Min Tian

INNOVATION THROUGH DIGITALIZATION

HOW SOCIOTECHNICAL TENSIONS DRIVE INNOVATION

STOCKHOLM SCHOOL OF ECONOMICS

INNOVATION THROUGH DIGITALIZATION

In the digital age, many firms seek to innovate through digitalization. Scholars of information systems (IS) have drawn upon the theoretical insights of the sociotechnical interrelations that accompany digitalization to analyze digital innovation. However, digitalization, which stimulates social technical changes, put the established sociotechnical interrelations repeatedly under pressure. This leads to sociotechnical tensions. This dissertation argues that sociotechnical tensions, stimulated by digitalization, are the key driving force for innovation. This dissertation aims to contribute to the current body of sociotechnical research by exploring how sociotechnical tensions drive digital innovation. It includes three papers and a cover text.

Paper 1 conceptualizes iterative digitalization as the ongoing result of resource-interaction practices, including systematic networking, flexible engineering, and scalable task coordination. By investigating five iterations of digitalization processes, Paper 2 analyzes how the interlinked practices of flexible engineering and scalable coordinating lead to the tensions of sociotechnical dissonances, thereby driving digital innovation at the micro level. Paper 3 argues that the interlinked practices of flexible engineering and systematic networking can lead to the tensions of sociotechnical intertwining. The sociotechnical intertwining drives the digital innovations of the macro level. Finally, the cover text provides a combined discussion of all the three papers, and concludes with a process model of dynamic digital innovation.

MIN TIAN is a researcher at the Stockholm School of Economics. Min Tian's research interests lie in the areas of digital innovation, digital transformation and service innovation.

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Min Tian

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To God

Foreword

This volume is the result of a research project carried out at the Department of Marketing and Strategy at the Stockholm School of Economics (SSE).

The volume is submitted as a doctoral thesis at SSE. In keeping with the policies of SSE, the author has been entirely free to conduct and present her research in the manner of her choosing as an expression of her own ideas.

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Director of Research
Stockholm School of Economics

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Professor and Head of the
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Stockholm, October 18, 2020

Min Tian

Contents

PART I: Summary of the dissertation

Chapter 1

Introduction

We take it for granted that the social and technical engage together to foster innovation in digitalization, forgetting most often that innovation is leveraged through sociotechnical tensions…

—A project manager of DIGITAL

In the digital age, many firms seek to innovate through digitalization. They are excited when talking about digitalization because of its potential to 'revolutionize' their innovation processes. When exploring how firms succeed in digital innovation, it is first essential to understand digitalization.

Digitalization can be considered as the embedding of digital technology into its sociotechnical context for innovation (Henfridsson et al., 2009; Hylving & Selander, 2012; Piccinini et al., 2015). This is conducted through both social and technical processes. The social processes include two aspects: building the social networks of heterogeneous organizations to combine their physical and digital resources (Vargo & Akaka, 2012; Vargo & Lusch, 2011; Ashurst et al., 2008), and coordinating people across the physical and digital fields (Zysman et al., 2013; Kane et al., 2015). The technical processes involve embedding digital technology within the traditional physical product to develop 'smarter' technical architectures (Yoo, 2010; Henfridsson et al., 2009; Svahn & Henfridsson, 2012).

Some firms take for granted the fact that the social and technical can engage together in a joint effort towards fostering innovation. The reality is

often that firms struggle to innovate through various sociotechnical tensions. Executive managers of different companies, who can be seen as macro-level designers of digitalization, have emphasized the challenges of finding a balance between the involved organizations' aspiration of digitalization and the affordability of the digital architecture. That is, they deal with the tensions of social network and digital architecture to facilitate digital innovation. Project managers, who are micro-level practitioners of digitalization, struggle to find the best fit between the people and their proper tasks for achieving digitalization. Thus, they deal with the tensions of task coordination and digital architecture to leverage digital innovation.

In accordance with empirical world scholars in the information systems (IS) field have drawn upon the theoretical insights of sociotechnical interrelations to analyze innovation in digitalization. Some of them have examined digital innovation from a macro-level perspective, focusing mainly on the relationship between social network and technical architecture (Henfridsson & Bygstad, 2013; Grisot et al., 2014; Lusch & Nambisan, 2015; Orlikowski & Scott, 2015; Eaton et al., 2015; Srivastava & Shainesh, 2015; Barrett et al., 2015). The notion of sociotechnical interrelation is conceptualized as sociotechnical adaptation, sociotechnical affordance, sociotechnical responsive relationship, etc. Here, the social and technical coevolves in an ongoing manner to create innovation opportunities. Scholars who have focused, meanwhile, on digital innovation at the micro level have started to examine the relationship between task coordination and digital architecture (Lee & Berente, 2012; Colfer & Baldwin, 2016; Cataldo et al., 2008; Baldwin & Clark, 2000; Svahn & Henfridsson, 2012). These researchers have classified sociotechnical interrelation as comprising of sociotechnical restructure, sociotechnical reconfiguration, sociotechnical constitution, etc. (Ashurst et al., 2008; Selander et al., 2010; Kane et al., 2015; Piccinini et al., 2015). And they have mainly explored how social and technical processes recursively configure and reconfigure each other to achieve innovation (Gawer, 2009; Arthur, 2009; Fichman et al., 2014; Nambisan, 2013; Henfridsson & Yoo, 2014; Lyytinen et al., 2015).

As illustrated above, sociotechnical interrelations at both the micro or the macro level have been depicted from a neutral perspective. The social and technical processes are seen to be related through an emergent process

of mutual influence. Scholars have primarily explored how organizing structure and digital architecture coevolve or configure with each other to achieve innovation. However, in this thesis, I will emphasize that digitalization is an iteratively developed process. Iterative digitalization stimulates social or technical changes and put the established interrelation repeatedly under pressure, thus leading to sociotechnical tensions. This dissertation will analyze innovation through an exploration of sociotechnical tensions in iterative digitalization.

1.1. Research problem

Many IS scholars have focused on innovation in the ever-changing context of digitalization. They have analyzed how digitalization triggers innovation (Tiwana et al., 2010; Henfridsson & Bygstad, 2013; Eaton, 2012; Grisot et al., 2014). They have particularly drawn upon theoretical insights of sociotechnical interrelations that accompany digitalization to analyze innovation (Tiwana et al., 2010; Henfridsson & Bygstad, 2013; Eaton, 2012; Grisot et al., 2014). Several researchers have even recognized that the social and technical related through tensions and stressed that digitalization stimulates sociotechnical tensions to drive innovation (Hylving & Selander, 2012; Hylving et al., 2012; Hylving, 2015; Piccinini et al., 2015; Lyytinen & Newman, 2008; Tilson, 2010). However, despite the explicit call for future research in this area, there seem to have been few attempts to address the typology of sociotechnical tensions and demonstrate empirically how to evolve different types of sociotechnical tension and drive digital innovation processes.

1.2. Research purpose and research questions

This dissertation will explore innovation through sociotechnical tensions stimulated by iterative digitalization. These sociotechnical tensions stand at the centre of my study of digital innovation.

The purpose of this thesis is to deepen our knowledge of how sociotechnical tensions drive digital innovation.

By investigating sociotechnical tensions in iterative digitalisation processes, this thesis will also explore how firms create sociotechnical tensions to drive innovation over time.

The first research question is 'how can we conceptualize iterative digitalization as practices?'[1] Iterative digitalization stimulates social or technical changes and leads to sociotechnical tensions. These social and technical tensions are the key driving force for the innovation processes.

The second research question is 'How do sociotechnical tensions drive digital innovation over time?' and will be answered by assessing the following two sub-questions:

- As we have seen, the research analyzing digital innovation at the micro level has mainly explored how social and technical processes recursively configure and reconfigure each other to achieve innovation. To deepen our understanding of micro-level digital innovation, I claim that social and technical processes are not merely mutually configurative; rather, they are mostly dissonant and challenge each other. These sociotechnical tensions at the micro level are thus conceptualized as sociotechnical dissonances. The first sub-question, therefore, is: How does a firm create sociotechnical dissonances that drive micro-level digital innovation?
- Scholars who have focused on digital innovation at the macro level have emphasized that the social and the technical coevolve to create innovation opportunities. To contribute to the literature on macro-level digital innovation, I argue that the social and technical processes do not coevolve in parallel; rather, they most often intertwine with each other. The sociotechnical tensions at the macro level are, therefore, conceptualized as sociotechnical intertwining. Thus, the second sub-question is: How does a firm create sociotechnical intertwining that drives macro-level digital innovation?

[1] The term 'practices' in this thesis is used to mean the actors' endeavours of combining various resources for achieving digitalisation.

1.3. Structure of the dissertation

The dissertation comprises two parts. Part I presents a summary of the dissertation. Part II consists of the three articles that are involved and discussed in this dissertation. Part I is divided into the following chapters:

- Chapter 1: This chapter has introduced the topic and put forth the research problem, research purpose, and the principal research questions.
- Chapter 2: This chapter reviews the previous research on digital innovation.
- Chapter 3: This chapter illustrates my own theoretical consideration for analyzing digital innovation.
- Chapter 4: This chapter describes the empirical foundations of the dissertation.
- Chapter 5: This chapter provides an overview of the methods used in this study.
- Chapter 6: This chapter provides brief summaries of each article in the dissertation.
- Chapter 7: This final chapter provides an overview of the crucial findings from the three papers, followed by a discussion of these findings in relation to each other.

Chapter 2

Literature review

This section reviews the literature from the field of information systems (IS) theory concerning digital innovation (e.g., Boland et al., 2007; Lee & Berente, 2012; Selander et al., 2010; Svahn, 2012; Svahn & Henfridsson, 2012; Yoo et al., 2010; Åkesson, 2009). The literature to date understands digital innovation from three angles. The first angle involves innovation through *digitization*, which is concerned with the technical aspects of digital innovation. The second angle focuses on innovation through *socially embedded digitization*, whereby scholars encourage a shift into the fundamentally social aspects of digital innovation. The third angle concerns innovation through *digitalization*, which will combine both the social and technical aspects of digital innovation. This dissertation puts most emphasis on having a conversation with the third angle. The research from this angle has evolved from a more abstract and static view to a dynamic view of sociotechnical interrelation. However, the sociotechnical interrelations have been mainly explored from a neutral perspective as involving mutual influence. In this dissertation, I will claim that iterative digitalization stimulates sociotechnical tensions, thereby driving innovation processes. Sociotechnical tensions are thus the primary focus of this dissertation.

2.1. Digitization and innovation

When the digital meets the physical

Digitization concerns creating a digital version of the physical product (Miles, 2008). It can be defined as carrying out new combinations of digital and physical components to produce novel products (Yoo et al., 2010, p 2). Much research has started to consider the ability of digital technology to transform traditional products into digital variants (Gassmann et al., 2014). Scholars have illustrated that digitization is to combine digital and physical components to produce digital architecture, platforms, and processes (Bockshecker et al., 2018). That is, digitization allows a traditional, physical product to engage in emergent, interactive, and dynamic innovation.

