np
import re

def doSubStr(x):
    res = re.sub('-','',x)
    res=int(res)
    return res
```

```
def doSubStr_1(x):
    if 'K' in x:
        res = float(re.sub('K','',x))
        res_1 = res * 1000
        return res_1

    elif 'M' in x:
        res = float(re.sub('M','',x))
        res_1 = res * 1000000
        return res_1

    else:
        return x

app_comment=pd.read_csv('social+comment.csv',encoding="utf-8", index_col=False)
iai_s=pd.read_csv(r'C:\Users\Eric\Desktop\iai_social_plus.csv',encoding="utf-8",
index_col=False)

#count monthly_review_diff
app_comment['E_review_diff']                                                    =
app_comment.groupby('app_id')['existed_comment'].apply(lambda i:i.diff(1))
app_comment['D_review_diff']                                                    =
app_comment.groupby('app_id')['deleted_comment'].apply(lambda i:i.diff(1))

# count accumulated review_comment
app_comment1=app_comment.copy()
iai_s.loc[:,'month'] = iai_s['update_date'].astype("str").str[0:7]
iai_s.loc[:,'month'] = iai_s.loc[:, 'month'].apply(doSubStr)
iai_s.comment_number=iai_s.loc[:,'comment_number'].apply(doSubStr_1)
iai_s.comment_number=iai_s.loc[:,'comment_number'].apply(pd.to_numeric)
appid=app_comment['app_id']
id_list=appid.unique().tolist()
iai_id=iai_s['app_id']
```

```
iai_id_list=iai_id.unique().tolist()
#iai_id_list = [ str(x) for x in iai_id_list ]
for ids in id_list:
    if ids in iai_id_list:
        df1=iai_s.loc[(iai_s.app_id == ids) & (iai_s.month < 201401)]
        df1=df1.set_index('update_date',drop=True)
        if len(df1)>0:
            cumulated_num=df1.comment_number.iloc[-1]
            num=app_comment.loc[(app_comment.app_id==           ids)           &
(app_comment.month=='2014-01-31'),'existed_comment'].iloc[0]
            total= num + cumulated_num
            app_comment1.loc[(app_comment1.app_id==            ids)            &
(app_comment1.month=='2014-01-31'),'existed_comment'] = total

app_comment1['cum_comment']=app_comment1.groupby(['app_id'])['existed_comment'].
cumsum()
app_comment.loc[:,'cum_comment']=app_comment1['cum_comment']

#delete extra data for the part before app is launched and after it is moved from
app store
cat=pd.read_csv('cat_final.csv',encoding="utf-8", index_col=False)
app_comment_final=pd.merge(cat,app_comment,on=['app_id','month'],how='left')
app_comment_final.loc[app_comment_final.category.isnull(),'existed_comment']
=np.nan
app_comment_final.loc[app_comment_final.category.isnull(),'deleted_comment']
=np.nan
app_comment_final.loc[app_comment_final.category.isnull(),'E_review_diff']
=np.nan
app_comment_final.loc[app_comment_final.category.isnull(),'D_review_diff']
=np.nan
app_comment_final.loc[app_comment_final.category.isnull(),'cum_comment'] =np.nan
app_comment_final.to_csv('app_review_final.csv',sep=',',header=True, index=False)
```

```
#3. data clean for app update history contents

# coding: utf-8

import pandas as pd
import re
import csv
pd.options.display.max_rows=20

class DataClean():
    def __init__(self,pre_file,pro_file='clear_data.csv'):
        self.pre_file=pre_file
        self.pro_file=pro_file

    def read_file(self):
        data=pd.read_csv(self.pre_file,encoding='utf-8', index_col=False)
        #data = pd.read_excel(self.pre_file, sheet_name="sheet1")
        return data

    def take_appdata(self,appid):
        data=self.read_file()
        data['app_id']=data['app_id'].astype('str')
        self.app_data=data.loc[data['app_id'] == str(appid)]