There are essentially two streams of research concerning digitization-generated innovation. Firstly, some scholars have explored how digitization influences the innovation process of the physical product (King & Lyytinen, 2005; Zammuto et al., 2007). For instance, Zammuto et al. (2007) suggested that digitization involves making a traditional product 'smarter' by integrating it with digital technology to imbue it with software-based digital capabilities, which then enable the product to perform a wide array of functions. Moreover, as Yoo et al. (2010) argued, digital technology enables a separation of the semiotic functional logic of the device from the physical embodiment of the traditional product that executes it, and then programs the functional logic to achieve feature variety Secondly, some scholars have started to explore why digitization enables innovation (Bockshecker et al., 2018), emphasizing that digital artefacts' material properties form the basis for the innovation process (Yoo et al., 2010; Zammuto et al., 2007; Svahn & Henfridsson, 2012; Lyttinen & Rose, 2003; Kallinikos et al., 2013). Yoo et al. (2010) determined that seven properties of the digital artefact are significant for innovation: programmability, addressability, sensibility, communicability, memorability, traceability, and associability. Inspired by this research, other scholars have begun to systematically explore how specific material properties can shape a physical product's evolutionary dynamics. For example, Eaton (2012) and Gawer (2009) explored the programmability of digital technology by examining how a digital artefact enables a physical product to accept new sets of logic, thus allowing it to modify its behaviours and functions. Examples

are embedded software systems (e.g., CAN bus) and artefact control systems (e.g., iTunes). Hedman et al. (2013) and Eaton (2012) explained that a digital artefact's sensibility enables it to monitor and respond to changes in the production context, as it contains sensors which allow diverse information from the production context to be transcoded into data for analyzing, to manipulate the changing product features. To illustrate, a thermometer sensor paired with a GPS chip can help monitor the temperature exposure of temperature-sensitive food products during transportation and storage.

Nonetheless, these two streams of research share a common foundation: that the digital technology integrates into the physical product to create an ongoing evolutionary technical system. Furthermore, digital technology leverages its properties throughout the system's lifecycle to facilitate dynamic innovation (Liu et al., 2011). According to the literature, this progressive digitization involves not the identification of generic structures, but rather a matter of identifying, describing, and using the generative schemes, helping us to create a 'living system' with duality regimes and thereby achieving dynamic innovation (Tiwana et al., 2010; Baldwin & Woodard, 2009; Grisot et al., 2014; Lee et al., 2012; Gawer, 2009). For instance, Tiwana et al. (2010) and Baldwin and Woodard (2009) noted that an ideal system should support variety in the present and resolvability over time. Grisot et al. (2014) argued that cultivating a flexible system, which can evolve over time and context to accommodate specific users' needs, can facilitate future innovation. Some scholars, moreover, have suggested that the living system always involves dual regimes to enable dynamic innovation. For example, Eaton (2012) proposed building open-closed architecture. Here, digital innovation concerns dealing with complex trade-offs between what is 'open' and what is 'closed' (Gawer, 2009). Nambisan (2013) further illustrated that ongoing digitalization exercises both openness (to promote innovation) and control (to maintain architectural integrity) to renew the system continuously. Finally, Simone and Ulrich (2012) emphasised that the dynamic process requires not only the realization of new ideas but also the recombination and optimization of existing resources to benefit from commonality and reuse of components to satisfy demand. The aforementioned research has been generally concerned with the technical processes of digital innovation.

2.2. Socially embedded digitization and innovation

When the digital meets the social

Over the past three decades, many researchers have been opening technical research up to engage with social concerns (Barley, 1986; Orlikowski & Robey, 1991, Clement & Halolen, 1998; Rose, 1999; Baskerville et al., 2000; Orlikowski & Barley, 2001). In light of this research, an increasing number of social scientists have realized that digitization is also deeply socially embedded (Selander et al., 2010). These scholars suggested that digitalization is something more than just a collection of affordances and properties of things (Leonardi, 2010; Orlikowski & Hofman, 1997); it changes our behaviour (Kaplan & Haenlein, 2010), is part of our identity (Schultze, 2014), and implies a new way of organizing (Hylving & Schultze, 2013; Svahn & Henfridsson, 2012). They encouraged a shift away from more abstract and materialistic images of the role of digital technology in organizations to a view of technologies as fundamentally social objects (Imran & Kantola, 2018; Katz & Koutroumpis, 2013; Bockshecker et al., 2018). Indeed, a growing number of scholars have started to leverage the social aspects of digitization and encouraged theorizing the organizational change of the digitization process (Majchrzak et al., 2016; Haffke et al., 2016; Horlacher, 2016; Nwankpa & Roumani, 2016; Schmidt et al., 2017). They recognized the numerous managerial challenges involved in digitization (Ashurst et al., 2008). For these scholars, digitization is a complex, revolutionary, and continuous process that demands fundamental changes in organizational structures (Romanelli & Tushman, 1994): they also claimed that organizational changes are needed to provide management support for digitization (Ashurst et al., 2008; Matt et al., 2015). Some of them even provided an empirical exploration of how managers deal with organizational changes triggered by the introduction of digital technologies (Daniel & Wilson, 2003; Jetter et al., 2009; Ranganathan et al., 2003).

After a systematic review of the literature, I found that the consensus reached by many scholars of organizations was that digitisation requires the development of new, coordinating ways of organizational units, and the

evolution of the organizations' social network, to achieve innovation (Henriette et al., 2015). Some scholars have asserted that an ideal organization, transformed by digital technologies and capabilities, will engage talent across the organizations (Kane et al., 2015) to perform innovation. Indeed, digitization engages people across organizations and encourages them to be digital-ready (Lee & Berente, 2012; Grisot et al., 2014; Eaton, 2013). The work of digitization draws on enactment from diverse organizational units (Lyytinen et al., 2016) and dynamic innovation is generated through the interplay of loosely coupled heterogeneous organizational units. Simultaneously, ongoing digitization also involves configuring an evolving network of heterogeneous organizations with different technological resources (Vargo & Akaka, 2012; Vargo & Lusch, 2011; Maglio & Spohrer, 2008; Vargo et al., 2008). Researchers have suggested that achieving digitization requires identifying appropriate value propositions to generate and strengthen the ties among organizations. For instance, Maglio and Spohrer (2008) claimed that establishing a set of value-proposing organizations that forge relationships with one another is significant for developing an evolutionary social network (Akaka & Vargo, 2014). This value identification perspective draws attention toward collective norms' significance in the value co-creation of digitization processes (Chandler & Vargo, 2011; Edvardsson et al., 2011). Some scholars further stated that ongoing digitisation endows the social networking process with specific characteristics for achieving innovation. For example, Lusch and Nambisan (2015) explained that digitization requires the social network's structural flexibility and integrity for creating perpetual innovation, while Sako (2009) posited that digitization needs to bridge the loosely coupled participating organizations to make value co-creation more scalable.

2.3. Digitalization and innovation

When the digital meets the sociotechnical

An increasing number of IS scholars have redefined the sociotechnical process initiated by the embedding of digital technology as digitalization. They have started to shift their focus to the sociotechnical process, emphasizing that both the social and the technical have to be taken seriously (Bailey et al., 2012; Leonardi, 2011, 2013; Leonardi et al., 2012; Orlikowski, 2009;

Orlikowski & Scott, 2008; Orlikowski, 2007; Sarker et al., 2013). For these scholars, digitization is characterized by a bidirectional influence of social and technological developments (Schneider, 2017). They have underlined that 'the phenomenon of digitalization is context-specific' (Bockshecker et al., 2018) and that digitalization is not simply a story of technology; it is, rather, a story of digital technology and its ever-shifting sociotechnical context (Liu et al., 2011). Researchers have articulated the dynamic negotiations between digital technology and its sociotechnical context. For instance, Zysman et al. (2013) noted that digitalization is a transition entailing different sets of bargains between digital technology and its resource context. Similarly, Bowersox et al. (2005) expressed that digitalization is a journey of digital technology's embedding into the sociotechnical context. They further asserted that digital technologies can not only adapt to a sophisticated technical environment but also cater to spatial switching within external social contexts. That is, the digital embedding is not simply an interaction between digital technology and a traditional product but a larger, more complex, systemic transition: a transition entailing different sets of interactions of digital technology with its social-technical context (Håkansson & Waluszewski, 2002; Zysman et al., 2013, Liu et al., 2011).

Three schools of research have emerged to analyze sociotechnical phenomena related to digitalization by focusing on different contextual levels of digitalization (individual, group, and organisational networks). Each school of research draws upon different theoretical insights provided by social and technical interrelations to analyze the innovation process.

The first school of research (see Table 1) emphasizes that innovation emerges through the interplay between the individual and technology in a complex web of mutual causality (Gaskin et al., 2014; Arthur, 2009). The pilot research of this branch of thinking has departed from the sociomaterial perspective to explore the entanglement of the individual and digital technology. From this basis, subsequent research has concerned examining the routines of sociomaterial entanglement for the achievement of innovation. The research of this school is largely historically coherent.

This research has been founded in the context of an individual's design and use of digital technology. It shifts away from more abstract and static images of digital technology's design and use to a view of digital technology's

dynamic interactions with an individual's design and use practices over time. The sociomaterial tradition has been considered as the dynamic and mutual interplay between the social and the technical through recursive interactions (Bijker, 1995; Latour, 1987; Williams & Edge 1996). The notion of sociomateriality has been used as a powerful and prominent ontological lens through which to explore the mutually engaged relationship between people and technology (Gaskin et al., 2014). As noted, by this thinking, humans or technologies have no inherent properties; rather, they acquire form, attributes, and capabilities through their interpenetration. This is a relational ontology that presumes that the social and the material are inherently inseparable and interdependent (Orlikowski & Scott, 2008). Building on this intellectual tradition, numerous articles have reviewed the evolution of scholarship on the relationship between the technical and the social elements of digitalization (Leonardi & Barley, 2008, 2010; Orlikowski & Scott, 2008; Zammuto et al., 2007; Mazmanian et al., 2013) to analyze the innovation process. Scholars have applied various terms to depict sociotechnical interrelation, including sociotechnical entanglement, sociotechnical constitution, sociotechnical intermingle, sociotechnical interpenetration, and sociotechnical fuse. Their core focus, however, is the constitutive entanglement; here, researchers are faced with the challenge of examining the mutual constitutive entanglement process (Dale, 2005; Orlikowski, 2007; Orlikowski & Scott, 2008; Mazmanian et al., 2013). These scholars have started to explore the recursive constitution of humans and technology in practice (Leonardi & Barley, 2008; Orlikowski, 2000; Orlikowski & Scott, 2008), arguing that people and digital technology are inextricably entangled in the sociomaterial practices of use and design. They have illustrated that designers collaborate with users to 'inscribe' their interests and perspectives to shape the design and meaning of technology. The technical content will also influence the designers and users' vision of the world. The literature has focused on exploring the mutually constitutive relationship between individual and technologies (Bennett & Joyce, 2010; Gaskin et al., 2014) to explore the innovation process. As the research progresses, a dominant stream has emerged which unpacks the routines of sociotechnical entanglement. Indeed, an increasing number of researchers have realized that the ongoing technology-in-practice has become regularized and routinized, and have indicated that the next

frontier of innovation scholarship ought to concern exploring latent regularities in observed association patterns between the social and the technical elements across contexts (Leonardi & Barley, 2008).

Table 1 Research school 1: Sociotechnical interaction on the individual level

Aim	Theoretical foundation	Terms	Pioneer research	Typical example	Dominant trends in contemporary research	Typical example
A shift away from more abstract and static images of digital technology to a view of the dynamic interactions between people and technology over time.	The theoretical foundation is the sociomaterial perspective (e.g. Orlikowski, 2000).	Sociotechnical entanglement; sociotechnical constitution; sociotechnical intermingle; sociotechnical interpenetration; sociotechnical fuse.	Innovation is generated through recursive interactions of people and technology. Researchers explore the mutually constitutive relationship between individual and technologies to explain the innovation process (Dale, 2005; Orlikowski, 2000, 2007; Orlikowski and Scott, 2008; Orlikowski and Barley, 2001; Robey et al., 2003; Dodgson, 2007; Scott and Orlikowski, 2012; Wagner et al., 2011; Nyberg, 2009; Wagner et al., 2010; Robey et al., 2003; Mutch, 2013).	The recursive constitution of humans and technology in practice. The individuals interact with technologies through their working practices. For instance, designers collaborate with users to 'inscribe' their interests and perspectives to shape the design and meaning of technology. The technical content will also influence the designers and users' vision of the world.	**Sociotechnical routines** The ongoing technology-in-practice has become regularized and routinized (Latour, 2010; Leonardi and Barley, 2008, 2010; Pollock and Williams, 2008; Sandberg and Tsoukas, 2009; Gaskin et al., 2011b; Leonardi, 2011, 2013; Gaskin et al., 2014; Pentland, 2003, 2008; Feldman and Pentland, 2003; Mazmanian et al., 2014).	The individuals interact with technologies through their working practices. Scholars unpack the latent routines across iterative digitalization.

The second school of research (see Table 2) departs from the context of various groups coordinating their tasks for achieving digitalization. This research shares a common belief that the interrelation of task coordination and technical architecture is the key to driving digital innovation. The first stream of this school argued that task coordination and technical architecture are essentially mirroring each other. This thinking is based on the theoretical foundation of the notion of 'dominant design' (Anderson & Tushman, 1990; Tushman & Anderson, 1986), which typically involves imposing tight linkages between established inter-organizational coordination processes and the standard expression of the product's design. The scholars proposed the mirroring hypothesis to explain the isomorphism links between the standard design and routinized coordination for achieving digitalization. They conceptualized the sociotechnical process as sociotechnical morphism, sociotechnical mirroring, fundamental isomorphism, and sociotechnical congruence. For these scholars, the technical architecture with loosely coupling components through standardized interfaces carries isomorphic implications for the task coordination that produces them. For instance, digitalization stimulates the trends toward product modularization, which enables the corresponding isomorphism modularized inter-organizational division of labour. As the school of research evolved, another stream of thinking emerged which challenged this mirroring hypothesis. Researchers proposed instead, for example, that flexible architecture designs rather than dominant designs are based on networks but not on hierarchy (Svahn & Henfridsson, 2012). They began to examine innovation as the dynamic mutual influence of technical architectures and innovative organizational arrangements and classified this dynamic sociotechnical mutual configuration as sociotechnical restructure, sociotechnical reconfiguration, sociotechnical synthesis, sociotechnical co-promotion, etc. Scholars claimed that digitization involves fundamentally reconfiguring both technical processes and organizational structures (Ashurst et al., 2008; Selander et al., 2010; Kane et al., 2015; Piccinini et al., 2015) to establish social and technical heterogeneity (Fichman et al., 2014; Nambisan, 2013; Henfridsson & Yoo, 2014; Lyytinen et al., 2015). These scholars have focused on how technologies and organizational structures reconfigure each other. They have highlighted that the social and the technical are configuring and reconfiguring in relation to each other in an ongoing manner to achieve innovation.

Table 2 Research school 2: Sociotechnical interaction on the group level						
Aim	**Theoretical foundation**	**Terms**	**Research stream 1**	**Typical example**	**Research stream 2**	**Typical example**
Understanding digital coordination not as fixed, determining, or a mediating platform through which people interact and complete tasks to achieve digitalisation, but rather as dynamic sociotechnical configuration.	The theoretical foundation is the 'dominant designs' theory (e.g. Anderson and Tushman, 1990; Tushman and Anderson, 1986).	Digital coordination; sociotechnical morphism; sociotechnical mirroring; fundamental isomorphism; sociotechnical congruence; sociotechnical restructure; sociotechnical reconfiguration; sociotechnical synthesis; sociotechnical co-promotion.	Many scholars proposed the mirroring hypothesis to explain the isomorphism links between the product design and tasks for achieving digitalisation (Baldwin, 2008; Brusoni, 2005; Alter, 2002, 2013; Hylving et al., 2012; Colfer and Baldwin, 2016; Cataldo et al., 2008; Baldwin and Clark, 2000).	Digitalization stimulates the trends toward product modularization, which enables the corresponding isomorphism modularized inter-organizational division of labour (e.g. Conway, 1968).	The progression of digital innovation is based on an interactive configuration between the social and technical architecture (Mumford, 2006; Lee and Berente, 2012; Boudreau, 2012; Hylving, 2015; Grisot et al., 2014; Eaton, 2013; Kallinikos et al., 2013; Dougherty and Dunne, 2012; Nambisan, 2013; Tiwana et al., 2010; Adler et al., 2011; Venters et al., 2014; Sahaym et al., 2007; Alter, 2013; Imran and Kantola, 2018; Faraj and Xiao, 2006; Faraj et al., 2011).	The dynamic sociotechnical mutual configuration creates innovation. Digital innovation emerges through webs of social and technical interactions. The scholars have started to examine digital innovation as an intersection of dynamic technical architectures and innovative organizational arrangements. The social and the technical acquire form and attributes through this sociotechnical interrelation.

The third research school (see Table 3) deviates from the context that different organizations build social networks to achieve digitalization. Its theoretical foundation is the sociotechnical system theory. When digital technology is embedded it enacts in a sociotechnical context, and complex sociotechnical systems will be composed (Piccinini et al., 2015; Hylving & Schultze, 2013). The system consists of a technical process (technical architecting) and a social process (social networking), and these technical and social processes coevolve in an ongoing manner (Trist & Bamforth, 1951) to achieve innovation. As this school of research developed, an intensive debate between two research streams was sparked. The first stream asserted that digitalization transfers a traditional product into a 'living sociotechnical system' (Yoo, 2010; Parker & Van Alstyne, 2018; Henfridsson & Bygstad, 2013; Henfridsson et al., 2009). The social and technical processes need to coevolve in parallel to achieve innovation. These scholars shared a hypothesis that the co-promotion of social and technical processes drives the innovation process. The social and technical processes jointly determine the evolutionary trajectories of the sociotechnical system to facilitate its innovation. Researchers classified this sociotechnical interrelation as sociotechnical co-promotion, sociotechnical assemblage, and sociotechnical coevolving. The second research stream, meanwhile, began to explore how the social and the technical processes adapt with each other to create innovation opportunities. This branch of thinking has primarily focused on exploring how the social and technical are dependent on, influence, and dynamically adapt to each other. Scholars have emphasised that the adaptation between the social and technical processes that accompany digitalization is the key driving force for creating the potential for innovation. They have provided a language to analytically explore the emergent and adaptive nature of this relationship, conceptualizing sociotechnical interrelation as sociotechnical adaptation, sociomaterial affordance, sociotechnical episodic change, and sociotechnical responsive relationship. This research stream is primarily concerned with how the social and the technical processes acquire form and attributes through the process of sociotechnical interrelation.

Table 3 Research school 3: Sociotechnical interaction on the social network level

Aim	**Theoretical foundation**	**Terms**	**Research stream 1**	**Typical example**	**Research stream 2**	**Typical example**
Understanding the digital service process as a sociotechnical system.	The sociotechnical system is defined as a cooperative technology environment in which symbiotic relationships are formed to create mutual value for its members. It consists of two processes: a technical process (technical architecture) and a social process (social network). Technical and social processes coevolve in an ongoing manner (Rice, 1953; Trist & Bamforth, 1951; Trist, 1981; Bostrom & Heinen, 1977).	Sociotechnical adaptation; sociotechnical co-promotion; sociotechnical assemblage; sociomaterial affordance; sociotechnical coevolving.	Sociotechnical co-promotion; digitalizing the traditional products into a sociotechnical system is the key to facilitate innovation. The social and technical processes jointly determine the evolutionary trajectories of the system to facilitate its innovation (Eaton et al., 2015; Hanseth and Lyytinen, 2010; Tilson et al., 2010; Grisot et al., 2014; Gaskin et al., 2010; Schatzki, 2005; Aral and Weill, 2007; Lusch & Nambisan, 2015; Scherer et al., 2015; Orlikowski and Scott, 2015; Srivastava & Shainesh, 2015; Barrett et al., 2015; Fichman et al., 2014; Nambisan, 2013; Henfridsson and Yoo, 2014; Lyytinen et al., 2016).	The co-promotion of technical architecture and the social network drives the innovation process of the sociotechnical system.	The interrelation between the social and technical processes that accompanies digitalization can create innovation opportunities (Tiwana et al., 2010; Henfridsson and Bygstad, 2013; Eaton, 2012; Grisot et al., 2014; Eaton et al., 2015; Sambamurthy et al., 2003; Tilson et al., 2010).	Digitalization stimulates the radical technical architecture redesign, which will encourage a reorganizing of the social network. Meanwhile, digitalization also stimulates the radical reorganizing of the social network, which will leverage the redesign of the technical architecture.

2.4. Summary of the literature

Broadly speaking, the research concerning digitization and socially embedded digitization reflect an ontological consensus that the social and the technical are largely independent but linked through unidirectional causal relationships. The research concerning digitalization is characterized by its general commitment to ensemble or web ontology, whereby the social and the technical are seen to be related through a reciprocal and emergent process of mutual influence.

Following the thinking of the sociotechnical research on digitalization, Paper 1 calls attention to the ways in which current digitalization research has difficulty articulating the dynamic negotiations between digital technology and its sociotechnical context. It conceptualizes digitalization as an iteratively developed process.

Many scholars have shifted their focus on innovation against the ever-changing contextual background of digitalization. The scholarship of digitalization asserts that sociotechnical interrelation is the key driving force of innovation (Tiwana et al., 2010; Henfridsson & Bygstad, 2013; Eaton, 2012; Grisot et al., 2014). Scholars such as Baldwin and Clark (2000), Cataldo et al. (2008) and Colfer and Baldwin (2016) have highlighted how design structures and organizing process are configured and adapted with each other. As we have seen, three research schools have emerged which analyze sociotechnical interrelation by focusing on different contextual levels of digitalization (individual, group, and organisational networks) to explore the process of innovation. While the research of the first school is historically coherent, comprehensive debates have been sparked by both the second and third research school.

Paper 2 promotes the debate of the second research school about the interrelation between task coordinating and technical architecting. It claims that these social and technical processes are not merely mutually configurative: most of the time, they are dissonant and challenge each other. Thus, this paper conceptualizes sociotechnical tensions as sociotechnical dissonances and focuses mainly on how sociotechnical dissonances drive micro-level digital innovation.

Paper 3 contributes to the discourse of the third research school on the interrelation between social networking and technical architecting. It states that these social and technical processes are not coevolving in parallel, rather, they most often intertwine with each other. This paper, therefore, considers sociotechnical tensions as sociotechnical intertwining. Thus, Paper 3 will mainly explore the extent to which sociotechnical intertwining drives macro-level digital innovation.

Chapter 3

Theoretical foundations

After reviewing the previous literature concerning digital innovation, this section will now present my own theoretical consideration for analyzing digital innovation. Firstly, I found that a resource-interaction perspective within the industrial marketing and purchasing (IMP) approach is critical for explaining digitalization. I will begin, therefore, by discussing how this perspective shed light on my understanding of iterative digitalization. Secondly, the systems integration perspective (Prencipe et al., 2003) is becoming increasingly relevant because it can help to demonstrate how innovation evolves in iterative digitalization (Lee & Berente, 2012). Thus, this section will also discuss the systems integration perspective and its relation to my understanding of digital innovation.

3.1. Digitalization as iterative processes

When trying to understand a phenomenon, the context should always be taken into account (Rousseau & Fried 2001). Digitalization is defined as the interaction of digital technology with its sociotechnical resource context. Iterative digitalization involves repeatedly embedding the digital technology within its changing sociotechnical resource context. We must, therefore, first focus on the evolving nature of the resource-interaction process (Ford & Mouzas, 2013) and explore the evolutionary resource interaction of digital technology with its embedded resource context.

Based on the resource-interaction perspective within the IMP approach, digital technology needs to interact with its contextual resources (Håkansson & Waluszewski, 2002; Ingemansson & Waluszewski, 2009) to be embedded. The dynamic characteristics of each type of resource interaction enable this embedding of digital technology to become dynamic, thereby facilitating iterative digitalisation.

This thesis uses the practice-oriented approach to capture the process of resource interaction. The resource-interaction practices (Tian, 2019) that perform on resource interfaces surrounding a digital technology are as follows:

- On the resource interface between the focal technology and organizational relationship, networking practices establish business relationships to knit resources across organizations over time.

- On the resource interface between the focal technology and its surrounding physical resources (the traditional products and technical facilities), engineering practices explore ways to configure the focal technology with its surrounding physical resources in various technical architectures.

- On the resource interface between the focal technology and organizational units, organizational units engage in task-coordination practices, which include collecting knowledge about the counterparts and understanding how to work with each other.

3.2. Sociotechnical tensions and innovation

In a digitalization process, the technical procedure concerns architecting digital technology with the traditional product (Anderson & Tushman, 1990; Baldwin, 2008; Lee & Berente, 2012) with the help of different facilities to make the product digitalized and thus 'smarter'. The social process comprizes two levels: the micro level, which involves engaging people across organizations to coordinate their tasks (Lee & Berente, 2012; Grisot et al., 2014; Eaton, 2013) and the macro level, which entails building social networks

among different organizations to achieve digitalization. The tensions that emerge are due to misalignments among the processes of technical architecture, task coordination and the social network (Lyytinen & Newman 2008). Each iteration of digitalization triggers technical or social changes, thus leading to sociotechnical tensions. Technical change involves the decomposition-integration of technical architecture (Eppinger, 1997; Browning, 2001; Amrit & Van Hillegersberg, 2008). Social changes include the task coordination's decomposition-integration or the social network's diversification-convergence. That is, each iteration of digitalization prompts new sociotechnical tensions between the digital architecture and the social organization producing them (Awodey, 2006). This thesis explores innovation by explicitly examining the sociotechnical tensions inherent in iterative digitalization. Moreover, it applies a relational view of sociotechnical practices (Barrett et al., 2012; Oborn et al., 2011) to capture and demonstrate the sociotechnical tensions.

3.2.1. The sociotechnical tensions and innovation of the micro-system

The micro-system executes, coordinates, and manages digitalization-related work (Alter, 2002; Mumford, 2003; Lyytinen & Newman, 2008). The sociotechnical tensions of technical architecture and task coordination drive the evolution and innovation of the micro-system. Furthermore, iterative digitalization triggers the unsynchronized decomposition or integration of the technical architecture and task coordination. These sociotechnical dissonances continuously challenge the established sociotechnical isomorphism of the micro-system, thereby driving its redesign; they also evolve the system and facilitate its innovation. Iterative digitalization stimulates the sociotechnical dissonances to drive the innovation of the micro-system.

By applying a practice-oriented approach, a technical process can be observed by investigating the engineering practices of decomposing or integrating the digitalized architecture. The social process can be considered by investigating the task-coordinating practices of decomposing or integrating the working partnership. Thus, *sociotechnical dissonances can be captured by observing the interlinked engineering practices and task-coordinating practices.*

Firstly, the engineering practices concern decomposing an integrative technical architecture into layers, modules, and module options. Task-coordination practices involve decomposing the integrative joint team to form a layer-oriented team, module-oriented teams, and module option-responsible individuals. It is nonetheless difficult for task coordination and technical architecture to achieve synchronized decomposition, which leads to sociotechnical dissonances. For instance, engineering practices decompose the integrative technical architecture into layered patterns. However, the task-coordination practices maintain the communication mechanism of the joint team but not transfer into a layer-oriented team.

Secondly, the engineering practices challenge the ongoing refined decomposition through end-to-end interaction or integration with the layers, modules, or module options. In such a situation, task-coordination practices often concern developing integrative communication patterns through end-to-end interaction or integration with the layer-oriented teams, module-oriented teams, and individuals. However, it is challenging for task coordination and technical architecture to achieve synchronized integration, leading to sociotechnical dissonances. For instance, the technical architecture transfers from an end-to-end interactive to an integrative pattern, while the task-coordination process is still in an end-to-end interactive pattern.

3.2.2. The sociotechnical tensions and innovation of the macro-system

The macro-system is an evolving network of organizational actors using an evolutionary technical architecture to achieve digitalization. The sociotechnical tensions of the technical architecture and the social network drive the evolution and innovation of the macro-system. Iterative digitalization stimulates the diversification and convergence of the value domains to spur the social network's development (Majchrzak et al., 2016; Lusch & Mambisam, 2015). Moreover, it decomposes or integrates technical interdependences to evolve the technical architecture (Kenney & Zysman, 2016). The intertwining of the technical architecture's decomposition/integration and the social network's diversification/convergence (Tilson et al., 2010) create innovation opportunities for the macro-system.

I have scrutinized the interlinked engineering practices and networking practices to capture the social-technical intertwining. Here, engineering practices are concerned with how to explore ways of decomposition and integration of technical interdependence (Baldwin & Clark, 2002). Decomposition entails dividing the technical architecture into layers, modules, and module options, which makes it possible to mix and match different components in various ways (Baldwin & Clark, 2002; Browning, 2001). Integration, meanwhile, can be defined as combining different components to allow for engagement in architecture-level improvement (Baldwin & Woodard, 2009).

Networking practices consider how to systematically establish a network through the diversification and convergence of different value domains. The network diversification is primarily about decomposing the social network into value domains and subdomains, thereby involving a variety of organizations (Lewicki & Brinsfield, 2009). Network convergence involves converging value domains by integrating value domains and subdomains through developing collective communication mechanisms (Kallinikos et al., 2013; Tilson et al., 2013; Lusch & Mambisam, 2015).

3.3. Innovation through digitalization

In summary, the concepts of iterative digitalization and sociotechnical tensions have been studied to analyze innovation through digitalization. The notion of iterative digitalization is used to address the first research question, 'How can we conceptualize iterative digitalization as practices?' I then started to focus on the idea that innovation evolves within iterative digitalization: indeed, that iterative digitalization stimulates sociotechnical tensions that drive innovation over time (Lyytinen & Newman, 2008). Thus, the concept of sociotechnical tensions addresses the second research question, 'How do sociotechnical tensions drive digital innovation over time?'

The analytical framework of this thesis is illustrated in Figure 1. This thesis investigates resource-interaction practices to better understand digitalization processes. Iterative digitalization can be achieved by the practices of engineering, task coordinating and networking, and innovation through iterative digitalization occurs at both micro and macro levels. Furthermore, iterative digitalization stimulates the interlinked engineering practices and

task-coordinating practices and leads to the tension of sociotechnical dissonances. These sociotechnical dissonances are the key driving force for innovation of micro-systems. Iterative digitalization also triggers the interlinked engineering practices and networking practices which leads to the tension of sociotechnical intertwining. The tension of sociotechnical intertwining is the driver for innovation of macro-systems. Thus, these sociotechnical tensions drive the micro-system and macro-system to revolutionize profoundly.

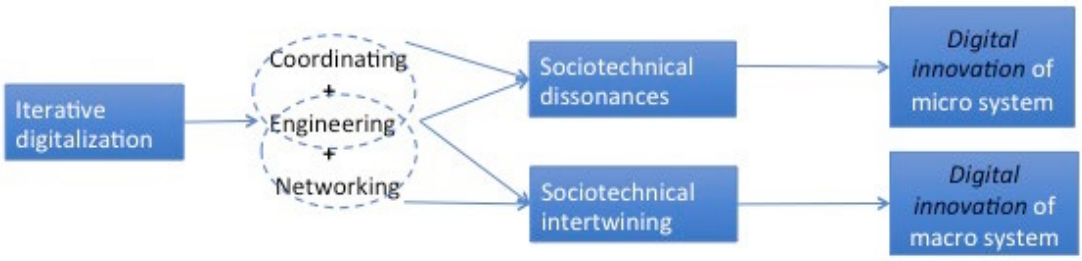

Figure 1. Sociotechnical tensions and digital innovation

Chapter 4

Empirical foundation

This chapter will provide the industrial background of the dissertation and explain the empirical materials of the two case studies.

4.1. The dilemma of 'dumb pipe' versus 'smart pipe'

DIGITAL is a Chinese subsidiary of a multinational provider of mobile network equipment and services. In the 1990s, the firm began to help Chinese operators to build the escalating mobile networks. The company was strong in mobile communications, boasting the largest mobile network and mobile subscriber base in 31 provinces in China. At that time, the mobile network functioned as a 'dumb pipe'[2] to primarily provide simple bandwidth and network speeds to transfer bytes between the subscriber's device and the Internet without considering the user experience.

Since 2010, the ICT industry has contended with the transformation dilemma of the 'dumb pipe' versus the 'smart pipe' [3]. Leveraging the mobile network's unique service abilities beyond simple connectivity became highly

[2] A dumb pipe means the mobile network that primarily provides simple bandwidth and network speeds to transfer bytes between the subscriber's device and the Internet without resonating the user experience.

[3] A smart pipe means the mobile network that can leverage its unique service capabilities beyond simple connectivity to resonate with the users.

significant. During my first fieldwork in 2013, DIGITAL was at the critical moment of transforming the mobile network to become a 'smart pipe'. DIGITAL's online articles and regular journals have demonstrated the firm's ambitions to help their customers to transfer from 'dumb pipe' to 'smart pipe'. Because of their background in helping Chinese operators to build the mobile networks, DIGITAL was able to develop insightful information systems to embed into the mobile network and make it 'smarter'. Striving to digitalize the mobile network, they developed information systems with innovative applications and customer views. The operators were particularly excited because the digitalization of the mobile network enables efficiency resonant with their subscribers' use experiences.

4.2. The two cases

This dissertation is based on two empirical cases concerning embedding information systems to allow mobile network equipment to become digitalized and smarter. In the 2010s, DIGITAL endeavoured to explore 'add-on' opportunities building on its existing mobile network equipment. A pre-sale explained the opportunity of 'add-on' sales metaphorically: 'Someone who paid for a hotel room will later need minibar items, dry cleaning, etc. TEL, who purchased the network equipment, may well buy supplementary information systems to make its business become smarter'. The two cases examined by this dissertation will explain how DIGITAL has embedded information systems to digitalize the mobile network and improve the innovation capabilities. Both information systems involve extracting the data assets from the mobile networks to gain the insights required to assist the operators in managing the relationship with their subscribers.

4.2.1. Case 1

TEL is a provincial branch of a nationwide mobile network operator in China. DIGITAL and TEL had built a close supplier-customer relationship for years. In 2010, DIGITAL developed a smart area management (SAM) system to profile subscribers' movement patterns in a specific area, thereby providing smart area management services (e.g. emergency services, disaster warnings, traffic congestion monitoring, and large venue management, etc.).

TEL intended to install the SAM system on the mobile network to develop a platform to support the smart-city-building of the province in which it is located. That is, TEL was the platform holder, and the city branches were the platform users. The SAM system's embedding involved the following three episodes: 1) the pilot episode: the SAM system was installed on TEL's mobile network and established a data management platform to support City Branch A's businesses; 2) the flourishing episode: DIGITAL encouraged the wide use of the SAM platform to support the businesses of eight city branches; 3) the upgrading episode: DIGITAL, TEL, and the city branches engaged in the SAM platform's upgrade.

4.2.2. Case 2

NET is a nationwide mobile network operator in China. In 2010, DIGITAL developed an information system of emotional intelligence (EQ) which could monitor the health status of a mobile network and report extreme abnormal events; this could thus be a foundation for mobile subscriber care. Therefore, EQ's embedding into the mobile network could digitalise its subscriber-care services. As NET resides in 31 provinces in China, DIGITAL intended to install its EQ on the mobile network of each provincial branch of NET to develop EQ-based platforms. These platforms were also associated with the subscriber-care businesses of the city branches in each province. Specifically, provincial branches were the platform holders/customers, and the city branches were the platform users. One senior marketing manager explained their strategy: 'We set the ball rolling from one provincial branch, then encouraged other branches to learn from it, thereby keeping the ball rolling to more and more branches.' Case 2 describes how DIGITAL facilitated the mobile network's digitalization to support service deliveries for an increasing base, which expanded from one to nine provincial branches. This project experienced five iterations of digitalisation: DIGITAL allowed for the EQ digitalization of the mobile network for the first branch, then three independent branches, then five independent branches; it moved into nine independent branches, and finally synthesised the digitalization of all nine branches.

Chapter 5

Research methods

5.1. Research approach

The inquiry objective of this study was to obtain an enhanced understanding of the sociotechnical tensions of digitalization processes and reveal how these tensions drive digital innovation. Seaman (1999) stated that the blend of social and technical aspects within complex innovation lends itself to qualitative studies: therefore, capturing the sociotechnical tensions of digitalization processes demanded a qualitative research method. To better understand digital innovation processes, this thesis used real-time and practice-based data as sources of evidence (Ford & Håkansson, 2006) to conduct in-depth case studies, designed to allow for further developments of different sociotechnical practices over time. The present study was based on two longitudinal and qualitative case studies (Yin, 1994), which were conducted in real-time and as follow-up studies (Halinen & Törnroos, 2005).

5.2. Defining the locating field sites

In June 2013, I began my fieldwork in the marketing section of DIGITAL. In the first week, I went through DIGITAL's online articles as well as monthly journals about or authored by the company. What caught my attention were the texts that encouraged embedding the mobile network with smart capabilities. In these articles, the authors described their ambitions of

transferring the mobile network into a 'smart pipe' and digitalize service processes. My tutor, a senior marketing manager at DIGITAL, was responsible for the demo show at the PT Expo, China in 2013, an annual exhibition to showcase new technologies in the ICT industry. During this demo show, DIGITAL focused on presenting its digitalization capability of transforming the mobile network to become smarter by embedding different information systems. I gained limited access to participate in the preparation activities of the demo show but found the transformative power of information systems extremely attractive. Based on the obtained knowledge from the demo show preparation activities, I gave an oral presentation on my understanding of digital transformation at the weekly meeting of the marketing section. They consequently suggested that I participate in a seminar concerning the real-time overview of emergent digitalization projects. Various case projects were introduced during the seminar; I selected the case projects for my thesis by following the guidelines from three dimensions:

1) The case projects can be followed longitudinally;
2) Cases involve moving from the information system design to achieving digitalization of the customers' businesses;
3) Cases clearly demonstrate DIGITAL's endeavours to facilitate the digitalization.

The SAM project sparked my strong interest in further research. At the recommendation of my tutor, I was fortunate enough to gain access and initiate further discussion with project members. I collected most of the data between June and September 2013. Based on deep reflection of my initial fieldwork, I realized the importance of putting equal emphasis on social and technical aspects. Thus, my second field trip (December 2015 – March 2016) was initiated in both the marketing section and product unit simultaneously to deepen my understanding of both the social and technical aspects. I explained my research interests to the head of digitalization projects and attached the reflection report of the first case, the SAM system. We later spoke via Skype, and I expressed my intention to continue to follow their stories; I was even eager to hear news of the success of the company's other digitalization projects. I was then invited to visit DIGITAL again. When I returned

to the company, I discovered that various new digitalization projects had emerged and developed very well. After my presentation about the case reflection of the SAM project, the head of digitization remarked that I might be interested in the sales conference of the year to learn about the overview of the digitalization projects' development. We booked meetings with key project managers and as a result, I selected the EQ project as my sample case because it provides a rich illustration of the landscape wherein innovation processes are increasingly questioned in five iterations of digitalization.

In both of the two case projects, the professionals involved with geographical distance developed the information system-based solutions for customers residing in different provinces. This lends an overarching cohesion to 'multi-sited' ethnographies. Nevertheless, I did not use a multi-sited approach; instead, I strategically defined a field site where several networks converged, and where people and objects came to me rather than the other way around (Burrell, 2009). In this way, I could stay in place to 'intercept' circulations of data, people, and goods, rather than follow them. A key organizational component of the digitalization process is the development team of the information system. I defined the key organizational component of the digitalization process, namely, the development team of DIGITAL, as the field site, where several networks converged (Burrell, 2009).

5.3. Data collection

To enable the data collection to be flexible enough to move across different methods and analysis, I used multiple methods to de-marginalize the voices of respondents: thus, different types of data provided cross-data checks to effectively enhance the data's validity (Patton, 2002). Qualitative data is typically collected progressively via intermix observation, interviews, and document analysis and online materials. The data collection process included data collection from DIGITAL and its customer organizations.

5.3.1. Data collection from DIGITAL

Figure 2 presents the timeline of data collection from DIGITAL. The data collection for each case involved on-site data collection and remote follow-ups.

Date	Company milestones	My field work	The field site
Jun – Sept 2013	• Preparing for PT expo • Information systems seminar	• Selecting SAM as the pilot case • Shadowing the pilot case	Marketing section
2013 – 2015	• SAM developed dramatically • A series of digitalization projects emerged	• Follow-up study of SAM	Marketing section
Dec 2015 – Feb 2016	• Sales meeting • Digitalization projects were well developed	• Further investigation of SAM • Selecting EQ as the second case • Shadowing EQ project	• Marketing section • Product unit
2016 – 2017	• EQ developed dramatically	• Follow-up study	• Marketing section • Product unit

Figure 2. The timeline of data collection

1) On-site data collection

During the on-site data collection for the two cases, I mainly used the internal and external communication of the development teams as the main research unit. This helped me to 'intercept' the circulation of information, actors, practices, and events to identify and trace the inherently fragmented practices (Burrell, 2009). I used semi-structured interviews to capture the core experiences and central dimensions of the teams' digitalization endeavours, participated in conferences of the project teams, or was physically present in public places (Green, 1999), such as the project teams' discussion forums or workshops, to gain a better observation of their endeavours of digitalization.

Shadowing and observing

A participating approach makes the collaboration between the researcher and the participant much closer and enables the researcher to approach the empirical setting and better understand the participants' actions (Crabtree & Miller, 1999). In addition to tracking the communication activities, I sat in the working area of the development team daily to experience their working passions, struggles, frustrations, and happiness. I made notes about their

practices and my ponderings and inquiries. Random talks with the team members was always a helpful channel to resolve my queries. Observing meetings served also as an important strategy for fieldwork (Sandler & Thedvall, 2017). I attended team meetings, discussion forums or workshops related to these two projects, and as soon as possible after the activities, I wrote up reflections based on my notes. This shadowing was particularly useful because it provided a way of answering research questions where the unit of analysis is not the individual, but the social relation (Gherardi, 2012) and their joint actions (La Rocca et al., 2017).

Semi-structured interviews

The semi-structured interview (Huberman & Miles, 2002) was an important means of examining the engineering practices, task-coordination practices, and networking practices. My tutors helped me to select the 'key people' of the digitalization process. These team members, who were involved in tailoring the concurrent information system and have participated in the creation of multiple versions for each information system, provided me with interview opportunities. They were program managers, project managers, key account managers, solution architects, R&D leaders and more. I conducted a total of 48 interviews. Each interview lasted between 30 and 90 minutes, and most were tape-recorded or noted. The interviews with these key people helped me to efficiently capture the core experiences and central dimensions of their digitalization endeavours.

2) Remote follow-up

Archival printed sources, such as numerous internal reports of the project status and brochures, were mainly employed for remote follow-up processes. As social interactions increasingly move online, new media-driven research provides ethnographers with opportunities to 'invisibly' observe social interactions, which allows for a previously unavailable type of ethnographic data (Murthy, 2008). I also participated in phone or videoconferences with the project teams to understand their ongoing practices. Simultaneously, telephone interviews with DIGITAL were conducted to clarify doubts and discuss those details of particular interest in the ongoing practices.

5.3.2. Data collection endeavours from the customer organisations

I believe that the sociotechnical practices that stretch across organisational borders and decisions are always part of collective processes, so I endeavoured to participate in customer-supplier co-events (e.g. video conferences, discussion forums, workshops or trial shows). Furthermore, I conducted fifteen interviews to understand the general procedures regarding the customers' implementation of similar kinds of projects. Despite my opportunity to conduct nine short talks with professionals from the projects focused on in this thesis, SAM and EQ, I was, due to access restrictions, unable to adequately understand the customers' corresponding practices systematically. This restriction, as well as the rich data provided by the supplier side, directed my analysis to focus on the supplier perspective. I mainly analyzed how the supplier engaged in various social and technical practices to manage the interaction of digital technology and the sociotechnical context of the digitalisation processes. Nonetheless, the data collected from the customer side are still significant to capture the status quo of the sociotechnical context.

5.4. Analysis

5.4.1. Systematic combining

The theoretical analysis and empirical data collection were interacted as well as "systematic combining" (Dubois & Gadde, 2014; Baraldi et al., 2011) during the research process.

The first paper aims to unravel the resource-interaction process of digital technology's dynamic embedding based on the SAM case project. I embarked on the first cycle of on-site fieldwork and remote follow-up between June 2013 and November 2015 at DIGITAL by means of the 4R model. I searched for the main issue concerning the actors' endeavours to allow digital technology to interact with its surrounding four types of resources to facilitate technology embedding. During this process, the networking practices that tie organizations, the engineering practices connecting the focal technology with other products and technical facilities, and the task-coordinating practices bonding the working process of organizational units were the focus

of the analysis (Håkansson & Snehota, 1995; Håkansson & Waluszewski, 2002). The preliminary findings demonstrated that the digital technology's embedding and re-embedding is a dynamic process. To collect further material concerning the resource-interaction practices that facilitated the digital technology's dynamic embedding, I orientated my data collection from December 2015 to January 2016 employing the notion of the three embedding settings, namely, 'developing', 'producing' and 'using' (Håkansson & Waluszewski, 2007; Ingemansson & Waluszewski, 2009). I then began to examine the dynamics of the resource-interaction practices (flexible engineering, systematic networking, and scalable coordinating) in the three settings, respectively.

The second case study was conducted over three years (2015 – 2017). Both Paper 2 and Paper 3 are based on the data of the EQ case project. I embarked on the process of systematic data collection between December 2015 and February 2016 as an academic researcher of the product management unit of DIGITAL. By means of systems integration theory, I examined the interlinked practices of engineering and coordinating was examined to capture the micro-level sociotechnical tensions. And then the interlinked practices of engineering and networking was investigated to explore the macro-level sociotechnical tensions. The preliminary results from this phase redirected my remote data collection from November 2016 – December 2017 to the collection of further material about the interrelation of sociotechnical tensions and digital innovation.

5.4.2. Bracketing strategy

The strategy for theorizing by using the process data can be described as a temporal bracketing strategy: that is, a type of temporal decomposition that is intended to structure the process analysis (Langley, 1999). This strategy '… move[s] from a shapeless data spaghetti toward some theoretical understanding that does not betray the richness, dynamism, and complexity of the data but that is understandable and potentially useful to others' (Langley, 1999, p. 694). Such a strategy enables the construction of comparative analysis units (here, I refer to the units as episodes) for investigating (Hylving et al., 2012). In the first case study, the author mainly explored the dynamic embedding of digital technology from the pilot episode through to the flourishing

episode and upgrading episode. Each embedding setting required the supplier to interact the digital technology systematically with the ever-changing social-technical context through a series of interactive episodes. The bracketing of the three episodes helped me to capture the dynamics of the resource interaction of the digital technology and existing resource structure. The second case study periodically revisited different innovation processes as the program unfolds. This led to a theoretical understanding of the interrelatedness between sociotechnical tensions and the innovation processes (Henfridsson et al., 2009). By identifying the interrelation of social and technical tensions and innovation in the pilot project, the multi-project, and the program, then, the second paper will analyze how different dissonances drive the ongoing process of digital innovation. Moreover, by identifying the interrelation of social-technical intertwining and digital innovation in the pilot project, the multi-project, and the program, the third paper examines how different intertwining can drive the service innovation over time.

Chapter 6

Summary of the papers

This chapter introduces the three research papers of this thesis. While the three papers provide different contributions to particular areas, they all strive to explore innovation through digitalization processes.

6.1. Paper 1

Title: Turning a technology into many solutions: A case study of embedding an information system
Published in *Journal of Business Research*
DOI: https://doi.org/10.1016/j.jbusres.2019.03.053
Author: Min Tian

A technology's dynamic embedding in the ever-changing context of businesses will undertake a complex journey when it needs to iteratively address the changing sociotechnical resource structure. This paper begins by understanding inter-organizational technical development within the industrial marketing and purchasing (IMP) approach. Research in inter-organizational technical development using the IMP approach has underlined that technology is inherently dynamic and can be embedded in businesses by interacting with contextual resources over time (Håkansson & Snehota, 1995; Håkansson & Waluszewski, 2002; Harrison & Waluszewski, 2008).

Many IMP scholars have focused on how to embed technology within the existing resource structure (Baraldi et al., 2011; Ingemansson, 2010;

Ingemansson & Waluszewski, 2009; Waluszewski, 2009), but the constantly changing existing resource context also strongly influences technology embedding. This paper emphasizes that these processes reflect two sides of the same coin. It is significant to explore the dynamic interrelation between technology embedding and its sociotechnical resource structure in iterative digitalization. The purpose of this paper is to investigate the dynamic interrelation between technology embedding and its social-technical resource context. It has developed a practice-oriented understanding of resource interaction to study it in the making, and thus to investigate resource interaction in real life (La Rocca et al., 2017). This can be an effective tool in scrutinizing the interrelation between the dynamic embedding and its ever-changing existing resource structure. This paper investigates digital technology's dynamic embedding by underlining the importance of its interaction with its sociotechnical resource context. It proposes a practice-oriented understanding of digital technology's dynamic embedding as systematic networking, scalable coordination, and flexible engineering.

6.2. Paper 2

Title: Creating sociotechnical dissonances to drive digital innovation: A case study of iterative digitalization processes
Submitted to *Information System Journal*
Author: Min Tian

Digitalization has been considered the creation of a sociotechnical system for achieving innovation. This study uses a sociotechnical approach to analyze how to innovate through the design and redesign of the sociotechnical system. As illustrated in the literature review, many IS scholars have emphasized the importance of isomorphic mirroring between the social coordination and technical architecture of the system for achieving innovation. The present study has empirically demonstrated that 'sociotechnical isomorphic mirroring' is merely a temporary phenomenon that can easily transform into bottlenecks, restricting further innovation. It challenges the thinking of isomorphism and claims that digital innovation emerges by continuously breaking up the established isomorphism between task coordination and technical

architectures. Thus, sociotechnical dissonance is the real driving force for digital innovation. By applying a dynamic integration theory to trace the interrelations of social coordination and technical architecture within iterative digitalization processes of a case study, I found that the focal firm used a decomposition-integration principle (Eppinger, 1997; Browning, 2001; Yoo et al., 2010) to create dissonances, thereby continuously breaking up the isomorphic mirrors of the system and facilitating its redesign. The results herein contribute to the sociotechnical research on digital innovation by developing two propositions on the connections between sociotechnical dissonances and digital innovation. Firstly, the more that the distributive redesign of the system is driven by sociotechnical dissonances, the more refined the component-level innovation that can be achieved. Secondly, the more that the aggregative redesign of the system is driven by sociotechnical dissonances, the more escalated the system-level innovation that can be achieved. This study represents an early step in the search for the sociotechnical processes of digital innovation by focusing on how sociotechnical dissonances drive digital innovation over time.

6.3. Paper 3

Title: Sociotechnical intertwining for driving service innovation: A case study of iterative digitalization processes
Submitted to *Information and Organization*
Author: Min Tian

In the digital age, what service means – and thus, how service innovation may develop – has become a primary concern for scholars of the service-dominant (SD) logic and IS fields. The literature has recognized that service has profoundly revolutionised through digitalisation. Some cross-field researchers have begun to encourage drawing from SD logic's social network view while using the IS field's technical architecture model as a foundation to pursue a sociotechnical approach (Henfridsson & Bygstad, 2013; Grisot et al., 2014; Luschand & Nambisan, 2015; Orlikowski & Scott, 2015; Eaton et al., 2015; Srivastava & Shainesh, 2015; Barrett et al., 2015). They have claimed that service innovation can be achieved through gradually digitalizing

a traditional product into a sociotechnical system and that the relation between the social network and the technical architecture that accompany digitalization is the driving force for evolving the system and facilitating service innovation. Furthermore, some scholars have argued that service innovation can be achieved through redesigning the technical architecture to leverage a radical reorganizing of the social network in the digitalization process (Tiwana et al., 2010; Henfridsson & Bygstad, 2013; Eaton, 2012), while others have suggested that service innovation can be achieved by reorganizing the social network to leverage a radical redesigning of the technical architecture of the digitalization (Grisot et al., 2014; Tilson et al., 2011). Paper 3 emphasizes that both processes are significant for achieving innovation and these two processes intertwine to drive innovation.

By investigating five iterations of digitalization processes, this paper explores how sociotechnical intertwining can drive service innovation in iterative digitalization processes: it thus represents contributions to the research niche of service innovation in digitalization processes. The sociotechnical system is profoundly revolutionized through digitalization. I found that the focal firm created the intertwining of the social network's diversification-convergence and technical architecture's decomposition-integration to evolve the system. Overall, digitalization stimulates the aligned and disaligned sociotechnical intertwining to drive the system's transformation between distributive and aggregative patterns. This transformation leads to the evolution of service innovation over time.

Chapter 7

Concluding discussion

This final chapter provides an overview of the crucial findings from the three papers, followed by a discussion of the findings in relation to each other. The chapter ends by observing the contributions to the wider theoretical background and proposes avenues for future research and managerial implications.

7.1. Findings

This section discusses the findings from the articles in relation to the dissertation's two research questions.

7.1.1. How can we conceptualize iterative digitalization as practices?

Paper 1 conceptualizes iterative digitalization as the ongoing result of interlinked resource-interaction practices, including systematic networking, flexible engineering, and scalable task-coordination.

Digitalization is considered as digital technology's dynamic embedding into its surrounding sociotechnical context. Based on an exploratory case study of a digital technology's dynamic embedding process, Paper 1 scrutinizes the interrelation of the digital technology's dynamic embedding and its ever-changing sociotechnical context. By investigating what actors are doing regarding the recursive interaction between the technology and its surrounding resources, I have explored the evolutionary resource interaction of the

technology with its embedded resource context. Iterative digitalization can be defined as digital technology's dynamic embedding which involves negotiating around the resource interfaces of the focal technology and its contextual sociotechnical resources.

On the resource interface between the focal technology and the organizational relationship, a systematic networking practice, which is to connect of previous network patterns and the current network structure (Ford & Mouzas, 2010) occur to evolve the social network. On the resource interface between the focal technology and its surrounding physical resources, moreover, flexible engineering practices explore ways to configure the focal technology with its surrounding physical resources to evolve the technical architecture. Finally, on the resource interface between the focal technology and organizational units, scalable task-coordination practices continuously improve the capability of nurturing from legacy partnerships and working with new counterparts.

7.1.2. How do the sociotechnical tensions drive digital innovation over time?

By applying a dynamic integration theory to trace the sociotechnical tensions within five iterations of a digitalization case, Paper 2 and Paper 3 observes how the focal firm engages in the linked practices to create different sociotechnical tensions and drive innovation (Eppinger, 1997; Browning, 2001; Yoo et al., 2010).

1) Sociotechnical dissonances and innovation

Paper 2 focuses on the research involving how sociotechnical dissonances drive the innovation of the micro sociotechnical system. The focal firm engaged in the interlinked practices of flexible engineering and scalable coordinating to create sociotechnical dissonances (Eppinger, 1997; Browning, 2001; Amrit & Van Hillegersberg, 2008). These dissonances drove the evolution and innovation of the micro-system.

In the first three iterations of digitalization, the focal firm engaged in the interlinked practices to create sociotechnical dissonances through decomposition principles. The task coordination and technical architecture were within unsynchronized decomposition. These dissonances drove the

system's distributive redesign into a layered pattern, a layered modularized pattern and a refined layered modularized pattern. The more that the distributive redesign of the system is driven by sociotechnical dissonances, the more refined the component-level innovation that can be achieved.
In the last two iterations of digitalization, the focal firm engaged in the interlinked practices to create sociotechnical dissonances through integration principles. The task coordination and technical architecture were within unsynchronized integration. The sociotechnical dissonances drove the system's increasing aggregation firstly into an end-to-end pattern and then into an integrative pattern. The more that the aggregative redesign of the system is driven by sociotechnical dissonances the more escalated the system-level innovation that can be achieved.

2) Sociotechnical intertwining and innovation

The research focus of Paper 3 is how sociotechnical intertwining drives the innovation of the macro sociotechnical system. The focal firm engaged in the interlinked flexible engineering practices of decomposition-integration and systematic networking of diversification-convergence to create sociotechnical intertwining. This sociotechnical intertwining facilitates the evolution of the macro-system (Tilson et al., 2010) and drives its innovation. In the first two iterations of digitalization, the focal firm created sociotechnical intertwining to drive the system's distributive redesigns. Both network diversification and the technical decomposition were focused on distributing the system. The intertwining of technical decomposition and social diversification drove the increasing distributive redesign of the system, while the sociotechnical intertwining drove the system's gradual distributive innovation.

In the third iteration of digitalization, the focal firm created sociotechnical intertwining to drive the system's aggregative transformation. Although the technical decomposition still focused on the distribution of the system, the network convergence initiated the system's aggregation. The intertwining of social convergence with technical decomposition stimulated the aggregation of the ongoing distributing system, thereby driving the distributive and aggregative innovation in parallel.

Finally, in the last two iterations of digitalization, the focal firm created the sociotechnical intertwining to drive the system's aggregative innovation.

Both network convergence and technical integration were focused on aggregating the system. The intertwining between technical integration and social convergence drove the increasing aggregative innovation of the system.

7.2. Combined discussion

This section will discuss the findings of all the three papers together and explore how digital innovation evolves over time.

7.2.1. Iterative digitalization can be achieved through practices

Paper 1 conceptualized iterative digitalization as digital technology's dynamic embedding by addressing the ever-changing context of digitalization. It investigated digital technology's dynamic embedding by underlining the importance of its interaction with the changing sociotechnical resource context. And it found that iterative digitalization can be achieved through ongoing interlinked resource-interaction practices of systematic networking, flexible engineering, and scalable coordination.

These interlinked practices led to two kinds of tensions which drive innovation processes: sociotechnical dissonances and sociotechnical intertwining. Paper 2 focused on how sociotechnical dissonances drive the innovation in the micro-system and Paper 3 concentrated on how sociotechnical intertwining can drive innovation in the macro-system. The micro-system and macro-system can be significantly revolutionized through iterative digitalization.

7.2.2. Creating sociotechnical tensions through practices to drive innovation

In the iterative digitalization processes, the sociotechnical tensions were created through the interlinked practices of flexible engineering, scalable coordinating, and systematic networking.

The harmonious distributive innovation of micro and macro-systems

In the first two iterations of digitalization, the focal firm engaged in the interlinked practices of scalable coordinating and flexible engineering to create sociotechnical dissonances through decomposition principles. These

sociotechnical dissonances drove the distributive redesigns of the micro-system. Simultaneously, the focal firm performed the interlinked practices of systematic networking and flexible engineering to create sociotechnical intertwining through decomposition principles. This sociotechnical intertwining drove the distributive redesigns of the macro-system. Thus, both the micro and macro-systems were in a consistent, distributive manner and evolved in harmonious, distributive innovation (see Figure 3).

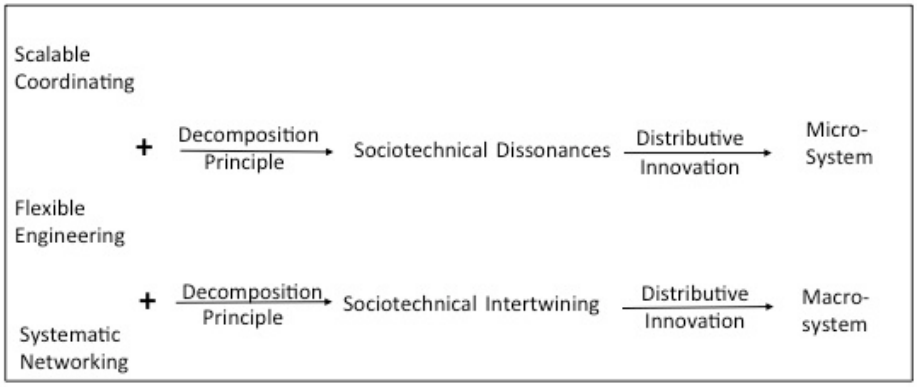

Figure 3. The harmonious distributive innovation of micro and macro-systems

The inharmonious innovation of the micro- and macro-systems

In the third iteration of digitalization, the focal firm engaged in the interlinked practices of scalable coordinating and flexible engineering to create sociotechnical dissonances through decomposition principles. These sociotechnical dissonances drove the micro-system's continuously distributive redesign. At the same time, the focal firm performed the interlinked practices of systematic networking and flexible engineering to create sociotechnical intertwining through decomposition-integration principles. This sociotechnical intertwining drove the aggregative redesign of the ongoing distributing macro-system. That is, the micro-system was in the process of distributive innovation, while the macro-system engaged in distributive and aggregative innovation. Digitalization thus drove the inharmonious innovation of the micro and macro-systems (see Figure 4).

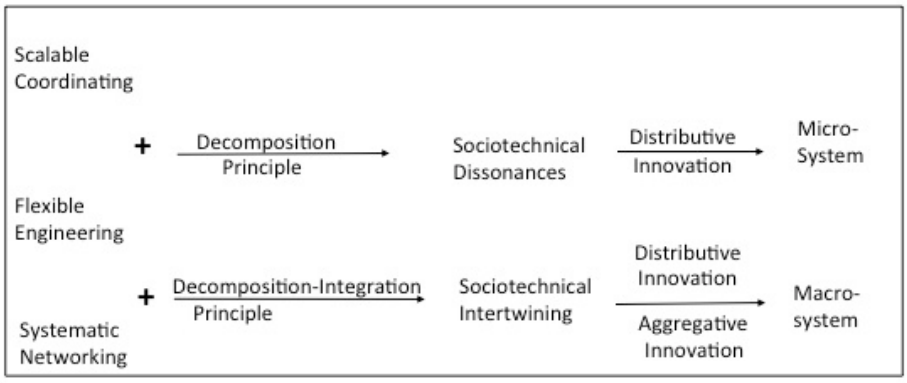

Figure 4. The inharmonious innovation of the micro and macro-systems

The harmonious aggregative innovation of the micro- and macro-systems

In the last two iterations of digitalization, the focal firm performed the interlinked practices of scalable coordinating and flexible engineering to create the sociotechnical dissonances through integration principles. These dissonances stimulated the aggregative redesign of the micro-system. In parallel, the focal firm interlinked their practices of systematic networking and flexible engineering to create sociotechnical intertwining through integration principles. This process of intertwining drove the macro-system's aggregative redesign, while the tensions drove the micro and macro-systems to evolve in line with each other and perform an aggregation redesign. Thus, the micro and macro-systems evolved in a harmonious aggregative innovation (see Figure 5).

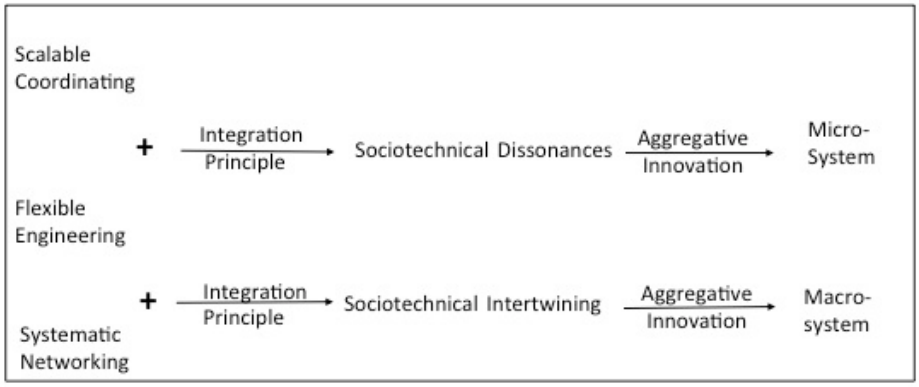

Figure 5. The harmonious aggregative innovation of the micro and macro-systems

7.2.3. Digital infrastructure evolution

As the micro and macro-systems are interactive in nature, there is an emerging literature that has adopted the notion of infrastructure as a way of conceptualizing the interconnected system (Tilson et al., 2010; Henfridsson & Bygstad, 2013). Digital infrastructure evolves in the complex interaction between the micro and macro-systems (Hanseth et al., 2006; Hanseth & Lyytinen, 2010). This section will shift attention from systems to infrastructure and emphasizes the urgent need to theorize the evolution of digital infrastructures to draw a holistic landscape of digital innovation.

The interaction of micro and macro-systems' innovation processes spurs the evolution of the digital infrastructure (Hanseth & Lyytinen, 2010; Tilson et al., 2010). Figure 6 illustrates the digital infrastructure's evolution. Firstly, the harmonious distributive innovation of the micro and macro-systems enables the gradual refinement of the existing digital infrastructure. The increasingly refined infrastructure proceeds in an orderly manner to support further distributive innovation of the systems. Secondly, when systems engage in inharmonious interactive innovation, the digital infrastructure escalates into disarray where it oscillates between upheavals and attempts to bring order (Henfridsson & Bygstad, 2013), and then challenges the infrastructure to migrate. The upheaval of infrastructure will support the systems' inharmonious innovation. Thirdly, the harmonious aggregative innovation of the micro and macro-systems enables the gradual migration of the existing digital infrastructure. The increasing migration of the infrastructure further proceeds in an orderly manner to continuously support harmonious aggregative innovation of the systems. That is, each cycle of the digital infrastructure's evolution includes three phases: refinement, upheaval, and migration. The harmony and inharmony of the micro and macro-systems' innovation drive the cyclic evolution of the digital infrastructure.

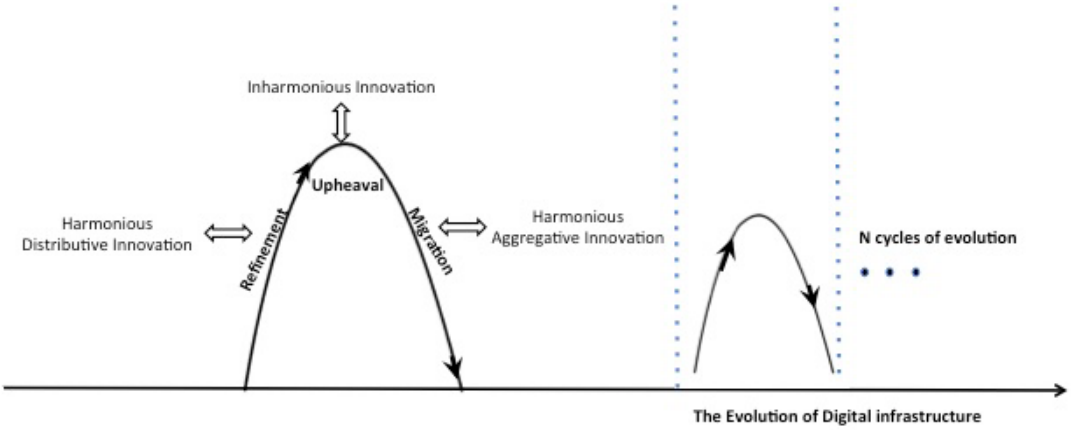

Figure 6. The evolution of digital infrastructure

7.2.4. Understanding digital innovation as digital infrastructure's evolution

Digital infrastructure's evolution is never fully complete (Zittrain, 2008). Indeed, digital infrastructure is characterized by dynamism and longevity; it is unbounded and consists of open installed bases of innovation (Hanseth & Lyytinen, 2010). Its inherently recursive nature fosters growth in scale and scope. Furthermore, the recursive nature of digital infrastructure has become fundamental in understanding digital innovation (Tilson, 2008; Tilson et al., 2010).

As emphasized in Tilson et al.'s (2010) research commentary, there is a critical need to theorize the evolution of digital infrastructures to understand digital innovation. Such a need calls for the exploration of how a digital infrastructure evolves. As we have seen, an emerging branch of literature has adopted the notion of infrastructure as a way of conceptualizing interconnected systems; moreover, considerable attention has been paid to the evolution of digital infrastructure as it evolves in complex interdependencies between sociotechnical systems (Braa et al., 2007; Ciborra & Failla, 2000; Hanseth et al., 2006; Henfridsson & Byggstad, 2013). Inspired by these studies, this thesis brings in the macro-micro mechanisms (Hagel et al., 2010) to view infrastructure evolution as a process by which micro and macro-systems

interact (Aanestad & Blegind Jensen, 2011; Yoo et al., 2005; Henfridsson & Byggstad, 2013). The infrastructure evolves through the ongoing interaction of the micro and macro-systems. In turn, the evolution of digital infrastructures forges novel interactions between the micro and macro-systems, which will create new 'cycles' of infrastructure migration. Therefore, capturing the interaction mechanisms of the micro and macro-systems is key for understanding the evolutionary trajectories of the digital infrastructure. To understand the interaction mechanisms of the micro and macro-systems, this thesis has applied a practice-oriented approach to scrutinize the innovation dynamics of the micro-system and the macro-system respectively through an analysis of their inner sociotechnical tensions.

Figure 7 presents a summary of Figure 3 through to Figure 6 in this section and develops a process model concerning how we understand digital infrastructure's evolution and digital innovation. As illustrated in the figure, the ongoing and interlinked practices of flexible engineering, scalable coordination and systematic networking create sociotechnical dissonances and sociotechnical intertwining. These tensions drive the innovation of the micro and macro-systems. The interaction of the micro and macro-systems' innovation process thereby drives the digital infrastructure's evolution. Consequently, digital innovation results from the interlinked practices that drive the evolution of the digital infrastructure. Systematic networking, flexible engineering and scalable task-coordination are thus the key to digital innovation.

In accordance with Tilson et al.'s (2010) call for infrastructure theory, we should seek explanations that consider both the dynamic character of digital infrastructures and the contingent causality characterizing their evolution. The process model makes sense in the specific industrial context it inhabits. It should not be considered as a covering law (Elder-Vass, 2010), but as a conjectural explanation, forming the basis of further refinement and verification based on context variations (Henfridsson & Byggstad, 2013).

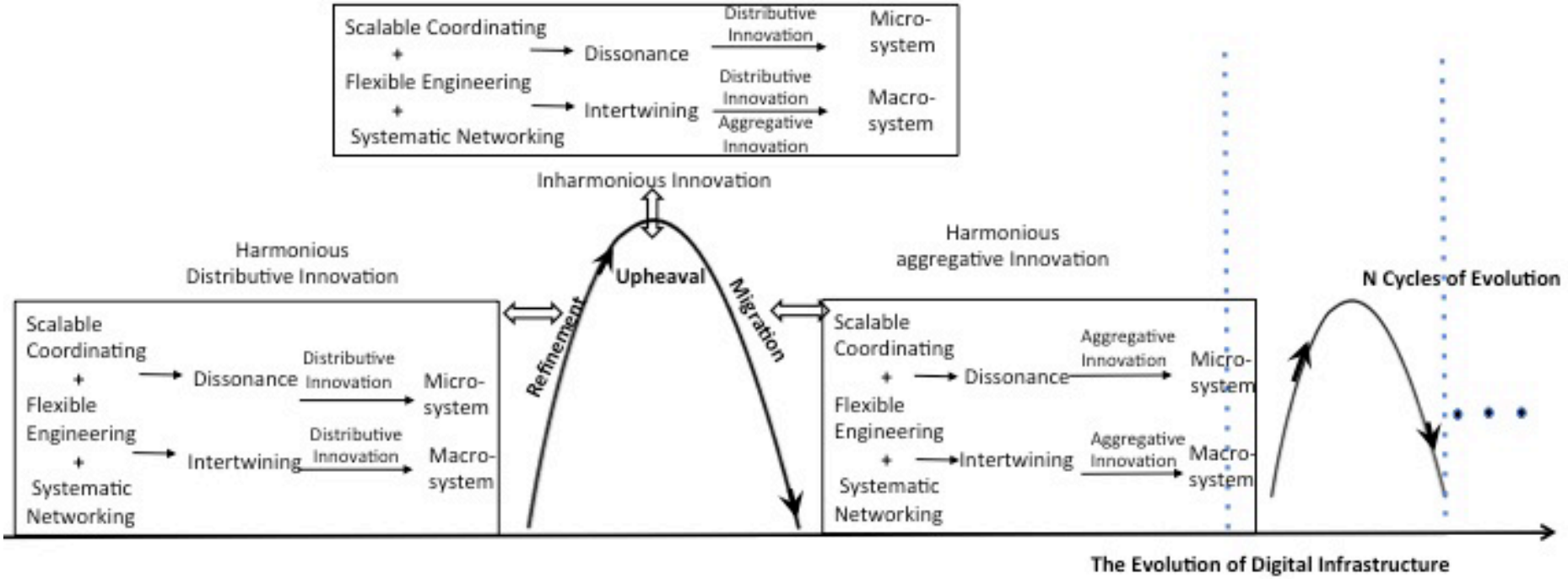

Figure 7. The evolution of digital infrastructure and digital innovation

7.3. Contributions to theory and avenues for future research

This thesis has shed light on how to innovate through digitalization. The following sections present specific contributions to digital innovation research and propose future research opportunities.

7.3.1. Conceptualization of digitalization

Many IS scholars have long acknowledged digitalization as the first step in digital innovation research because understanding the context of digitalization is the first necessary condition for digital innovation. Researchers have explained that digitalization is about digital technologies' embedding with its sociotechnical context. To emphasize the iterative characteristics of digitalization, this thesis has extended the theoretical concept of digitalization as digital technology's dynamic embedding. Iterative digitalization has been conceptualized as embedding the digital technology dynamically with its surrounding sociotechnical context. Paper 1 adopted an IMP lens to investigate digital technology's dynamic embedding by underlining the importance of its interaction with the constantly changing social and technical resource context. Articulating the dynamic negotiations between digital technology and its sociotechnical context can be used to effectively capture and understand iterative digitalization processes.

7.3.2. Sociotechnical studies in the digitalization

For a long time, digital innovation has been understood as being driven by sociotechnical interrelations. This thesis has enriched the current digital innovation research by compiling and reviewing research focusing on sociotechnical interrelations. The literature review has indicated that the sociotechnical interrelations have been mainly depicted as mutual influence from a neutral perspective. This thesis engages with this strand of sociotechnical literature but claims that iterative digitalization stimulates the social or technical change, which will put the established sociotechnical interrelations repeatedly under pressure, thus leading to sociotechnical tensions. This thesis,

therefore, substantially enriches the current body of sociotechnical research by exploring how these tensions drive digital innovation. Specifically, this thesis fills the gap in the literature by exploring how different sociotechnical tensions drive micro and macro-level innovation. The sociotechnical tensions have been conceptualized as sociotechnical dissonances and sociotechnical intertwining. To deepen our understanding of micro-level digital innovation (Baldwin & Clark, 2000; Lee & Berente, 2012; Hylving et al., 2012; Colfer & Baldwin, 2016; Cataldo et al., 2008; Hylving, 2015), Paper 2 has explained how sociotechnical dissonances drive the innovation of micro sociotechnical systems. To contribute to knowledge concerning macro-level digital innovation (Henfridsson & Bygstad, 2013; Grisot et al., 2014; Lusch & Nambisan, 2015; Orlikowski & Scott, 2015; Eaton et al., 2015; Srivastava & Shainesh, 2015; Barrett et al., 2015), Paper 3 explored how sociotechnical intertwining drives the innovation of macro sociotechnical systems.

A number of IS scholars have considered the sociotechnical tensions accompanying digitalization as the fundamental basis for innovation research. However, despite the explicit call for future research in this area, few scholars have addressed the typology of the sociotechnical tension; furthermore, few have empirically demonstrated how to evolve different types of sociotechnical tension and drive digital innovation processes. Accordingly, a dynamic and enriched perspective of sociotechnical tension presented by this thesis brings future research opportunities for a comprehensive understanding of digital innovation.

7.3.3. Conceptualizing the lifecycle of the digital innovation

Through a synthesis of the findings of all three papers, I found that analyzing the interaction between micro and macro-systems can offer answers to questions such as why digital innovation evolves overtime. The dissertation has explored how the micro and macro-systems' interactive innovation can stimulate the cyclical evolution of digital infrastructure.

The interactions of micro and macro-systems' innovation processes spur the evolution of the digital infrastructure (Hanseth & Lyytinen, 2010; Tilson et al., 2010). When the systems' innovation is in harmonious interaction, the digital infrastructures will proceed in an orderly manner to support the innovation processes of the systems. Conversely, when the systems engage in an

inharmonious interactive innovation, the digital infrastructure will escalate into upheavals and attempts to migrate (Henfridsson & Bygstad, 2013). Iterative digitalization stimulates the transformation of harmonious and inharmonious innovation of the micro and macro-systems, thereby evolving the digital infrastructure's cyclical evolution and driving digital innovation over time.

7.3.4. Conceptualizing digital innovation as practices

This thesis has proposed a practice-oriented understanding of digitization and demonstrated that the interlinked practices of systematic networking, flexible engineering and scalable coordination provide the key to enabling the dynamic interaction of digital technology with its surrounding resources, thus facilitating iterative digitalization. The practice-oriented approach to understanding digitalization can, therefore, be seen as one plausible way to broaden our understanding of digital innovation.

By using systems integration theory as a stepping-stone, this dissertation contributes to the IS field by providing empirical insights into how firms engage in the linked practices to create sociotechnical tensions and drive digital innovation. By applying dynamic integration theory to analyze the iterative digitalization process, Paper 2 demonstrates that the focal firm created sociotechnical dissonances by decomposing and integrating technical architecture and task coordination to drive micro innovation. Paper 3 further explained that the focal firm stimulated the intertwining of the social network's diversification-convergence and the technical architecture's decomposition–integration to drive macro innovation.

Different principles for creating tensions have been proposed; however, the principles of developing sociotechnical tensions need to be empirically tested further. Therefore, future empirical studies are necessary to test the theoretical arguments presented in Papers 2 and 3. This practice-oriented method approached the study from the focal firm' perspective: with this in mind, then, future studies that are designed to include other actors' viewpoints are strongly recommended.

7.4. Managerial implications

This dissertation has highlighted the issues for practitioners who are exposed to design and organizational changes in digitalization processes. The results presented in this thesis challenge established sociotechnical interrelation research in digitalization by claiming that innovation thrives within sociotechnical tensions. The thesis has developed process model that pinpoint the importance of understanding how to engage in various sociotechnical practices to create tensions and, therefore, drive innovation forward. The practical implication is to consider the process model as tools with which to manage digital innovation more effectively.

Paper 1 suggested that the firm could engage in the practices of flexible engineering, scalable coordination, and systematic networking to drive iterative digitalization. Furthermore, by providing empirical and theoretical insights, the study could also enhance the awareness of the firm to create the sociotechnical tensions and thus to drive the innovation in the iterative digitalization processes. The findings in Paper 2 and Paper 3 demonstrated that the firm engaged in the interlinked practices by following the decomposition-integration principles to create sociotechnical tensions and drive the innovation.

Dissonances and micro innovation

Engaging in the interlinked practices of coordination and engineering could create sociotechnical dissonances which would drive the innovation of the micro-system. Firstly, the firm could create dissonances to stimulate distributive innovation. They could decompose the social process of task coordinating to initiate S-dominant dissonances or decompose the technical process of architecting to initiate T-dominant dissonances. The firm may then perform the technical processes' isomorphic decomposition to respond with S-dominant dissonances and engage in the social processes' isomorphic decomposition to respond with T-dominant dissonances. Both the S-dominant dissonances and T-dominant dissonances would stimulate the distributive redesign of the micro-system. Secondly, the firm could create dissonances to stimulate the aggregation of the micro-system. They could, for example, integrate the social process of task coordinating to initiate S-dominant

dissonances or integrate the technical process of architecting to initiate T-dominant dissonances. As a result, the firm may drive the technical processes' isomorphic integration to react with S-dominant dissonances and facilitate the social processes' isomorphic integration to react with T-dominant dissonances. Both the S-dominant dissonances and T-dominant dissonances could enable the aggregative redesign of the micro-system.

Intertwining and macro innovation

The findings suggest that the interlinked practices of flexible engineering and systematic networking can create sociotechnical intertwining to drive the macro-level innovation. The firm should engage in systematic networking by diversifying and converging social networks and engage in flexible engineering by decomposing and integrating technical architecture. Thus, the firm could create aligned and dis-aligned intertwining to drive the macro innovation.

Firstly, the firm could create aligned intertwining of technical decomposition and social diversification to drive the increasingly distributed innovation. They could also create aligned intertwining of technical integration and social convergence to drive the increasingly aggregative innovation. Secondly, the firm could create dis-aligned intertwining to drive distributive and aggregative innovation. This dis-aligned intertwining can be achieved by intertwining the social convergence with technical decomposition or intertwining the social diversification with technical integration.

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PART II: Papers