    def split_sentences(self,sentences):

split_punctuation='(。)|(:)|(： )|(-)|(； )|(\*)|(、)|(＊)|(✓)|(✔)|(♥)|(●)|(■)
|(★)|(☆)|(\+)|(\?)|(#)|(【)|(】)|(\[)|(\])|(「)|(」)'
        split_punctuation += '|(『)|(』)|(\{)|(\})|(!)|(◆)|(~)|(…)|(・)|([1-9][0-
9]?)|(\.)|(\n)|(\s)|(\r)|(\()|(\))|(\|)'
        self.splited_sentences=[]
        ss=re.split(split_punctuation,sentences)
        for s in ss:
```

```
            if s != None:
                self.splited_sentences.append(s)

    def delete_punctuation(self):
        words_list=self.splited_sentences
        deleted_punctuation='[0-9’ !"#$%&\'()*+-./: ： ； ； <=>?@ 。 ?★☆ *
◆♥●■✔✓ 、 •… [ ]【】() 《》 ? “” ‘’ 「」『』'
        deleted_punctuation += '—！ [\\]ˆ_`{|}~1 2 3 4 5 6 7 8 9 1 0 1 1 1 2 1
3 ]+'
        remove_chars=deleted_punctuation
        recombined_words=[]

        for i in words_list:
            rw=re.sub(remove_chars, '', str(i))
            recombined_words.append(rw)
        a=len(recombined_words)
        while '' in recombined_words:
            recombined_words.remove('')
        pro_words_list = [x.strip() for x in recombined_words if x.strip() != '']
        return pro_words_list

    def join_words_list(self, pro_wordlist):
        recombined_sentence=' '.join(pro_wordlist)
        return recombined_sentence

    def data_header_save(self):
        with open(self.pro_file, 'w', newline='', encoding="utf8") as file_object:
            writer=csv.writer(file_object)

writer.writerow(['app_id','update_date','app_version','update_content'])
        file_object.close()

    def data_content_save(self,dict_items):
```

```
        with open(self.pro_file, 'a',newline='', encoding="utf8") as file_object:
            fileheader=list(dict_items.keys())
            dict_writer=csv.DictWriter(file_object, fieldnames=fileheader)
            dict_writer.writerow(dict_items)
        file_object.close()

    def content_compare_save(self):
        first_app_data={}
        second_app_data={}
        self.data_header_save()

        data=self.read_file()
        appids=list(data['app_id'])
        sole_appids=list(set(appids))
        for sole_appid in sole_appids:
            self.take_appdata(sole_appid)
            lines=len(self.app_data)
            for i in range(0,lines-1):
                app_data_1=self.app_data.iloc[i]
                app_data_2=self.app_data.iloc[i+1]

                first_app_data['app_id']=app_data_1['app_id']
                first_app_data['update_date']=app_data_1['update_date']
                first_app_data['app_version']=app_data_1['app_version']

                second_app_data['app_id']=app_data_2['app_id']
                second_app_data['update_date']=app_data_2['update_date']
                second_app_data['app_version']=app_data_2['app_version']

                app1=str(app_data_1['update_content'])
                app2=str(app_data_2['update_content'])
                if type(app1) != 'nan':
                    self.split_sentences(app1)
```

```
            first_clean_wordlist=self.delete_punctuation()
        else:
            first_clean_wordlist = None
        if type(app2) != 'nan':
            self.split_sentences(app2)
            second_clean_wordlist=self.delete_punctuation()
        else:
            second_clean_wordlist = None

        recombined_sentence1=self.join_words_list(first_clean_wordlist)
        first_app_data['update_content']=recombined_sentence1

        pro_wordlist=[]
        for second_clean_word in second_clean_wordlist:
            if second_clean_word not in first_clean_wordlist:
                pro_wordlist.append(second_clean_word)
        recombined_sentence2=self.join_words_list(pro_wordlist)
        second_app_data['update_content']=recombined_sentence2

        if i == 0:
            #print(first_app_data)
            #print(second_app_data)
            self.data_content_save(first_app_data)
            self.data_content_save(second_app_data)
        else:
            #print(second_app_data)
            self.data_content_save(second_app_data)
```

Appendix 3.3. Sample Natural Language Proceeding by BERT

```
# coding: utf-8
import tensorflow as tf

pip install pytorch-pretrained-bert
pip install tensorflow-gpu==1.15.3
```

```
BERT_BASE_DIR = '/home/itibia/chinese_L-12_H-768_A-12/'
arg_dic = {
    "data_dir": './data/',              # data catalogue
    "output_dir": './output/',          # ckpt output catalogue
    'pb_model_dir':'./pb/',
    "bert_config_file": BERT_BASE_DIR + 'bert_config.json',
    "task_name": 'cnews',  # "The name of the task to train.
    "vocab_file": BERT_BASE_DIR + 'vocab.txt',  # The vocabulary file that the BERT model was trained on.
    "init_checkpoint": BERT_BASE_DIR + 'bert_model.ckpt',
    # "Initial checkpoint (usually from a pre-trained BERT model).
    "do_lower_case": True,
    "max_seq_length": 150,
    "do_train": True,  #train model parameter with 'train set'
    "do_eval": True,  #evaluate trained model with 'evaluate set'
    "do_predict": False, #predict unclassifed dataset with trained model
    "train_batch_size": 32,
    "eval_batch_size": 8,
    "predict_batch_size": 8,
    "learning_rate": 3e-5,
    "num_train_epochs": 5,
    "warmup_proportion": 0.1,  # "Proportion of training to perform linear learning rate warmup for. "
    # "E.g., 0.1 = 10% of training."
    "save_checkpoints_steps": 100,    # How often to save the model checkpoint."
    "iterations_per_loop": 1000,    # "How many steps to make in each estimator call.

    "use_tpu": False,
    "tpu_name": False,
    "tpu_zone": False,
```

```
    "gcp_project": False,
    "master": False,
    "num_tpu_cores": False,  # "Only used if `use_tpu` is True. Total
number of TPU cores to use."
}

import os
os.environ["TF_CPP_MIN_LOG_LEVEL"] = "3"
#os.environ['CUDA_VISIBLE_DEVICES'] = '0,1,2,3'
!python train_eval.py
```

Appendix 2.4. Sample Survival Regression Codes in Stata

```
COX PH (cross-section): stcox app_cat_change n_previous_up social_app
cat_app_num log_app_users log_use_time social non_social maintenance channeling
same_cat_app diff_cat_app cum_comment rating cat_ranking app_ranking,
shared(category)

COX PH (time-varying): stcox app_cat_change n_previous_up monthly_log_user
log_use_time social non_social maintenance channeling same_cat_number
different_cat_number cum_comment average_rating log_app_ranking
log_sub_cat_ranking, forceshared shared(category)

Weibull (cross-section): streg app_cat_change n_previous_up social_app
cat_app_num log_app_users log_use_time social non_social maintenance channeling
same_cat_app diff_cat_app cum_comment rating cat_ranking app_ranking,
distribution(weibull) frailty(gamma) shared(category)

Weibull (time-varying): streg app_cat_change n_previous_up monthly_log_user
log_use_time social non_social maintenance channeling same_cat_number
different_cat_number cum_comment average_rating log_app_ranking
log_sub_cat_ranking, distribution(weibull) frailty(gamma) forceshared
shared(category)

Discrete-time logic: melogit y i.date launch_month app_cat_change
n_previous_update monthly_log_user log_use_time social non_social maintenance
```

channeling same_cat_number different_cat_number average_rating cum_comment l_monthly_sub_cat_ranking l_monthly_app_ranking, or || category: