

**UNDERSTANDING PLATFORM
EMERGENCE AND OPENNESS IN THE
MOBILE TELECOMMUNICATIONS
INDUSTRY USING PLATFORM ECOSYSTEM
AND TECHNOLOGICAL INNOVATION
SYSTEMS PERSPECTIVES**

THESIS

HANNE KRISTINE HALLINGBY

CENTRE FOR TECHNOLOGY, INNOVATION AND CULTURE

UNIVERSITY OF OSLO

TELENOR RESEARCH

Abstract

The mobile telecommunications industry is complex, involving many heterogeneous and interdependent technologies and actors. Over time, former hierarchies in the industry have become decoupled and platform ecosystems have emerged, consisting of a central platform surrounded by many complementors. It has been held that open technical connectors on platform interfaces affect a platform's ability to attract innovation on the part of complementors, thereby fueling ecosystem innovation and growth. This thesis investigates how a platform actually emerges, and the role of platform interface openness in this development.

The thesis is composed of three related research articles and an introductory part. Two articles are case studies of the emergence of platforms: on SMS application-to-person in Norway, and on the mobile number as a general-purpose identifier in Norway and in Pakistan. The third article is a multiple case study of five global platforms in the mobile telecommunications industry and the constitution and role of platform interface openness. The main theoretical lenses used for explaining the empirical findings are the platform ecosystem and the technological innovation systems approach.

The case of SMS application-to-person in Norway (Article 1) describes the emergence of a platform ecosystem in the mobile telecommunications industry: many actors were involved in the decisions and events central to the further evolution of the platform—such as regulatory bodies, aggregators, and large users. Formal and informal institutions were significant in creating critical levels of trust and legitimacy, as shaped by regulations, the signaling of roles, transparency, and market sharing. Two-sided network effects were involved in spurring market growth; however, positive knowledge and systemic self-reinforcing effects were also important. Open technical connectors on the platform interfaces were seen as necessary, but not sufficient, for spurring further innovation.

The positive self-reinforcing effects were even more important in the case of the mobile number as a general-purpose identifier (Article 2). Decisions and the shaping of formal and informal institutions strengthened the mobile number as an identifier. Gradually, the mobile number was incorporated into existing information infrastructure, further reinforcing its position as a relevant and useful resource.

The case study of five global platforms (Article 3) found that platform interface openness involved more than technical connectors: the openness of a platform interface was highly affected by non-technical aspects such as rules for participation, documentation, and community building. The article shows that these non-technical factors in turn may have affected innovation processes such as knowledge sharing and legitimation and thus, the further growth of the platform ecosystem.

These three related articles demonstrate how the emergence of a platform ecosystem is a complex and unpredictable process involving many actors, beyond the platform and complementors. Actors and events affect each other and take the evolution of the ecosystem in a certain direction, due to distinct, positive self-reinforcing effects that are not only two-sided market effects. In addition, the many-faceted relationships that develop between the actors with regard to legitimacy and knowledge are central for enabling growth, as are the systemic feedback effects from incorporation into existing information infrastructures.

The three studies show that there are many non-technical factors that affect platform interface openness; moreover, they indicate how such non-technical factors can affect innovation processes like knowledge sharing, legitimation, experimentation, and belief in business opportunities. These are processes that decades of empirical research have shown to be important for innovation and growth in technological systems. Combining the openness of platform interfaces with such processes can open up for a new understanding of the role of interface openness.

This thesis contributes to the platform ecosystem approach by expanding our understanding of how a platform emerges, and the constitution and role of platform interface openness. It contributes to the technological innovation systems approach by introducing the phenomenon of platform ecosystems, along with the role that platform interface openness may play in innovation dynamics. Platforms managers could take advantage of new insights into structures and processes that affect the diffusion of their platforms; policymakers could use these insights to understand the effects of their institutional role better, and also how to assess, regulate, and incentivize such markets.

Preface

This thesis emerged out of a research project in Telenor in 2013. The topic back then was how the concept of platform ecosystems could be used as an approach to understanding structures and dynamics in the mobile telecommunications market. The concept of platform ecosystems was still in its infancy and its usefulness unclear. Luckily, I was allowed to start a PhD project which embraced also the idea of platform ecosystems. In the ensuing years, the term and concept of platforms and platform ecosystems have gained considerable traction.

My hope is that this may help in clarifying our understanding of platform ecosystems, showing that it is indeed a vibrant management concept. In this respect, I feel that thesis takes an important step: it is made explicit that ecosystem as well as innovation systems approaches are based on the underlying assumption of the market as being systemic and complex. This makes it possible to apply the existing literature on technological innovation systems to discuss how a platform ecosystem emerges as the result of many existing shaping factors.

This fruitful combination of insights and approaches was possible because my PhD work has been conducted at the Centre for Technology, Innovation and Culture (TIC) at the University of Oslo (UiO). From my own background I brought insights into the mobile telecommunications market and the management concept of platform ecosystems; at TIC this was combined with approaches like technological innovation systems. These fields, I find, have far more in common than generally acknowledged.

Three single-authored articles were written in connection with this thesis. Two are studies of specific cases, whereas the third is a more conceptual case study. All three are stand-alone studies and can be read independently. In the introductory part the articles are integrated into a more general discussion where I draw lessons for the platform ecosystem concept.

Acknowledgements

This thesis is an Industrial PhD thesis, financed by Telenor Research and the Research Council of Norway (project number 237241/O3). I am deeply grateful to Telenor Research for making it possible to carry out the project. Financial support from the Research Council of Norway has been a necessary and generous framework condition. At the University of Oslo, the Centre for Technology, Innovation and Culture welcomed me warmly into their workplace and networks of highly professional and inspiring innovation researchers.

Many people have made this PhD project possible. At Telenor Research, Patrick Waldemar, vice-president and Head of Technology—my department—has been instrumental: he chose to believe in the project and has strongly supported it throughout, not least by arranging my working day to make room for PhD activities. He also took on the challenge to be my supervisor in Telenor.

I had been toying with the idea of applying for a PhD project for some time, but it was the encouragement from department and project colleagues that pushed me further. In discussions with them, I learned how this could be done, and which research approaches might prove relevant. Especially in our research project on the Internet economy, headed by Olai Bendik Erdal, I got to know many inspiring people, and first encountered TIC. Silvia Elaluf-Calderwood, then affiliated with the London School of Economics (LSE), was incredibly supportive and interested in my initial ideas. At TIC, Jarle Hildrum was very positive and extremely helpful with my project application when I first approached the Center. My colleague at Telenor, Gjermund Hartviksen, inspired me to believe it was possible. Later, I benefitted from collaborations with Ben Eaton, LSE, and Ole Hanseth, UiO.

At Telenor, Per Jonny Nesse made it possible for me to combine involvement in Telenor internal projects with the collection of empirical data for a doctoral project. Together, we have researched mobile financial industries and written several articles.

Colleagues in Telenor Research have been very important throughout the PhD work. My closest colleagues in the department of Next Generation Technology were mostly technologists; however, they proved to be highly curious, supportive and encouraging about my social scientist approach to innovation and technology development. Further, colleagues across Telenor have opened up their networks and helped me getting access to unique data.

I also wish to thank all the people at TIC who have welcomed me and provided me with insights into the tacit knowledge of the innovation field, and the art of writing academic

articles. The administration has taken good care of me, with all my queries and requirements. Their warm inclusion has opened up a new world to me. Especially my long-time office-mate Simen Enger has been a good discussion partner with regard to both academic and administrative concerns. We have shared the same preferences regarding noise, heat, light, and the appropriate level of interruptions. In the final stage of writing, Susan Høivik increased the quality substantially by helping me out with proof-reading and copy-editing the manuscript.

Finally, Professor Magnus Gulbrandsen, my supervisor at TIC, has been wise and timely in his feedback. His most important piece of advice was to start working with empirical data early: and that has served me well. It is something I will carry with me in my future research. In his comments on thesis, he has been specific and constructive and always helped me to take the project many steps further.

Work on this PhD has been motivated and supported not only by professional relationships, but also by my family. My husband, Trond Holtvedt, and our children Solveig, Sigrid, and Hågen, have continuously expressed their firm belief in my abilities. When I was in doubt, they reassured me that yes, everything would work out. I also wish to thank my parents, Bente and Even Hallingby; I like to think I got my brains from my mother, while my father has been a role model for standing up for my ideas. I also wish to thank the large and wonderful community of family and friends who are extremely open, smart, supportive and engaged.

Table of content

Abstract	1
Preface	3
Acknowledgements	4
1 Introduction	11
1.1 Background.....	12
1.2 Research questions, theoretical foundations, and motivation.....	13
1.2.1 Platform emergence.....	13
1.2.2 Platform interface openness	14
1.3 Scope of the thesis	15
1.4 Findings	16
1.5 Structure of the thesis	17
2 Theoretical framework	18
2.1 Platform ecosystems	18
2.1.1 Origins of the platform ecosystem approach.....	19
2.1.2 Core dynamics of platform ecosystems	21
2.2 Technological innovation systems (TIS).....	23
2.2.1 Origins of the TIS approach	24
2.2.2 The TIS framework	24
2.2.3 TIS and self-reinforcing effects.....	27
2.2.4 TIS and technical connectors	29
2.2.5 TIS and agency.....	29
2.3 Summary.....	30
3 Summary of articles and methodology.....	32
3.1 Article 1: Key success factors for a growing technology innovation system based on SMS Application-to-Person in Norway	32
3.1.1 Contribution to research questions	32

3.1.2	Publication history, Article 1	34
3.2	Article 2: Mobile phone number as a general-purpose identifier: status and future	34
3.2.1	Contribution to research questions	34
3.2.2	Publication history, Article 2	36
3.3	Article 3: Platform openness and innovation: A case study from the mobile telecommunications industry.....	36
3.3.1	Contribution to research questions	37
3.3.2	Publication history, Article 3	38
3.4	Methodology.....	39
4	Discussion	44
4.1.1	The platforms studied.....	44
4.1.2	Platform emergence: a complex process unfolding over time	46
4.1.3	Positive feedback effects: driving platform emergence	48
4.1.4	Platform interface openness	49
4.2	Contributions to theory	50
4.2.1	Platform ecosystems.....	50
4.2.2	Technological innovation systems	51
4.3	Management implications for an emerging platform ecosystem.....	52
4.3.1	Expect and prepare for several potential paths.....	54
4.3.2	Ensure complete and efficient actor network.....	55
4.3.3	Identify and manage innovation functions and reinforcing mechanisms.....	56
4.3.4	Balance platform interface openness and closure	57
4.4	Limitations of the findings	59
5	Conclusion.....	61
5.1	Results	61
5.2	Significance of findings.....	62
5.3	Future research	63

6	References	65
	Articles appended.....	72
	Article 1: Key success factors for a growing technology innovation system based on SMS Application-to-Person in Norway	73
	Abstract	73
1	Introduction	74
2	Background and theory	75
	2.1 Growth of SMS A2P.....	75
	2.2 Theory and expectations.....	75
3	Method	77
	3.1 Defining the innovation case	77
	3.2 Data collection and analysis	78
4	Structural components.....	79
	4.1 New demand for SMS	79
	4.2 Actors and relationships	80
	4.2.1 Mobile operators' role	82
	4.2.2 Aggregators' role.....	82
	4.2.3 Actors' recognition of role	82
	4.2.4 Incentives and technological connectors between actors	83
	4.3 Institutions	84
5	Functional pattern of the TIS	85
	5.1 Functional patterns and their goodness	85
	5.2 Legitimation.....	86
	5.3 Assessing the phase and comparative status of TIS	88
6	Discussion and conclusion	88
	6.1 Inducement mechanisms.....	88
	6.2 Blocking mechanisms and policies.....	91

6.3	Contribution to theory	91
7	Conclusion.....	92
8	References	93
Article 2: Mobile phone number as general-purpose identifier: status and future.....		97
Abstract		97
1	Introduction	97
2	Theory	99
2.1	Evolutionary and systemic innovation, and path-dependency	99
2.2	Path-dependency aspects of mobile numbers	100
2.3	Design principles for a general-purpose identifier	101
2.4	Summary of factors affecting mobile number as general-purpose identifier	102
3	Method	104
4	Results	106
4.1	Status and growth of mobile number as a general-purpose identifier	106
4.2	Global strength and availability of mobile numbers	107
4.3	Status and use of mobile numbers in Pakistan and Norway	109
4.3.1	Norway	110
4.3.2	Pakistan	113
5	Discussion	116
6	References	119
Article 3: Platform openness and innovation: A case study from the mobile telecommunications industry.....		125
Abstract		125
1	Introduction	125
2	Theory	127
2.1	Platforms.....	127
2.2	Platform interfaces.....	128

2.3	Platform interface openness – technological approach	129
2.4	Conceptual and evaluative literature on platform openness	130
2.5	Platform interface openness – a technological innovation system	131
2.6	Effects of platform openness	133
2.7	Propositions	134
3	Method	135
4	Results	137
4.1	Platform assessment	138
4.2	Platform vendor and complementor interface	138
4.3	Vendor interface openness.....	139
4.3.1	Knowledge generation and diffusion	139
4.3.2	Legitimation	140
4.3.3	Entrepreneurial experimentation	142
4.3.4	Guidance of the search	142
4.4	Complementor interface openness.....	145
4.4.1	Knowledge generation and diffusion	145
4.4.2	Legitimation	145
4.4.3	Entrepreneurial experimentation	146
4.4.4	Guidance of the search	148
5	Discussion and conclusions.....	148
5.1	Theory contribution	152
5.2	Management implications.....	153
5.3	Limitations and further work.....	153
6	References	154
	Appendix 1	159

1 Introduction

“It should be so easy to get somebody to start making something for your platform or making something for the APIs,” one expert said, adding: “It is...this is not so much about technical stuff anymore.” (Article 3, 2018)¹

Increasingly, human, public, and business activities are becoming digitalized and software-based. Much of this activity is concentrated around a few technologies and firms, as exemplified by huge actors like Facebook and Google. In turn, these firms let others use and embed their technology in further applications, web pages and technologies. Technologies and firms like this, which attract considerable innovation activity, are called *platforms*; the platform together with all the complementing firms that innovate with it is referred to as a *platform ecosystem*. Interaction between the platform and other firms takes place on *platform interfaces*. It is essential for interfaces to be sufficiently open and easy for others to use, in order to spur innovation in the whole ecosystem. Many profit-seeking firms position themselves so as to become platforms; policymakers strive to understand platforms so as to incentivize and regulate them efficiently. However, we do not understand very well how a platform ecosystem emerges, nor the role played by platform interface openness in the emergence of platforms. This thesis addresses these topics.

The thesis consists of three articles and an introductory part. Each article has its specific research questions; this introductory part combines and compiles the articles and discusses how platforms emerge and the role of openness in platform interfaces. The articles analyze specific empirical phenomena from the mobile telecommunications industry that are seen as examples of platforms: the growth of SMS Application-to-Person, the mobile phone number as general-purpose identifier, and the constitution of interface openness for platforms such as Google and 3GPP. Two main theoretical lenses are applied for addressing the research questions: the platform ecosystem approach, and the technological innovation system approach.

The findings reported here show how platform ecosystem emergence is systemic and evolutionary, whereas platform interface openness in the form of a technical connector is found to be less significant. Insofar as platform interface openness affects innovation and emergence of a platform, the findings illustrate how this is also a result of non-technical factors embedded in the socio-economic innovation processes in a technological system.

¹ All such references are to the three articles that comprise the bulk of this thesis

1.1 Background

The information and communications technology (ICT) industry has become increasingly complex, involving many interdependent technologies and actors (Hanseth & Lyytinen, 2010). These interdependencies used to be governed within monolithic and hierarchical organizations (Baldwin & Clark, 2000). Today, both technologies and organizations are increasingly decoupled: they are independent entities, but are interdependent in their deliveries to users and customers (Yoo et al., 2010).

Technologies such as telecommunications have long been recognized as interdependent socio-technical systems (Hughes, 1987; Schmidt & Werle, 1997). One early example of decoupling was the modularization of IBM's software in the 1960s (Baldwin & Clark, 2000). The TCP/IP protocol of the Internet has decoupled content from the network. More recently, mobile app stores have led to a decoupling of mobile services from the network and device providers. This decoupling has had massive effects on the volume and pace of innovation, far beyond the technologies involved (Baldwin & Clark, 2000; Gawer & Cusumano, 2002).

Major efforts are now underway to fulfill the ambition of 5G—the next generation of mobile telecommunications networks. The 5G vision entails a decoupling of current technology and industry in order to take advantage of the innovation dynamics of platform ecosystems (5GPPP, 2017). Compared to earlier, more integrated, mobile generations, 5G will become an even more complex system of dynamic heterogeneous elements.

Studies of decoupled technologies (Gawer & Cusumano, 2002; Iansiti & Levien, 2004; Moore, 1993) find that some technologies often assume a more central position than others, growing relatively large, accompanied by organizational solutions (Baldwin & Woodard, 2009). Examples of such large, central companies include Intel, Microsoft, and Google, offering technologies such as microprocessors, the Windows operating system for computers, Google maps, the Android operative system for smartphones (Gawer, 2009; Gawer & Cusumano, 2002). Within the field of social media and online shopping, we may note Facebook and Amazon.

These central technologies are surrounded by many smaller actors who build new products and services by using the core technologies. Among such actors there may be hardware start-ups experimenting with microprocessors in computing devices, large providers of accountancy software seeking to integrate with Excel, or tourist websites wishing to display

hotels on a map. In the mobile telecommunications industry, independent developers and news outlets have built applications for Android-based smartphones.

One term used for such technology with a more central role is the *platform* (Gawer, 2014; Baldwin & Woodard, 2009; Iansiti & Levien, 2004; Tiwana et al., 2010). The many technologies and firms using and innovating with the platform also employ terms like niches (Iansiti & Levien, 2004), complementors (Gawer & Cusumano, 2014), and developers (VisionMobile, 2017). In this thesis the term *complementor* is used to describe the firm or technology that uses the platform. The complementors and platform together are referred to as a *platform ecosystem* (Gawer & Cusumano, 2002).

1.2 Research questions, theoretical foundations, and motivation

1.2.1 Platform emergence

During the last two decades, academics and practitioners have started to investigate how platform ecosystems enable innovation and growth across many actors and technologies (Gawer & Cusumano, 2002; Iansiti & Levien, 2004; Moore, 1993; 5GPPP, 2017). These approaches have been concerned mainly with platform ecosystems as something that already exists, and have not focused on their origins and initial phases. How a platform and its ecosystem *emerge* has been left to future research (Gawer & Cusumano, 2014). This thesis addresses this theoretical gap with the question:

Research question 1: How does a platform emerge?

It has been indicated that platforms may emerge through an evolutionary process (Baldwin & Clark, 2000). Subsequently, more general innovation theories and approaches may shed light on central dynamics within platform ecosystems. This thesis looks for factors that affect the emergence of a platform in technological innovation systems (TIS) approaches (Bergek et al., 2008; Hekkert et al., 2007) and also evolutionary economics (David, 2007; Fagerberg, 2003; Tushman & Murmann, 2003). These perspectives acknowledge the passing of time, as opposed to a snapshot of a current market situation. With time comes the concept of a path that a technology can take throughout its various phases (Jacobsson & Bergek, 2004).

In a systemic process positive self-reinforcing effects can lead to high growth and a central position for the technology in question (Bergek et al., 2008; Suurs & Hekkert, 2009). Positive self-reinforcing effects may have various sources, such as indivisibilities, learning, using, or direct network externalities (Fagerberg, 2003; Klitkou et al., 2015). The effects may lead to a

clear preference for certain standards, technologies, or firms (David, 1985). They are also used to explain path dependencies, monopolizing technologies, and dysfunctional lock-ins (Hanseth & Lyytinen, 2010).

1.2.2 Platform interface openness

Platform *interface openness* is a recurrent theme in discussions of the innovation capabilities and growth of a platform ecosystem. It is held that technical connectors on interfaces should be open, so as to make the platform easy to use in other innovations (Gawer, 2014; Baldwin & Clark, 2000; Gawer & Cusumano, 2014). This is in line with the view that innovation is recombination of pre-existing technologies and knowledge, and that this occurs through a process of variety creation and selection (Fagerberg, 2003).

The significance of interface openness for innovation can be illustrated by Lego. That it is so easy to combine the interlocking Lego bricks affects the structures your children can build at home, but also how children around the neighborhood can jointly build a whole Lego city. When recombination and variety are limited by low degree of openness—for instance, if the Lego bricks do not match very well—the selection process and subsequently total innovation dries out (Fagerberg, 2003).

Even though openness is essential for innovation, the concept of openness on platform interfaces is still fuzzy and many-faceted (Gawer, 2014). Hence, openness on platform interfaces is an important research topic for technologies that are increasingly decoupled but still interdependent (Benlian et al., 2015; Yoo et al., 2010). This thesis addresses this theoretical gap with the question:

Research question 2: How does interface openness play a role in platform emergence?

Again, this study finds the main theoretical explanations within the systemic and evolutionary field of innovation (Bergek et al., 2008; Fagerberg, 2003; Hekkert et al., 2007; Tushman & Murmann, 2003). The call for research on platform interfaces has mainly concerned technical connectors or “application programming interfaces” (APIs) towards complementors. (For example, Google Maps APIs allow Google maps to be embedded into web pages.) However, this thesis emphasizes an *additional* platform interface towards other types of stakeholders, who are involved in the specification and development of the platform.

With this additional interface, openness takes the form of standards and open source. These are topics that have been subject to research but not closely linked to the concept of platforms

(Schmidt & Werle, 1997; West, 2003). Especially in the telecom sector, standards have been central in making interoperability and recombination possible. The use of open-source code is a different route to achieving many of the same objectives of compatibility in the software industry (West, 2007). In either case, in a world with increasingly decoupled but interdependent technologies, openness on all types of platform interfaces may play a role in enabling technologies to fuel innovation and growth.

1.3 Scope of the thesis

The cases studied in this thesis are mainly from the mobile telecommunications industry. The discussion on platforms, complementors and ecosystems is relevant in this context.

This is an industry where many different roles have had to be filled and interact, in order to deliver the final result to customers. The operation of mobile telecommunications is regulated by national authorities as well as international bodies like the EU. Mobile telecommunications are based upon the natural resource spectrum, and regulatory authorities administer and offer access to this spectrum within a country. Mobile operators, for instance Telenor and Telefónica, acquire time-limited spectrum licenses and invest in network infrastructures to operate mobile services. The infrastructure caters to the transmission of radio signals between devices, the main services being Internet access, voice, and SMS. Vendors and other technology firms develop, build, provide, and even operate the network infrastructure; Ericsson is long-time European vendor, whereas Huawei is a more recent Chinese multinational. Another role is to provide systems for authentication and access to the network infrastructure, currently through SIM cards, provided by, for instance, the firm Gemalto. Firms like Samsung and Apple develop and provide devices, while Google provides the device operating system used by Samsung. Based on the existence of this system, many other firms and actors provide content and communication services, locally and globally. Underlying all these services are agreements on standards, so that the systems are compatible within and between all the various firms. Standards are developed jointly by organizations such as 3GPP, IETF, and W3C; however, Google and Apple provide and manage highly influential private operative systems. This industry has the characteristics of a complex system with many heterogeneous but interdependent technologies and actors.

In addition, I see the findings in this thesis as applicable not only to the mobile telecommunications industry, but also in sectors that display characteristics of complex systems. In an extended Pavitt taxonomy of sectors (Tidd et al., 2005), software-based

information-intensive firms are those held to be systemic by nature: this is a result of digitalization and interconnection of previously separate activities, where interface technologies for systems integration have become increasingly important, as in finance, travel, and publishing, for instance. Firms and industries *not* defined as complex systems include agriculture, scale production, chemicals and pharmaceuticals, machinery and instruments; these create and capture value in very different ways (Tidd et al., 2005). However, with growing digitalization and reliance on software, various sectors may be taking on the characteristics of complex systems as well.

1.4 Findings

Two articles in this thesis analyze phenomena in the mobile telecommunications sector that could be interpreted as platforms: SMS Application-to-Person, and the mobile phone number. Complementors have increasingly used and integrated these resources in other applications and services, constituting a platform ecosystem. The third article presented here explores large platform ecosystems in the mobile telecommunications industry, like Google and W3C with regard to platform openness. These three articles have their distinct research questions, narrative and findings. In various ways, all three contribute to answering the research questions of this thesis.

The SMS Application-to-Person case (Article 1) shows that many actors and institutions were involved in decisions and events that affected the emergence of the platform. The innovation processes emphasized in that article are entrepreneurial experimentation, and legitimation in the form of building trust, collaboration, and expectations between stakeholders and end-users. This is shown to have been an unpredictable, evolutionary process where the effects of decisions and events, although not always anticipated, served to prepare the way for a specific path. The positive self-reinforcing effects concern two-sided network effects, but also knowledge and systemic feedback loops.

The positive self-reinforcing effects for formal and informal institutions were found to be present also in the case of mobile numbers as general-purpose identifiers (Article 2). The findings indicate that although the mobile number is a standardized resource, its attractiveness in digital services has been influenced by its strength and availability. Both strength and availability are concepts specific to the market in question. Strength concerns to what degree it could be confirmed that an individual was connected to a given mobile number. Availability concerned how the mobile number was integrated in pre-existing information infrastructures.

This article shows how these factors have affected integration into digital services, and thus the further emergence of the mobile number as a general-purpose identifier. In both these articles, influential factors for further diffusion were found to differ from country to country, integrated in each country's formal regulations, history and culture. Thus, the platform ecosystems were to some degree local even though the platforms discussed were global.

As one informant put it, platform interface openness "is not so much about technical stuff anymore." Platform interfaces are governed also by non-technical aspects such as rules for participation, documentation and community building. This in turn affects innovation processes like knowledge sharing and legitimation, which are recognized as spurring innovation (Article 3). In the SMS Application-to-Person case, the technical connectors were regarded as a necessary but not sufficient factor for spurring innovation and growth.

In summary, as regards the research questions, the findings are as follows. The number and quality of actors and institutions that affect platform emergence must be extended far beyond the platform and complementors. There are innovation processes and positive self-reinforcing effects that drive the evolution in unintended ways; it is essential to grasp these in order to capture the full complexity of a platform ecosystem's evolution. The technical aspect of platform interface openness is important for platform emergence; however, our understanding of platform interface openness must include non-technical factors as well, and how these in turn affect innovation processes. Finally, these non-technical factors can be specific to a given market, so that innovation becomes localized even for universal technologies.

1.5 Structure of the thesis

Chapter Two introduces a theoretical framework for explaining the findings of the three articles. In Chapter Three, the articles are summarized and compared, and the methodological approach is presented. The discussion in Chapter Four turns to the research questions. It also notes the theory contributions of this work and further implications for management, as well as some limitations of this thesis. Chapter Five presents conclusions and suggestions for further work.

2 Theoretical framework

This thesis studies decoupled technologies in the mobile telecommunications industry, with one central technology and many peripheral technologies. The platform ecosystem approach is a main lens used for interpreting the structures and dynamics observed. However, this approach cannot fully explain the research questions (see above) about how a platform emerges and the role of platform interface openness. Therefore it is complemented with the technological innovation systems (TIS) approach, which can provide a broader set of actors and processes, and also an understanding of how a technological system develops over time. The following is a review of these approaches—their origins, similarities, differences, and gaps—with a summary of how they together address the research questions.

2.1 Platform ecosystems

The platform ecosystem approach aims to explain observed structures and dynamics in high-tech industries, also the mobile telecommunications industry (Gawer & Cusumano, 2002; Iansiti & Levien, 2004). This literature finds that it is quite common to have one stable, central technology, and many smaller and peripheral complementing technologies (Baldwin & Woodard, 2009; Murmann & Frenken, 2006).

I start out by defining the actors and dynamics in this structure. *Platforms* are defined as “products, services, or technologies developed by one or more firms, and which serve as foundations upon which a larger number of firms can build further complementary innovations and potentially generate network effects” (Gawer & Cusumano, 2014, p. 420).

The firms innovating with the platform are referred to as *complementors*, and the platform and complementors together make up the *platform ecosystem* (Gawer, 2014; Gawer & Cusumano, 2002). The complementors expand the total demand for the ecosystem and, accordingly, the platform as well. The “network effects” mentioned in the definition above act as a self-reinforcing mechanism that fuels this growth (Gawer, 2014).

The literature further holds that, to spur ecosystem growth, the platform must incentivize complementors to innovate (Gawer, 2014). According to Gawer and Cusumano (2014, p. 421) “interfaces around the platform should be sufficiently ‘open’ to allow outside firms to ‘plug in’ complements as well as innovate on these complements and make money from their investments.” Interface openness may also be referred to as technical connectors and application programming interfaces (APIs): basically, that they are technical means for enabling complementors to use the platform for new innovations. In addition to technical

means, it is necessary to incentivize complementors financially (Gawer, 2014): the platform and complementors' interests must be aligned, and the complementors' margins must be taken into consideration.

Based on this, I emphasize two important aspects of the platform ecosystem. First, the creation of value is conducted across firms and technologies—more specifically, across the platform and complementors. Second, how the interfaces between these firms and technologies are constituted affects how and if value will be created. To explain the logic and assumptions behind these aspects, I turn to the origins of platform ecosystems and accompanying perspectives.

2.1.1 Origins of the platform ecosystem approach

The platform ecosystem approach applied in this thesis is based on an engineering design perspective where platforms are viewed as technological architectures (Gawer, 2014). This contrasts with the literature where platforms are understood mainly as two-sided markets characterized by network effects (Gawer, 2014; Eisenmann et al., 2009); in the technological architecture approach, network effects are treated as one among several factors that affect a technological architecture.

The platform ecosystem as a technological architecture originates partly in an analytic stream and partly in a more empirical and practical stream. The analytic stream elaborates on how large complex systems become difficult to handle, and how de-composing them into modules can increase flexibility and efficiency. Examples from this literature include complex systems such as de-composed and stable modules (Simon, 1962), a theory of general modular systems (Schilling, 2000), and modularization as a strategy for enabling innovation and growth (Baldwin & Clark, 2000).

A second stream of literature has discussed the practical implications of a disintegrated product architecture (Ulrich, 1995), or used empirical analyses to build models for the advantages and effects of innovation in a modular system (Langlois & Robertson, 1992), and suggested advantages of product platform innovation (Robertson & Ulrich, 1998). Again, the literature finds innovation and efficiency advantages from a modular architecture due to greater variety and independence. The literature has also discussed how such architectures may take the path from internal platforms to disintegration of organizations (Gawer, 2014). Also the more analytic modularity theory (Baldwin & Clark, 2000) was accompanied by the

case of IBM's organizational disintegration, which followed the modularization of IBM's tightly coupled technology.

In parallel with these two streams of literature, it has been suggested that complex business environments can be better understood by using an ecological equivalent like the *ecosystem* (Peltoniemi & Vuori, 2005). Moore (1993) used the term ecosystem to describe the presence of many different interdependent actors who together catered to value creation in a market, and suggested strategies in the different stages from birth to maturity. The ecosystem-term was taken up by others in the field of strategic management, with the ecological analogy (Iansiti & Levien, 2004) and without it (Adner, 2006). These contributions have been influential in diffusing and gaining acceptance for the term in academia and in practice.

Modularity theory (Baldwin & Clark, 2000) embraces both the analytic and empirical perspectives described above, and has become important in explaining the significance of interface openness in a platform ecosystem (Gawer, 2014). Modularity implies that modules still are interdependent in providing the total system; however, they are made independent of each other through well-known design rules on the module interfaces (Baldwin & Clark, 2000). When design rules are implemented, complexity decreases; work on one module can be undertaken without having to change all the others. This allows others to adapt the technology, experiment, and make new modules and combinations without having to worry about the technology hidden behind the interfaces of other modules (in the introduction, I used the example of Lego bricks). One important effect is that this has the potential to boost the rate of innovation.

This view on how innovation is promoted is aligned with two core dynamics within the field of evolutionary economics: variety creation and selection (Fagerberg, 2003; Nelson & Winter, 1982; Tushman & Murmann, 2003). Innovation is the “new combination of existing ideas, capabilities, skills, resources etc.” (Fagerberg, 2005, p. 10), and a selection process caters to this recombination. However, unless new variety can be created, the sources of recombination will dry up: variety is necessary for continued innovation (Fagerberg, 2003). Within both the evolutionary economics perspective and modularity theory, the lack of new variety or modules with open interfaces can lead to a lock-in or path dependency situation where further development and changes become difficult and costly (Baldwin & Clark, 2000; Fagerberg, 2003). Over time, self-reinforcing mechanisms are expected take the market onto a path where activity centers on one technology or standard (David, 1985).

Thus, in the first case, modularity is a theory that opens the way to infinite recombination of modules; in the second case, even a modular technological system encounters self-reinforcing effects and decreased variety that can lead to path dependence. Arguably, a common structure in modular systems is the stable core platform with many dynamic peripheral complementors (Baldwin & Woodard, 2009). One factor leading to a core/periphery structure is that endless recombination opportunities entail too heavy a cognitive burden (Murmann & Frenken, 2006), so complementors will appreciate simplicity and less choice. After all, actors in a complex system may be rationally bounded without indefinite imagination capabilities (David, 2007).

An additional rationale for not allowing full recombination opportunities may be to ensure the integrity and quality of the platform (Tiwana et al., 2010). Further, there is a recognized trade-off between enabling innovation and ensuring profit (Baldwin & Woodard, 2009; Gawer & Cusumano, 2014); openness ensures innovation and adoption, while closure ensures profit. Firms in control of one technology will seek to balance this trade-off, often with the ambition of becoming the stable platform module in the ecosystem because this is more profitable (Murmann & Frenken, 2006).

In summary, the platform ecosystem approach is oriented towards technological architectures. It is rooted in concerns about ways to reduce complexity and increase flexibility and efficiency with modularity. The modularity perspective explains how well-designed rules on the interfaces between modules allow independence in development and recombination, and interdependence in system performance. Even with full recombination opportunities, self-reinforcing effects may take a system onto a path where one technology or standard is preferred; thus, core/periphery is a common structure also in a modular system. Additional explanations for the emergence of a core/periphery structure include cognitive limitations, security and profit concerns. However, the flexibility achieved from interface openness can be cost-efficient—and, not least, boost variety creation and thus innovation.

2.1.2 Core dynamics of platform ecosystems

In the above I have described the organizational structures referred to as platform ecosystems, consisting of one platform with many complementors; this mimics a modular technological architecture with a core and periphery. Furthermore, in a platform ecosystem, the interface between the platform and complementors is intentionally open—with well-known design rules—in order to spur innovation and growth.

However, it cannot be taken for granted that a platform has sufficient legitimacy to attract complementors, or that complementors will necessarily join a platform ecosystem collective (Gawer & Phillips, 2013). Here it is essential for the platform to signal that it wants and expects also complementors to profit (Gawer & Henderson, 2007). Studies of platform ecosystems indicate that platforms should focus on four levers of strategic actions (Gawer & Cusumano, 2002); these levers have developed into four leadership practices for a platform (see Table 4-1) (Gawer & Cusumano, 2014).

Basically, a platform is assumed to have agency (Gawer, 2014). Thus, drawing on the field of strategic management, the platform ecosystem approach sees a platform ecosystem as managed by a platform leader who undertakes deliberate decisions and actions, although rationally bounded (Gawer & Cusumano, 2014). Also the modularity approach sees actors as being equipped with foresight as well as intent (Baldwin & Clark, 2000). Further, it is assumed that actors want to control what they consider to be the core technology, as this is held to be more profitable (Murmann & Frenken, 2006).

Three of the four suggested strategic levers are technical in orientation (Gawer & Cusumano, 2014; Gawer & Cusumano, 2002). The first lever is a call to identify an attractive core platform technology and complementary firms and technologies, and to develop a vision for the ecosystem. The relevant actors are to be the core platform and complementors. With the second lever, the platform is advised to adopt a modular architecture and use technical connectors to make the platform readily available for complementors. Technical connectors are accorded an important role as a proactive means of fueling innovation and growth throughout the ecosystem. One additional way to incentivize complementors and signal the intention of sharing the market is to allow access to the platform's intellectual property at reasonable levels (Gawer & Henderson, 2007). The fourth strategic lever mainly involves retaining the strength of the platform core while maintaining the fine balance with complementors.

It is primarily the third strategic lever that includes social factors that govern the platform ecosystem. This lever concerns the character of the relationship between the platform and complementors, emphasizing practices such as mutually enhancing business models, evangelizing, risk sharing, legitimacy, reputation, and collective identity (Gawer & Cusumano, 2002). Such practices have been analyzed in the platform ecosystem literature as formal and informal institutions governing relationships (Gawer & Phillips, 2013).

For instance, it has been shown that it is important for the platform to signal expectations regarding roles and how to fill them; this builds collective identity and thereby legitimacy. The platform should, consistently and repeatedly, communicate collective intentions for the whole ecosystem, and especially regarding adherence to platform openness. To earn and retain trust requires being perceived as a neutral and fair platform leader. To establish sound relationships, a platform should drive industry standards and initiatives, provide tools to stimulate innovation, and manage tensions wisely. This can be done through activities like training complementors, and sharing tools, knowledge, and beta versions of new technologies (Gawer & Phillips, 2013).

In summary, the platform ecosystem approach provides valuable insights into the structure as well as the dynamics and practices that govern this type of technological system. However, the approach lacks a systematic framework that can explain how a platform comes into being. Indeed, the emergence of a platform has been recognized as a field for further research; and that, for instance, the literature on technological change and institutions can offer supplementary and useful approaches (Gawer, 2014; Gawer & Cusumano, 2014).

Furthermore, in the platform ecosystem approach it is agreed that openness of platform interfaces is essential for innovation and growth. This is a topic in my studies; however, the ecosystem approach does not elaborate on the constitution of openness beyond technical connectors, and admits that this is fuzzy and many-faceted (Gawer, 2014). Also the role of interfaces is a topic for further theory development (Gawer, 2014; Benlian et al., 2015; Gawer & Cusumano, 2014; Yoo et al., 2010).

My focus in this thesis is the emergence of a platform and the role of platform openness. To supplement the platform ecosystem approach, I turn to other types of literature.

2.2 Technological innovation systems (TIS)

The technological innovation systems (TIS) approach (Bergek et al., 2008; Hekkert et al., 2007) can mitigate some of the shortcomings of the platform ecosystem literature. Primarily, the TIS approach is used for explaining the process that has brought a technological system to its current status. The institutional and legitimation processes (Gawer & Phillips, 2013), also acknowledged in the platform ecosystem approach, are here complemented by five more processes known to drive innovation. TIS also substantially expands the number of actors involved in a technological system.

2.2.1 Origins of the TIS approach

TIS originated in the 1990s (Markard et al., 2015), in parallel with national (Edquist, 2005) and regional (Malerba, 2005) innovation systems approaches (Weber & Truffer, 2017). Early and important contributors to the national systems approach include Lundvall (1992), Nelson (1993), and Edquist (1997). Later the TIS approach converged into a framework focused on a key product, a group of products or technological knowledge embedded in a technological system (Bergek et al., 2008; Hekkert et al., 2007).

All the various innovation system approaches distance themselves from a linear line of thinking that cannot capture the iterative and complex processes of innovation (Edquist, 2005). This also implies distance from neo-classical economics and a rejection of rational actors and equilibrium (Fagerberg, 2003). Instead, according to Weber and Truffer (2017), rules and routines (Nelson & Winter, 1982), technological trajectories (Dosi, 1982), and institutions (Scott, 1995; North, 1990) are important lenses for understanding innovation. The non-linearity and implicitly self-reinforcing effects in such systems are explained by path dependency (David, 1985) and also other types of network externalities (Katz & Shapiro, 1994). Also general systems theory has inspired innovation system approaches for understanding how interactions on the actor level affect the emergence of new paths (Weber & Truffer, 2017). However, innovation system approaches should not be interpreted as a strong systems theory.

Two important contributions to the TIS approach (Bergek et al., 2008; Hekkert et al., 2007) have been around for a decade now, and have found application mainly in the energy sector. The absence of TIS studies of the ICT sector is striking, as two ICT cases were central to the development of the framework: “IT in the home care” and “Mobile data” (Bergek et al., 2008). I consider this framework to be highly relevant and applicable to analyses of innovation and technology development in the mobile telecommunications sector, as it captures a complexity, dynamic and actor presence familiar from my own work.

2.2.2 The TIS framework

The TIS approach (Bergek et al., 2008) supplements the platform ecosystem approach by providing an extensive description of the *structures* and *processes* that take a technological system from the formative phase to the growth phase (Hekkert et al., 2007). To study the emergence of a platform ecosystem with the TIS approach, a focal technology or group of products must be identified (Bergek et al., 2008). Here I understand this as being the platform

and platform ecosystem, although the TIS approach itself does not elaborate on technological systems similar to the platform ecosystem.

The TIS approach is a framework for analyzing a technological system at a specific time-point, and analyzing past events that have affected the process leading towards its current status. A TIS analysis is intended to capture what is inducing or blocking further diffusion. It looks back to investigate what took the platform to where it is today. Looking ahead, it seeks to identify all the current factors that could affect further diffusion, and to indicate the best ways to proceed. As such, TIS is well equipped to understand emergence and also to discuss strategies for further diffusion.

The *structures* in a TIS consist of actors, institutions and networks (Bergek et al., 2008; Hekkert et al., 2007). It is rich in elements to be identified and analyzed, and explanations of the role of these elements. For instance, in addition to the core platform and complementors, TIS indicates relevant actors, such as politicians, regulators, research institutes, suppliers, installers, banks, and industry associations. The institutions included in the TIS structure are formal laws, regulations and rules, and informal culture, norms, and routines. Networks may be formal or informal networks and alliances, as well as the relationships among and between actors, institutions, and technologies (Hekkert et al., 2011).

The TIS framework indicates forces, or *innovation processes*, which influence the growth and path of a technological system (Bergek et al., 2008; Hekkert et al., 2007). The approach can draw on decades of empirical research on success and failure factors in technology diffusion. This research has converged into six innovation processes (Weber & Truffer, 2017): knowledge generation and diffusion; legitimation; entrepreneurial experimentation; search guidance; resource mobilization; and market formation (Bergek et al., 2008; Hekkert et al., 2007). Some of these innovation processes embrace the legitimation and institutional dynamics noted also in the platform ecosystem literature (Gawer & Phillips, 2013). However, the TIS approach operates with a broader, more precise and better-grounded set of processes that drive innovation in a technological system. In introducing TIS, I combine observed actions and strategies reported in the platform ecosystem approach with existing concepts that capture their significance and potential effects.

In the TIS framework, the generation and availability of knowledge are critical to the creation of variety, which in turn enables the selection process and innovation and growth (Hekkert et al., 2007). Central to knowledge as a key innovation process is the ability to learn in a context where knowledge cannot be fully codified: knowledge is often tacit (Lundvall & Johnson,

1994; Hekkert et al., 2007). In a platform ecosystem, activities that could be interpreted as affecting knowledge sharing and development include coordinating events, training/education, and tools such as software developer kits (Gawer & Phillips, 2013).

Legitimacy is necessary in order to mobilize stakeholders to use the platform for innovations, and contribute to forming the demand for the platform (Bergek et al., 2008). Legitimation is the process that leads to new institutions for a technology (Bergek et al., 2008) through forming expectations and visions and mobilizing actors. Legitimacy is created in “a collective social process involving organizations such as technology developers, experts, associations or interest groups” (Markard et al., 2016). Here, the platform ecosystem literature finds support for emphasizing legitimacy and formal and informal institutions; for platform ecosystems, activities that affect legitimacy include clarifying expectations as to roles, intentions, and profits, and building—and not betraying—trust (Gawer & Phillips, 2013).

Uncertainty about applications and markets is a persistent and fundamental feature of technologies; entrepreneurial experimentation is essential for dealing with and decreasing this uncertainty. “From a social perspective, the main source of uncertainty reduction is entrepreneurial experimentation, which implies a probing into new technologies and applications, where many will fail, some will succeed and a social learning process will unfold” (Bergek et al., 2008, p. 416). The further growth of a platform requires vibrant experimentation. In the platform ecosystem approach, the importance of allowing and spurring entrepreneurial experimentation is only implicit; however, a platform’s open standards, stimulating activities, and tools will potentially affect the levels of experimentation (Gawer & Phillips, 2013).

The innovation process referred to as search guidance concerns establishing incentives to select the technology in question, and belief in its further proliferation (Hekkert et al., 2007). For innovation to happen, other firms must choose a platform; “there must then be sufficient incentives and/or pressures for the organizations to be induced to do so” (Bergek et al., 2008, p. 415). This process matches the platform ecosystem approach’s emphasis on how platforms must signal willingness to share revenues and profits with complementors (Gawer, 2014; Gawer & Henderson, 2007); for platform ecosystems, this is done through activities like conveying consistent messages and willingness to share the platform’s intellectual property (Gawer & Phillips, 2013).

Resource mobilization concerns the need to get actors to invest in people, money or other assets (Bergek et al., 2008). Such allocation of resources is “necessary to make knowledge

production possible” (Hekkert et al., 2007, p. 425). In the platform ecosystem approach, activities like cross-industry initiatives, storytelling, and care for the collective welfare of the industry may promote resource mobilization (Gawer & Phillips, 2013).

Finally, market formation is an innovation process that identifies the current phase of a technological system (Hekkert et al., 2007). Early and late phases have distinct characteristics, and other processes must be interpreted in light of these. For instance, low implementation of technologies may in early phases be signs of new technology paths, while in later phases they may be taken as complementing the technologies of pre-existing systems (Bergek et al., 2008). One suggestion from the platform ecosystem approach is that a platform emerges from a hierarchical architecture to become a platform ecosystem (Gawer, 2014); Moore (1993) indicates that an ecosystem goes through four evolutionary stages, each with its own challenges. Otherwise, little is said about the phases from infancy to maturity.

Although the TIS approach identifies and describes the major innovation processes that affect platform emergence, it does not elaborate extensively upon the logic of the self-reinforcing dynamics that lead to growth in technological systems. Therefore I turn to literature on path dependencies, to clarify how self-reinforcing effects may lead to a situation with one central platform and many peripheral complementors.

2.2.3 TIS and self-reinforcing effects

The TIS approach does recognize self-reinforcing feedback effects as a core mechanism for fueling growth in a technological system (Bergek et al., 2008; Suurs & Hekkert, 2009)—for instance, “acceleration in system change may occur when functions interact and lead to virtuous cycles” (Hekkert et al., 2007, p. 427). However, it remains challenging to grasp what these self-reinforcing effects are, and their underlying assumptions.

Both the platform ecosystem and TIS, as well as several other innovation approaches, are based on the assumption that innovation is a complex and systemic phenomenon (Bergek et al., 2008; Edquist, 2005; Fagerberg, 2003; Hekkert et al., 2007; Tushman & Murmann, 2003). Characteristic of complex systems are non-linearity and the existence of positive feedback effects. In the literature, positive feedback effects have been seen as increasing returns (Arthur, 1989), cumulative causation (Bergek et al., 2008; Myrdal, 1957; Suurs & Hekkert, 2009), or network effects (Katz & Shapiro, 1994). Recently Klitkou et al. (2015) proposed nine specific types of self-reinforcing processes that can be found in technology transition processes: learning effects, economies of scale, economies of scope, network externalities,

informational increasing returns, technological interrelatedness, collective action, institutional learning effects, and the differentiation of power.

These approaches all aim at explaining how trends are positively reinforced by how actors and previous events are mutually dependent (David, 2007). This dependence is reflected in the definition of complex system as “comprised of a population of interacting, heterogeneous agents in which the behavior of each agent can be described as a function of the behaviors of other agents, as well as of other factors” (Durlauf, 2012, p. 46). This dependence leads to a positive feedback loop, defined as follows: “A positive, or reinforcing, feedback loop reinforces change with even more change. This can lead to rapid growth at an ever-increasing rate” (Kirkwood, 1998, p. 9). Self-reinforcing effects imply an exponential growth curve.

There is empirical support to show that positive self-reinforcing effects can lead to path dependencies (Tushman & Murmann, 2003), and that one design or technology may emerge as more central and dominant, even locking the market into an inferior technology (David, 1985). The theory of path dependencies is based on the additional assumption that actors are rationally bounded with limited imagination capabilities (David, 2007). Critics of path dependencies, as theory and as empirical fact (Liebowitz & Margolis, 1995), hold that a market always will move to a better path. This point is relevant if actors are assumed to be fully rational, with full information and able to free themselves from history; thus, it misses on some of the core ideas of path dependencies (David, 2007). Indeed, there are examples of mature industries where several technologies exist side by side (Onufrey & Bergek, 2015) indicating that there are forces that modify the occurrence of only one path.

Positive feedback effects, combined with a strict assumption of bounded rationality, imply that it is highly uncertain which path will be taken in a technological system. In later phases the path-dependent process may reach a stable state which can be escaped only by an external shock or force (David, 2007). Note also that path-dependent processes may end up in states that can be perceived as both favorable and non-favorable.

Despite the unpredictability of future paths, two policies are suggested for avoiding undesirable paths (David, 2007): keeping options open for a longer period; and building knowledge and information that can enable better actions. Standards are seen as important for the evolution and continuity of technological systems (David, 1985), and as a way to mitigate blockings (Bergek et al., 2008). This is also in line with advice about keeping platform interfaces open in the platform ecosystem (Gawer & Cusumano, 2014) and having well-known design rules in modular systems (Baldwin & Clark, 2000).

In summary, the constitution of complex systems, self-reinforcing effects, bounded rationality, and path dependencies can explain the dynamics that drive the evolution of a technological system; this also indicates how one technology may become more important than others. Dysfunctional lock-ins might be avoided by, for instance, having appropriate standards. TIS does not emphasize the role of standards or technical connectors as a proactive tool in innovation processes. That is the topic of the next section.

2.2.4 TIS and technical connectors

Having well-known design rules (Baldwin & Clark, 2000) and open platform interfaces (Gawer & Cusumano, 2014) resonates with standards and compatibility within the TIS approach. However, TIS does not accord to them the same significant role—with important exceptions in cases from the telecommunications industry (Edquist, 2003).

The TIS approach does not focus on the technology itself: the focus is on “all components that influence the innovation process for that technology” (Bergek et al., 2008, p. 409). Still, there are aspects of technology that may call for further elaboration. For instance, the presence of positive feedback effects between complementary technologies has not been elaborated upon until recently (Weber & Truffer, 2017). Standards and compatibility are extremely important for complementary technologies; this is recognized in TIS, where it is embedded in the institution component.

Standards—or lack of such—are used as an example of a significant blocking mechanism for further development (Bergek et al., 2008; Markard & Erlinghagen, 2017) and inducement mechanism in the mobile telecommunications innovation system (Edquist, 2003). Recently, important contributions have been made regarding the significance of complementarity (Markard & Hoffmann, 2016) and the dynamics of standardization processes in the energy sector (Markard & Erlinghagen, 2017). These findings are relevant also for the telecommunications sector.

In sum, the TIS approach does not emphasize the role of technical connectors or open interfaces as a means of fueling innovation—only for resolving blockings. In this respect, the platform ecosystem approach (Gawer, 2014) can add new insights.

2.2.5 TIS and agency

The lack of focus on technical connectors as a proactive tool for spurring innovation brings us to how TIS differs from the platform ecosystem approach with respect to agency. The TIS

approach assumes that “actors do not necessarily share the same goal, and even if they do, they do not have to be working together consciously towards it” (Bergek et al., 2008, p. 408). Actors in a TIS may have agency on behalf of some local purpose. Further, they are seen as rationally bounded—as assumed in all branches of the innovation systems approaches and evolutionary economics (Nelson & Winter, 1982). Bounded rationality, lack of agency on the system level, and the presence of positive self-reinforcing effects all lead to fundamental uncertainty about what may happen next (David, 2007). This calls into question the ability of the platform leader to manage and plan an evolution towards a vibrant platform ecosystem.

The idea of path creation re-establishes the belief that platform leaders have capacities for management and planning (Garud et al., 2010). Here, actors are assumed to have some capabilities in constructing initial conditions, reacting to emerging situations or contingencies, manipulating and cultivating self-reinforcing mechanisms, and escaping dysfunctional paths through creative destruction. If we rely on these assumptions, it is still possible to draw on the lessons from the TIS approach (Bergek et al., 2008) for the ambitious platform leader who aims to govern the platform ecosystem (Gawer & Cusumano, 2014). Hence, actors can attempt to exert influence; however, they must also recognize they cannot determine the processes that unfold (Garud et al., 2010).

With this as a background, I see the TIS framework as helpful in explaining how a platform emerges. It can also indicate ways of dealing with challenges and managing the further evolution of a platform and platform ecosystem.

2.3 Summary

This theory review has combined the platform ecosystem and TIS approaches to form a framework that can capture my empirical observations and enable me to address the research questions on platform emergence and the role of platform interface openness. We have seen that both approaches view technologies as socio-technical systems with self-reinforcing effects, driving the technological system in a given direction. There are still some important differences, as well as some topics which neither covers sufficiently.

The platform ecosystem approach addresses the dynamics underway in the mobile telecommunications industry and can be used as a lens for understanding what we observe. This approach refers to a structure of central platforms such as Google and Facebook, with an ecosystem of complementors surrounding the platforms. It captures a focus of importance today: technical connectors on the platform interface play an essential role in spurring

innovation throughout the ecosystem. The approach signals that a platform leader can act strategically and assume a central position in an ecosystem.

However, the platform ecosystem approach is less useful for explaining how a platform and platform ecosystem actually emerge. The platform ecosystem approach includes only the platform and complementors in the technological system. Institutions, networks, and other actors are not dealt with, nor are the various types of processes driving the innovation systemized or explained. To a large extent, the TIS approach helps to correct these shortcomings. The relevant structure includes more actors, institutions, and networks, and the processes essential for driving innovation are described and explained.

However, TIS lacks something where the platform ecosystem is strong: the role of *interface openness* is not emphasized, except for indicating standards as a way to mitigate blockings in a technological system. Neither is the structure that consists of one platform and complementors elaborated upon, even though this is common in markets today.

Furthermore, actors in a TIS are not ascribed agency on behalf of the whole system—and that lessens its value as a tool for strategizing on behalf of a platform ecosystem. That being said, it has been suggested that actors in a TIS can act to shape the path on which they find themselves—knowing, however, that they cannot fully determine its direction.

We see how the two approaches complement each other. In addition, we have seen that the approaches share two shortcomings. First, even though both address technologies as complex systems, neither of them fully explains the assumptions, mechanisms, and implications of this perspective. In that respect, the review has clarified and described in greater detail how the existence of heterogeneous, interacting, interdependent events and rationally bounded actors may lead to positive self-reinforcing effects and, in turn, to path dependencies. This is a context characterized by high uncertainty.

Secondly, neither approach can fully describe the constitution of platform interface openness. Arguably, the platform ecosystem approach, with good help from modularity theory, can explain how well-known design rules on module interfaces may spur innovation. However, this fails to explain the non-technical factors that affect the openness of platform interfaces, nor are such factors combined with processes already known to affect innovation. This thesis contributes empirical research that can help to fill this gap in theory.

3 Summary of articles and methodology

This thesis is built around three articles. In this chapter I briefly summarize each of them, and then indicate how they relate to my research questions. Four themes are central here: the platform in each article, the complex process of platform emergence, positive feedback effects, and platform interface openness. These themes are also the headings for my general answer to the research questions in the discussion in Chapter Four.

The publication history of each article is presented; and, in the concluding section, the articles are described and compared according to research design and methodological choices. Table 3-1 presents a brief comparison with regard to all these aspects.

3.1 Article 1: Key success factors for a growing technology innovation system based on SMS Application-to-Person in Norway

This article on SMS Application-to-Person in Norway analyzes the re-emergence of SMS as a significant channel for customer dialogs, particularly in Norway. SMSs are increasingly used for everything from arranging dental appointments to communicating with the tax authorities. SMS Application-to-Person is a recent phenomenon. As it was not known which factors could explain the current growth, a case-study approach was appropriate. Many data sources were used, but interviews with actors from technological innovation systems were especially valuable. The platform ecosystem approach was the main theoretical lens used in developing the interview guides. Later, the TIS approach proved appropriate for systemizing and explaining the findings. The growth of SMS Application-to-Person appears to be an evolutionary process that has taken a specific path, with reinforcing feedback loops.

3.1.1 Contribution to research questions

In this article SMS Application-to-Person is interpreted as a platform. The platform here refers to the functionality of SMSs sent between applications and private persons. More specifically, platform ownership is shared among several mobile network operators. The complementors here are the firms that aggregate, integrate and use SMSs in yet other dialoguing solutions with consumers. This constitutes the platform ecosystem. Using the TIS approach, the technological system is seen as consisting of all the actors, networks, institutions involved in the evolution, dynamics and innovation processes that have brought the system to where it is today.

An early hypothesis in the work with the article was that an existing open platform interface—an application programming interface—could explain the success, in line with theories on platform ecosystems.

However, an open-minded approach to tracing historic events and status indicated that the explanations were much richer than merely the existence of an open platform interface. Thus, one important finding is that an open interface is a necessary but far from sufficient condition for the emergence of a well-functioning technological innovation system.

It emerged that institutional factors such as collaboration and trust between actors induced further innovation. The relationship between mobile operators and aggregators—the platform and complementors—is governed by informal rules and expectations. The mobile operator assumed a withdrawn role, letting the aggregators add value, front the market, and extract revenues. Thus, aggregators were willing to experiment and invest. The actors' ability to collaborate and strike a balance between developing and sharing the market proved crucial.

Furthermore, strong processes of legitimizing the use of SMS for business and public purposes were found to be important. Also many formal decisions and events regulating the mobile subscriptions and use of SMS in marketing have influenced platform emergence. These decisions were basically beyond the control of the firms involved—a situation they were skeptical of, only at a later stage acknowledging as positive. For instance, regulation of SMS in customer dialogs had been expected to restrict revenue potential; later, this regulation ensured an attractive spam-free channel.

The article reveals the complexity and richness of the process, from the initial technology opportunity to a profitable market. Strong positive feedback effects were also found—two-sided market network effects, and system and knowledge feedback loops. The article shows how users developed skills in marketing dialogs with SMS, how the market increasingly recognized the SMS as a convenient channel for communications, and also how the mobile number and SMS became integrated into software and systems.

The case of SMS Application-to-Person took place in an existing market structure where actors were already present in a dense network, with considerable sharing of knowledge. Thus, the network structure was well-suited for enabling the growth of SMS Application-to-Person, a factor known to enable innovation. As such, this article can also be taken as showing the strength of a pre-existing path, where a stable core and dynamic periphery were reinforced, but in a new direction.

Finally, the growth of this specific use of SMS has varied between countries, depending on local regulations, but also whether consumers are accustomed to this way of communicating. Positive feedback effects emerged between actors and institutions directly connected in local networks. Thus, the case also indicates how the evolution of a platform ecosystem maybe locally bounded.

3.1.2 Publication history, Article 1

Published:

Hallingby, H. K. 2016. Key success factors for a growing technology innovation system based on SMS Application-to-Person in Norway. *Technology Analysis & Strategic Management*, 28(10), 1123–1137.

3.2 Article 2:

Mobile phone number as a general-purpose identifier: status and future

Article 2 is a multiple case study of the mobile number as a general-purpose identifier. It demonstrates that strength and availability are self-reinforcing factors that affect the continued relevance of the mobile number as identifier.

The article begins by assessing the current global status of strength and availability of the mobile number, before turning to the analysis of two cases, from Norway and Pakistan, where the mobile number was already a trusted resource. These two cases involve a developed and developing economy, respectively; but both are characterized by strong, readily available mobile numbers, and innovative uses of digital services. Interview data from Pakistan and Norway were central for understanding the position the mobile number can have in digital services. Several additional data sources also shed light on the strength and availability of the mobile number across the world.

This study draws on insights from theories on evolutionary economics, technological systems, and information infrastructure. The use of theory served two main purposes: conceptualizing the mobile number as a phenomenon, and explaining the relationship between the mobile number and explanatory factors through theory pattern-matching.

3.2.1 Contribution to research questions

Article 2 built on an observation in Article 1: a resource provided by the mobile network operators—the mobile number—found new application as a general-purpose identifier.

Previously, mobile numbers had been discarded partly as identifier in the current web and Internet context, in favor of identifiers from Facebook and Google for digital services. However, the mobile number is an extremely open resource, not only because it is standardized: the holder of the mobile number may choose to share it and immediately start an interaction where the mobile number serves as identifier.

This article does not rely explicitly on the platform ecosystem approach. Still, the mobile phone number can be interpreted as a platform, where the complementors are all the technology and service providers who use it as a resource for identifying customers and clients. The technological innovation system in this article can be interpreted as being the mobile number, and all the actors, networks, institutions, and innovation processes affecting its evolution. Given these perspectives, the self-reinforcing factors found to affect further diffusion of the mobile number were particularly interesting.

Strength and availability are concepts developed in the article to capture important elements such as institutions and existing information infrastructures. The article elaborates on how these aspects of the mobile number could spur its further evolution—depending on local conditions. Together with a general review of the global status, the two studies from Norway and from Pakistan illustrate this point.

The *strength* of the mobile number concerns requirements for ID credentials when purchasing a prepaid SIM card. Depending on how strict these requirements are, different informal institutions may develop; people and firms situated in different regimes tend to develop differing levels of trust and expectations to what the mobile number represented. Around the world, increasingly stricter ID requirements had been introduced in 2012; today, most global mobile connections are subject to strict requirements especially in large developing (often Asian) countries like India and China. Among the minority that does not practice strict ID requirements we find high-tech countries such as the USA and the UK.

Both Norway and Pakistan practice strict requirements for ID credentials. Even though these countries are very different, we see that a strengthened mobile number has opened the way to new innovations and applications in the ecosystem. In Norway, SMS Application-to-Person has grown continuously, and in Pakistan the digital mobile wallet has taken a leap.

The *availability* of a mobile number refers to its implementation in existing databases and directories. In the Nordic countries, for instance, mobile operators were obliged to support directories of mobile numbers; the mobile number also seemed deeply coded into

technological solutions as well as human minds. In Pakistan, by contrast, public directories for mobile numbers have not existed; however, an advanced public ID database has served many governmental and also commercial purposes. In different ways, how the mobile number has been integrated into existing databases and directories has reinforced its further growth.

The study reported in Article 2 shows how the strength and availability of the mobile number have been important non-technical factors for further diffusion; however, these have been predominantly local structures and processes, despite the presumably open characteristic of the mobile number. It will be interesting to follow the future evolution of the mobile number as an example of local versus global forces, with the majority of developing economies versus a minority of high-tech countries.

3.2.2 Publication history, Article 2

As of March 2018:

This version submitted to *Telematics and Informatics*

Previous version:

Hallingby, Hanne Kristine. 2016. The status of the mobile number as a general-purpose identifier: elaboration on cases from Norway and Pakistan. Paper presented at 27th European Regional International Telecommunications Society Conference, September 7–9, 2016, Cambridge, UK.

3.3 Article 3: Platform openness and innovation: A case study from the mobile telecommunications industry

Article 3 investigates the openness of platform interfaces beyond technological specifications, and how this affects innovation processes. It thus concerns a frequently reiterated statement of a relationship: platform interface openness in the form of technical connectors such as application programming interfaces (API) affects innovation and growth.

The article draws on a two-stage multiple case study research. The first stage analyzed interface openness of existing platforms in the mobile telecommunications industry: Google, Apple, IETF, W3C and 3GPP. This entailed developing a conceptual model for platform interfaces and non-technical criteria to assess their openness. Next this assessment was downplayed; however, the conceptual model was used as a foundation for discussing different aspects of interface openness with informants. The case-study method was chosen, in order to

identify and understand the complex relationships between interface openness and innovation. Many other data sources were used in addition to the valuable interviews.

The article reveals the complex and many-faceted association between platform interfaces and increased innovation and growth. The study systemized non-technical factors that affect interface openness, seeing platform openness as more than application programming interfaces (API), standards and open source. Precisely how these non-technical factors affect innovation and growth was explained by combining them with concepts familiar from the technological innovation system approach.

3.3.1 Contribution to research questions

Platform emergence and the extended platform ecosystems are not elaborated on in Article 3, which focuses on the non-technical factors affecting platform interface openness, and how this in turn may affect innovation processes.

The article indicates that a platform has two interfaces where openness has significant effects on innovation and growth: the complementor and the vendor interface. The complementors here were the actors known from the platform ecosystem approach. The analysis in Article 3 indicated quite early that platform openness also concerns the development of the platform, and an interface towards all those suppliers, vendors, institutes, universities and experts who contribute to building and innovating with the core platform. With the complementor interface, the technological means for governing openness was found to be application programming interfaces; with the vendor interface, it was standards and open source.

For each of these two interfaces, the study developed lists of specific non-technical factors affecting platform interface openness. Some of these overlapped between the interfaces, others were substantially different. Factors involved here included documentation of the platform and the interfaces, fees and rules for participating in development and use, well-functioning systems for experimenting and operation, and administration of contracts and obligations. Other less tangible factors included how decisions were made, the transparency of the system itself, and how it was governed. The existence and enabling of a community with other stakeholders was also found to be important for platform interface openness.

The study also shows how these non-technical factors in turn affect innovation processes familiar from technological innovation systems: knowledge generation and sharing, legitimation, entrepreneurial experimentation, and guidance of the search. This can help us to

understand how and why non-technical factors may serve to open platform interfaces, thereby boosting innovation and growth of the ecosystem.

The platforms in question were complex, and knowledge was tacit. Available documentation opened up the platform, as did communities where such knowledge was developed and shared. Insight into decisions and intentions, exclusion and inclusion in forums and communities, professionalism in handling stakeholders—all emerged as factors that can build or disrupt the legitimacy of a platform. A platform that fails to understand the significance of legitimacy and trust may effectively close down platform interfaces and deter further adoption, innovation, and growth. Conversely, a platform can increase its openness by making it easy to explore and experiment with its resources, and by letting others find out for themselves if there are business opportunities in view. The study further found effective closure of the platform if it did not signal reliably its intention to share market profits with other stakeholders.

Finally, Article 3 indicates the need to acknowledge closure in order to profit, but noted that there were more (and less) legitimate ways of doing this—a recurrent consideration. For instance, closure that violates end-user experience is not well regarded. Legitimate ways of closing a platform and achieving a position where profits can be extracted build on knowledge generation and sharing. Acceptable ways of profiting from closure might include tacit knowledge advantages, private data, module secrecy, or private code on top of open code.

3.3.2 Publication history, Article 3

As of March 2018:

This version submitted to *Technological Forecasting and Social Change*

Previous versions:

Hallingby, Hanne Kristine. 2016. Platform openness in the mobile ecosystem: implications for adoption and appropriation conditions. Paper presented to 3rd World Open Innovation Conference, December 15–16, 2016, Barcelona, Spain.

Hallingby, Hanne Kristine. 2016. Interface standard governance and openness in the mobile ecosystem: implications for innovation. In: *Proceedings, 21st Annual Standardisation Conference, “Co-opetition and Open Innovation,”* June 29–July 1, 2016, Montpellier, France.

Hallingby, Hanne Kristine. 2014. Analysing standardisation processes as technology trajectories in the mobile ecosystem: implications for competition and innovation. Paper

presented to ITS Biennial Conference, November 30–December 3, 2014, Rio de Janeiro, Brazil.

Hallingby, Hanne Kristine. 2014. Revealing of technology: a strategy to meet the open innovation paradox in the mobile ecosystem. Paper presented at ASIALICS, October 24–26, 2014. Daegu, South Korea.

3.4 Methodology

This section explains the prerequisites and methodological choices in the articles of this thesis. A foundation and major element has been my affiliation with Telenor, a global mobile telecommunications operator, where I am employed as a research scientist. This thesis is an industrial PhD, financed by a firm, in this case Telenor, together with the Norwegian Research Council. Clearly, my work affiliation has shaped the research direction and focus of this thesis. It may have brought greater research efficiency through increased access to data, but it may also have also introduced some limitations as to research validity. I return to these aspects in further detail below.

As noted, the main design for the studies in this thesis was case-study research (Yin, 2014). This seemed appropriate as I was studying platform ecosystems as contemporary empirical phenomena beyond my personal control. The research questions focused on *why* and *how* platforms emerge. I sought to uncover the non-technical factors that contribute to platform interface openness, and explain *how* they contribute to innovation, and *why* they are important. Obviously, I was concerned with factors that cause yet other things to happen, while acknowledging that these relationships would be complex and many-faceted.

This urge to explain could be understood as *abduction*. This involves first observing a fact, and then explaining how it happened by using a theory (Valsiner, 2012). As there may be several theories that can explain the same fact, abduction implies an effort to find the best explanation. In my research, the platform ecosystem approach was the initial lens used for describing the phenomenon in question. Later, I drew heavily on the technological innovation systems approach to explain how a platform ecosystem can evolve from infancy to maturity.

Abduction is often contrasted to *induction*, which does not have this clear characteristic of explaining. An inductive approach is more exploratory; it is about collecting, interpreting, and making sense of data in order to fill gaps and build new theory (which may involve explanations of relationships) (George & Bennett, 2005; Pratt, 2008). Especially in Article 3,

the first stage of the research process was more inductive; in the next stage, I was able to draw on existing theory and concepts.

Table 3-1 Overview of PhD articles

<i>Article</i>	<i>Article 1</i>	<i>Article 2</i>	<i>Article 3</i>
Title	Key success factors for a growing technology innovation system based on SMS Application-to-Person in Norway	The status and future of the mobile phone number as a general-purpose identifier	Platform openness and innovation: A case study from the mobile telecommunications industry
Research question	What are the success factors of a rapidly growing SMS-based mobile commerce ecosystem?	How do strength and availability affect the mobile phone number as general-purpose identifier, locally and globally?	How and why do platforms open their interfaces beyond technological specifications?
Phenomenon in focus	Platform diffusion: SMS Application-to-Person in Norway	Platform diffusion: Mobile phone number as general-purpose identifier	The concept of platform openness
Method	Explanation-building single case study	Explanation-building multiple case study	Explanation-building multiple case study
Sources	Interviews, web-sites, regulatory documents, service descriptions, reports, media outlets	Interviews, web-sites, wiki-data, regulatory documents, industry reports, industry intelligence web-sites, survey, media outlets	Interviews, company web-sites, white papers, conceptual evaluative documents
Analytic approach	Open-ended approach; induction and abduction. Several cycles of coding. Seeking deeper meaning, rather than counting code occurrence. Data and theory pattern-matching.		
Main contribution to thesis' research question	Processes from the TIS approach explain well the emergence of a platform ecosystem for SMS A2P; technical connectors are a necessary, but not sufficient condition.	Concepts from the evolutionary and systemic innovation approaches, and information infrastructures explain well how the mobile number can evolve into a significant general-purpose identifier.	Platform openness in the form of technical connectors must be complemented by non-technical factors. Together, these factors affect processes from the TIS approach, recognized as important for innovation and growth.

I myself conducted most of the research for this thesis, the exception being the design and collection of data from Pakistan in Article 2. That research was done as a part of a different Telenor project on mobile financial services, where I was able shape, collect, and analyze data

that could shed light on my specific research questions. These data were then combined with data I had collected in Norway concerning SMS Application-to-Person.

Article 1 is a single case study of SMS Application-to-Person in Norway, a market where this service had grown exceptionally fast. Both the uniqueness of this case and my extraordinary access to data justified a single case study approach (Yin, 2014), only superficially compared to the situation in other countries. In Article 2, data from Norway were combined with data from Pakistan to discuss the mobile number as a general-purpose identifier; thus, Article 2 is a multiple case study. Again, my access to data helped to justify combining these two cases.

Article 3 is also a multiple case study in the sense that I collected data and interviewed informants concerning five platforms. The platforms were expected to differ in their practices as to platform interface openness, but be similar in processes affecting their practices. Thus, this was a theoretical replication case study where I expected to find contrasting results for predictable reasons (Yin, 2014). The multiple cases ensured that a broad set of factors affecting interface openness could be discovered, analyzed, and matched with theory.

In all the case studies and articles, I relied on a range of data sources, such as interviews, websites, white papers, regulatory documents, surveys, and media outlets. This triangulation of data sources ensured greater research validity. While drawing on many sources, I found my interview respondents to be an especially valuable source of insights. In all three articles, my respondents had various roles and backgrounds, for instance in firms, public bodies, and industrial and non-governmental organizations. This provided a broad set of inputs.

Informants were recruited by “snow-balling” of colleagues and experts, and I focused on including many perspectives. I conducted most interviews alone; in Pakistan we were four researchers who together interviewed informants.

Interviews were basically open-ended, although the concept of platform ecosystems shaped the questions in the interview guides. The platform ecosystem approach was helpful in evoking respondents’ deeper opinions on relevant themes; and I encouraged them to elaborate on how they perceived the dynamics in their sectors, and to offer explanations for how and why things had turned out in a specific way. My aim was to capture their beliefs, assessments, and views on tensions with regard to the platforms we discussed (Saldaña, 2013). In the case of platform openness in Article 3, two rounds of interviews were conducted, with different respondents. The second round was more focused, and respondents also gave feedback on a conceptual model of platform interfaces and openness.

I transcribed most of the interviews myself; I also coded and analyzed the data, primarily using NVivo, a software tool for qualitative analysis. The platform ecosystem approach was important in the first cycles of coding, but did not provide further useful concepts for theorizing—hardly surprising, as the research questions concerned gaps in the platform theory (Gawer, 2014; Gawer & Cusumano, 2014). For all articles, the collection of qualitative data and subsequent coding was aimed chiefly at grasping meaning about a phenomenon (Miles et al., 2014), not for descriptive counting of code occurrence (Saldaña, 2013).

Later, in the second and theoretical coding cycle (Saldaña, 2013), it became clear that the technological innovation systems perspective could provide pre-existing concepts that I could use. These concepts, their role and relationships in technological systems were already well defined, and matched my interpretations. Article 2, concerning mobile numbers, drew on yet other approaches to technological systems.

In case-study research, the building of explanations for observed empirical data through theoretical pattern matching is important to increase validity. This is an iterative process where “the case study evidence is examined, explanatory propositions are revised, and the evidence once again from a new perspective” (Yin, 2014, p. 146). As noted, platform ecosystem proved useful in designing the investigation (for instance, the interview guides), but was later supplemented by other approaches. This pattern matching of the data with technological innovation systems both validated my findings and made possible a more general theoretical contribution.

My affiliation with Telenor gave access not only to informants, but also to other sources. The traffic data for growth of SMS Application-to-Person came directly from Telenor. Through the regulatory departments in Telenor I was able to survey conditions for the mobile numbers in very different markets in Scandinavia, Eastern Europe, and Asia. My affiliation also provided access to the GSMA intelligence database (GSMA, Database). The combination of sources in Telenor and externally enabled me to validate my findings. For instance, I was able to qualify the data I found in a wiki on ID requirements for SIM cards, by comparing them against detailed insights from a Telenor inquiry; thus, I found the external source to be trustworthy. Likewise, I was able to validate figures from the State Bank of Pakistan with information on growth for Easypaisa, a mobile bank controlled by Telenor.

However, my association with Telenor and use of Telenor sources might also have skewed the results. I may have been insufficiently objective, unable to recognize the broader picture of the topics under study. Perhaps a sense of loyalty to Telenor and similar actors may have

hindered me in identifying or pursuing topics that should have been scrutinized in greater detail. I approached these possible problems by taking care to have a broad set of perspectives represented among my respondents. Further, the use of multiple sources, respondents' feedback on concepts, and theory pattern-matching were intended to increase the validity of my case study research; this should also have mitigated any tendency to overlook important patterns and suppress findings that could be negative for Telenor or similar firms.

4 Discussion

Here I return to the research questions underlying this thesis. I then discuss its contributions to theory, and the managerial implications, before concluding with some remarks on the limitations of this work.

The literature indicates that the concept of platform ecosystems can explain the empirical phenomenon of one central and many peripheral, complementing technologies (Baldwin & Woodard, 2009; Gawer & Cusumano, 2002; Iansiti & Levien, 2004; Murmann & Frenken, 2006). However, the platform ecosystem approach cannot sufficiently explain how a platform emerges, or the role of platform openness. Therefore, this thesis asked:

- How does a platform emerge?
- How does interface openness play a role in platform emergence?

These are important questions, both for firms seeking profit and for policymakers regulating or incentivizing innovation in such settings. Based on the theory section and the three articles presented in this thesis, I now return to the research questions by commenting on four themes. First, I explain what I understand as platforms in this discussion, as well as reflecting on the reach and relevance of this concept. Second, I discuss how platform emergence is a complex process that unfolds over time. Third, I emphasize positive self-reinforcing effects as drivers in this process. Fourth, I discuss the role played by platform interface openness.

4.1.1 The platforms studied

In this thesis I employ the concept of platform ecosystems to explain the technological phenomena to be studied. In Article 1, the case of SMS Application-to-Person is explicitly analyzed and denoted as a platform ecosystem; also the case of the mobile phone number (Article 2) can be understood as a platform. These examples are platforms in the sense that they are services provided by many mobile operators together. They serve as a foundation upon which aggregators, firms and public bodies can build further complementary services and innovations: together, this constitutes a platform ecosystem. Both SMSs and mobile numbers are sufficiently open to allow others to plug in, innovate and profit. This is all according to the definitions of platform ecosystems introduced in section 2.1 above (Gawer & Cusumano, 2014). In Article 3, the cases analyzed were already acknowledged as platforms. In the subsequent sections I discuss the research questions as if my cases were platforms. First, however, some words on whether the cases I discuss fit into the platform definition—

after all, they involve a quite heterogeneous collection of companies and technologies. One obvious justification for putting them in the same category lies in the chosen methodology approach, where I search for relevant existing theory, adapt it to the data, and seek to develop theory further (Yin, 2014). Moreover, these cases were already referred to as platforms (Gawer, 2009).

Still, there are some issues regarding denoting my cases as platforms. For instance, many of the large global platforms (Manjoo, 2016) are controlled by *one* company, as is the case with Facebook, Apple, and Google. And yet, the definition of platform indicates that platforms may be developed and managed by more than one firm (Gawer & Cusumano, 2014). In that sense, then, mobile telecommunications, the Web and the Internet can be seen as platforms (Gawer & Cusumano, 2014), however, not so often advanced as examples.

All the same, the shared platform ownership has made development, diffusion and use more complex; it has involved far more actors, concerns and obstacles (Reuver et al., 2014; Schmidt & Werle, 1997). In this respect, the platform ecosystem concept is an oversimplification. For instance, in this thesis, I have emphasized that a well-functioning relationship between mobile operators was very important in enabling the expansion of the total market for SMS Application-to-Person in Norway; in other markets, failed relationships were seen as an obstacle to growth. Joint collaboration became *the* winning platform, whereas continuing to compete represents a huge challenge. Further, assuming that the platform is the only attractive role may affect both creativity and collaboration in an ecosystem that involves so many interdependencies.

In my view, using the TIS approach in this thesis has mitigated these shortcomings of the platform ecosystem approach, by extending volume and types of relevant actors and their relationships, and the institutions regulating them. In particular, the discussion of the many interdependencies in technological systems (Bergek et al., 2008; Hekkert et al., 2007; Hughes, 1987) and information infrastructures (Hanseth & Lyytinen, 2010) holds that actors encounter a far more complex landscape of roles, relationships, and business opportunities than communicated in the platform ecosystem approach.

I feel that applying the platform definition to my cases can be very well justified as regards the second half of that definition (Gawer & Cusumano, 2014): a platform serves as a foundation for the further innovation of complementors. This aspect concerns a fundamental mechanism for innovation—variety creation and recombination (Baldwin & Clark, 2000; Fagerberg, 2003)—so that the innovation system does not dry out or stagnate. In Article 3 in

this thesis, I note how the mobile telecommunications industry, despite its extensive collaboration with other operators and actors in the industry, has remained introverted, allowing less innovation in its ecosystem. Thus, the emphasis on the relationship between the platform and complementor roles is an important supplement.

That being said, a more prosaic explanation for the difference between single- and multiple-control platforms may be the latter's maturity and exposure to market regulations. The telecommunications industry and Internet have been subject to strict regulations regarding licenses, competition, and user rights. In the aftermath of the presumed Russian interference in the 2016 US election campaign there have come increasing calls for control and regulation also of Google, Amazon and Facebook platforms (Coy, 2017), in order to protect user rights and ensure fair competition. What remains to be seen is whether and how these companies will be regulated and will thus have to tackle shared platform ownership.

In summary, it can be said that the platform concept is too narrow for the very different cases discussed in this thesis. Still, I would argue that the comments and answers to my research questions concerning platforms (see below) are valid for the whole assembly of cases. In part, this is because I have also used the TIS approach, and implicitly understood the platform as a technological system that is broader and more multi-faceted than indicated by the platform ecosystem approach. In addition, the platform ecosystem approach contributes important insights on the relationship between a platform and complementors. In my view, it is precisely this combination of these two approaches that makes possible relevant and valid responses to the research questions on platform emergence and openness.

4.1.2 Platform emergence: a complex process unfolding over time

The first point I want to make is that a platform emerges as a result of a complex process over time. Together, the articles have shown that there are many interdependent actors involved in a web of decisions, actions, and responses. The description of platform emergence with such structures and dynamics relies to a great deal on TIS (Bergek et al., 2008; Hekkert et al., 2007) and is an addition to the platform ecosystem approach (Gawer & Cusumano, 2014).

One important contribution from TIS has been to expand the set of actors that influence the emergence of a platform, beyond the platform and complementors. Actors identified in this thesis include mobile operators, regulatory bodies for telecommunications and financial services, significant firms and public bodies using the services, aggregators and integrators,

industry associations, non-governmental organizations, investors, consumer rights organizations, and consumers.

The TIS approach also introduced institutions as an important element in the structure of a platform ecosystem. In the cases studied, some of the decisions made were formal institutions in the form of regulations, rules or requirements. Although a formal institution was originally implemented for specific reasons, with time it became important for taking the evolution of the cases in new, unforeseen directions. This underscores how the emergence of a platform may be both unintentional and unpredictable.

For instance, the requirements for ID credentials for mobile subscriptions in the Norwegian and Pakistani context (Article 2) were based in security concerns. When digital services became more common, this meant that service providers could know that the mobile numbers used in their services belonged to a person. The strict regulations of SMS as a marketing channel in Norway (Article 1) had the unintended effect that this channel was later less exposed to spam.

The cases also showed how informal institutions like norms and expectations affected their emergence. Norms may be embedded in a culture, but they may also be formed over time. For instance, mobile operators' use of SMSs in their own customer support shaped consumer expectations and practices; consumers became used to interacting with an application via SMS and sharing their mobile number with commercial firms and official bodies.

In all the cases presented in this thesis, the legitimation process was especially important for building the informal relationship between the platform and the complementors using it. In the SMS Application-to-Person case, a trust-based relationship was built over time, based on predictability, sharing of revenues and roles, and transparency. Mobile operators had to demonstrate that they would leave part of the market to other actors. Subsequently, complementors took the risk of experimenting, investing and developing services that in turn expanded the whole market. In this dynamic, also innovation processes like search guidance and entrepreneurial experimentation were important.

This all illustrates how relationships between actors in an emerging platform ecosystem are finely tuned and a result of decisions, actions, and signaling over time. In such relationships it is not possible for one platform manager to dictate the premises; it is a much more complex process where acceptance and trust from other stakeholders must be earned.

For managers, this is vital to platform governance throughout all phases. Also public bodies should be aware of the potential formative effects of their regulations and innovation policies.

4.1.3 Positive feedback effects: driving platform emergence

The second point I wish to make is how the complex innovation processes in platform emergence is subject to distinct positive self-reinforcing effects, for instance regarding legitimation and guidance of the search. In this thesis I presented the mobile telecommunications industry as a complex system where actors and technologies interact and are interdependent in their development and operations. In such complex systems we should expect positive feedback effects (David, 2007); arguably, feedback effects are integrated in both the platform ecosystem (Gawer & Cusumano, 2014) and TIS approach (Bergek et al., 2008; Suurs & Hekkert, 2009).

In the SMS Application-to-Person case there were two-sided network effects in the sense that a huge base of mobile subscribers attracted “the other side”—firms and official bodies (Gawer, 2014). There were also other types of self-reinforcing effects, like strong knowledge and system feedback loops. End-users gradually developed skills in SMS-based dialogs, easily handling different codes. Service providers and public bodies implemented the mobile number and associated functionality into their software.

The positive system feed-back effects were even more explicit in the case of mobile phone numbers as general-purpose identifier. For instance, the integration of mobile numbers into existing information infrastructures such as public and private mobile-number databases (Hanseth & Lyytinen, 2010) appears to have had significant reinforcing effects on the technological system.

Positive feedback effects were also a force behind legitimacy, trust, and expectations. For instance, when one large actor signaled its intentions, this incentivized others to join. In the SMS Application-to-Person case, large banks and public bodies legitimized the use of SMS in customer dialogs, probably fueling its further evolution. In the case of mobile numbers, the joint effort of transferring financial funds to impoverished female beneficiaries in Pakistan built bonds between actors. Thus, positive feedback effects may include a quite comprehensive set of processes; the above examples indicate reinforcement processes such as learning effects, technological interrelatedness, institutional learning effects, and collective action (Klitkou et al., 2015).

These findings are important, as they show how positive feedback effects are present in complex technological systems. This sets expectations as to how a platform will emerge and grow; it also underscores the fundamental uncertainty present in a system with interdependent actors and self-reinforcing effects (David, 2007). It extends our understanding of the breadth of potential positive feedback effects regarding knowledge, economics, relationships, systems, institutions, and legitimacy. In sum, positive feedback effects concern much more than the two-sided network effects emphasized in the platform ecosystem approach (Gawer, 2014).

These are dynamics that platform leaders and politicians should acknowledge in their strategies and regulations. These insights are relevant to the growth curves used in planning, to how they relate to uncertainty and prepare for unexpected events, and how they attempt to govern different types of positive self-reinforcing effects.

One implication of introducing more actors and processes that affect the emergence of a platform is that a fair share of these can be local. Arguably, many of the factors discussed in the case studies in this thesis were specific and local to a given market. For instance, requirements for ID credentials for mobile subscriptions varied across markets. End-users' willingness to supply their mobile numbers was a cultural factor embedded both in history and recent practices. When local factors play a significant role, the positive self-reinforcing effects may lead to local growth and innovation, as seen in the cases of SMS Application-to-Person and mobile numbers as general-purpose identifier.

Interestingly, even “universal” resources like SMS and mobile numbers may take local evolutionary paths. Thus, in settings where local institutions, culture, and past events matter, these processes should be catered to locally.

4.1.4 Platform interface openness

The final point to be made concerns the role of interface openness in platform emergence. I see platform interface openness as only one of many factors that may affect platform emergence over time—for instance, in the SMS Application-to-Person case, technical connectors were necessary but not sufficient to drive the evolution. In addition, I hold that the concept of platform interface openness itself must be supplemented by many non-technical aspects in order to capture the degree of openness.

Article 3 explicitly assessed and discussed platforms in the mobile telecommunications industry in terms of interface openness. The results were clear: platform interface openness is not merely a matter of open technical connectors. Many non-technical factors were found to

affect the openness of platform interfaces, such as fees, documentation, administration, user interfaces, transparency, and the building of communities. In turn, these non-technical factors served to build legitimacy, expectations, knowledge, and trust. Thus, we see that the non-technical factors of interface openness affect innovation processes known from the TIS approach, such as knowledge generation and sharing, legitimation, entrepreneurial experimentation, and guidance of search (Bergek et al., 2008; Hekkert et al., 2007).

This finding is important, because it expands our understanding of platform interface openness beyond technical connectors. Specifically, the findings list many different non-technical factors that affect platform innovation openness, together with an explanation of which innovation processes that are affected. This helps to lessen the mystique and fuzziness surrounding technical connectors and platform interfaces (Gawer, 2014). Managers can take advantage of these insights in their governance of platforms, and politicians can better assess and propose innovation policies.

4.2 Contributions to theory

By addressing the two research questions on platform emergence and openness, this thesis contributes to theory on the platform ecosystem approach. Further, the findings on platform interface openness provide new perspectives that could be added to the TIS approach.

4.2.1 Platform ecosystems

This thesis contributes to theory on platform ecosystems (Gawer, 2014; Baldwin & Woodard, 2009; Iansiti & Levien, 2004; Tiwana et al., 2010) by proposing a specific lens for explaining how a platform emerges, and how technical connectors must be supplemented by non-technical factors.

First, the use of the TIS framework enables a better understanding of how a platform emerges. In addition to platform and complementors, the ecosystem consists of many highly influential actors, institutions, and their relationships. For example, Article 2 has shown how both formal and informal institutions regulate the use and expectations of mobile phone numbers as a general-purpose identifier. Regulatory authorities, official bodies that are also users, consumer rights organizations, investors and industry associations are actors that were involved in cases in Pakistan and Norway.

Furthermore, the platform ecosystem approach can draw on the innovation processes that the TIS approach sees as taking place in the relationships between these actors and institutions. In

the cases presented in this thesis, ability to experiment and profit, legitimation, and shaping of informal institutions and trust were important processes for further diffusion. These innovation processes are subject to positive reinforcing feedback effects that go beyond the two-sided network effect emphasized by the platform ecosystem approach. For instance, the SMS Application-to-Person case indicates knowledge and system feedback loops, while the mobile number case notes the reinforcing effect of existing information infrastructures.

Second, the thesis provides insights into the constitution and role of openness on platform interfaces beyond technical connectors. For instance, the studies of SMS Application-to-Person and mobile numbers indicate that well-known design rules (Baldwin & Clark, 2000) are important factors for diffusion in systemic technologies, but are not sufficient conditions for innovation and growth. This finding helps to lessen the fuzziness surrounding the constitution of platform openness (Gawer, 2014).

Thus, this thesis systematizes several non-technical factors found to be equally important as the technical connectors on the platform interface, such as participation, fees, documentation and transparency. Next, the thesis explains the role of these specific non-technical factors in terms of how they affect the above-mentioned innovation processes in a technological system. The platforms contribute to openness through knowledge generation and sharing, legitimation, entrepreneurial experimentation, and search guidance. For instance, in the case of SMS Application-to-Person, the high levels of trust and predictability developed between mobile operators and aggregators were vital for inducing investment and innovation.

Thus, the thesis indicates that platform interface openness—and thus “well-known design rules”—is a concept that must be understood far beyond reference to technical connectors. This is relevant also for the modularity approach (Baldwin & Clark, 2000): the full effect of design rules and modularity can be grasped only when platform openness is acknowledged as both a technical and a social concept.

4.2.2 Technological innovation systems

This thesis indicates that there exist market structures that resemble platform ecosystems in current high-tech industries (Gawer, 2009). Such phenomena should be recognized as one specific outcome of technological innovation system (Bergek et al., 2008; Hekkert et al., 2007). This insight is important: it indicates an effective way of achieving profitability, and may also shed light on how society should understand and relate to platforms within, for instance, health, education and transportation. On a high level, there are references to core and

peripheral technologies in technology trajectories (Dosi, 1982) and techno-economic paradigms (Perez, 2009); still, such structures should also be recognized as important meso-level phenomena.

By paying attention to the concept of platform openness, the TIS approach could provide new insights into the role of variety creation in technological systems. Arguably, standards and compatibility are already a topic, especially in analysis of telecommunications systems (Edquist, 2005). Complementarity in technological systems has also recently received deserved attention (Markard & Erlinghagen, 2017; Markard & Hoffmann, 2016). That being said, the concept of platform interface openness introduces instruments such as application programming interfaces and open source code as a proactive way of facilitating recombination of technologies and knowledge. It relates to a core innovation process (Fagerberg, 2003) that, however, has not been made explicit in the TIS approach.

This thesis also makes it clear that platform interface openness cannot be reduced to merely a question of technical connectors. As we have seen, innovation processes such as knowledge sharing and legitimation play a significant role in perceptions of platform interface openness and the subsequent effects. In the study of platform interfaces (Article 3), respondents noted how platform communities can pass on insights, and spur sharing and developing of knowledge among stakeholders. Platforms give signals to vendors so that appropriate levels of expectations are set, thereby providing incentives to their search for new opportunities.

4.3 Management implications for an emerging platform ecosystem

This thesis aims to contribute to management of platforms and platform ecosystems. As a starting point I refer to four proposed platform leadership practices, set out in Table 4-1 (Gawer & Cusumano, 2014). The discussion in this thesis has indicated that these practices do not sufficiently address the emergence of a platform and role of interface openness. Therefore, I now draw on additional approaches and findings from this thesis to discuss how to manage a platform, from its formative stage and into a growth phase.

The four platform leadership practices (Gawer & Cusumano, 2014) are formulated from a platform perspective, assuming a strategic platform leader with agency and insight. First, a platform leader must identify an attractive core platform technology, and the accompanying complementors and technologies. Second, the platform must be easily accessible for complementors—this advice concerns technical connectors as well as financial incentives. The third piece of advice concerns the character of the relationship between the actors, with

terms like mutually enhancing, evangelize, share risk, legitimacy, reputation, and collective identity. Fourth, other firms must continuously be persuaded to contribute to the ecosystem.

Table 4-1 Effective practices for platform leadership (Gawer & Cusumano, 2014, p. 429)

-
1. Develop a vision of how a product, technology, or service could become an essential part of a larger business ecosystem
 - a. Identify or design an element with platform potential (i.e., performing an essential function and easy for others to connect to)
 - b. Identify third-party firms that could become complementors to your platform (think broadly, possibly in different markets and for different uses)
 2. Build the right technical architecture and “connectors”
 - a. Adopt a modular technical architecture, and in particular add connectors or interfaces so that other companies can build on the platform
 - b. Share the intellectual property of these connectors to reduce complementors’ costs to connect to the platform. This should incentivize and facilitate complementary innovation.
 3. Build a coalition around the platform: Share the vision and rally complementors into *co-*creating a vibrant ecosystem together
 - a. Articulate a set of mutually enhancing business models for different actors in the ecosystem
 - b. Evangelize the merits and potentialities of the technical architecture
 - c. Share risks with complementors
 - d. Work (and keep working) on firm’s legitimacy within the ecosystem. Gradually build up one’s reputation as a neutral industry broker
 - e. Work to develop a collective identity for ecosystem members
 4. Evolve the platform while maintaining a central position and improving the ecosystem’s vibrancy
 - a. Keep innovating on the core, ensuring that it continues to provide an essential (and difficult to replace) function to the overall system, making it worthwhile for others to keep connecting to your platform
 - b. Make long-term investments in industry coordination activities, whose fruits will create value for the whole ecosystem
-

The management implications suggested below rest heavily on the TIS approach (Bergek et al., 2008; Hekkert et al., 2007). The TIS approach does not ascribe full overview and agency on behalf of the platform ecosystem to actors; still, actors are assumed to act strategically on their level. However, I hold that a path can be strategically managed through path creation (Garud et al., 2010); actors can attempt to influence the direction of the path in a platform ecosystem—recognizing, however, that this is subject to high uncertainty. Even within the TIS perspective, it is assumed that by revealing what is currently blocking or inducing the system, it is possible to propose sound strategic actions. In the following I differ from the TIS approach on one important point: I take the perspective of an actor that aims to become a leading platform in a platform ecosystem. However, the management implications presented

here can also be relevant for actors with other ambitions, or for policymakers wanting to incentivize or regulate such markets.

Before proceeding with *what* to manage, I want to emphasize *how* to conduct management in today's context of an emerging complex technological system. A manager must cater to many actors and processes at the same time, and under conditions of high uncertainty. There will be a continuous assessment of their status and the balance between them, taking the system from an early formative phase into growth. In line with the TIS approach, innovation processes should be evaluated according to how they serve either to induce or to block the further evolution of the platform ecosystem. Next, appropriate actions should be implemented in order to reinforce the smoothly functioning processes and deal with those that block further diffusion. However, there will always be uncertainty as how the system will respond to actions; thus, this is a cycle of 1) assessing status; 2) probing actions; 3) monitoring response; and 4) adjusting.

First, managers must acknowledge that the evolution of a platform is highly uncertain. Second, the network of actors and their relationship must be complete and efficient. Third, the self-reinforcing processes that can occur, taking the platform ecosystem in one direction or another, must be continuously evaluated and managed so as to affect the further development. Fourth, the platform interfaces must be governed carefully, to achieve a level openness that will attract other actors.

4.3.1 Expect and prepare for several potential paths

A market based on complex technological systems is highly unpredictable, because of the various positive self-reinforcing effects; however, the emergence of *one* path should be expected in later phases. A structure with one platform and many complementors may then occur as a result of this process. This implies that, in the early phase, managers will not know if the technology they are managing will become “the” platform, and will have to expect and prepare for several paths to emerge. Many expectations and future scenarios will need to be identified, nurtured, and monitored; when some paths become more prevalent, platform leaders must reorganize this and consider positioning within these.

In line with advice on management of product and service innovation (Dodgson et al., 2008), this implies to ensure a larger portfolio of initiatives in early phases, which are narrowed down to one or a few in later phases through a screening process. Preferably, large investment should be delayed to a stage where there is more certainty about the potential success of a

platform. In order to reduce risks a firm can adapt lean innovation methods, and aim for better understanding of users' need, and cheap and early experimentation, testing and evaluation (Furr & Dyer, 2014). The point here is not to repeat general advice on innovation management, but to emphasize that also for the emergence of platforms and platform ecosystems, we can take advantage on familiar advice on handling innovation uncertainty.

The SMS Application-to-Person is an example of a platform with a high degree of uncertainty in early phases. For instance, it was not possible to foresee that private messages would transfer to Facebook and Snapchat, or that people would accept SMSs about flights and parcels in their previously private SMS feeds. Neither could anyone predict the many uses of SMS that have emerged within private and public dialogs.

4.3.2 Ensure complete and efficient actor network

As a basis, a platform manager should see the platform as a part of a larger network of actors, institutions and technologies that are interdependent. There are many more relevant actors than the platform and complementors, and an overview should include all those with stakes or influence in the technological system, today or in future.

Throughout the emergence of a platform, it is essential to ensure that the network or structure is sufficiently complete, by building more and tighter connections between actors, technologies, and institutions. In the case of SMS Application-to-Person (Article 1), mobile operators alone could not deliver this service to business customers: it was necessary to support an aggregator role that could operate independently across all mobile operators. To be in line with consumer rights, new institutions were developed, and a complaints administration was established.

Thus, a manager must identify all roles necessary for delivering value, and, maybe design new ones. If certain roles or positions within the network are not filled, these can be created—by the platform itself, or by incentivizing others to take up the challenge. If institutional rules are lacking, these can be proposed and formulated. This may be a matter of formal rules, but also joint initiatives underpinned by trust-based agreements on how to drive further market development. Continuous assessment and fine-tuning of the structure and relationships in the system should be at the core of platform management.

4.3.3 Identify and manage innovation functions and reinforcing mechanisms

One important reinforcing effect thought to drive the growth of a platform ecosystem is the two-sided market effect. This will often be based on a pre-existing “side” that is attracting “the other.” Arguably, the universal presence of the mobile number serves to boost its attraction as a general-purpose identifier.

The field of innovation indicates that there are many more reinforcing mechanisms that drive technology diffusion in contexts like the platform ecosystem. The TIS approach suggests six innovation functions, each subject to reinforcing effects; in this thesis I have emphasized knowledge generation and sharing, legitimation, entrepreneurial experimentation and search guidance. Other scholars have proposed a list of nine reinforcing mechanisms (Klitkou et al., 2015), of which technological interrelatedness and collective action have been relevant in this thesis. These innovation functions and reinforcing mechanisms flow and interact within the structure of a platform ecosystem, creating further feedback effects.

In the case of the mobile number as a general-purpose identifier (Article 2), technological interrelatedness and presence in existing information infrastructure could help to explain its increasing relevance and diffusion. With SMS Application-to-Person (Article 1), the uses of SMS for new purposes gradually gained legitimacy because of the large and trusted firms and public bodies that started to use it. Instead of investing heavily themselves, the mobile operators receded more into the background, and left it to the aggregators to build and profit from the market.

In the case of new ID requirements for mobile number subscriptions in Pakistan, the local mobile wallet provider saw the potential for using this opportunity to fuel demand for its own digital solution. This firm prepared an onboarding process that took advantage of IDs connected to mobile numbers, and guided users to the opening of digital mobile wallets.

In a complex and interrelated system of technologies and actors, all these positive self-reinforcing processes may take a platform in one direction, or block its further diffusion. These processes also create high uncertainty. Platform managers must be aware of all these processes, assessing their status, taking into consideration their positive and negative effects, and then acting accordingly. However, these processes are still on a fairly high strategic level; identifying exactly what to do can be a complex task.

The findings of this thesis indicate that actions for inducing self-reinforcing effects may be anything from user habituation to easy system integration, and may involve, for instance:

- getting a large and trusted actor to be a pilot user
- promoting activities that habituate users and stakeholders to resources from precisely this platform
- enabling easy integration of resources into existing information infrastructure
- arranging knowledge-sharing events
- participating in projects where knowledge is shared openly
- clearly communicating expectations as to roles and market sharing
- being transparent and accessible
- showing, over time, that other actors are allowed to profit
- making it easy for others to experiment with this platform and its technologies
- taking advantage of any large platform “side” that can attract the “other side.”

Lastly, when the market changes because of new regulations or competition, it is important to react quickly, using this as a stepping-stone for shaping new opportunities.

In specific market contexts there will of course be many more things to be done, impossible to suggest on the general level here. The role and effect of the various innovation processes must always be borne in mind—specific actions are heavily dependent on context. In each case, they have to be identified and managed accordingly. In the next section, some of these aspects are discussed in the context of opening the platform interfaces.

4.3.4 Balance platform interface openness and closure

In a platform ecosystem approach, it is strategically important to open platform interfaces in the form of technical connectors, so that other actors may explore, experiment, and use the platform resources. This is a way of dealing with uncertainty while also fueling the evolution of a complex and interrelated technological system. The findings of this thesis have indicated that technical connectors alone are not sufficient to *drive the emergence of a platform*: the emergence of a platform ecosystem is also dependent on ensuring that business roles are filled, that formal institutions serve the system, and that appropriate levels of expectations and trust are set between the actors.

Moreover, technical connectors are not sufficient to *open the platform’s interfaces*: they need to be supplemented by many non-technical elements, ranging from documentation to signaling of intentions. These non-technical factors must be understood as essential elements in the more generic processes that affect the innovation in the ecosystem. Thus, *what a good*

platform manager does is to ensure documentation and community building. And *why*? In order to build and share knowledge and legitimacy.

For instance, for the platform interfaces to be perceived as open, knowledge must be developed and shared between those that use the platform. Good documentation of the platform, platform interfaces and governing terms provide everyone with the same level of insight. Examples of social settings where tacit knowledge can be built and shared include communities, standardization forums, conferences, and joint projects.

Building platform legitimacy is linked with how knowledge is shared. Low legitimacy acts to close the platform: a platform must be able to prove its intentions of being seen as open, by showing itself as inviting, promising, and trustworthy. Legitimacy hinges on such factors as rules and fees for participating, how decisions are made and promises kept, transparency, and professionalism in delivery.

Experimentation is central for mitigating the uncertainty entailed in a complex and interdependent technological system; thus, how easy it is to experiment with the platform is important for the perceived openness of the platform. This is not only a matter of available technical connectors, but also concerns the costs and administration of experimentation, testing capabilities, and the transfer into operations.

Finally, platform interfaces may be effectively closed down if the complementors cannot see any opportunities for extracting profit from the market. Thus, a platform must communicate and demonstrate, in a trustworthy manner, that it will let other actors look for, find, and capture business opportunities.

In fact, some kind of closure is also important in order for a platform—or other actors—to profit. Drawing up the line between openness and closure involves retaining legitimacy while drawing on knowledge advantages. Closure that violates end-user experiences is never well regarded. One way to practice closure is to build services based on tacit knowledge of complex systems. Another way is to safeguard knowledge within modules with open interfaces. Likewise, if data can be kept private, they can act as closure in an otherwise open environment. And closed code can be built on top of open code. There are many ways to practice closure and extracting of profit: the main message is the importance of experimenting with aspects of tacit knowledge while building and retaining legitimacy.

Finally, it should be noted that full variety, or full ability to re-combine everything, may be too heavy a cognitive burden. This is one reason why a stable core technology component

emerges, accompanied by a periphery of various components. Moreover, closure may play a more important role when platform integrity, security, and reliability are vital concerns.

In sum, in order to open platform interfaces a manager should not only cater to technical connectors, but also the strategic innovation processes of knowledge development and sharing, legitimation, entrepreneurial experimentation, and search for business opportunities; the specific means at hand can be such as documentation, communities, rules and fees, transparency, and testing capabilities. However, means will to some degree be dependent on context and should be shaped accordingly to support for instance experimentation. When a manager chooses to close platform interfaces in order to extract profit or ensure integrity, this should be carefully designed and balanced against the effect on the innovation processes.

4.4 Limitations of the findings

This thesis is based on single and multiple case studies with multiple sources. A case study is suitable when the research addresses why and how questions, as in this thesis, and when the studies shed empirical light on contemporary phenomena. The findings have relevance as analytic generalizations (Yin, 2014). However, there are some design choices that may influence the interpretation of the findings and their generalizability.

My affiliation with Telenor may be seen as one potential limitation. On the one hand, having access to cases and data within Telenor has been a huge advantage; I have also had the opportunity to triangulate and validate external sources. On the other hand, these data are not openly available for other researchers to access or replicate—and that reduces reliability. An additional possible drawback is that I might make errors of judgment in interpreting data and findings, due to my own internalized perspectives on the industry under study here. To reduce potential constraints on generalizability from my Telenor affiliation, I have sought to include external sources and broad perspectives in my research.

One way to increase validity in case studies is to carry out multiple case studies, so my choice of a single case study for SMS Application-to-Person in Norway represented a potential limitation to the generalizability of my research. I found it acceptable, as the case itself was quite unique and as a Telenor employee I had extraordinary access to data. However, including cases from other countries could have strengthened the external validity. To deal with this, I used theory pattern-matching, as well as some inputs on other markets that could put the Norwegian case into perspective. Within the chosen theory setting, the findings are non-controversial: thus, I consider the research highly applicable to practice.

Article 3 on platform openness is a case study assessing five platforms; still, the design does not include enough sources and informants to enable a comprehensive comparative analysis. An extensive comparison of interface openness for two or more different platforms would have been a way to ensure high generalizability of the study. Instead, I opted to increase generalizability by developing a conceptual model that I then introduced to a new set of informants together with further questions. Together with a process of theory pattern-matching, the study reached a level where it was possible to generalize analytically.

This thesis concerns sectors that have characteristics of being complex systems with many interdependent technologies and actors. Such characteristics apply to the information and communications technology industry in general, and mobile telecommunications. An important possible limitation of the thesis is its relevance for industries with quite different structures and dynamics—for instance, industries with high risk of knowledge-spoiling such as pharmacy, and with less dependency on other actors and technologies in provisioning services, such as agriculture.

5 Conclusion

The ICT industry is characterized as being a complex system with many interdependent technologies and actors. In this setting we can observe a structure with one stable core technology surrounded by many dynamic peripheral technologies. This constellation has been denoted and analyzed as “platform ecosystems,” with the platform as the central core and complementors as the dynamic periphery. The complementors use and embed the platform’s technology in their own applications, webpages or technologies; thus, the openness of platform interfaces is seen as affecting complementors’ innovation activities. The platform ecosystem approach focuses on how to develop and promote a successful platform. However, that approach offers less guidance as to how a platform emerges, or the constitution of platform interface openness beyond technical connectors. This thesis contributes by addressing precisely those topics.

The three articles presented here document three studies of technological systems in the mobile telecommunications industry. Local implementations of SMS Application-to-Person and mobile numbers as general-purpose identifier are here interpreted as “platforms,” as are global actors such as Google and 3GPP. Thus, in the context of mobile telecommunications, the platform ecosystem approach captures important structures and dynamics and can serve as a useful starting point for analyses and strategy. This thesis provides important further insights by using additional approaches to complex technological innovation systems.

5.1 Results

One insight is that platform ecosystems comprise more actors than the platform and complementors. This is an important point, because these interdependent actors make decisions and carry out actions that shape the evolution of the system. For instance, in the mobile telecommunications industry actors include regulatory authorities, large signaling users, and investors.

The dynamic between these actors takes the form of processes concerning development and sharing of knowledge, legitimation, experimentation, and the search for business opportunities. In a technological system these processes must function well in order to spur innovation. The actors are not isolated in their actions: previous events and decisions affect the current situation, and lead to positive feedback effects in the system.

In this thesis, the case of SMS Application-to-Person (Article 1) was an example of a platform ecosystem where legitimation, experimentation, and positive expectations were important for evolution. Relations between the platform and complementors were built on trust and complementors' beliefs in getting a fair share of the market; in turn they were willing to experiment and invest, to promote further growth of the system. In parallel, many formal and informal institutions were implemented, thereby shaping the expectations and dynamics in this market.

In the case of the mobile number as general-purpose identifier (Article 2), we saw how formal and informal institutions shaped the status and expectations of the mobile number; and also noted the positive feedback effects related to being part of an existing information infrastructure. Because relevant actors, institutions and processes often are specific to one country or market, the evolution of such a platform may be a local phenomenon.

In a platform ecosystem, the platform interfaces must be open to attract and engage complementors (Article 3). An open technical connector is not sufficient to spur this innovation: it must be supplemented by non-technical factors. Non-technical factors such as participation rules, documentation, and transparency may affect platform interface openness; in turn these factors affect innovation processes such as knowledge sharing and legitimation.

5.2 Significance of findings

The findings of this thesis can assist managers of technologies who aim to play a role in markets that resemble a platform ecosystem. In addition, policymakers can learn how to incentivize and regulate markets with such characteristics.

The findings are important because they shape expectations as to the emergence of platform ecosystems, and enable platform managers and policymakers to act accordingly. Also in the case of a fairly new concept like the platform ecosystem, we can turn to existing knowledge on the evolution of technological innovation systems. We should include a larger set of actors, institutions and technologies, and their relationships. It is also important to discuss innovation processes such as knowledge generation and legitimation. Further, the findings of this thesis emphasize the unpredictability surround the evolution of a platform, due to the possibility of various positive self-reinforcing effects; these should be borne in mind in seeking to shape the further evolution of platform—always recognizing that full control is not possible.

Actors and institutions that are significant for a platform's evolution may be local, and innovation processes can take place on the local scene. This implies that the evolution of a

platform ecosystem, at least initially, can be a local process. For platform managers who aim for a global presence, this is an important finding.

The platform ecosystem approach indicates that platform interface openness, in the form of technical connectors, is important for attracting and incentivizing complementors to innovate. This thesis has taken that one step further by elaborating on all the non-technical factors necessary in order to create an interface that is “really, really open,” as one respondent put it. By explaining how these non-technical factors are elements in the innovation processes, this thesis expands our understanding of platform interface openness, and its strategic role. By realizing the importance of knowledge sharing, legitimation, experimenting and profit expectations, platform managers can expand their ability to take advantage of and develop new non-technical factors to govern the platform interfaces.

The research questions in this thesis address an acknowledged gap in theory on the platform ecosystem literature as to how a platform emerges. The thesis has helped to fill this gap by using cases from the mobile telecommunications industry and by applying existing theory lenses to how technological innovation systems emerge. The platform ecosystem and technological innovation system approaches both concern complex and systemic technologies; this should offer impulses to fruitful combinatory studies also in the future.

The second theory gap addressed in this thesis concerns the constitution of platform interface openness and the role it plays in platform ecosystem emergence. Existing insights in technological innovation systems could not provide direct answers to the question. However, after non-technical factors that affect platform interface openness were identified, it emerged that processes known from technological innovation systems could explain how and why platform interface openness plays a role in spurring innovation in a platform ecosystem. This represents a contribution to the field of platform ecosystems and technological innovation systems, and also paves the way for further research on the constitution, significance, and effects of platform interface openness.

5.3 Future research

The author of this thesis will investigate 5G, the next generation of mobile telecommunications. The first versions of 5G are piloted already (2018), with implementation expected from 2020 and onwards. The promise of 5G lies in its flexibility and openness to experimentation and recombination (5GPPP, 2017). As it is a heterogeneous complex system

aimed at keeping recombination opportunities open, the evolution of 5G may take various paths. Two topics here are of particular interest for further research.

First, how will the 5G community practice openness on platform interfaces? One empirical approach to this question can involve investigating current practices and expectations from potential actors in this ecosystem. In particular, allowing for experimentation and testing is an interesting feature, as is the recognition of financial incentives for all parts of the system.

Second, within the mobile telecommunications sector, there are already technology paths that may deeply affect the direction of future paths. For instance, actors like Google dominate global IP connectivity, whereas local in-house wireless connectivity is provided by many micro-actors. The potential self-reinforcing effects on future developments is a relevant topic for further study.

As indicated above, platform openness as such is a topic for further research, perhaps approached through various theory approaches. Today, open source, APIs, and standards challenge decisionmakers to go beyond their first intuitive rejection—and many decisionmakers are apparently choosing to participate. As noted by Ostrom (1990), the question then become how actors organize themselves to govern and manage these commons, and what the underlying design principles of such a commons in a platform ecosystem might look like. Such a study should include the challenging relationships between multiple owners of one platform, and between the platform and its complementors.

Another topic of interest is the role of entrepreneurial experimentation in inducing—or blocking—an emerging technology in an open platform setting. Entrepreneurs have been regarded as important in technological innovation systems, but little is known of how/whether entrepreneurs are now accessing technologies or platforms and experimenting and testing to assess business opportunities. In extension, studies could investigate the role played by new types of software and applications, such as GitHub.

Finally, this thesis has noted the need to close platform interfaces in order to profit, and to balance this with openness. This invites further research on at least two topics. First, respondents have acknowledged that there is a need, and that it is legitimate, to close in order to profit. Further research could study how this line between openness and closure is drawn, and which factors affect it. Second, knowledge is gradually becoming commoditized, losing its tacit characteristics. This opens the way to examination and discussion of how this line is continuously drawn and redrawn, adding old knowledge to the public domain and generating new knowledge that can serve as a basis for extracting profit.

6 References

- 5GPPP, 2017. *5G - Innovations for new business opportunities*. [Online]
Available at: <https://5g-ppp.eu/wp-content/uploads/2017/03/5GPPP-brochure-final-web1-with-Author-credits.pdf>
[Accessed 23 5 2017].
- Adner, R., 2006. Match your innovaton strategy to your innovation ecosystem. *Harvard Business Review*, 84(4), pp. 98–107.
- Arthur, B. W., 1989. Competing technologies, increasing returns, and lock-in by historical events. *The Economic Journal*, 99(394), pp. 116–131.
- Baldwin, C. & Clark, K., 2000. *Design rules. Volume 1. The power of modularity*. Cambridge, MA: The MIT Press.
- Baldwin, C. & Woodard, J., 2009. The architecture of platforms: a unified view. In: A. Gawer, ed. *Platforms, markets and innovaton*. Cheltenham: Edward Elgar, pp. 19–44.
- Benlian, A., Hilkert, D. & Hess, T., 2015. How open is this platform? The meaning and measurement of platform openness from the complementors' perspective. *Journal of Information Technology*, 30(3), pp. 209–228.
- Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. & Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy*, 37(3), pp. 407–429.
- Bergek, A., Jacobsson, S. & Sandén, B., 2008. "Legitimation" and "development of positive externalities": two key processes in the formation phase of technological innovation systems. *Technology Analysis & Strategic Management*, 20(5), pp. 575–592.
- Coy, P., 2017. *It's harder to fix a problem than to identify it. That goes quadruple for Apple Inc., Alphabet Inc.'s Google, Amazon.com Inc., and Facebook Inc.* [Online]
Available at: <https://www.bloomberg.com/news/features/2017-11-29/how-to-tame-google-facebook-amazon-and-apple>
[Accessed 28 2 2018].
- David, P., 1985. Clio and the economics of QWERTY. *The American Economic Review*, May, 75(2), pp. 332–337.

- David, P., 2007. Path dependence, its critics and the quest for 'historical economics'. In: G. Hodgson, ed. *The Evolution of Economic Institutions: A Critical Reader*. Cheltenham: Edward Elgar, pp. 120–144.
- Dodgson, M., Gann, D. & Salter, A., 2008. *The management of technological innovation*. Oxford: Oxford University Press.
- Dosi, G., 1982. Technological paradigms and technological trajectories. *Research Policy*, 11(3), pp. 147–162.
- Durlauf, S. N., 2012. Complexity, economics, and public policy. *Politics, Philosophy & Economics*, 11(1), pp. 45–75.
- Edquist, C., 1997. *Systems of innovation. Technologies, institutions and organizations*. London: Pinter.
- Edquist, C. (ed), 2003. *The Internet and mobile telecommunications system of innovation. Developments in equipment, access and content*. Cheltenham: Edward Elgar.
- Edquist, C., 2005. Systems of innovation: perspectives and challenges. In: J. Fagerberg, D. Mowery & R. Nelson, eds. *The Oxford handbook of innovation*. Oxford: Oxford University Press, pp. 181–208.
- Eisenmann, T., Parker, G. & Alstyne, M. V., 2009. Opening platforms: how, when and why?. In: A. Gawer, ed. *Platforms, markets and innovation*. Cheltenham: Edward Elgar, pp. 131–162.
- Fagerberg, J., 2003. Schumpeter and the revival of evolutionary economics: an appraisal of the literature. *Journal of Evolutionary Economics*, 13(2), pp. 125–159.
- Fagerberg, J., 2005. Innovation. A guide to the literature.. In: J. Fagerberg, D. Mowery & R. Nelson, eds. *The Oxford handbook of innovation*. Oxford: Oxford University Press, pp. 1–27.
- Furr, N. & Dyer, J., 2014. *The innovator's method. Bringing the lean start-up into your organization*. Boston, MA: Harvard Business Review.
- Garud, R., Kumaraswamy, A. & Karnøe, P., 2010. Path dependence or path creation? *Journal of Management Studies*, 47(4), pp. 760–774.
- Gawer, A., 2009. Platform dynamics and strategies: from products to services. In: A. Gawer, ed. *Platforms, markets and innovation*. Cheltenham: Edward Elgar, pp. 45–76.

- Gawer, A., 2014. Bridging differing perspectives on technological platforms: toward an integrative framework. *Research Policy*, 43(7), pp. 1239–1249.
- Gawer, A. & Cusumano, M. A., 2002. *Platform leadership: How Intel, Microsoft, and Cisco drive industry innovation*. Boston, MA: Harvard Business School Press.
- Gawer, A. & Cusumano, M. A., 2014. Industry platforms and ecosystem innovation. *Journal of Product Innovation Management*, 31(3), pp. 417–433.
- Gawer, A. & Henderson, R., 2007. Platform owner entry and innovation in complementary markets: evidence from Intel. *Journal of Economics & Management Strategy*, 16(1), pp. 1–34.
- Gawer, A. & Phillips, N., 2013. Institutional work as logics shift: the case of Intel's transformation to platform leader. *Organization Studies*, 334(8), pp. 1035–1071.
- George, A. & Bennett, A., 2005. *Case studies and theory development in the social sciences*. Cambridge, MA: MIT Press.
- GSMA, Database. www.gsmaintelligence.com
- Hanseth, O. & Lyytinen, K., 2010. Design theory for dynamic complexity in information infrastructures: the case of building the internet. *Journal of Information Technology*, 25(1), pp. 1–19.
- Hekkert, M., Negro, S., Heimeriks, G. & Harmsen, R., 2011. *Technological innovation system analysis: A manual for analysts*. [Online]
Available at: http://www.innovation-system.net/wp-content/uploads/2013/03/UU_02rapport_Technological_Innovation_System_Analysis.pdf
[Accessed 17 February 2015].
- Hekkert, M., Suurs, R., Negro, S., Kuhlman, S. & Smits, R., 2007. Functions of innovation systems: a new approach for analysing technological change. 74(4), pp. 413–432.
- Hughes, T., 1987. The evolution of large technological systems. In: W. Bijker, T. Hughes & T. Pinch, eds. *The social construction of technological systems*. Cambridge, MA: The MIT Press, pp. 51–82.

- Iansiti, M. & Levien, R., 2004. *The keystone advantage. What the new dynamics of business ecosystems mean for strategy, innovation and sustainability*. Cambridge, MA: Harvard Business School Press.
- Jacobsson, S. & Bergek, A., 2004. Transforming the energy sector: the evolution of technological systems in renewable energy technology. *Industrial and Corporate Change*, 13(5), pp. 815–849.
- Katz, M. L. & Shapiro, C., 1994. Systems competitions and network effects. *The Journal of Economic Perspectives*, 8(2), pp. 93–115.
- Kirkwood, C., 1998. *System dynamics methods: a quick introduction*. Tempe, AZ: College of Business. Arizona State University.
- Klitkou, A., Bolwig, S., Hansen, T. & Wessberg, N., 2015. The role of lock-in mechanisms in transition processes: the case of energy for road transport. *Environmental Innovation and Societal Transitions*, Volume 16, pp. 22–37.
- Langlois, R. & Robertson, P., 1992. Networks and innovation in a modular system: Lessons from the microcomputer and stereo component industries. *Research Policy*, 21(4), pp. 297–313.
- Liebowitz, S. & Margolis, S., 1995. Path dependence, lock-in, and history. *Journal of Law, Economics and Organization*, 11(1), pp. 205–226.
- Lundvall, B.-Å. & Johnson, B., 1994. The learning economy. *Journal of Industry Studies*, 1(2), pp. 23–42.
- Lundvall, B. Å., 1992. *National systems of innovation. Towards a theory of innovation and interactive learning*. London: Pinter.
- Malerba, F., 2005. Sectoral systems of innovation. In: J. Fagerberg, D. Mowery & R. Nelson, eds. *The Oxford handbook of innovation*. Oxford: Oxford University Press, pp. 380–406.
- Manjoo, F., 2016. *Tech's "Frightful 5" will dominate digital life for the foreseeable future*. [Online]
Available at: <https://www.nytimes.com/2016/01/21/technology/techs-frightful-5-will-dominate-digital-life-for-foreseeable-future.html>
[Accessed 28 2 2018].

- Markard, J. & Erlinghagen, S., 2017. Technology users and standardization: game changing strategies in the field of smart meter technology. *Technological Forecasting and Social Change*, Volume 118, pp. 226–235.
- Markard, J., Hekkert, M. & Jacobsson, S., 2015. The technological innovation systems framework: response to six criticisms. *Environmental Innovation and Societal Transitions*, Volume 16, pp. 76–86.
- Markard, J. & Hoffmann, V., 2016. Analysis of complementarities: framework and examples from the energy transition. *Technological Forecasting and Social Change*, Volume 111, pp. 63–75.
- Markard, J., Wirth, S. & Truffer, B., 2016. Institutional dynamics and technology legitimacy – A framework and a case study on biogas technology. *Research Policy*, 45(1), pp. 330–344.
- Miles, M., Huberman, M. & Saldaña, J., 2014. *Qualitative Data Analysis. A Methods Sourcebook*. London: Sage.
- Moore, J., 1993. Predators and prey: a new ecology of competition. *Harvard Business Review*, 71(3), pp. 75–86.
- Murmann, J. P. & Frenken, K., 2006. Toward a systematic framework for research on dominant designs, technological innovations, and industrial change. *Research Policy*, 35(7), pp. 925–952.
- Myrdal, G., 1957. *Economic theory and underdeveloped regions*. London: Ducksworth.
- Nelson, R., 1993. *National innovation systems: a comparative analysis*. Oxford: Oxford University Press.
- Nelson, R. R. & Winter, S. G., 1982. *An evolutionary theory of economic change*. Cambridge, MA: Harvard University Press.
- North, D., 1990. *Institutions, institutional change and economic performance*. Cambridge: Cambridge University Press.
- Onufrey, K. & Bergek, A., 2015. Self-reinforcing mechanisms in a multi-technology industry: understanding sustained technological variety in a context of path dependency. *Industry and Innovation*, 22(6), pp. 523–551.

- Ostrom, E., 1990. *Governing the commons. The evolution of institutions for collective action*. Cambridge: Cambridge University Press.
- Peltoniemi, M. & Vuori, E., 2005. *Business ecosystems as the new approach to complex adaptive business environments*. Tampere, Proceedings of eBusiness research forum 2, pp. 267–281.
- Perez, C., 2009. Technological revolutions and techno-economic paradigms. *Cambridge Journal of Economics*, 34(1), pp. 185–202.
- Pratt, M., 2008. Fitting oval pegs into round holes. Tensions in evaluating and publishing qualitative research in top-tier North American journals. *Organizational Research Methods*, 11(3), pp. 481–509.
- Reuver, M. d., Verschuur, E., Nikayin, F., Cerpa, N. & Bouwman, H., 2014. Collective action for mobile payment platforms: A case study on collaboration issue between banks and telecom operators. *Electronic Commerce Research and Applications*, 14(5), pp. 331–344.
- Robertson, D. & Ulrich, K., 1998. Planning for product platforms. *Sloan Management Review*, 39(4), pp. 19–31.
- Saldaña, J., 2013. *The Coding Manual for Qualitative Researchers*. London: Sage.
- Schilling, M., 2000. Towards a general modular system theory and its application to interfirm product modularity. *Academy of Management Review*, 25(2), pp. 312–334.
- Schmidt, S. & Werle, R., 1997. *Coordinating technology: studies in the international standardization of telecommunications*. Cambridge, MA: The MIT Press.
- Scott, R., 1995. *Institutions and organizations*. Thousand Oaks, CA: Sage.
- Simon, H., 1962. The architecture of complexity. *Proceedings of the American Philosophical Society*, 106(6), pp. 467–482.
- Suurs, R. & Hekkert, M., 2009. Cumulative causation in the formation of a technological innovation system: the case of biofuels in the Netherlands. *Technological Forecasting and Social Change*, 76(8), pp. 1003–1020.
- Tidd, J., Bessant, J. & Pavitt, K., 2005. *Managing innovation. Integrating technological, market and organizational change*. Hoboken, NJ: Wiley Publishing.

- Tiwana, A., Konsynski, B. & Bush, A. A., 2010. Platform evolution: coevolution of platform architecture, governance, and environmental dynamics. *Information Systems Research*, 21(4), pp. 675–687.
- Tushman, M. & Murmann, J. P., 2003. Dominant designs, technology cycles, and organizational outcomes. In: R. Garud, A. Kumaraswamy & R. Langlois, eds. *Managing in the modular age. Architectures, networks, and organizations*. Oxford: Blackwell, pp. 316–347.
- Ulrich, K., 1995. The role of product architecture in the manufacturing firm. *Research Policy*, 24(3), pp. 419–440.
- Valsiner, J., 2012. Axiomatic bases for experiential (empirical) knowledge construction. In: J. Valsiner, ed. *A guided science: history of psychology in the mirror of its making*. New Brunswick: Transaction Publishers.
- VisionMobile, 2017. *Developer economics – State of the developer nation Q1 2017*, London: VisionMobile.
- Weber, M. & Truffer, B., 2017. Moving innovation systems research to the next level: towards an integrative agenda. *Oxford Review of Economic Policy*, 33(1), pp. 101–121.
- West, J., 2003. How open is open enough? Melding proprietary and open source platform strategies. *Research Policy*, 32(7), pp. 1259–1285.
- West, J., 2007. The economic realities of open standards: black, white and many shades of grey. In: S. Greenstein & V. Stango, eds. *Standards and public policy*. Cambridge: Cambridge University Press, pp. 87–122.
- Yin, R. K., 2014. *Case study research*. 5 ed. Thousand Oaks, CA: Sage.
- Yoo, Y., Henfridsson, O. & Lyytinen, K., 2010. Research commentary – The new organizing logic of digital innovation: an agenda for information systems research. *Information Systems Research*, 21(4), pp. 724–735.

Articles appended

Article 1:

Hallingby, Hanne Kristine. "Key success factors for a growing technology innovation system based on SMS Application-to-Person in Norway." *Technology Analysis & Strategic Management* 28, no. 10 (May 2016): 1123-1137.

Article 2:

Hallingby, Hanne Kristine. The status and future of the mobile phone number as a general-purpose identifier.

Submitted to *Telematics and Informatics*

Article 3:

Hallingby, Hanne Kristine. Platform openness and innovation: A case study from the mobile telecommunication industry.

Submitted to *Technological Forecasting and Social Change*

Article 1:

Key success factors for a growing technology innovation system based on SMS Application-to-Person in Norway

Hanne Kristine Hallingby

Published:

Hallingby, Hanne Kristine. "Key success factors for a growing technology innovation system based on SMS Application-to-Person in Norway." *Technology Analysis & Strategic Management* 28, no. 10 (May 2016): 1123-1137.

The article presented here is the proofreading version before publication.

Abstract

The case of short message service (SMS) Application-to-Person in Norway documents how SMS has re-emerged as a significant channel for customer dialogue: SMS is increasingly used for everything from dentist appointments to communicating with tax authorities. The Technology Innovation Systems perspective is the basis for an assessment of inducement mechanisms for the case, and thus the critical success factors. More specifically, the case serves as an example of a platform-based business ecosystem where the ownership of the platform is shared and a core resource is provided by the mobile network operators. It is shown how the current growth of the SMS channel is founded on collective action in the system, and how the subsequent legitimation process has aligned the SMS channel with user expectations and practices. The actors' ability to collaborate and strike a balance between developing and sharing the market has been critical.

Keywords: SMS, technology innovation system, platform-based business ecosystem, legitimation, key success factors

1 Introduction

SMS-based mobile commerce used to be a growth field (Mylonopoulos & Doukidis, 2003; Scornavacca & McKenzie, 2007), however, the field took a different path. It is recognized that a shift came with smartphones (GSMA, 2014; West & Wood, 2013). Apple and Google took mobile commerce into the era of Web 2.0 and social media such as Facebook and Twitter (Kourouthanassis & Georgiadis, 2014). New use of social media led to a stagnation of SMS for person-to-person communication (Norwegian Communications Authority, 2015), and has since challenged mobile network operators (GSMA, 2014).

It is a puzzle why the market for SMS Application-to-Person (A2P) in Norway is growing by 25% annually according to figures released from the incumbent mobile network operator in Norway, end of 2014. SMS A2P is a submarket of the mobile industry and coordinates organisations' SMSs to their clients and customers; the messages sent through applications concern such things as appointment notifications, purchase statuses or flight information. To the knowledge of the author there is no documentation of how and why SMS A2P has started to grow in the shadow of new social media and communication channels. This paper therefore asks: what are the success factors of a rapidly growing SMS based mobile commerce ecosystem?

Previously, mobile commerce has been studied as socio-technical systems and ecosystems (Kourouthanassis & Georgiadis, 2014; Kourouthanassis & Giaglis, 2012; Mylonopoulos & Doukidis, 2003). A holistic view that incorporates technology push, user demand and contextual aspects is recommended for analysing the complex and networked telecommunication technologies (Gao & Damsgaard, 2007; Ghezzi et al., 2013; Peppard & Rylander, 2006). This resonates with the technological innovation system (TIS) approach, which is a socio-technical systems perspective on how technology is developed, diffused and used (Bergek et al., 2008; Hekkert et al., 2007; Negro & Hekkert, 2008). Also other more normative management theories explain market dynamics in industries that are systemic and interdependent, for instance platform-based business ecosystem (Gawer & Cusumano, 2002; 2014) and ecosystems (Iansiti & Levien, 2004; Moore, 1993). In this paper TIS is the main theoretical lens to guide the search for explanations of the current growth of SMS A2P. It is useful due to the step-by-step analytic scheme, the focus on emergence of technologies, weight on technologies rather than firms and the stock of potential explanatory factors such as legitimization. However, platform-based theories are used to supplement the TIS approach.

The research contributes in three ways. First, it suggests new and reinforces explanations for diffusion and use of a networked and interdependent mobile technology application. Second, the platform approach used in the case adds to the TIS analytic scheme with a better understanding of the dynamics between technology platform and complements. Third, the TIS approach supplements the platform perspective by highlighting how platforms emerge and the role legitimation processes and collective dimension play when taking an innovation system into a growth phase.

In the following section the research background and theory are described. Section three describes the method. In section four and five the Norwegian market for SMS A2P is analysed. Section six discusses inducing and blocking mechanisms, policies and suggests theoretical contributions. The last section concludes.

2 Background and theory

2.1 Growth of SMS A2P

This case tries to explain the high growth of SMS A2P in Norway. Table 2-1 shows SMS A2P annual growth for the incumbent mobile network operator, Telenor. Telenor holds 50% of 6 million subscribers in Norway (Norwegian Communications Authority, 2015). About 550 million SMSs were sent in Telenor’s network in 2014, which implies that about 1.1 billion SMSs were sent from applications in 2014. In comparison about 6.1 billion SMSs were sent between persons (Norwegian Communications Authority, 2015).

Table 2-1 Telenor SMS A2P traffic in Norway 2007-2014

	2007	2008	2009	2010	2011	2012	2013	2014
Traffic SMS A2P, thousands	79.093	167.284	209.598	246.583	301.064	362.714	443.079	557.280
Growth		112 %	25 %	18 %	22 %	20 %	22 %	26 %

Source: Telenor Norway

2.2 Theory and expectations

The main theoretic approach in this paper is *Technological innovation systems* (Bergek et al., 2008; Hekkert et al., 2007). TIS provides six steps that guide research and suggest explaining variables for growth (Bergek et al., 2008). First, the technology and the greater innovation system it is part of are defined. Second, the structural components actors, networks and

institutions are identified, and how actors create value. Third, seven key innovation functions are described, and fourth, how well each system function is fulfilled (Hekkert et al., 2011). At this point, it is discussed how mature the innovation is, how far it has come in the ‘emergence’ phase, and status compared to other innovation systems. Fifth, inducing or blocking mechanisms are described and discussed. Sixth, based on the analysis, effective policies are outlined from both a societal and business perspective for further development, diffusion and use of the innovation in question.

TIS is a generic approach to understand the emergence of systemic technologies. Other theories more specifically explain dynamics for interdependent and networked technologies with a core player and complements, for instance platform-based business ecosystem (Gawer & Cusumano, 2002; 2014) and ecosystems (Iansiti & Levien, 2004; Moore, 1993). Such platform approaches have been applied to analyze structure and dynamics in the mobile industry (Basole & Karla, 2011; Peppard & Rylander, 2006). A platform is: ‘products, services or technologies developed by one or more firms, and which serve as foundations upon which a larger number of firms can build further complementary innovations and potentially generate network effects’. (Gawer & Cusumano, 2014, p. 420). SMS A2P can be understood as a platform.

TIS is the focal approach in this paper, supplemented by the platform perspective. First, TIS provides a guide for empirical investigation with its steps and functions. Second, this analysis takes advantage of TIS’ focus on *technology* rather than organizations, and technology as a result of collective action of several organizations (Hekkert et al., 2011). In contrast, the platform approach mostly concerns one firm in control of one technology platform (Gawer & Cusumano, 2014). The firm focus is also a major drawback of value network analysis (Peppard & Rylander, 2006). According to West and Wood ‘the platform literature has largely ignored the potential tensions of shared (or divided) platforms’ (West & Wood, 2013, p. 62), and recently de Reuver et al (2014) have put challenges with shared ownership of a platform or technology on the agenda.

Third, TIS focuses on the *emergence* of a technology. Much of the explanatory power of TIS’ success and failure can be found by assessing seven innovation functions (Bergek et al., 2008) which also provide sources for explanations that complement more normative platform theories. Gawer and Cusumano (2014, p. 27) recognize the need to develop better methods to assess emergence of a platform-based business ecosystems and call on ‘concepts such as legitimacy, collective identity and institutional work’.

Fourth, TIS conveniently emphasizes institutions such as culture, norms and regulations (Bergek et al., 2008), and a subsequent legitimation process which leads to the social acceptance and compliance with relevant institutions (Bergek, Jacobsson & Sandén, 2008).

The above assessment of TIS and platform approaches reveal potential explanations for growth in SMS A2P. All the suggested TIS functions are sources for explanations, and a successful legitimation process is a necessary condition (Bergek, Jacobsson & Sandén, 2008). The relationship between technology owners can explain failure (Reuver et al., 2014) and success (Eaton et al., 2014). Platform-based views provide best practices of how to regulate the relationship between the platform and its complements. Although acknowledging governance shortcomings (Boudreau & Haigiu, 2009), sharing of revenues and risks is essential as well as giving access to platform via ‘technical connectors’ and open interfaces (Gawer & Cusumano, 2014). Such connectors are hardly mentioned by the TIS approach. Finally, the significance of network effects is emphasized both by the TIS (Bergek, Jacobsson & Sandén, 2008) and platform approaches (Gawer & Cusumano, 2014; Boudreau & Haigiu, 2009). Both perspectives acknowledge the significance of network externalities that have to do with advantages stakeholders take from shared and standard structures, resources and knowledge. However, platform perspectives put more weight to same-side and multisided network effects between the users of a platform as an explanatory factor (Boudreau & Haigiu, 2009).

3 Method

The methodological approach in this paper is an explanation-building single case study (Yin, 2014). The dependent variable is the growth of SMS A2P in Norway, and the research is aimed at exploring factors that can explain this growth. The use of TIS (Bergek et al., 2008) implies that the case study can be carried out in a more confirmatory way (Miles et al., 2014). Initial ‘soaking and poking’ with empirical data and theory (George & Bennett, 2005) indicated that certain factors had more explanatory power, for instance legitimation and role balancing, and contributed to build a conceptual framework of the case study (Miles et al., 2014).

3.1 Defining the innovation case

Short Message Service (SMS) is a standard communication protocol developed for the

mobile industry, first applied in 1992 (Hillebrand et al., 2010). In line with Bergek et al. (2008) SMS A2P is a product – rather than a knowledge field – that is provided by mobile network operators as a platform. The spatial scope is Norway and time the frame is 2007-2016. The growth of SMS A2P is a phenomenon easy to isolate from stagnation of other SMS uses and the current growth of social media. Thus, it is also easier to identify explanatory factors. Even though previous work touches on factors that affect use and diffusion of SMS (Scornavacca & McKenzie, 2007; Peppard & Rylander, 2006) the current distinction of the phenomenon can add strength to explanations.

Table 3-1 Data sources

<i>Data</i>	<i>Sources</i>
Market figures	Statistics SMS A2P: Telenor General statistics: Norwegian Communications Authority: web, direct communication.
Aggregators	Interviews: six senior executives/actors Web-sites, Press, accounting data (www.proff.no)
Mobile network operators	Telenor, incumbent: Interview Product manager, Press, Web, prices, contractual documents All operators: Press, Web-sites: prices, contractual documents
Policy institutions	Interviews telecom and consumer regulators Web-sites: Regulating documents, Statistics
Users	Interviews three large users Statistics on end-users' use of SMS, e-mail, social media (Statistics Norway)
Other markets (countries)	Participation international seminar (2014) on Telecom application programming interfaces Presentations, Reports, Web-sites

3.2 Data collection and analysis

The data were collected in 2014-2016 (Table 3-1). Aggregators, a mobile operator, regulators and significant users were interviewed, and other sources of evidence collected such as documents and web-sites on regulations, contractual guidelines and technology descriptions

(Yin, 2014). Only the incumbent operator Telenor was interviewed;² however other types of data have been obtained from other operators. The responses from the incumbents were only be elaborated on when they differed significantly. The semi-structured questionnaires were designed to illuminate explanations suggested by theories as well as capture new aspects. All interviews were recorded, transcribed and subject to open coding, however, aligned with the conceptual frameworks implicit in theoretical approaches (Miles et al., 2014). Coding was done in NVivo by the author.

4 Structural components

The TIS structural components are actors and institutions, and networks between them. The TIS for SMS A2P is well established with regards to institutions. SMS provisioning is regulated by Norwegian post and telecommunication authorities, and the Consumer Council and Consumer Ombudsman regulate the use of SMS in customer dialogues and sale. SMSs paid by subscribers are measured by public authorities, while SMS A2P is not. The technology is mature and incorporated into research and education. The novel aspects of this TIS are the revitalised relevance of the technology and dynamics between the actors.

4.1 New demand for SMS

How private and public organizations are using SMS for messages to their customers and clients is exemplified in Table 4-1.

Efficient delivery of messages is important to firms and public bodies and can save costs, make operations more effective and increase customer satisfaction. One actor holds that ‘It is nowadays an expectation about getting a notification when the car is ready and can be picked up from the garage. You expect to get a message when something is not working according to schedule.’

Table 4-1 Examples SMS A2P use

<i>Firms and public bodies</i>	<i>Messages in customer and client dialogues</i>
Libraries, Dentists, Doctors, Airlines, Hospitals, School authorities, Trains, Banks, Utilities, Retailers, Clubs, Online subscriptions	Notifications, Appointment reminders, Delays, Shipment delays, Offerings, Discounts, Service renewals, Change requirements, Log-in passwords, Customer service evaluations, Due dates, Statuses, News, Check-in data, Verifications, Order confirmations, Warnings

² The author is affiliated with this mobile operator.

Statistics Norway (2015) reports that 75% of the population sent an SMS, while only 39 used email on the mobile on an average day in 2015; this illustrates the general diffusion of SMS. The case study provides additional insight into why SMSs are used. Attributes 1-6 described in Table 4-2 signal network effects between users on both sides of a market, as well as effects caused by evermore integration of mobile numbers into databases and systems dealing with customers and clients.

Table 4-2 Perceived SMS attributes

	<i>SMS attribute</i>	<i>Explanations</i>
1	The mobile number	Everybody has a mobile number and accustomed to share it
2	Reach and accuracy	SMS reaches any phone, anywhere, and only those relevant
3	Authentication	ID of mobile user easy to confirm
4	Regulation: opt-in and spam	Spam is illegal, subject to fees. Opt-in and stop functionality required.
5	'Codes' and format	High end-user skills and acceptance of for SMS A2P
6	SMSs are read	95% of SMSs are read, most within 10 minutes
7	Simplicity	Mobile needs only to be on to receive SMS
8	Effectiveness	Perceived value higher than cost
9	Reports	Companies get a status of actual reception, and failures

4.2 Actors and relationships

The revitalising of SMS is intertwined with the emergence of a working business model. The actors and relationships are depicted in Figure 4-1 and illustrate how resources are combined to create value, and the role of each actor.

The model depicted is not new in the telecom sector but serves to explain the setting for new growth. There are four core actors also described in Table 4-3: mobile network operator, aggregator, commercial or public organization and end-user. Two important relationships are between end-user and mobile network operator and between end-user and a commercial or public organization.

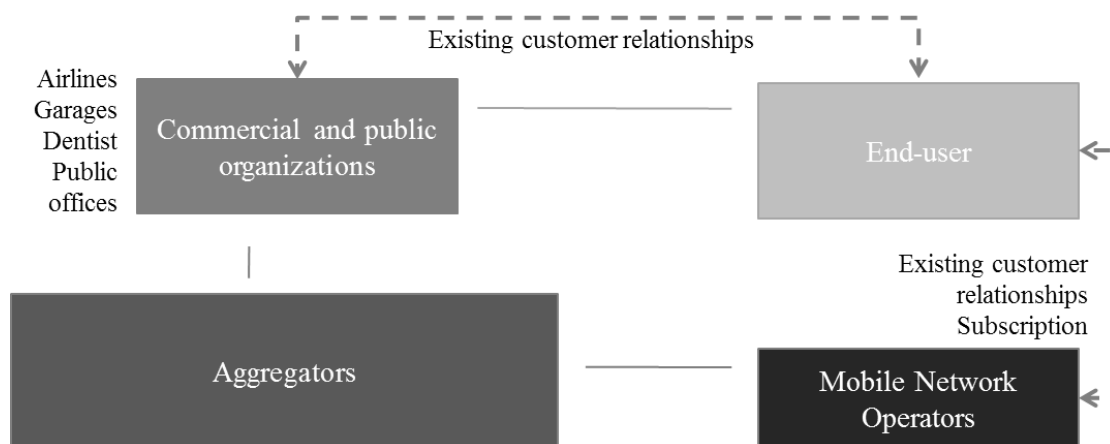


Figure 4-1 Actors and relationships in the SMS A2P TIS

Table 4-3 Actors in the innovation system for SMS A2P

Actors	Description	Number of actors	Market size
Mobile network operator	Provide mobile subscriptions to end-users	6	6 million subscribers 1.1 billion SMS A2P Approx. Norwegian kroner (NOK) 0.20 per SMS A2P, that is, market is NOK 220 mill. in total
Aggregators	Compile SMS across mobile operators and resell Integrate SMS A2P into new services	5-10 larger actors 250 smaller actors in total Some global actors	NOK 220 mill. plus aggregator margins Satisfying ROI
Commercial and public organizations	Buying and using SMSs	All firms and public bodies in Norway	-
End-user	Mobile subscribers. Customers and clients	5 million inhabitants 6 million mobile subscriptions	-

The number of aggregators has stayed around 250 since 2007, mostly smaller firms. Each year one medium sized firm has entered the market. Several aggregators turned their firms around towards SMS A2P after the Smartphones and apps led to a stagnation of mobile content in 2008. The interviewed aggregators' revenues follow the market growth of SMS A2P; the return on investment (ROI) is more varied. Most of the aggregators had satisfying

ROI in 2013; three of them were rated as very good. This gives an indication of a sound financial status of the SMS A2P business. Actors expect the market to grow with new types of utilization and smaller firms' uptake.

4.2.1 Mobile operators' role

The mobile operators' contribution to value creation is firstly the established base of mobile subscriptions which include SMS, and secondly giving other actors' access to the SMS A2P resource for further innovation. Access is given through a technological interface and commercial contracts. In general mobile network operators have a withdrawn role towards commercial and public organizations, also when it comes to innovation beyond core SMS A2P functionality; this is left to the aggregators and third parties. This withdrawn role is partly described as a necessary condition, however almost becoming too passive.

4.2.2 Aggregators' role

The aggregators have three main fields of value creation. First, they aggregate SMS functionality across mobile operators and resell a combined functionality. One aggregator explains: 'I guess that it is this, that is one of your assets, or your – you a kind of handle all this complexity, all these relationships, all the different mobile operators and make that into one unit'.

Second, the aggregators integrate the SMS A2P functionality into new advanced solutions. 'And that value creation – the additional value we put on the SMS enables a third party firm to receive a message from their customers, to process it, get it through the systems, and ensure that we deliver a functionality that is value-added', says one aggregator. The aggregators combine the SMS functionality with other qualified data. The data are processed for customer dialogue, which subsequently is documented and traceable.

Third, aggregators build operations to handle the high volume of SMS A2P. This includes user friendly web-sites, dedicated salesforce and customer support. To the mobile operators SMS A2P is a niche product and not prioritized. As one aggregator puts it: 'All the sale and support activity has been done by the partners; that is actors like us. The mobile operators have one or two persons each, barely that, on their side.'

4.2.3 Actors' recognition of role

The description of the SMS A2P core actors and their value creation signals clear recognition of roles. Furthermore, aggregators and mobile operators recognize high interdependency in

several dimensions that serve as institutions regulating the market. In the first instance, operators have established shared approaches to the market between them, without violating competition laws and regulations (for instance application programming interfaces and grey traffic elimination).

In the second instance, the market is a balance between the aggregator and mobile network operators; they both want to make money at an acceptable risk level. It is held as imperative that the mobile network operators keep away from the aggregator role.

One argument for balancing the market is that the mobile operators are dependent on the aggregators to innovate and invest: 'Because - yes, the operators must keep fingers off. If you want that variety - if we can call it that - in innovation. Right'. The value creation and selection processes driving innovation must not be obstructed by uncertainty about operators' intentions. Aggregators' willingness to invest will decrease if they risk competition from the operators, and one aggregator explains what happens where operators have not struck the balance: '... then they must change. So partners find it attractive to invest in development and innovation and sales based on them'. The aggregator adds that worldwide there are very few examples of such a well-functioning market as the Norwegian. The mobile operator has experienced that growth comes when aggregators take part in value creation, and is not threatened by the operator's competition. Also, a double role towards other operators could further complicate their joint effort to enable the market.

The aggregators appreciate that operators are predictable and transparent. It comes through when the aggregators comment on the core attributes of the SMS channels (see Table 4-2), and prices. One aggregator elaborates on the significance of a transparent pricing regime in the market: 'Equal treatment, you can say is an element in this. The incumbent has been very clear: OK, this is our price. If you send this much, you will get that price. And that applies to all. If you send for two million NOK it cost this much whether you are A or B. It gives a form of predictability. You are assured that a previous university acquaintance at the competitor does not get a better price than you. That would obstruct the competition - right? Neither does it create innovation.'

4.2.4 Incentives and technological connectors between actors

Innovation incentives are connected to economic incentives and price levels, one of the few areas where the interviewees divide. Aggregators describe SMS A2P as a monopoly resource controlled by mobile operators. Although prices seem to be harmonized across the operators, aggregators have a direct relationship to all in order to avoid 3-4 higher prices through the

operators' interconnection agreements. All interviewees saw it as imperative that SMS A2P is based on a historic pricing system, and a price that signals its value compared to for instance 'free' email; furthermore, spam is deterred when the sender has to pay for the message. One half found the existing price level and division of revenues unfair; mobile operators' limited contribution to creation and operation of the market does not justify their share of revenues. The other half found that their own value creation made a difference that customers were willing to pay for in any case. However, it is recognized that the pricing system with incentives for the aggregators to innovate is a core element in this market. One aggregator says: 'I am convinced that if you want an innovative industry, and where all parts work to make the cake larger, then you need a model where there is something in it for all parts. I have zero confidence in those actors that make a solution where they themselves shall control everything. That is a fatal strategy, I think'. Some aggregators also reflect on a high fixed fee which favours larger aggregators, while this is the operators' intention; operators want to avoid administering many small actors.

It is seen as critical that all mobile network operators give access to SMS A2P through technological connectors; however, it is not identical across the operators. The aggregators even suggest that it would decrease their significance if the operators introduced highly standardized interfaces.

4.3 Institutions

Both formal regulations and agreements between the actors are held as prerequisites for the innovation system and the perceived attributes it produces for the actors. Thus, they can be considered as institutions within the innovation system. Number portability regulation and practices implemented in 2001 and mandatory ID-requirements for subscriber registration increase the strength of mobile number as consumer identifier and brand building for firms across mobile network operators (National Communication Authority, 2015); it decreases risks when building systems and customer dialogues around the mobile number. 'The number portability, I would say, was a milestone. An important milestone for the value of SMS. Because then the mobile number becomes your ID – you carry it with you throughout your life – it is an important element.' says one aggregator. The database for numbers – Nasjonal referansedatabase – is jointly owned by network operators in Norway (Nasjonal referansedatabase, 2015). The growing use and diffusion of the mobile number in systems and customer dialogues create network effects.

Mobile network operators coordinate short numbers for content; this fuelled the market, and thus end-users' accustoming to codes such as STOP and SEND in dialogues. 'It is a format that is introduced, accepted; ordinary people are starting to get accustomed to using code words.' says one aggregator.

The elimination of grey traffic (irregular traffic avoiding invoicing) is imperative for being able to claim a quality SMS service and charge a premium. One aggregator says: 'The closing of grey traffic that the large operators have done, has been important... It has been important to get rid of some actors that abuse the opportunities, it does not generate business neither to the operators nor the aggregators'. The incumbent's elimination already in 2007 set the market conditions and Norway is regarded as a pilot market in this field (Matthews, 2015).

5 Functional pattern of the TIS

5.1 Functional patterns and their goodness

The TIS' behaviour can be characterized in terms of seven key innovation functions (Bergek et al., 2008). All in all the innovation function of the TIS is strong. In Table 5-1 the different functions for SMS A2P are assessed with regards to positive aspects that explain why the system is sound and potential negative aspects. To a large degree the foundation for this assessment is drawn from the above description of the structural components and therefore only summarily repeated in the table.

The function Knowledge development is fulfilled in a good way due to the forward leaning aggregators, however with some potential drawbacks because mobile network operators are too passive.

Functions 2-4 and 6 are collapsed into one assessment; although the aggregators believe in market growth and explore alternatives they also report some risk factors such as threat of spam, price pressure, and too passive network operators. In addition, their willingness to explore includes investigating alternatives. These risk factors together with alternative attractive technologies can explain weak recruitment. Legitimation is discussed in detail below since it is found to have substantial positive effect on the status of the TIS. Likewise, there are positive externalities with regards to functional and knowledge aspects as well as network effects between user groups; however, spam can turn into a negative externality.

Table 5-1 Summary assessment of TIS functions for SMS A2P

<i>Function</i>	<i>Positive for function</i>	<i>Negative for function</i>
Knowledge development	Well known technology, business dynamics give opportunities both for aggregators and mobile network operators High recognition by aggregators, aggregators are forward leaning and competent	Passive mobile network operators Market only partly measured and reported by authorities and actors
Search, Experimentation, Resource mobilization, and Market formation	High growth rate among firms and users Growth beliefs: the smaller firms are expected to start using SMS, perceived positive SMS attributes Aggregators explore alternatives, turn crises around, are enthusiastic	Potential deflation of SMS through spam Perceived price pressure Aggregators are willing to substitute Passive mobile network operators Risk averse aggregators Weak recruitment: mediocre ROI and few new, well-performing firms
Legitimation	Strong legislation User learning processes Large firms presence Historic use of SMS Spam in other channels	
Positive externalities	Mobile subscriber base attracts ‘the other side’ – firms and public bodies User «skills» and acceptance enhance value to ‘other side’ Strong functionality and knowledge feedback loops between actors, high degree of interdependence Use and diffusion of mobile numbers chosen as person identifier in market leading systems	Potential deflation of SMS through spam

5.2 Legitimation

Legitimacy is a matter of social acceptance and compliance with relevant institutions (Bergek, Jacobsson & Sandén, 2008). Legitimacy is not given; it is developed through a legitimation process.

The history of SMS as a medium for communication between persons has legitimized it widely for receiving and sending messages. The current widespread use of other channels

for private purposes such as Facebook messenger has indirectly turned SMS to a more formal channel. One aggregator explains that SMS used to be a private medium; the intrusion of a company message in this private sphere was unthinkable. This has changed completely. ‘If we look ten years back – or only six or seven years – then I would never have sent an SMS to a business acquaintance or someone I did not know in person. It was a more private channel. [...] Those limitations are completely gone. Now you can send SMS to anyone. There is nothing private about sending SMS. And I think more and more actors started to use the channel. You see the Tax Authorities use it, other public bodies use it. You have had some of these drivers that have legitimized the channel to a large degree’.

As mentioned above, the phenomenon of content provider access contributed to developing codes for communicating with SMS. The Consumer Ombudsman has together with mobile network operators developed a set of principles and tools ruling this field (Forbrukerombudet, 2013 a), for instance specification of the code STOP to stop a service.

Large firms’ use of SMS to communicate with customers has legitimized it. Mobile network operators have used SMS in their own customer service, and banks and public bodies to communicate with clients. Also this field has been subject to strict regulation, formally ruled under Norwegian legislation of marketing. The law is administered by the Consumer Ombudsman who provides principles for marketing via email, SMS etc. (Forbrukerombudet, 2013 b). The principles concern such things as approval, age, incentives and type of use allowed. The Consumer Ombudsman has a digital interface for complaints and there is a fee for SMS-spam violating the principles. The aggregators are united in the importance of SMS regulation as a fundament for current and future position in communication. One aggregator puts it this way: ‘And it is so ingenious that you are not allowed to spam. There are fees for spamming. It is very important that this is maintained. You have to ask for confirmation; you have to have opt-in for communicating. This is what makes it so incredibly good’. Although the legislation also rules e-mail and regulators treat them as identical it comes through that the mailbox is spammed to a much larger degree than SMS; this is held as one important attribute for SMS and the reason for why so many firms prefer SMS to the free e-mail.

The growth and legitimation of SMS A2P have taken place alongside the growth of social media such as Facebook, WhatsApp and Twitter. This does not appoint SMS as better than other media, but rather illuminates the evolutionary process that accompanies the diffusion.

5.3 Assessing the phase and comparative status of TIS

The current high growth for SMS A2P justifies that it is in a take-off phase (Hekkert et al., 2011). The actors perceive that the Norwegian growth is relatively high compared to the rest of Europe. This impression is supported by available predictions on 4-5% global revenue growth (Juniper Research, 2014; Transparency Market Research, 2014). It is held as particularly important mobile operators in Norway are not aggregators, an explanation put forward for less growth in other countries.

Further explanations for a comparatively higher growth in Norway are an acceptable price level and effective price structure, early elimination of the grey traffic, advanced mobile market, pioneering firms, and trust in vendors and willingness to give away phone numbers. In general phone numbers are readily available in public databases.

6 Discussion and conclusion

In the TIS approach inducement and blocking mechanisms are those factors that are found to most affect functions. The mechanisms can be found in the 'structural components of the emerging TIS and in the larger context surrounding it' (Bergek et al., 2008, p. 420), in this case described above. Figure 6-1 depicts the mechanisms found to mostly affect how well each functions is fulfilled.

6.1 Inducement mechanisms

There are three major categories of inducement mechanisms that positively affect SMS A2P. The first is aggregator optimism, a necessity for a system in a take-off phase (Hekkert et al., 2011). Aggregators demonstrate an ability to experiment, innovate and acquire customers in their continuous recombination of SMS with other resources. History shows that they have turned crises around and have a positive belief in future opportunities. Both aggregators and mobile network operators acknowledge the role aggregators have in variety creation with SMS. It is the steady willingness to invest despite the more passive attitudes from the mobile operators in the market that is remarkable. It is a good thing that mobile operators are withdrawn; nevertheless, being too passive is described as a blocking mechanism below. The aggregators' accumulated insight into new applications and markets positively feeds the function knowledge development. It is their experimentation and – after all – optimistic future outlook that affect the good status of the TIS functions search, experimentation, and market formation.

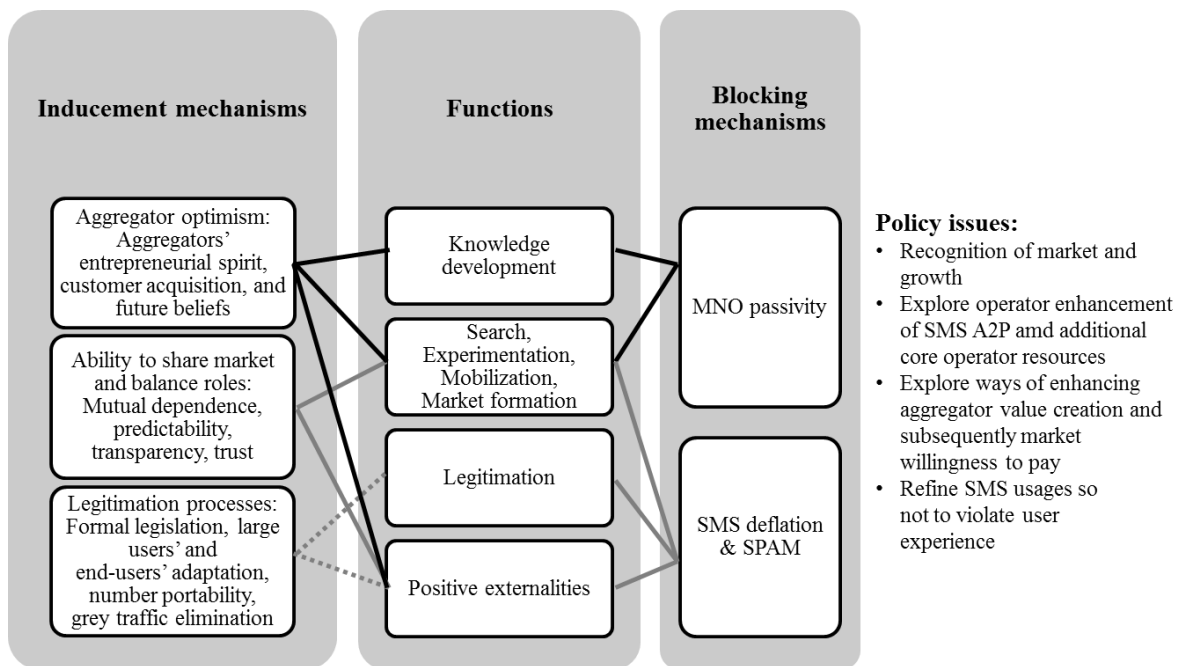


Figure 6-1 The TIS' inducement and blocking mechanisms, and policies

The second inducement mechanism is the actors' ability to share market and balance roles; collaboration between the mobile network operators is one aspect of this. The value of SMS A2P is present only when all operators are included; thus, the platform ownership is shared. This is a challenge since operators continuously work to differentiate from others in order to attract end-users. The willingness to cooperate in the Norwegian market is not new. However, this aspect becomes more distinct when Norway is compared to other countries and firms' willingness to collaborate signals a climate of trust.

Aggregators have an important role for variety creation in the market; mobile operators are dependent on aggregators both to take the risk to scale innovation and market resources, and must share revenues with aggregators with adequate financial incentives. The mobile operators work to attract both end-users and aggregators in order to sustain the ecosystem, but have themselves a withdrawn role. To strike this balance is a challenge; both sides refer to trust based on predictability, shared revenues and transparency as key success factors in Norway compared to other markets and speak well of the other part.

This understanding of mutual dependence and ability to build trust positively affect belief in future market opportunities, risk taking and decisions to enter markets, and thus the functions search, experimentation and market formation. The subsequent strong system and knowledge feedback loops between actors lead to positive externalities.

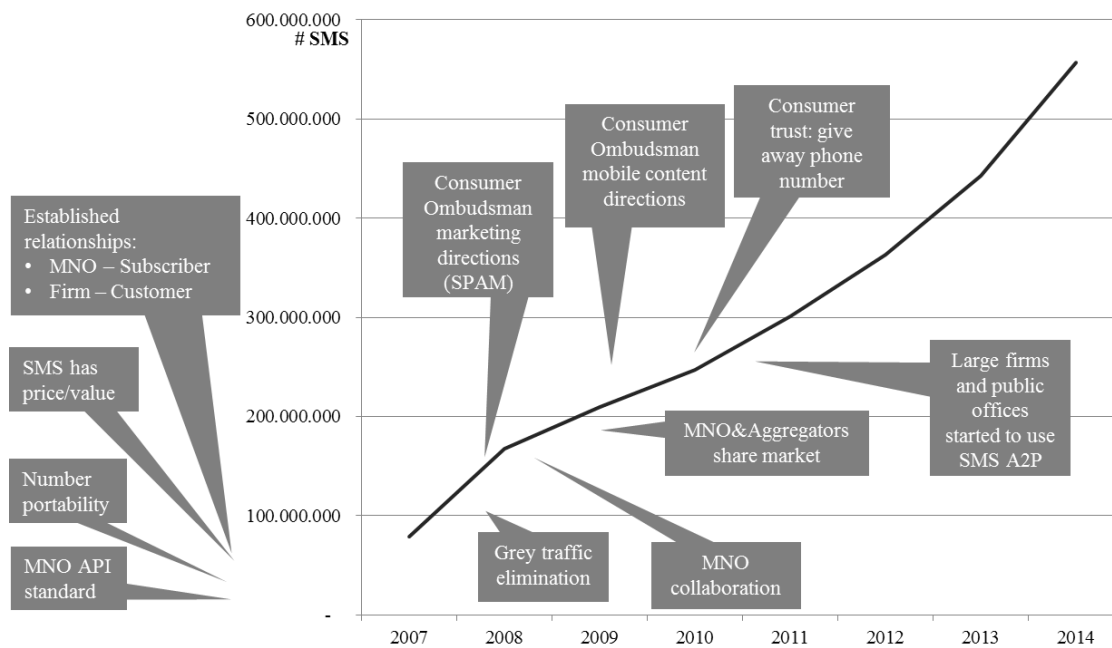


Figure 6-2 Growth process of SMS A2P in Norway 2007-2014

The third inducement category consists of processes that have led to a strong legitimation of use of SMS in communication between firms and users. This involves what now appear as institutions such as a shared understanding for SMS-codes, mobile numbers as ID and shared rules for dealing with grey traffic. Formal legislation and informal legitimation have affected how SMS is used. End-users' uptake of new channels for person-to-person communication and adaptation to large firms' use of SMS in customer interfaces have repositioned SMS. The increased use itself would lead to direct network effects, while the shared SMS practices and implementation of mobile numbers and SMS into market leading systems have strong positive network effects and further fuel the market growth.

This indicates how legitimacy is formed, not given. Arguably, the collective willingness to share market and balance roles is a part of the legitimation process (Bergek, Jacobsson & Sandén, 2008). This is all illustrated in Figure 6-2. Although the significance of legitimation is predicted by the TIS approach in this phase (Hekkert et al., 2011) it is still surprising how actors emphasise this aspect when explaining success. They are all very positive when they refer to regulating formalities, and again the partaking from different actors in the processes (Bergek, Jacobsson & Sandén, 2008). Altogether this positively affects legitimation, and also positive externalities.

6.2 *Blocking mechanisms and policies*

The withdrawn role of mobile operators is to some extent perceived as passivity and indicated to negatively affect the opportunity for further growth either if due to not knowing or choosing not to get involved. Operators' passivity blocks further knowledge development, search, experimentation and market formation and can explain the low recruitment.

Aggregators recognize the fine balance between themselves and operators but still call for operator involvement. Policies that could encounter these issues are clearer recognition of market significance, operators' enhancement of SMS A2P quality-of-service, and joint effort to increase the perceived value created in order to increase appropriability conditions for all actors.

A potential negative network effect is the possibility of SMS A2P turning into spam. The actors should jointly address how to increase SMSs sent without evoking end-users' negative perceptions.

6.3 *Contribution to theory*

The case of SMS A2P in Norway contributes as middle-range theory (George & Bennett, 2005) for a networked and interdependent technology. While the approaches of TIS and platform-based business ecosystem suggest generic factors that affect prosperity, this case suggests that especially three factors explain efficient innovation functions and platform growth in the telecom ecosystem: aggregator optimism, legitimation and balancing of roles. The importance of aggregator optimism is well founded in the TIS and platform approaches' weight on experimentation and sufficient incentives with regards to revenues and risks. The significance of legitimation and balancing of roles provide new insight to the field.

The case affirms the significance of the *legitimation* process suggested by Bergek, Jacobsson and Sandén (2008) while it adds insight to the platform literature. In the SMS TIS regulatory authorities, mobile operators, aggregators, large firms and governmental bodies have over time implemented contextual prerequisites, institutional frameworks and solutions that govern the current market. It has been a bottom-up evolutionary process and subsequent virtuous circle resulting in a growth of SMS A2P. The evolution has legitimized use of the service as well as its integration into systems operating the services. The latter has led to positive externalities predicted by both TIS and platform approaches. However, platform approaches mostly focus on network effects between users on multiple sides of the platform; thus, the significance of systems and knowledge feedback loops add to the platform approach.

Notably, SMS also provide strong cross-side effects between third parties and end-users; the significance of such dynamics adds to the TIS approach.

Furthermore, the actors clearly ‘identify themselves as a part of a system, see the common problems and opportunities they face and the value of collective action’ (Bergek, Jacobsson & Sandén, 2008, p. 588). Collective action and shared technology ownership is at the core of TIS (Hekkert et al., 2011), while the platform approach focuses on relationships between a single-owner platform and its complements (Gawer & Cusumano, 2014). Thus, the emphasis on overcoming tensions between platform owners to grow a market adds to the platform perspective. Recently this aspect has been suggested to explain both failures (Reuver et al., 2014) and successes (Eaton et al., 2014) of networked and interdependent technologies; Eaton et al. add that the Norwegian context is extraordinarily trust-based, and the climate of trust thus may serve as an underlying explanatory factor.

The significance of a balanced relationship with regards to revenues, risks, sale and customer services between the *platform and complements* is as expected by the platform perspective but adds to the dynamics described in the TIS approach. The case also refines the platform-based business ecosystem perspective on the necessity of standardized *technical connectors*. In the case it is held that the technical connector across the providers of the platform is critical but they must not be identical. Thus, one standardized connector is not a necessity to grow the market; however, it could still affect growth positively if present.

Finally, the case analysis proves how the TIS analytic scheme can add to platform approaches as a useful way to investigate *emergence* of a platform-based business ecosystem, better understand success and failure factors and potential intervening strategies.

7 Conclusion

This paper explores the emergence and growth of SMS A2P in Norway. First, optimism among the aggregators in the system is important for growth. Second, aggregators and mobile network operators have been remarkably good at finding a balance between sharing the market, collaborating and competing; this is vital for willingness to invest and fuel off positive feedback loops. The collaboration between mobile network operators to provide core technology is specific for this case with shared platform ownership. Third, both formal and informal legitimation processes have been critical for developing the acceptance and skills for using SMS in customer relationships. Continued prosperity requires that mobile network operators recognize the significance of the market and take initiatives to enhance the SMS

service further. Furthermore, actors should take joint actions to protect SMS from spam perceptions, and enable even more value created with SMS A2P.

The research provides managers in the mobile industry with key success factors for networked and interdependent technologies where mobile network operators share and provide the core platform. From a theoretical perspective the research provides new insight to both the approaches TIS and platform-based business ecosystems. The TIS focus on collective action in innovations is enriched with understanding from the dynamics between platform and complements, as well as network effects between different user groups. The platform approach can draw on the weight TIS put on the legitimation processes, positive externalities for functions and knowledge, and a thorough analytic scheme for assessing how a technology emerges.

8 References

- Basole, R. & Karla, J., 2011. On the evolution of mobile platform ecosystem structure and strategy. *Business & Information Systems Engineering*, 3(5), pp. 313–322.
- Bergek, A., Jacobsson, S. & Sandén, B., 2008. "Legitimation" and "development of positive externalities": two key processes in the formation phase of technological innovation systems. *Technology Analysis & Strategic Management*, 20(5), pp. 575–592.
- Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. & Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: A scheme for analysis. *Research Policy*, Volume 37, pp. 407–429.
- Boudreau, K. & Haigiu, A., 2009. Platform rules: multisided platforms as regulators. In: A. Gawer, ed. *Platforms, Markets and Innovation*. Cheltenham: Edward Elgar, pp. 163–191.
- Eaton, B., Hallingby, H. K., Nesse, P.-J. & Hanseth, O., 2014. Achieving payoffs from an industry cloud ecosystem at BankID. *MIS Quarterly Executive*, December, 13(4), pp. 223–235.
- Forbrukerombudet, 2013 a. *Forbrukerombudets veiledning for fellesfakturerte tjenester [The Consumer Councils guide for services that are jointly invoiced]*. s.l.:Forbrukerombudet.

- Forbrukerombudet, 2013 b. *Forbrukerombudets veiledning om markedsføring via e-post, SMS o.l.- markedsføringsloven § 15 [The Consumer Council's guide for marketing via e-mail, SMS etc - Marketing law § 15]*. s.l.:Forbrukerombudet.
- Gao, P. & Damsgaard, J., 2007. A framework for understanding telecommunications market innovation: a case of China. *Journal of Electronic Commerce Research*, 8(3), pp. 184–195.
- Gawer, A. & Cusumano, M. A., 2002. *Platform leadership: How Intel, Microsoft, and Cisco drive industry innovation*. Boston: Harvard Business School Press.
- Gawer, A. & Cusumano, M. A., 2014. Industry platforms and ecosystem innovation. *Journal of Product Innovation Management*, 31(3), pp. 417–433.
- George, A. & Bennett, A., 2005. *Case studies and theory development in the social sciences*. Cambridge: MIT Press.
- Ghezzi, A., Rangone, A. & Balocco, R., 2013. Technology diffusion theory revisited: a regulation, environment, strategy, technology model for technology activation analysis of mobile ICT. *Technology Analysis & Strategic Management*, 25(10), pp. 1223–1249.
- GSMA, 2014. *The mobile economy 2014*, London: GSMA.
- Hekkert, M., Negro, S., Heimeriks, G. & Harmsen, R., 2011. *Technological innovation system analysis: A manual for analysts*. [Online]
Available at: http://www.innovation-system.net/wp-content/uploads/2013/03/UU_02rapport_Technological_Innovation_System_Analysis.pdf
[Accessed 17 February 2015].
- Hekkert, M., Suurs, R., Negro, S., Kuhlman, S., Smits, R., 2007. Functions of innovation systems: a new approach for analysing technological change. *Technological Forecasting and Social Change*, 74(4), pp. 413–432.
- Hillebrand, F., Trosby, F., Holley, K. & Harris, I., 2010. *Short message service (SMS); The creation of a personal global text messaging*. Chichester: John Wiley.
- Iansiti, M. & Levien, R., 2004. *The keystone advantage. What the new dynamics of business ecosystems mean for strategy, innovation and sustainability*. Boston: Harvard Business School Press.

- Juniper Research, 2014. *Press Release: A2P messaging worth almost \$60bn by 2018, driving overall SMS revenues, Juniper Research finds*. [Online]
Available at: <http://www.juniperresearch.com/viewpressrelease.php?pr=444>
[Accessed 4 November 2014].
- Kourouthanassis, P. & Georgiadis, C., 2014. Analysing m-commerce research: technology, applications and research themes. *International Journal of Mobile Communications*, 12(1), pp. 1–11.
- Kourouthanassis, P. & Giaglis, G., 2012. Introduction to the special issue: The past, present, and future of mobile commerce research. *International Journal of Electronic Commerce*, 16(4), pp. 5–18.
- Matthews, G., 2015. *SMS special report: Confronting SMS fraud*. [Online]
Available at: <http://www.capacitymedia.com/Article/3483282/Home/SMS-SPECIAL-REPORT-Confronting-SMS-fraud.html>
[Accessed 15 January 2016].
- Miles, M., Huberman, M. & Saldaña, J., 2014. *Qualitative Analysis: A Methods Sourcebook*. Los Angeles: SAGE.
- Moore, J., 1993. Predators and prey: a new ecology of competition. *Harvard Business Review*, May-June, 71(3), pp. 75–86.
- Mylonopoulos, N. & Doukidis, G., 2003. Introduction to the special issue: Mobile business: technology pluralism, social assimilation, and growth. *International Journal of Electronic Commerce*, 8(1), pp. 5–22.
- Nasjonal referansedatabase, 2015. *Om oss [About us]*. [Online]
Available at: <http://nrdb.no/om-oss/>
- National Communication Authority, 2015. *Flytting av nummer mellom tilbydere (nummerportabilitet)*. [Online]
Available at:
<http://www.nkom.no/teknisk/nummerforvaltning/nummerforvaltning/flytting-av-nummer-mellom-tilbydere-nummerportabilitet>
- Negro, S. & Hekkert, M., 2008. Explaining the success of emerging technologies by innovation system functioning: The case of biomass digestion in Germany. *Technology Analysis & Strategic Management*, 20(4), pp. 465–482.

- Norwegian Communications Authority, 2015. *Det norske markedet for elektroniske kommunikasjons tjenester 2014 [The Norwegian market for electronic communication services]*, Lillesand: Norwegian Communications Authority.
- Peppard, J. & Rylander, A., 2006. From value chain to value network: Insights for mobile operators. *European Management Journal*, 24(2-3), pp. 128–141.
- Reuver, M. d., Verschuur, E., Nikayin, F., Cerpa, N., Bouwman, H., 2014. Collective action for mobile payment platforms: A case study on collaboration issue between banks and telecom operators. *Electronic Commerce Research and Applications*, Volume 14, pp. 331–344.
- Scornavacca, E. & McKenzie, J., 2007. Unveiling managers' perceptions of the critical success factors for SMS based campaigns. *International Journal of Mobile Communications*, 5(4), pp. 445–456.
- Statistics Norway , 2015. *Statistic bank: Table: 05242: Share that have used electronic offerings and number of private phone calls an average day.* [Online] Available at: <https://www.ssb.no/statistikkbanken> - open log in solution [Accessed 19 January 2016].
- Transparency Market Research, 2014. *A2P SMS market expected to reach USD 70.32 Billion in 2020.* [Online] Available at: <http://www.transparencymarketresearch.com/pressrelease/a2p-sms-market.htm> [Accessed 4 November 2014].
- West, J. & Wood, D., 2013. Evolving an open ecosystem: the rise and fall of the Symbian platform. In: R. Adner, J. Oxley & B. Silverman, eds. *Collaboration and competition in business ecosystems.* Bingley: Emerald group, pp. 27–68.
- Yin, R. K., 2014. *Case study research..* 5. ed. Thousand Oaks, CA: Sage.

Article 2:

Mobile phone number as general-purpose identifier: status and future

Hanne Kristine Hallingby

Submitted to Telematics and Informatics

Abstract

This article strengthens and extends the relevance of evolutionary and systemic innovation processes into the complex mobile technology sector. Through a case study, it examines how the strength and availability of the mobile phone number affect its position as a general-purpose identifier for digital services. This seemingly global and standardized resource is conditional on many local factors. Evolutionary and innovation system perspectives are used in analyzing observations from Norway and Pakistan, complemented by sector-specific insights. In Norway, mobile numbers have long been subject to strict ID credential requirements, with implementation of formal and informal institutions, and integration in existing information infrastructure. In Pakistan, a recent change in ID requirements has fundamentally changed the role of mobile phone numbers as identifiers for financial services. Globally, more and more mobile subscriptions are made subject to stricter requirements on ID credentials and registration, as in developing countries like India and Pakistan – in contrast to developed high-tech economies like the USA and the UK. This study finds that managers in the mobile telecommunication sector should focus on the mobile number as identifier in local markets, preferably in large developing economies if the ambition is a global identifier. Policymakers should recognize the role they play in enabling a well-functioning digital market through formal rules and regulations.

Keywords: mobile number, general-purpose identifier, innovation

1 Introduction

Online IDs and sign-on solutions have proven important for further diffusion of digital services (Igari, 2014; Komorowski et al., 2016). Digital IDs (Jøsang, 2014) are used in digital services such as healthcare, banking, entertainment, and shopping. These services vary in

their ID requirements, and how they conduct initial registration and later use of digital IDs. A digital service provider may own and manage a digital ID itself or use the ID of others. Today, Facebook and Google's ID solutions dominate the social login market (Dhamija & Dusseault, 2008; Larralde, 2015; Loginradus, 2016).

Availability and strength are important factors that may explain the use and diffusion of specific IDs. In this article, the "strength" of an ID refers to the degree to which it is confirmed that a real person is connected to the ID, through requirements for authentication credentials. "Availability" refers to how the ID is integrated and available in pre-existing information infrastructure. Facebook Connect is the most used login ID for web-services due to its easy availability: however, its strength is low (Dhamija & Dusseault, 2008; Larralde, 2015). Banks, official institutions, and the media have higher requirements not met by social login (World Bank, 2016). Strong and local IDs have been developed for banking (Eaton et al., 2014), governmental (Igari, 2014), and media services (Komorowski et al., 2016).

The mobile industry has proposed the mobile number as a good general-purpose identifier for digital services across industries and countries (GSMA and SIA, 2014), arguing that an ID provided by mobile operators based on the mobile subscription is both strong and widely available. The foundation for this is the IMSI standard (International Mobile Subscriber Identity), a unique identifier for mobile subscribers in any mobile network globally. IMSI contains up to 15 digits which constitute the mobile number, stored on the SIM card (Jøsang, 2014). In some markets, the mobile number already plays a substantial role in customer dialogues with SMS (Hallingby, 2016). However, as the ID credential requirements for subscribing and registration for prepaid SIM cards vary across markets, the strength of the mobile number as ID also varies. Further, the public availability of mobile numbers varies across markets, due to regulations and practices regarding number-sharing and directories.

These factors call into question the future of the mobile number as a global general-purpose identifier. Moreover, the market for digital services has previously rejected the mobile number as identifier, fearing market dominance of mobile operators (Jøsang, 2014). Thus the paradox: using a global and standardized resource like the mobile phone number as a general-purpose identifier is still highly conditional on local factors.

How do strength and availability affect the mobile phone number as general-purpose identifier, locally and globally? Using industry data on the global use of the mobile number as identifier, the present study analyzes its strength and availability globally, and reports on how strength and availability have affected its use in digital services in two country case studies.

The aim is not to compare all the various types of IDs but to examine the varying status and significance of the mobile number.

The analysis uses theories on evolutionary and systemic innovation (Bergek et al., 2008; David, 1985), and related literature on information infrastructures (Eriksson & Ågerfalk, 2010) and telecommunication regulation (Milne, 1997) to explain observed dynamics of positive self-reinforcement and path dependency. The research draws on design principles for IDs (Dhamija & Dusseault, 2008; Jøsang, 2014) to identify the specific factors that affect the emergence of mobile numbers as general-purpose identifiers. This study contributes to our understanding of what is necessary for a global path to emerge, and why local path dependence is more common. In particular, it sheds lights on the significance of formal and informal institutions for the evolution of a general-purpose identifier.

2 Theory

This section begins by presenting a theoretical approach for explaining how the mobile number can emerge as a general-purpose identifier in an evolutionary process with self-reinforcing effects. Next, related literature on design principles for identifiers is presented; this literature branch is inspired by the same theoretical approach. The combination of these enables an operationalization of how strength and availability affect the role of the mobile number as identifier.

2.1 Evolutionary and systemic innovation, and path-dependency

According to evolutionary and systemic innovation perspectives, technology diffusion is subject to positive self-reinforcing feedback effects and subsequent unintentional path dependence (David, 1985; Fagerberg, 2003). In a technological innovation system, technology is diffused through networks of stakeholders; in early phases, uncertainty is high and various final outcomes are possible (Bergek et al., 2008). Later, certain technologies become more dominant due to positive self-reinforcement, especially when there is strong technical interrelatedness, economies of scale and irreversibility due to learning and habituation (Arthur, 1989; David, 1985). Self-reinforcement can have negative and positive implications: it may imply lock-in to a dysfunctional technology, but a technology may also have a non-controversial, deserved and relatively strong position. With mobile numbers, we find characteristics that may lead to path dependence; there is technical interrelatedness and

possible irreversibility due to learning and habituation, fueling self-reinforcing feedback effects (David, 1985) .

2.2 Path-dependency aspects of mobile numbers

Two perspectives in particular contribute to the discussion of the mobile number as a general-purpose identifier: the regulatory approach, and the information infrastructure approach. Both draw on evolutionary and systemic innovation theories and concern challenges with dysfunctional lock-in due to the self-reinforcing mechanisms of systems. They also indicate that a generally available resource may spur variety creation and innovation by other actors.

The regulatory approach has been employed in analyzing the regulation of phone numbers, the conclusion being that (mobile) numbers are an “extremely valuable resource for all industry players and users” (Milne, 1997, p. 155), also for service development. However, nothing was said about using phone numbers as a resource beyond the telecommunications domain. Any concerns with dysfunctional lock-in were restricted to competition between mobile operators and limited number space. These issues have since been solved by institutional solutions such as delegating mobile-number management to a neutral part, number portability, and number-plan extensions (Rood, 2000). Recently, worries have been voiced concerning dysfunctional lock-in with reliance on mobile numbers for ID (Jøsang, 2014). Such lock-in to one specific identifier may arise from, for instance, listing in databases and on business cards, and individuals’ recognition of codes and patterns (Rood, 2000).

The second approach introduces the concept of information infrastructures, which refers to the systems, databases, and interfaces underlying digital services (Eriksson & Ågerfalk, 2010; Hanseth & Lyytinen, 2010); “identifiers and registers of identifiers constitute a naming infrastructure, which is an important part of the overall information infrastructure” (Eriksson & Ågerfalk, 2010, p. 435). An information infrastructure can enable further evolution of information infrastructures by efficiently allowing sustainable innovation and growth. However, an information infrastructure may become a constraint to infrastructure evolution and introduce negative lock-in when it is not efficient and sustainable, or difficult to alter (Hanseth & Lyytinen, 2010).

Identifiers played “a major role in causing lock-in situations” regarding the Swedish PID number and Student Identifier because of challenges with descriptive information in the identifier, the choice of inappropriate identifiers, and lack of institutional control of identifier (Eriksson & Ågerfalk, 2010, p. 434). Further, an information infrastructure tends to originate

from local implementations (Hanseth & Lyytinen, 2010) – in line with evolutionary and systemic innovation perspectives where technology is initially selected by stakeholders for specific and local purposes (Bergek et al., 2008). Also organizations like the World Bank and GSMA recognize that the “landscape of identification that already exists in the country will shape the development of digital identity ecosystems” (Clark et al., 2016, p. 27).

The two perspectives above are founded on theories of self-reinforcing effects but address forces in the ICT sector more specifically. As with general evolutionary and systemic innovation processes, there are various end-games for mobile numbers as general-purpose identifiers: as the only general-purpose identifier, or completely bypassed by others, or co-existing with and complementing other identifiers (Hanseth & Lyytinen, 2010; Jøsang, 2014). Furthermore, they may evolve into well-functioning general-purpose identifiers – or lead to a dysfunctional lock-in situation.

2.3 Design principles for a general-purpose identifier

The discussion so far has concerned more general factors that can reinforce the mobile number’s position. This section focuses on the literature indicating more specific factors that may affect the diffusion of an ID and how it becomes part of digital services.

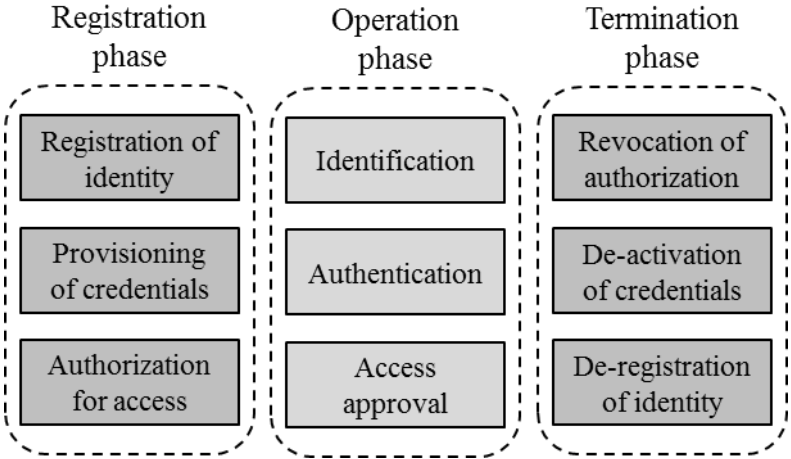


Figure 2-1 Phases of management of ID for web-services, adapted from (Jøsang, 2014)

It has been suggested that there are three phases for the management of ID and access: registration, operation and termination, as illustrated in Figure 2-1 (Jøsang, 2014). In the registration phase, authentication credentials are required and registered, so a real person can be connected to an identity and allowed access to a specific service. The strength of any ID will hinge on the formal requirements concerning credentials and registration routines in this

first phase. In the operation phase, the identified person uses the service; and the identity is de-activated in the termination phase.

Eriksson and Ågerfalk (2010) propose design principles for identifiers based on the assumption that path dependence and lock-in are inevitable – thus the negative consequences of strong positive self-reinforcing mechanisms and obstacles for transitions must be minimized already in the design. However, it takes more than a technical decision to counter negative effects: design principles must include usage, institutional, and infrastructural aspects. Implicitly, these principles offer indications for fueling the evolutionary self-reinforcing mechanisms for an ID. The basic criteria to be fulfilled are:

- identifier stability to support knowledge network effects
- mnemonic – easy for end-users to learn and remember
- check-digit, to facilitate manual use in digital services
- patterns to ease manual recognition and information exchange when in use
- database-friendly – easy to implement and use in databases
- transition plan for redesign in a lock-in situation.

These six criteria ease the use and adaptation for different actors: end-users, administrators and managers of systems. End-users are not willing to invest much time in privacy and security in any phase, and tend to choose ease-of-use over security (Dhamija & Dusséault, 2008); thus, simplicity in all phases is critical. In addition, when identifiers are stable, they are reinforced by knowledge network effects. These are all elements that resonate with the learning and habituation mechanisms noted by David (1985), and the importance of simplicity in existing information infrastructures (Hanseth & Lyytinen, 2010).

In addition, according to Eriksson and Ågerfalk (2010), an ID solution must be managed and coordinated on the institutional level, to achieve the right level of quality and efficiency. Thus, an ID can gain trust and legitimacy through institutional processes that complement the strength of the credentials required in a registration phase, similar to the evolutionary and systemic nature of technology diffusion (Bergek et al., 2008).

2.4 Summary of factors affecting mobile number as general-purpose identifier

This review indicates that the role of mobile numbers as general-purpose identifiers is subject to an evolutionary process. Self-reinforcing effects may take the evolution onto one path;

however, the path may differ among countries, due to local factors. The identifier-specific literature has noted concrete factors that affect the success or failure of an identifier, and the potential role of strength and availability.

Before proceeding with strength and availability, let us look at the significance of ease-of-use and stability. First, the literature emphasizes the importance of ease-of-use for end-users and service providers in order to drive the diffusion of the ID. Second, stability reinforces ease-of-use: the end-user remembers the ID, and; the end-user's ID remains correct over time in a service provider's database. The point here is that the mobile number is generally easy to remember and use; it is also stable and already subject to self-reinforcing processes. The easiness comes from its predictable and universal format even globally; for the individual, the learning and habitual aspects increase this element. It is stable on the individual level partly due to institutions like number portability, which allows individuals to retain a number for a long time, ensuring stability in databases. However, the strength and availability of the mobile number are subject to many contradictory and diverse forces.

The strength of an identifier is conditional on credential requirements in the registration phase – but is also affected by the emerging institutions that accompany the ID throughout the lifecycle, such as number portability and data privacy. An information infrastructure where the ID is already implemented and readily available in systems and databases makes possible more use for digital services. Operationalization of the mobile number's strength and availability depend on its credentials, institutions, and existing information infrastructure, summarized in Table 2-1.

The strength of the mobile number through credentials is relevant primary for prepaid SIM cards, as post-paid mobile subscriptions are by nature connected to a person who pays an invoice. A set of informal institutions and trust is expected to build up around the mobile number through a legitimation process (Bergek et al., 2008), affecting its further use in digital services.

Availability depends on the use of the mobile number in existing information infrastructures, which again is partly dependent on the regulations concerning public directories (Eriksson & Ågerfalk, 2010; Hanseth & Lyytinen, 2010). Mobile numbers are already widely available: as of August 2017, there were more than five billion subscribers (National Communication Authority, 2017). However, “availability” may also refer to being able to get a number confirmed, to consult databases for, say, the name and address of the person in question. Number portability in a market is a formal institution that increases strength as well as

availability by linking a person more tightly to a number over time, and the continued reliability of a mobile number in customer databases. Requiring stricter credentials would stabilize the mobile number as ID. Data privacy affects strength and availability through resistance to stricter requirements in the first place, and then how to manage data in accordance with regulations.

Table 2-1 Strength and availability for the mobile number

<i>Factor</i>	<i>Theoretical foundation</i>	<i>Operationalization of mobile phone number</i>
Strength	Formal credentials Formal and informal institutions	<ul style="list-style-type: none"> • Authentication credentials for prepaid SIM-cards • Formal institutions <ul style="list-style-type: none"> ○ number portability ○ data privacy • Informal institutions <ul style="list-style-type: none"> ○ norms, trust, expectations towards mobile number and context
Availability	Existing information infrastructures	<ul style="list-style-type: none"> • Formal institutions <ul style="list-style-type: none"> ○ number portability ○ data privacy ○ data-sharing obligations • Existing databases and directories <ul style="list-style-type: none"> ○ look-up, confirmation, enriching • Use in existing applications and services

This study uses the above-described understanding of factors that determine the strength and availability of the mobile number to assess its position as general-purpose identifier in global and local settings. We expect to find that these factors are part of evolutionary processes which vary across countries, leading to varying statuses for the mobile number as identifier. When strong and readily available, the mobile number should be able to play a significant role as ID in digital services.

3 Method

This research is an explanation-building multiple case studies (Yin, 2014) of how the dual factors of strength and availability affect the role that mobile numbers can play as a general-purpose identifier, locally and globally. This relationship is subject to ongoing processes in complex and varied contexts. This study has operationalized strength and availability to guide data collection and analysis, and relies on multiple sources of evidence (see Table 3-1). Three approaches are used for data collection. Industry data indicate the status of use of the mobile number as general-purpose identifier. Two different datasets – a survey and Wiki data – enable assessment of the status of strength and availability across many markets, primarily

regarding ID requirements and availability in public directories. Such data can be difficult to obtain through public sources. As a researcher in a global mobile network operator, the present author has been able to survey internal sources. These internal data have boosted construct validity by qualifying the data drawn from public sources. The data on strength have been combined with data from GSMA intelligence.

Table 3-1 Data sources

<i>Type of sources</i>	<i>Sources</i>
Public documents	<ul style="list-style-type: none"> • Regulatory websites, factsheets, guidelines, rulings • Newspaper articles • Stakeholder websites • Industry reports
Survey	Mobile operator’s staff, Asia and Europe, 2016
Wiki data	<p>Wiki data on prepaid SIM cards in 187 countries, including status and implementation of ID credential requirements. Four countries reported on in the wiki are blacklisted and not included, among them North Korea. March–April 2017.</p> <p>http://prepaid-data-sim-card.wikia.com/wiki/Prepaid_SIM_with_data</p>
GSMA intelligence Resource center for mobile operators	<p>Data on prepaid SIM cards: market share, mobile connections, and population. Retrieved March 2017, data from Q4 2015.</p> <p>https://www.gsmaintelligence.com/</p>
Interviews	<ul style="list-style-type: none"> • Norway: Official bodies, regulators, third parties, aggregators and mobile operators. 13 interviews. 2014–2016. • Pakistan: Official bodies, regulators, market analysts, non-governmental organizations, investors, mobile operators, mobile financial services. 12 interviews. 2015.

Two countries – Norway and Pakistan – were analyzed regarding how and why the mobile number has succeeded as identifier there. The network operator with which this researcher is affiliated has operations in these countries: this enabled simple and close access to data and informants, but might have prevented a better balance between cases. However, the two countries have proved to be illustrative examples of the contrast and similarities between developed and developing countries in this study. Norway is an example of a mature implementation in a developed and small country; Pakistan is a large developing country with early but successful implementation thus far. Both countries have mobile numbers that are strong and in some ways score high on availability; data privacy has not been an issue with regard to requirements for ID. The interview data in this article have also been published in articles with other purposes and research questions (Hallingby, 2016; Nesse et al., 2017).

Experts and others working within the field were interviewed and additional documents obtained. Interviews were transcribed, and data were analyzed manually and in NVivo. The

interviews and first cycle of coding were open and explorative, aimed at evoking reflection; they were also guided by the platform ecosystem approach. The objective was to capture informants' explanations, beliefs and judgments so as to address the research question in a deep and meaningful way (Saldaña, 2013). After many rounds of rereading data, coding, analysis, and theory comparison, a pattern emerged in the empirical data; this proved to match pre-existing theories and concepts such as evolutionary innovation and information infrastructures (Yin, 2014). Validity has been strengthened by using such theory pattern matching and explanation building.

4 Results

4.1 Status and growth of mobile number as a general-purpose identifier

Even though firms increasingly seem to collect mobile numbers from customers who use their web-services, data are difficult to obtain. Some general market observations can serve as indicators here.

A survey in EU countries conducted in 2010 reported that on average 46% of consumers were willing to disclose their mobile number for eCommerce purposes, and 23% for social networking sites; for eCommerce the willingness was around 75% in Scandinavia, and 42% in the UK (Lusoli et al., 2012). This indicates that it is common for service providers to obtain mobile numbers as part of signing-in to a service, but that there is also some reluctance from consumers, depending on localization and the type of service.

The use of SMS in customer dialogues is another indicator that digital services use mobile numbers as customer identifiers. Articles from the marketing industry report that 40–50% of marketers worldwide use SMS (eMarketer, 2015); however, e-mail is an even more common way to communicate with customers. Salesforce is a customer relationship management system with a 33% world market share in 2015 (Hollar, 2015). The relative high use of and growth of SMS that Salesforce reports globally for 2017 – 59% use in 2017, a 142% growth from 2015 – indicate that the mobile number is a common data-field in customer databases and part of existing information infrastructures (Salesforce, 2017).

The US-based Pew Research Institute has carried out a comprehensive investigation of which data the apps in Google's Play Store require from their users (Olmstead & Atkinson, 2015). One indication of the relevance of the mobile number is that 35% of all apps – more than 350,000 – “access the phone features of the device. This permission allows the app to

determine the phone number and device IDs” (Olmstead & Atkinson, 2015, p. 22). The motivation behind that study was to increase the awareness of data requirements and privacy issues with apps. Regardless of whether 35% is too high in that respect, it is still an indication of service providers’ interests in the mobile number and its position as part of an existing information infrastructure.

Finally, the mobile number plays an increasing role in the ID landscape through the “two-factor” password model (Schreiner, 2016) used for many digital services.

All in all, this indicates that the mobile number often is used as an identifier in digital services, and that tendency is on the rise. That being said, it does not seem outperform or replace other forms of identifiers, but follows its own evolutionary path. In addition, use of the mobile number may have many further limitations not discussed here.

4.2 Global strength and availability of mobile numbers

The strength of a mobile number is conditional on the requirements for ID credentials when the user registers. In the following section data on credential requirements for SIM-cards are presented, collected from a Wiki source (Anon., 2018). This is combined with data for markets shares of prepaid SIM-cards, to assess the consequence of requirements. The analysis covers about 6.6 billion active connections used by some 5 billion unique mobile subscribers. (The difference is due to some subscribers having more than one SIM card.) The present author is affiliated with a mobile operator and has been able to collect and qualify the Wiki data with a survey from certain specific markets.

The analysis shows that the majority, 73%, of all mobile connections currently have strict ID credential and registration requirements. There are altogether 59 countries with such practices (see Figure 4-1), including large countries like China and India. Prepaid SIM cards are dominant in most of these countries. Ten countries alone account for 79% of these connections.

However, 27% of mobile connections do not have strict ID requirements, altogether 124 countries. In these countries the identities are not registered in any databases, although some sort of ID may be required to purchase a prepaid SIM card. The USA is the largest country in this category, with a share of prepaid SIM cards as high as 25%.

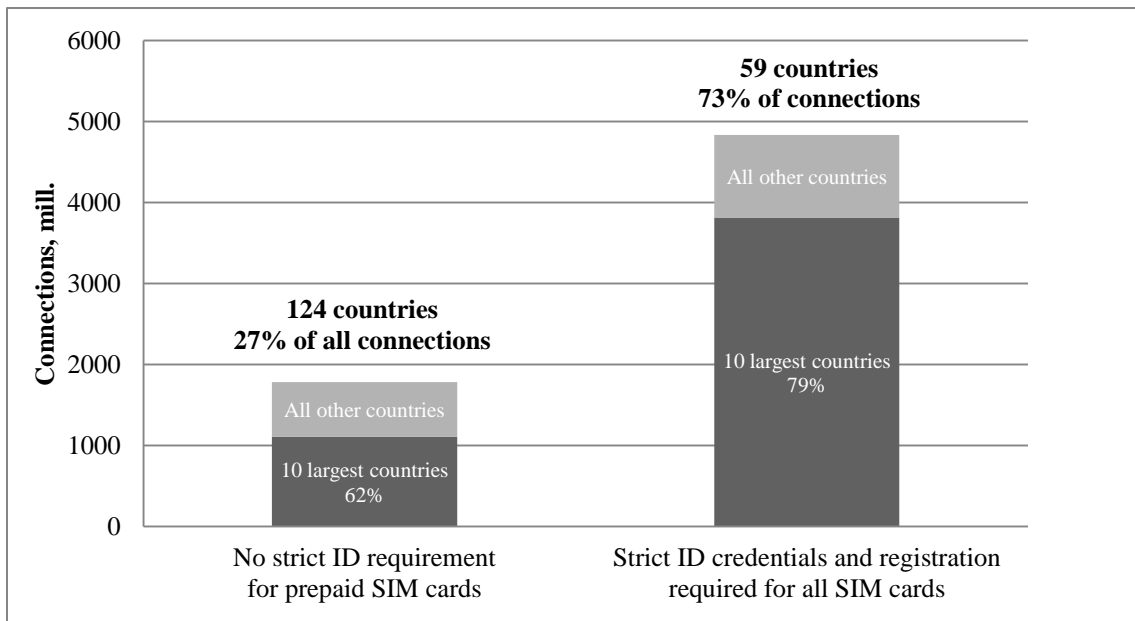


Figure 4-1 ID credential and registration requirements for SIM-cards around the world

Thus, most markets have strict ID credential and registration requirements for mobile subscriptions. This is due to recent changes; in 29 of these 59 countries, stricter requirements have been introduced since 2012.

Among countries that have introduced strict requirements, this seems to have become a common, recognized practice; however, some of these countries are weak on implementation. In the Wiki data it was commented that Russia is the least able to enforce the requirements: “There are four different ways of buying a SIM card in Russia: the official, the semi-official and two unofficial” (Anon., 2018). Germany introduced the shift in 2017, and then only for new SIM-card purchases. This author’s qualifying inquiry indicates that implementation in large countries like India, Pakistan and Bangladesh has been enforced strictly, also for existing SIM cards; the Pakistani case is described below. In China, 100 million Chinese still had not linked their names to SIM cards as recently as June 2016, but were required to do so by June 2017 (Custer, 2016).

No systematic relationship was found between a country’s economic status and restrictions. There are developing and developed economies among the strict and not strict; there are also some leading mobile high-tech countries that are strict, and others not. On the top ten list of strict countries are China and Japan. The USA tops the list of countries that are not strict; both the USA and the UK are arguably high-tech contributors with no requirements.

The pros and cons of more stringent requirements have been discussed in many markets, and decisions have gone both ways in both developing and developed economies. In developed

economies, arguments of data privacy are often put forward: that such requirements represent an unnecessary collection of user data, and an infringement of data privacy. In developing economies, the arguments focus not so much data privacy as on the extra burden such ID requirements put on socially disadvantaged people who lack official identity papers.

Emplacing ID requirements for SIM cards could potentially decrease access to economic growth through digitalization and development (GSMA, 2016; GSMA, 2013).

Thus, the picture is mixed; on the one hand, the share of mobile numbers with strict ID credential and registration requirements is large and growing. This is mainly in countries with a high share of prepaid SIM cards, many of them developing countries. On the other hand, some signal-sending high-tech countries like the USA and the UK have less strict ID requirements, and arguments have concerned the protection of data privacy and the right to remain anonymous. These reinforcing effects create a tension where influential high-tech countries may counteract the large majority of countries around the globe.

The detailed inquiry into ten countries indicates availability as a demarcation between developing and developed economies. It is primary European countries that have required and implemented solutions where mobile numbers are available in public directories. Still, for instance in Denmark and Sweden, registering prepaid SIM cards is voluntary. Asian countries do not make mobile numbers available, also if fixed numbers are made available. In Malaysia and Bangladesh it is strictly forbidden to share mobile numbers in open directories. In India, operators are obliged to provide numbers in directories; however, this has not been implemented. As of early 2018 it is still unclear how the new EU General Data Protection Regulation will affect public mobile-number directories. Requiring number directories to reconfirm subscribers' consent to be included in such directories is assumed to be highly negative for public directories (Samferdselsdepartementet, 2017).

4.3 Status and use of mobile numbers in Pakistan and Norway

Both Norway and Pakistan have mobile numbers that serve as strong ID indicators. Norway has a readily available mobile number for efficient use in digital services, unlike Pakistan. These markets are of course different, one being a developed and the other a developing economy, with different political statuses. It is therefore interesting to note that in both countries there are recent indications of the growing relevance and use of mobile numbers as identifiers in advanced digital services. While Norway has mature implementation in a small,

stable and affluent economy, the case of Pakistan can shed light on a process in its infancy, in a large developing country. Both countries are subject to local self-reinforcing effects.

Table 4-1 General indicators and status, Pakistan and Norway

	<i>Pakistan</i>	<i>Norway</i>
Country (Q42015)	191 mill inhabitants	5.2 mill inhabitants
	128 mobile connections	6.3 mobile connections
	Developing economy	Developed economy
Strength	High	High
	Strict biometric ID requirements and implementation regime, from 2015.	Strict ID requirements and implementation regime, from 2004.
	Number portability from 2007 with an operator-owned shared database.	Number portability from 2001 with an operator-owned shared database.
Availability	High availability through biometric ID solution and central database	Highly available in public and digitized databases
	Low: no general number directory. However, obligation for fixed-line numbers, but not for mobile numbers, for privacy.	Obligation to share number-information with public directories
	No active market for mobile-number directories.	Well-functioning, profitable market for directories. Some directories have become advance look-up databases for third parties providing credit inquiries.
Firms using the mobile numbers for digital services	Early phase in use of mobile financial services – kick-starting the use of mobile numbers as ID	High volume of use in applications and services:
	Money-transfer programs an influential force	Mobile operators use for own purposes
		Services use the mobile number: public services, banks, e-commerce, retailers
Data privacy	Data privacy not issue, because of strict ID requirements. Mobile numbers not shared in public directories due to privacy concerns.	Data privacy not an issue as regards strict ID requirements or sharing mobile numbers in public directories. However, customer databases in general subject to stringent regulations.

4.3.1 Norway

Recent research has explored explanations for why the use of SMS Application-to-Person has grown so rapidly in Norway (Hallingby, 2016). SMS Application-to-Person refers to SMSs sent via an application, such as flight notifications, parcel delivery, or public warnings. Figure 4-2 shows the growth for the incumbent operator Telenor till 2014; the numbers continued to grow throughout 2017 (Telenor, 2018). These messages play a role in third-party strategies

for customer dialogue, even though they imply a cost per message. Interestingly, interviews with aggregators and third parties in Norway indicate that the mobile number is increasingly included in customer databases for communications throughout the provision of service. The mobile number has become an ID; as one aggregator says: “I recommend all my customers to collect mobile numbers. The mobile number is much, much more important than email.”

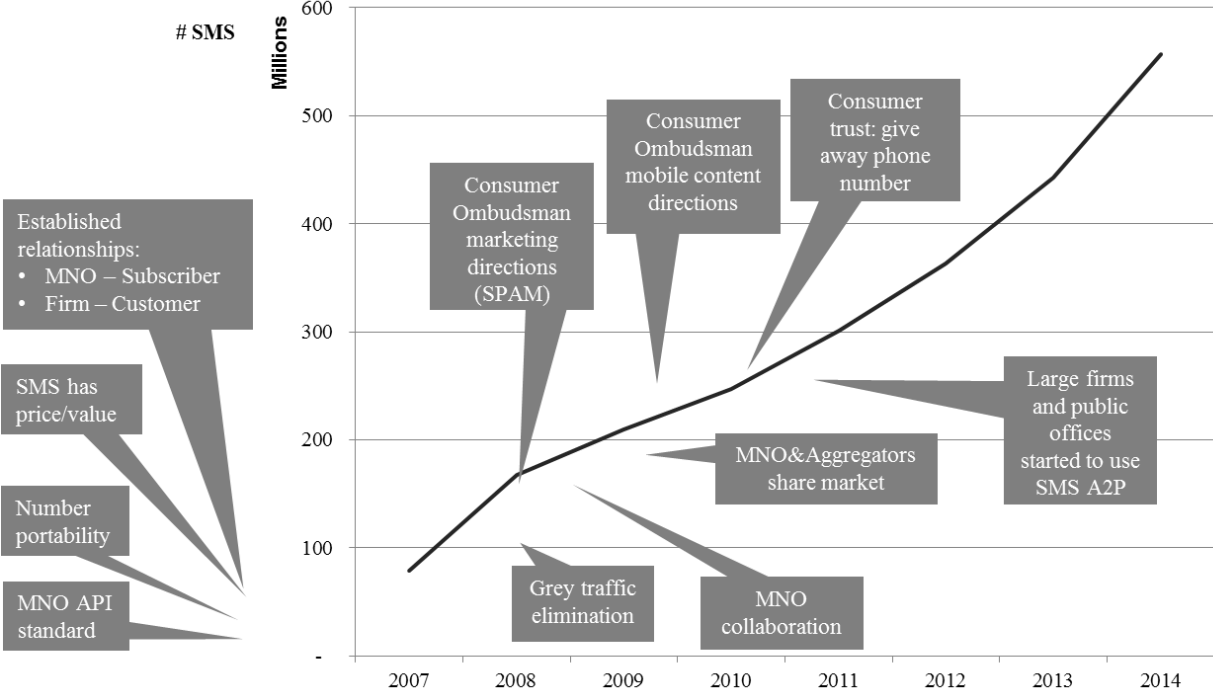


Figure 4-2 Growth process of SMS A2P in Norway, adapted from (Hallingsby, 2016)

The current high growth of SMS Application-to-Person in Norway is only one indication of the role of mobile numbers in customer databases and dialogues. Figure 4-2 shows the many events and factors that have enabled its diffusion. The strength of the mobile number is based on the strict ID requirements that were implemented in 2004. Number portability (Nasjonal referansedatabase, 2017), and MNO obligations to share number-information with directories (National Communication Authority, 2017) have led to a situation where mobile numbers are stable, closely linked to a real person, and are readily available. That being said, such regulations have not been implemented without resistance from mobile operators, who report, for instance, that their capacity to compete for customers was reduced by number portability. Eventually, a well-functioning directory market evolved, offering services for qualifying, analyzing and using customer data. One aggregator describes the effect for the mobile number: “Everybody [in Norway] has a national identity number – that is your personal identity. You do not share that – and you are not supposed to do that. Then there is your mobile number. It is open out there – and identifies you immediately. No one has the same

number, full stop. This means that by using a directory service, if anybody registers his or her mobile number anywhere, you can immediately identify the person.”

Also other events have reinforced the institutions governing the mobile number and increased its legitimacy as an identifier. Telenor was the first local mobile operator to eliminate irregular “grey” traffic (Matthews, 2015): this means excluding unauthorized and free traffic and implicitly protects the opportunity to set a price above zero for the communication channel. Regulators of consumer rights introduced directions for how to use SMS as a communications channel (Forbrukerombudet, 2013 b). This has all normalized the use of SMS in customer dialogues: consumers became accustomed to identifying themselves by the mobile number, the identifier became predictable for other actors – and all this built a climate of trust between them and towards the formal and informal institutions governing the sector. Data privacy with regard to ID requirements for mobile subscription and public directories was never a major issue in the Norwegian debate; however, customer databases are generally subject to strict data privacy regulations.

One important factor has been that large, trustworthy firms began using the service in their customer dialogues. The mobile operators have themselves used SMS, banks use it, and – not least – its use by official bodies has boosted the legitimacy of and trust in the mobile number as a general-purpose identifier. One aggregator explains how official bodies use SMS: “I think, more and more actors have started to use this channel. DIFI [the Norwegian Agency for Public Management and eGovernment] uses SMS. You have some of these drivers that forcefully have legitimized the SMS as a channel.” One of DIFI’s responsibilities is to make public information and services accessible for citizens and public agencies. On the way to a digitized public sector, they have built up a database containing four of 5.2 million Norwegian citizens. The database contains email address and mobile number as identifiers. It is up to public agencies to determine communication channel strategies; however, digital post to citizens is always to be noted by sending an email or SMS. DIFI expects that in future around 50% of all communications will be accompanied by an SMS despite the higher cost compared to email. SMS is already used for communications in the education and healthcare sector (Helse Vest, 2016) where also the above-mentioned DIFI database is used for confirmation of mobile numbers. The majority of Norwegian citizens want SMS to be used in their dialogue with the healthcare sector (Ankjell, 2015). Thus, the mobile number constitutes a strong identifier and has already become an essential part of the information infrastructure for digital citizen services in the Norwegian public sector.

The banking industry in Norway has a long history of shared infrastructure solutions based on trust and institutions (Eaton et al., 2014). As immediate mobile payment is becoming more common in Norway, the banking sector foresees that mobile numbers will be more used than bank account numbers (Bækken, 2016). This is partly because the bank account number has proved to be difficult to port due to routing and settlements between banks. The mobile number has a more stable character in the Norwegian context and may function better as an identifier. This is all made possible by regulations (FinansNorge, 2015) governing the shared account and address register of whole banking sector; more specifically, governing the establishment and control of the relationship between bank account, mobile number, and names. Again, this indicates how the mobile number in Norway is a strong identifier, readily available through existing information infrastructures.

4.3.2 Pakistan

Pakistan is a large and developing economy. As mobile phones are quite common, access to financial services through mobile phones has been proposed as a means to enable people to escape from poverty (World Bank, 2016). The aim has been to transfer mobile financial transactions from manual over-the-counter solutions, to digital accounts. The World Bank and mobile financial service providers like Easypaisa (World Bank, 2016; Khan, 2016) support this transformation, as digital accounts are a necessity for uptake of loans and savings.

However, a major obstacle has been the very stringent requirements set by the banking regulatory authorities as to “knowing-your-customer” and subsequently also to identification procedures when a customer acquires such products. The low ID credential requirements for SIM cards in the mobile sector have been an obstacle to the establishment of mobile bank accounts, loan and saving products. As Figure 4-3 indicates, up till 2014 the uptake of mobile accounts – in the Figure termed “branchless bank accounts” – was low and slow.

The mobile industry embarked on a significant change in 2015, when it was decided that all SIM cards were to be re-verified and linked to a biometric ID provided by the National Database & Registration Authority (NADRA, 2017). This requirement was already in place for new purchases of new mobile subscriptions from 2013 (GSMA, 2016). It was made mandatory for all mobile subscriptions after a terrorist attack in December 2014, and completed in May 2015. In the re-verification process, mobile operators bore the costs and have later had to administer the new ID regime. Mobile operators have argued against too strict requirements for SIM cards, claiming that this entails unnecessary expenses and

bureaucracy (GSMA, 2016). However, the re-verification brought a major strengthening of the mobile number as identifier; and more recently, the positive consequences for mobile financial services have been recognized. As one expert said about the mobile operators after the re-verification: “They are claiming that their transition has not been bad – because they are giving people incentives to actually transact over the wallet”. In Pakistan, some 115 of 215 million SIM cards were re-verified, connected to approximately 45 million unique persons (IDs), according to an interview session with the Pakistani telecommunication authorities. One expert reflected on the success of the re-verification and how it may affect the uptake of financial services: “The fact that mobile operators were able to make that transition in 90 days is extremely impressive – and to me it is evidence that you can actually convert people to wallet” [the mobile bank account].

The re-verification of SIM cards found huge support in Pakistan after the terrorist attack. Interviewees were not concerned about data privacy, and expressed confidence in the governing institutions. One informant explained that things are different in Pakistan: “I have lived in Europe for five years. So I know what their concerns are and what are ours. Data privacy and things like that, your personal privacy – these are the considerations of a developed world.” Furthermore, NADRA seems to have earned a trusted position in Pakistan, regarding technical standards as well as handling of data. One interviewee involved in public services said: “The NADRA database is like the security base in the USA: they have also the data on the population, but the population trust them and that the data are secure with them. It is the same with the NADRA. NADRA has almost the same system – same security protocol and everything. All of Pakistan is not verified with NADRA, but people trust NADRA.” Interviewees acknowledged inquiries about data privacy in the Pakistani context but emphasized the opportunities for economic development and increased transparency, to the benefit of the population.

After the re-verification of SIM cards was completed in 2015, branchless bank accounts started to grow steeply as shown in Figure 4-3: by 2017, financial transactions using accounts had reached about the same level as over-the-counter (State bank of Pakistan, 2015; 2017; 2014; Khan, 2016). The temporary drop in growth in 2016 was due to the closure of 2.6 million inactive accounts (State Bank of Pakistan, 2016). This steep growth coincides not only with the re-verification of SIM cards, but also with the opportunity for mobile customers to dial a string and easily open a new account in line with the strict “knowing-your-customer” requirements (Easypaisa, 2016 b). Behind this string was the now-strong mobile ID at work,

fulfilling the knowing-your-customer requirements for banks (at the lowest level – Level 0). The string-solution, implemented by Easypaisa already in mid-2014, was originally directed towards new SIM-card customers. The technicalities were already in place when all SIM cards had to be re-verified in 2015. This being said about successful uptake of mobile bank accounts, achieving financial inclusion in Pakistan is still a long way off, and many obstacles remain beyond ID (Intermedia, 2017).

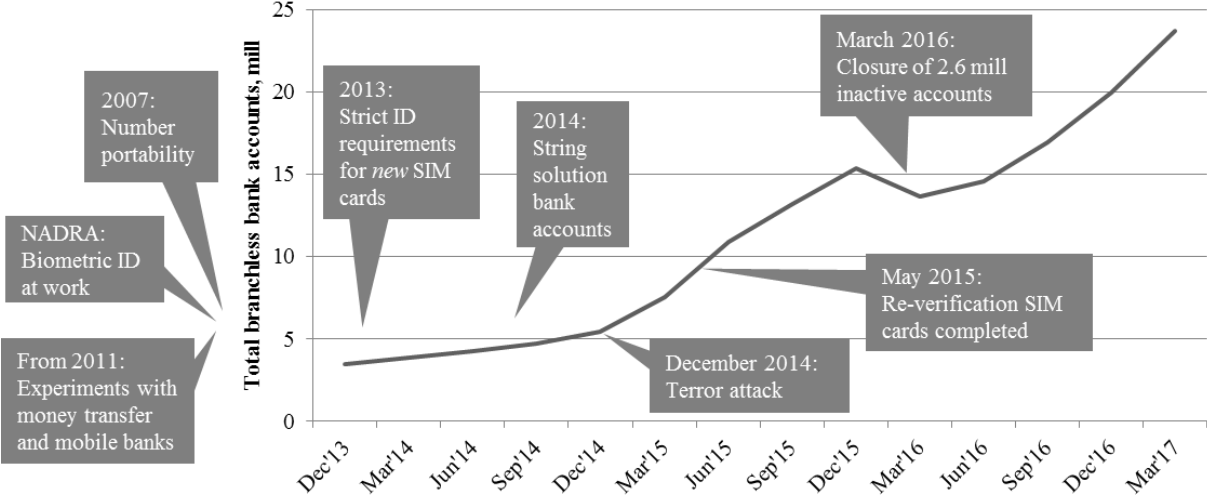


Figure 4-3 Branchless bank accounts, Pakistan (State Bank of Pakistan, 2014; 2015; 2017)

In parallel with the development of mobile financial services, also other actors are taking advantage of the biometric IDs from NADRA and further ensuring its position as a trustworthy institution in Pakistan. One example concerns the organizations that transfer money to the poorest Pakistani women, the most prominent being BISP (Benazir Income Support Programme) (BISP, 2017). These programs have faced huge challenges in ensuring the correct identity of people. It has not been easy to find solutions for confirming identity, and safely transferring money to the right person in a transparent way. Representatives of the BISP program explained: “We are like an experiment center. The reason is – we are facing all kinds of problems, and eventually we have to find a way out of it.” By 2017, most Pakistanis had a biometric ID provided by NADRA.

BISP did experiment with mobile financial services, but hit on a simplified biometric identification solution as the main way to transfer money to beneficiaries. The SIM card and mobile financial services now play a complementary role, providing a physical point of money withdrawal using available biometric verification devices. In addition, a SIM card can be tagged to a bank account in order to enable messages about account status (BISP, 2017). Mobile financial services and the evolution of BISP’s solutions have become highly

intertwined. As one informant put it: “Telcos are not only partners – they are brothers (...) we are sitting on their shoulders. They are carriers.” Developing today’s solution has involved a massive learning process: “If you had been here in Pakistan four years before – you would have seen this nightmare we had. Like four million beneficiaries, money orders. [...] But now – we’re in a good position – we’ve got this thing moving.”

All in all, the strength the mobile number has gained as identifier has promoted mobile financial services in Pakistan. This has been an evolutionary process of trial and error, where one specific event strengthening the mobile number seems to have fueled the further development of financial services. The telecom authorities, the state bank, mobile operators, banks and large enterprises like BISP are players who, step by step, are bringing this further. The biometric ID provided by NADRA has become a trusted central element in local information infrastructures, enabling the further evolution of many digital solutions in Pakistan. However, there are no public directories that make mobile numbers available, partly because of privacy issues. The availability of the ID for mobile numbers differs here from the case of Norway.

5 Discussion

This article has investigated how strength and availability affect the mobile number as a general-purpose identifier, locally and globally. Closer examinations of two markets – Norway and Pakistan – has shown that strength and availability are important factors in processes (Bergek et al., 2008; Fagerberg, 2003; Hanseth & Lyytinen, 2010) where the mobile number is getting a foothold as identifier (Dhamija & Dusseault, 2008; Eriksson & Ågerfalk, 2010).

In Norway we found substantial use and mature integration of the mobile number into digital services. This evolution has been subject to strict ID requirements, institutions and trust, and a pre-existing information infrastructure. Early events such as closing of irregular traffic and regulations proved essential in kicking off growth.

In Pakistan, a recent change in ID requirements for mobile numbers has fundamentally changed their position as identifier, spurring growth in financial services. We see that trust and institutionalization can be built also in Pakistan, paving the way for further innovation. However, the availability of information on mobile number in information infrastructures in Pakistan is still low. In both Norway and Pakistan, it is the overall combination of many

factors in complex and local processes that is the main explanation for the position of mobile number as a general-purpose identifier today.

The patterns observed in the empirical data match the propositions from theory which see socio-economic aspects like institutions and norms as important; as expected, the observed strength of mobile numbers was first based on formal rules as to ID requirements, later followed by a legitimation process that built informal norms for what to expect and how to behave (Bergek et al., 2008; Eriksson & Ågerfalk, 2010). In the markets examined here, actors now expect a mobile number to represent a real person, and that this information can be verified. End-users have grown accustomed to providing their mobile number as ID in digital services, and they expect certain benefits in return. A stable and predictable institutional context seem to be a prerequisite for innovation that may be applicable far beyond the discussion of the mobile number as identifier.

Also as expected, the mobile number gradually becomes accessible in public directories through an evolutionary, path-dependent process. All types of service providers are starting to integrate the mobile number into their customer databases and systems – as a part of the information infrastructure on which other digital services are based (David, 1985; Hanseth & Lyytinen, 2010). The processes at work in the Norwegian and Pakistani cases can be seen as exemplifying how a self-reinforcing process takes an innovation onto a specific path (Arthur, 1989; David, 1985), with the mobile number the preferred identifier for certain types of digital services. In Norway, the mobile number has become an increasingly important element in customer identification for many digital services; in Pakistan, the recent surge in mobile financial services indicates the strength of the mobile number for certain types of services.

Norway and Pakistan are similar in how the strength and availability of the mobile number have played a significant role in an evolutionary process; however, local causal mechanisms and subsequent paths differ, as also indicated by theory (Bergek et al., 2008; Hanseth & Lyytinen, 2010). Theory also suggests that there will initially be a high degree of uncertainty as to which path an evolutionary process will take, given the many factors that can affect the final outcome (Arthur, 1989; David, 1985). In both cases examined here, we found initial uncertainty about the role of the mobile number as identifier. Later, at least in Norway, the growth and use of the mobile number have become more directed and forceful.

Because of this high initial uncertainty and the many potential evolutionary paths, it may well be that strict ID requirements on mobile numbers will not always be accompanied by increased use of digital services. For instance, the issue of data privacy seems to vary across

countries, independent of economic factors. Other identities that fill the same role as a mobile number may be relevant: in Denmark, the national Central Persons Registration Number is widely used as ID for public, banking, and video services (Igari, 2014). The research reported in this article has noted the reluctance of mobile operators to the implementation of new regulations as a factor that affects the role of the mobile number; in some cases, other actors, fearing the dominance of mobile operators, have opted for other identifiers (Jøsang, 2014). Still, in order to be increasingly used in digital services with strict ID requirements, the strength and availability of the mobile number are important mobilizing factors.

More broadly, this study has indicated two forces that affect the possibilities for the mobile number to become a global identifier. On the one hand, the majority of mobile connections are now subject to stringent requirements on ID credentials and registration. On the other hand, several important high-tech economies do not practice strict requirements, and especially the USA is an influential counterforce here. Today, the majority can be said to be dominated by either large developing economies – or significant Asian technology leaders. Among the developing countries we find only very early local examples of the significance of the mobile number, as in Pakistan. Achieving the global rise of the mobile number as general-purpose identifier will probably hinge on successful local implementation in huge developing economies like those of India and Pakistan, as well as Asian technology leaders like China, Japan or South Korea. Norway represents a small market here, but may serve as an example of how mobile numbers can emerge as a legitimate identifier in a developed country.

The implication for managers in the mobile telecommunication sector is that the strength and availability of the mobile number do matter for its use as identifier in local markets. And these are factors that managers can influence, by drawing on the significance of formal and informal institutions (Bergek et al., 2008) and principles for designing information infrastructures (Hanseth & Lyytinen, 2010). Influencing the global evolution is, of course, more difficult. A realistic ambition might be to support implementations in developing economies to counter leading high-tech countries like the USA. There are lessons also for policymakers. Formal rules and regulations can be important factors in enabling well-functioning digital processes. Formal regulations may not always be non-controversial, or the effects always intended. Although this is difficult to foresee, in an evolutionary process one main policy focus can be to avoid dysfunctional lock-in. This study has also shed light on the need for different types of identifiers in a digital society, and the ongoing debate about the right to remain anonymous vs the obligation to reveal identity.

The theory contribution of this article lies in its empirical support to evolutionary and systemic innovation theories, extending these into the complex mobile telecommunications sector and digital services. Greater use of the mobile number as identifier has not been a given: it happens despite resistance and the dominance of other log-in solutions. The cases reported here support the existence of positive self-reinforcing effects, path dependency, and local processes. As regards information infrastructures, both formal and informal institutions emerge as important factors affecting local growth and evolution, for instance concerning strict ID credential requirements, public number directories, expectations and trust.

Further research should investigate other countries in greater detail – where the mobile number is strong and available, and less so; cases of differing economic status, and where other factors take the evolution in new directions. Continued increase in the mobile number as identifier should be followed up, as it offers an interesting case for strong self-reinforcing paths in the mobile telecommunications industry. Discussions on the significance of identity and authenticity of actors in the digital sphere should be expected to continue, and this too calls for further research.

6 References

Ankjell, H., 2015. *Moving power to the patients*. [Online]

Available at: <https://www.ikt-norge.no/wp-content/uploads/2015/11/Presentasjon-Holly-Ankjell.pdf>

[Accessed 11 August 2016].

Anon., 2018. *Prepaid Data SIM Card Wiki*. [Online]

Available at: http://prepaid-data-sim-card.wikia.com/wiki/Prepaid_SIM_with_data

[Accessed 22 2 2018].

Anon., 2018. *Prepaid Data SIM Card Wiki/Russia*. [Online]

Available at: http://prepaid-data-sim-card.wikia.com/wiki/Russian_Federation

[Accessed 2 1 2018].

Arthur, B. W., 1989. Competing technologies, increasing returns, and lock-in by historical events. *The Economic Journal*, 99(394), pp. 116–131.

Bergek, A., Jacobsson, S. Carlsson, B., Lindmark, S. & Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: A scheme of analysis.

Research Policy, 37(3), pp. 407–429.

- BISP, 2017. *About us - Overview*. [Online]
Available at: <http://bisp.gov.pk/overview/>
- BISP, 2017. *Payments distribution mechanism*. [Online]
Available at: <http://bisp.gov.pk/cash-grant/#Mechanism946d-4435>
- Bækken, K. E., 2016. *Sjekk ditt "nye" kontonummer*. [Online]
Available at: <https://www.nrk.no/livsstil/mobilnummeret-blir-ditt-kontonummer-1.13228572>
[Accessed 19 1 2017].
- Clark, J., Dahan, M., Desai, V., Ienco, M., Labriolle, S., Pellestor, J-P., Reid, K. & Varuhaki, Y., 2016. *Digital identity: towards shared principles for public and private sector cooperation*, Washington: The World Bank.
- Custer, C., 2016. *China to start seriously enforcing real-name mobile registration, government claims*. [Online]
Available at: <https://www.techinasia.com/china-start-enforcing-realname-mobile-registration-government-claims>
[Accessed 31 7 2017].
- David, P., 1985. Clio and the economics of QWERTY. *The American Economic Review*, May, 75(2), pp. 332–337.
- Dhamija, R. & Dusseault, L., 2008. The seven flaws of identity management - usability and security challenges. *IEEE Security & Privacy*, 6(2), pp. 24–29.
- Easypaisa, 2016. *Easypaisa mobile account*. [Online]
Available at: <https://www.easypaisa.com.pk/consumer/mobile-account/easypaisa-mobile-account>
[Accessed 11 August 2016].
- Eaton, B., Hallingby, H. K., Nesse, P.-J. & Hanseth, O., 2014. Achieving payoffs from an industry cloud ecosystem at BankID. *MIS Quarterly Executive*, December, 13(4), pp. 223–235.
- eMarketer, 2015. *Businesses are going mobile - but how?*. [Online]
Available at: <http://www.emarketer.com/Article/Businesses-Going-Mobilebut-How/1012581>
[Accessed 11 August 2016].

- Eriksson, O. & Ågerfalk, P., 2010. Rethinking the meaning of identifiers in information infrastructures. *Journal of the Association of Information Systems*, 11(8), pp. 433–454.
- Fagerberg, J., 2003. Schumpeter and the revival of evolutionary economics: an appraisal of the literature. *Journal of Evolutionary Economics*, 13(2), pp. 125–159.
- FinansNorge, 2015. *Regler om bankenes felles konto- og adresseringsregister.* [Rules for the banks shared account and address register] [Online]
Available at:
<https://www.finansnorge.no/contentassets/03e54f40fca64140bb0be0d7675051fb/regler-om-bruk-av-konto--og-adresseringsopplysninger---vedtatt-15.03.25.pdf>
[Accessed 19 1 2017].
- Forbrukerombudet, 2013. *Forbrukerombudets veiledning om markedsføring via e-post, SMS o.l.- markedsføringsloven § 15* [The Consumer Council's guide for marketing via e-mail, SMS etc - Marketing law § 15]. s.l.:Forbrukerombudet.
- GSMA and SIA, 2014. *Mobile identity - unlocking the potential of the digital economy*, London: GSMA.
- GSMA, 2013. *The mandatory registration of prepaid SIM card users*, London: GSMA.
- GSMA, 2016. *Mandatory registration of prepaid SIM-cards - addressing challenges through best practice*, London: GSMA.
- GSMA, Database. www.gsmainelligence.com
- Hallingby, H. K., 2016. Key success factors for a growing technology innovation system based on SMS Application-to-Person in Norway. *Technology Analysis & Strategic Management*, 28(10), 1123–1137.
- Hanseth, O. & Lyytinen, K., 2010. Design theory for dynamic complexity in information infrastructures: the case of building the internet. *Journal of Information Technology*, 25(1), pp. 1–19.
- Helse Vest, 2016. *Bedre oppmøte med utvida SMS-varsling* [Better attendance with SMS notification]. [Online]
Available at: <http://www.helse-vest.no/no/nyheter/Sider/Bedre-oppm%C3%B8te-med-utvida-SMS-varsling.aspx>
[Accessed 11 August 2016].

- Hollar, K., 2015. *CRM industry user research report*. [Online]
Available at: <http://www.capterra.com/customer-relationship-management-software/user-research>
[Accessed 11 August 2016].
- Igari, N., 2014. How to successfully promote ICT usage: a comparative analysis of Denmark and Japan. *Telematics and Informatics*, 31(1), pp. 115–125.
- Intermedia, 2017. *Pakistan - Wave 4 report FII tracker survey*. [Online]
Available at:
<http://finclusion.org/uploads/file/Pakistan%20Wave%204%20Report%2019-July-2017.pdf>
- Jøsang, A., 2014. Identity management and trusted interaction in Internet and mobile computing. *IET Information Security*, 8(2), pp. 67–79.
- Khan, Y., 2016. *Telenor: Financial inclusion is a good sustainability initiative and business opportunity*. [Online]
Available at: <http://blogs.worldbank.org/psd/telenor-financial-inclusion-good-sustainability-initiative-and-business-opportunity>
[Accessed 16 August 2016].
- Komorowski, M., Coppens, P., Broeck, W. V. d. & Braet, O., 2016. Lowering the barriers for online cross-media usage: scenarios for a Belgian single sign-on solution. *Telematics and Informatics*, 33(4), pp. 916–924.
- Larralde, A., 2015. *Social login trends across the web: Q1 2015*. [Online]
Available at: <http://janrain.com/blog/social-login-trends-across-the-web-q1-2015/>
[Accessed 26 February 2016].
- Loginradius, 2016. *Q1 2016 Report - Customer identity preference*, Edmonton: Loginradius Inc.
- Lusoli, W., Bacigalupo, M., Lupiañez, F. Andrade, N., Monteleone, S., Maghiros, I., 2012. *Pan-European Survey of practices, attitudes and policy preferences as regards personal identity management - Report EU 25295 EN*, Luxembourg: European Commission. Available at:
http://is.jrc.ec.europa.eu/pages/TFS/documents/EIDSURVEY_Web_001.pdf

- Matthews, G., 2015. *SMS special report: Confronting SMS fraud*. [Online]
 Available at: <http://www.capacitymedia.com/Article/3483282/Home/SMS-SPECIAL-REPORT-Confronting-SMS-fraud.html>
 [Accessed 15 January 2016].
- Milne, C., 1997. The design and management of numbering systems. In Melody, W. H. (ed): *Telecom reform: Principles, policies and regulating practises*. Lyngby: Technical University of Denmark, pp. 141–155.
- NADRA, 2017. *About us*. [Online]
 Available at: <https://www.nadra.gov.pk/about-us/>
- Nasjonal referansedatabase, 2017. *Om oss [About us]*. [Online]
 Available at: <http://nrdb.no/om-oss/>
- National Communication Authority, 2017. *Utvexling av nummeropplysningsinformasjon (Exchange of number data)*. [Online]
 Available at:
<https://www.nkom.no/marked/nummeropplysning/nummeropplysning/utvexling-av-nummeropplysningsinformasjon>
- Nesse, P. J., Hallingby, H. K. & Risnes, O., 2017. Management of mobile financial services - review and way forward. In Tan, L-M., Hock, E., Tang, C. (ed): *Finance & Economics Readings; Selected papers form Asia-Pacific Conference on Economics & Finance, 2017*. Singapore, Springer.
- Olmstead, K. & Atkinson, M., 2015. *Apps permissions in the Google Play Store*, Pew Research Center.
 Available at: www.pewinternet.org/2015/11/10/apps-permissions-in-the-google-play-store/
- Rood, H., 2000. What's in a name, what's in a number: some characteristics of identifiers on electronic networks. *Telecommunications Policy*, 24(6-7), pp. 533–552.
- Saldaña, J., 2013. *The Coding Manual for Qualitative Researchers*. London: Sage.
- Salesforce, 2017. *State of marketing*, San Francisco: Salesforce.
- Samferdselsdepartementet, 2017. *Forslag til kommunikasjonsvernforordning [Suggestion for regulation of privacy and electronic communication]*. [Online]
 Available at: <https://www.regjeringen.no/no/sub/eos->

- notatbasen/notatene/2017/juni/forslag-til-kommunikasjonsvernforordning/id2555751/
[Accessed 21 2018].
- Schreiner, E., 2016. Securing identities two-factor authentication in the hacking age. *Blog*.
[Online]
Available at: <http://www.janrain.com/blog/securing-identities-two-factor-authentication-in-the-hacking-age/>
[Accessed 10 August 2016].
- State Bank of Pakistan, 2014. *Branchless banking newsletter Issue 14*. [Online]
Available at: <http://www.sbp.org.pk/publications/acd/2014/BranchlessBanking-Oct-Dec-2014.pdf>
- State bank of Pakistan, 2015. *Quarterly Branchless Banking newsletter - Issue 17*. [Online]
Available at: <http://www.sbp.org.pk/publications/acd/2015/BranchlessBanking-Jul-Sep-2015.pdf>
[Accessed 10 August 2016].
- State Bank of Pakistan, 2016. *Branchless banking newsletter - Issue 19*. [Online]
Available at: <http://www.sbp.org.pk/publications/acd/2016/BranchlessBanking-Jan-Mar-2016.pdf>
- State Bank of Pakistan, 2017. *Branchless Banking Newsletter Issue 23*. [Online]
Available at: <http://www.sbp.org.pk/publications/acd/2017/BranchlessBanking-Jan-Mar-2017.pdf>
- Telenor, 2018. *SMS-rekord og Snap-dominans inn i det nye året [SMS record and Snap-dominance in the new year]*. [Online]
Available at: <http://www.mynewsdesk.com/no/telenor/pressreleases/sms-rekord-og-snap-dominans-inn-i-det-nye-aaret-2285734>
- World Bank, 2016. *Financial Inclusion/Financial Inclusion overview*. [Online]
Available at: <http://www.worldbank.org/en/topic/financialinclusion/overview#1>
[Accessed 2016 May 25].
- Yin, R. K., 2014. *Case study research*. 5 ed. Thousand Oaks: Sage.

Article 3:

Platform openness and innovation:

A case study from the mobile telecommunications industry

Hanne Kristine Hallingby

Submitted to *Technological Forecasting and Social Change*

Abstract

Platforms must open up their interfaces in order to get complementors to adapt and innovate, and must close interfaces in order to profit. But how to open or close a platform, beyond technological specifications such as application programming interfaces, standards, and open source? This case study of platform openness in the mobile telecommunications sector suggests that openness must be discussed on two platform interfaces: the complementor and vendor side. The article identifies and systemizes non-technical factors that affect platform openness. Through a technological innovation systems approach, these factors are combined with familiar innovation processes: knowledge generation and sharing, legitimation, entrepreneurial experimentation, and guidance of the search. This deepens our understanding of how platform openness can lead to innovation and growth. The paper contributes theoretically to the field of platform ecosystems by anchoring its fundamental claim of adaption and innovation in a well-known approach. Further, the study is a domain-specific elaboration of a technological innovation system, addressing the platform ecosystem as a phenomenon worth attention. For managers, the study indicates how platform interfaces can be governed so as to balance openness and closure, and innovation and profit.

1 Introduction

The platform ecosystem is a phenomenon observed in many industries involving digitalization (Gawer, 2009). A platform is here defined as “products, services, or technologies developed by one or more firms, and which serve as foundations upon which a larger number of firms can build further complementary innovations” (Gawer & Cusumano, 2014). Platforms are exemplified by the Apple and Google operating systems for mobile phones, and technologies such as the Internet and mobile telecommunications (Gawer, 2009). The technological architecture of a platform is modular with a core and periphery (Gawer, 2014), where

modules are connected through interfaces. Interfaces are “the rules governing interactions among the different parts” of the platform ecosystem (Baldwin & Woodard, 2009, p. 19).

According to the platform literature, the more interoperability that is allowed through open interfaces surrounding a platform (Eisenmann et al., 2009), the more innovation and growth will there be for the whole platform ecosystem (Baldwin & Clark, 2000; Gawer, 2014; Ghazawneh & Henfridsson, 2013; Ruutu et al., 2017). In the first instance, platform openness on interfaces is achieved through application programming interfaces (API), standards, and open source – a purely technical approach to openness. In the second instance it is acknowledged that interface openness goes beyond the technical, and is fuzzy and many-faceted (West, 2007; Gawer, 2014). In either case, the platform is regarded as a purposeful actor capable of influencing innovation and growth through its interfaces (Gawer & Cusumano, 2014). Thus, an open interface is not seen here as the outcome of a standardization process: it is a strategic tool used to achieve a certain outcome.

Platform approaches are empirically founded in the information and communications technology (ICT) industry (Gawer, 2009); mobile telecommunications is one sector where openness on platform interfaces takes the form of standards, open sources and APIs (Edquist, 2003; Funk & Methe, 2001; Schmidt & Werle, 1997; West, 2007). However, mobile network operators worry: will openness lead to further innovation and success – or imitation and substitution of their services (GSMA, 2014)? It is recognized that there is a need for some kind of closure in order to profit (Gawer & Cusumano, 2014). Thus, in both theory and practice we find intensified tensions between platform openness and closure, and innovation and profit – a trade-off referred to as the “paradox of openness” (Laursen & Salter, 2014). It is a challenge to balance innovation with profit with only a limited understanding of how to open platform interfaces beyond technological specifications. Summing up half a century of innovation studies, Martin (2016) holds that achieving a balance between openness and closure is one remaining task here.

The platform ecosystem can be understood as a technological innovation system (Hekkert et al., 2007); it is a complex socio-technical system aimed at facilitating innovation and growth, while acknowledging the necessity of economic incentives. The technological innovation systems approach indicates some core enabling processes for innovation and growth, such as knowledge development and diffusion, and legitimation (Bergek et al., 2008). An API, standard, or open source is basically a way to share knowledge – a factor known to boost innovation by allowing the creation of variety and recombination (Hekkert et al., 2007).

Studies of technological innovation systems have analyzed the emergence of standards (Markard & Erlinghagen, 2017) and standards as policies for resolving bottlenecks in technological innovation systems (Markard & Hoffmann, 2016). However, well-established constructs such as knowledge diffusion and legitimation have not been used to examine the role of platform openness as a strategic tool enabling innovation and growth; our understanding of the constitution and dynamics of openness has remained black-boxed (Yin, 2014).

This article addresses this lack of understanding with the research question: How and why do platforms open their interfaces beyond technological specifications? The empirical approach involves a multiple case study of platform openness where the units of analysis are platforms in the mobile telecommunications sector. The understanding of platforms and platform openness is broad, drawing on the literature (Eisenmann et al., 2009; Gawer & Cusumano, 2014; Henkel et al., 2013; West, 2007). The findings on various factors that affect platform openness are explained by the technological innovation systems approach (Bergek et al., 2008; Hekkert et al., 2007).

2 Theory

2.1 Platforms

Here platforms are defined as a “products, services, or technologies developed by one or more firms, and which serve as foundations upon which a larger number of firms can build further complementary innovations and potentially generate network effects” (Gawer & Cusumano, 2014, p. 420). Complementary innovations are marketed towards yet other users, and platforms are subject to strategic management aimed at innovation and growth. The interactions between the core platform and the firms that build complementary innovations are central to the platform concept; together they form a market structure often called an *ecosystem* (Iansiti & Levien, 2004; Jansen & Cusumano, 2013).

Complementary innovations increase total user-demand for the ecosystem and, accordingly, the platform. Thus, it is important for the platform to incentivize complementing firms to innovation; “interfaces around the platform should be sufficiently ‘open’ to allow outside firms to ‘plug in’ complements as well as innovate on these complements and make money from their investments” (Gawer & Cusumano, 2014, p. 421). However, there is an unresolved trade-off between open and closed interfaces (Gawer & Cusumano, 2014). Open interfaces

may increase innovation and ensure growth in the whole ecosystem (Ruutu et al., 2017), while some form of closure can ensure profit to the platform (Laursen & Salter, 2014; Tiwana et al., 2010). Further, there is a tension between openness and control as regards providing the right levels of quality (Benlian et al., 2015; Eaton et al., 2015; Ghazawneh & Henfridsson, 2013).

2.2 Platform interfaces

In the above definitions, the platform is presented with an interface mainly towards complementary firms, or “complementors” (Gawer & Cusumano, 2014). A broader definition of platforms focuses on its role as a technological architecture enabling several interfaces: “a set of stable components that supports variety and evolvability in a system by constraining the linkages among the other components” (Baldwin & Woodard, 2009, p. 19). Eisenmann et al. (2009) extend the platform model with an interface towards firms involved in developing the platform. They see the platform as having two roles: as platform provider, as sponsor. The platform provider role is equivalent to the definition of platform above (Gawer & Cusumano, 2014). As to the other role, platform sponsors “do not deal directly with users; rather, they hold rights to modify the platform’s technology. They design the components and rules, and determine who may participate in the network as platform providers and users” (Eisenmann et al., 2009, p. 135). Thus, when acting as a *sponsor*, the platform engages stakeholders in modifying and delivering the platform. It is a strategic question which decision rights the platform shall retain, and when to allow input from other stakeholders (Tiwana, 2014).

The two platform interfaces are aligned with Henkel et al.’s (2013) division of a technical system into two technical subsectors: one that engages numerous, diverse and heterogeneous innovators; and one that engages collaborating vendors and partners. These two sides also correspond to the north- and southbound interfaces used for future communications networks (Jarschel et al., 2014). The sponsor role can be held by several firms. Furthermore, actors on different interfaces may act as both platform vendors and complementors: for instance, a complementor may engage in coding the core platform in order to enhance interoperability on the complementor side (Ghazawneh & Henfridsson, 2013).

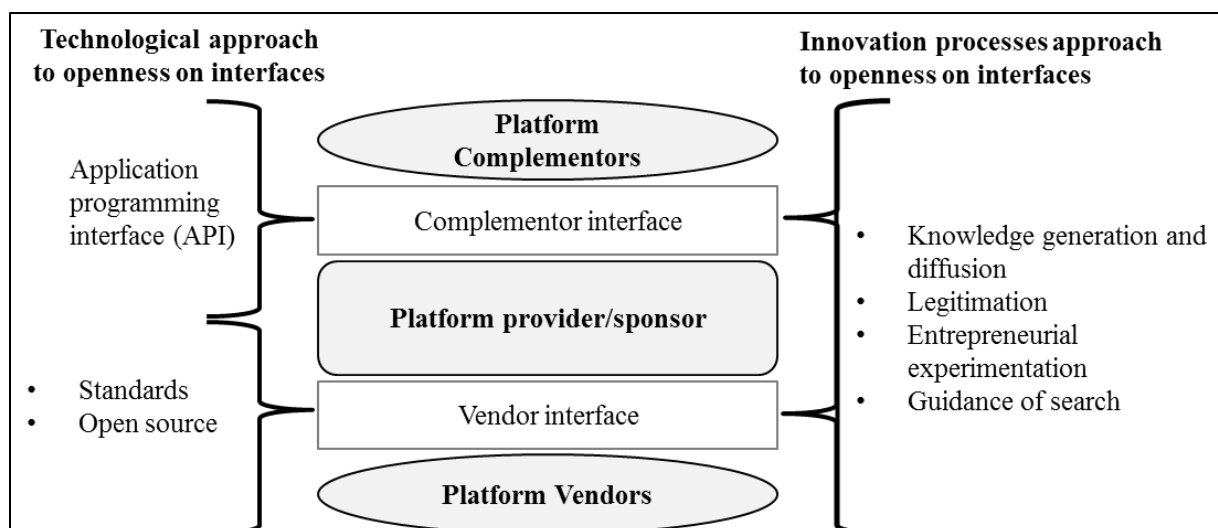


Figure 2-1 Platform interfaces and how to open them: technological specifications and innovation approaches

Figure 2-1 presents a simplified model of the two platform interfaces. On the lower side, the platform has an interface towards external firms involved in building and delivering the core platform – *vendors*. On the upper side, the platform has an interface towards firms that innovate with the platform to the best of end-users – *complementors*. Openness can be discussed on both the vendor and complementor interfaces. These two roles must not be confused with the two-sided market on the complementor interface, between the complementor and end-users of the services (Eisenmann et al., 2009). With Internet, mobile telecommunication 4G, or Google Android, there are many stakeholders involved in the development of the platform, and yet others have access to and use the platform. The relationship between those developing, delivering and using the platform may be more complex than shown in the simplified model in Figure 2-1.

2.3 Platform interface openness – technological approach

From a pure technical perspective, openness on platform interfaces is a technological specification that provides full interoperability between elements, allowing efficient knowledge sharing and recombination (Gawer, 2014; Baldwin & Clark, 2000). Concerning the complementor interface, application programming interfaces (API) are regarded as the normal way to achieve compatibility between the platform and external applications (asymmetric interoperability) (West, 2007; West & Dedrick, 2000). APIs are sets of rules that define how a software application interacts with an underlying platform (West & Dedrick, 2000). With the vendor interface, standards are the normal way to achieve compatibility and full interoperability between elements in a platform (asymmetric interoperability), or across

similar platforms (symmetric interoperability) (Schmidt & Werle, 1997; West, 2007); recently, these have also been called APIs in a telecommunications network setting (Jarschel et al., 2014). Open source is seen as “the ultimate form of an open standard because implementations are provided freely for all to use” (West, 2007, p. 89). Figure 2-1 illustrates how these different ways of providing openness predominate on either the complementor or vendor interface. Standards that provide asymmetric interoperability are to some degree equivalent to APIs; however, here they are reserved for two different interfaces.

APIs, standards, or open source are necessary for achieving interoperability and thereby platform openness. However, it takes more than technology specification to make an interface fully open (Gawer, 2014; West, 2007). A broad range of specific factors have been indicated in the literature (Benlian et al., 2015; Greenstein & Stango, 2007; Schmidt & Werle, 1997; Takanashi & Lee, 2013; West, 2007), to which we now turn.

2.4 Conceptual and evaluative literature on platform openness

The conceptual literature and evaluations provide many specific suggestions as to non-technical factors that affect openness, both on the vendor and complementor interfaces. As to the former, the openness of interfaces can be affected by documentation of and accessibility to standards and code, decisionmaking processes, reliance on existing solutions, transparency, standard price, IPR, norms, and knowledge advantages (Andersen, 2008; Farrell & Simcoe, 2012; Funk & Methe, 2001; NO-REST, 2005; Takanashi & Lee, 2013; West, 2007; West & O'Mahony, 2009). Also in the process of developing standards there are certain factors that affect actual interface openness, like the rules and costs of participating in development (West, 2007). More generally, open source and standardization are proposed as ways of broadening sponsorship for platforms, signaling concerns for legitimacy and mitigating, for instance, political maneuvering, majority dominance and complex coordinating processes that may obstruct the intended openness (Eisenmann et al., 2009).

Concerning the complementor interface, the conceptual and evaluative literature (Benlian et al., 2015; Eaton et al., 2015; Ghazawneh & Henfridsson, 2015; Tiwana, 2014; Tiwana et al., 2010) and reports (Laffan, 2011) have noted documentation, developer tools, fees, membership, access to code, transparency, intellectual property rights (IPR), review processes, and decision rights as important formal ways of opening platform interfaces. An active community for complementors and developers can ensure adequate sharing of knowledge (Laffan, 2011; Tiwana, 2014; West, 2003). The existence and quality of a

marketplace for the complements developed, like Apple's app store, can help complementors to make money (Ghazawneh & Henfridsson, 2015; Jansen & Cusumano, 2013). On the other hand, restricted backward compatibility for complements, exclusive rights for complementors, and risk of absorption are mechanisms that might decrease perceived openness (Eisenmann et al., 2009); it is also deemed risky if multiple platform providers must collaborate to provide APIs.

This stream of literature notes many specific and significant factors that will affect actual and perceived platform openness. Importantly, openness may be affected in both the creation and implementation phases – by rules for participation in standard development, or by how well APIs are documented (West, 2007). Furthermore, the degree of openness may increase or decrease over time. Increased openness typically occurs because “implementations tend to become commoditized as tacit knowledge becomes widely dispersed” (West, 2007, p. 110); decreased openness may result from the increased power of one actor. This approach, seeing openness as a dynamic concept that evolves over time, is supported by research on the tuning processes of boundary resources (Eaton et al., 2015). However, the factors do not appear to have been theoretically grounded in innovation approaches capable of explaining how they affect innovation processes, and in turn innovation and growth.

2.5 Platform interface openness – a technological innovation system

In a technological innovation system, innovation is very broadly understood as the development, diffusion, and use of knowledge (Bergek, Jacobsson & Sandén, 2008; Hekkert et al., 2007). The technological system innovation approach offers six theoretical constructs to explain the core innovation processes (Weber & Truffer, 2017, p. 113), four of them relevant for platform openness: knowledge generation and diffusion; legitimation; entrepreneurial experimentation; guidance of the search. These innovation processes are at play between actors, institutions and networks, and may induce or block a technology from further growth (Bergek et al., 2008). They affect openness on both interfaces, as shown in Figure 2-1. Even though a platform has open APIs, standards or source code, innovation and growth may still be blocked or induced by other non-technical factors. However, the innovation processes are far too general for explaining and assessing the specific domain of platforms (Hekkert et al., 2007) and must be complemented with domain-specific factors. In the following, an account of the relevant innovation processes is combined with examples of specific non-technical factors that may open or close a platform.

A knowledge base is a core element in driving innovation (Bergek et al., 2008). The generation and availability of knowledge is critical to the creation of variety, in turn enabling the selection process and innovation and growth (Hekkert et al., 2007). Fully public knowledge – as opposed to private – is assumed to lead to more innovation. However, knowledge is usually somewhere between the extremes of private/tacit and public/codified (Lundvall & Johnson, 1994); knowledge diffuses slowly, and is delayed by social processes and human inability to share, search, absorb, and take advantage of new information (Cowan, 2004; Castellacci, 2008). In the first instance, technological specifications on platform interfaces are fully codified knowledge, such as APIs and standards. In the second instance, even APIs and standards on platform interfaces may include knowledge and knowledge processes that are tacit and private in character – which may function as closure, affecting innovation and growth. Such closure can be mitigated by further codifying knowledge through documenting, illustrating, or guiding the development and use of APIs and standards. One way to mitigate the tacit characteristic of knowledge is to enable sharing and development in social settings where humans interact.

Legitimacy is necessary in order to mobilize stakeholders to use the platform for innovations, and further demand for the technology in question to form (Bergek, Jacobsson & Sandén, 2008). Formal and informal institutions play a significant role in the evolution of technological innovation systems – and thus platforms. Legitimation is the process that leads to new institutions for a technology; only slowly is it “considered appropriate and desirable by relevant actors” (Bergek et al., 2008, p. 417) through forming expectations and visions and mobilizing actors. A set standard can be regarded as a formal institution that has been decided upon (Markard & Erlinghagen, 2017), but that still may be subject to further legitimation processes (Markard et al., 2016). Ways of building legitimation include transparency and predictability in rules and decisionmaking processes. Engagement in a platform community can build legitimation through the development of shared norms and values.

Entrepreneurial experimentation is a critical activity for addressing and decreasing the uncertainty about applications and markets that is a fundamental feature of technologies. “From a social perspective, the main source of uncertainty reduction is entrepreneurial experimentation, which implies a probing into new technologies and applications, where many will fail, some will succeed and a social learning process will unfold.” (Bergek et al., 2008, p. 416). Further growth of a platform depends on experimentation. For a platform, the

experimentation can be enabled by access to resources to experiment with, and by providing prototyping tools and testing environments.

The guidance of search process involves having the incentives to select a technology and believing in the further proliferation of that technology (Hekkert et al., 2007). For innovation to happen, other firms must choose to use a platform and “there must be sufficient incentives and/or pressures for the organizations to be induced to do so” (Bergek et al., 2008, p. 415). IPR and patents are well-established ways of ensuring economic incentives for actors. In the view of knowledge as being tacit and difficult to share and absorb, lies a way to extract profit that is built on knowledge advantages. For platforms, the model for and expectations to how revenues are shared between the stakeholders serve as concrete incentive mechanisms.

One distinction is important when applying the technological innovation system approach in analyzing platform openness (Markard & Hoffmann, 2016). Within this approach, platform openness is interpreted as technological complementarity where standardization plays an important role. The goal is to create benefits for a technology: and “technology level complementarities are those that generate such benefits” (Markard & Hoffmann, 2016, p. 66). However, APIs, standards and open source will here be seen as necessary strategic initial prerequisites – not as a later response to “resolving bottlenecks” (Markard & Hoffmann, 2016, p. 72), or the result of a cumbersome standardization process (Markard & Erlinghagen, 2017).

2.6 Effects of platform openness

These core innovation processes affect the development, diffusion, and use of a technology (Hekkert et al., 2007). The efficiency of the processes is important for the further evolution of the system: they can act as either inducing or blocking mechanisms with regard to the further innovation and growth of a technology (Bergek et al., 2008). In this study, the platform is subject to such innovation processes in connection with opening interfaces to assist complementors and vendors in achieving sufficient levels of innovation. More generally, a fundamental explorative result of openness is an expanding market where the platform can obtain a fair share (Ritala et al., 2014; Ruutu et al., 2017). There are also more exploitive effects regarding efficient use of resources, most prominent on the vendor side.

The innovation effects of open platform interfaces differ on the vendor and complementor interfaces (Henkel et al., 2014; West, 2003). Concerning the vendor interface, innovation effects are seen as the result of getting more vendors to engage in and adopt a technology; the specific effects are both explorative and exploitive – including service reliability, lower costs,

lower end-user prices and customized services, better debugging, ensured compatibility, and access to new markets. Further, opening up a platform sends a market signal that is positively perceived by users and customers of the technology in question (Henkel et al., 2014; Schmidt & Werle, 1997).

Innovation effects on the complementor interface come mainly from getting complementors to adopt the technology through APIs, and creating further innovation for consumers (West, 2007; West & Dedrick, 2000). This creates variation for users (Gawer & Cusumano, 2014; Iansiti & Levien, 2004; MacCormack & Iansiti, 2009) and fine-tunes innovations to consumer needs (Langlois & Robertson, 1992). The effects of using APIs to spur innovation are especially pronounced when customer needs are heterogeneous and unpredictable (Henkel et al., 2013).

Innovation and growth do not automatically occur when APIs and standards are introduced (Ghazawneh & Henfridsson, 2013). Precisely that point lies at the core of technological innovation systems which discuss inducing and blocking mechanisms in the various innovation processes that drive the growth of a technology further. Also, although not in focus here, closure may sometimes be advantageous in some settings – for instance, control can be important to ensure platform integrity (Tiwana et al., 2010); the cognitive burden may lead to less openness (Frenken & Mendritzki, 2012); and achieving closure with patents is critical in chemical industries (Tidd et al., 2005).

2.7 Propositions

The emerging theory on platforms sees platform openness as vital to explorative innovation and growth; however, openness is discussed mainly in the form of APIs, open source and standards. The literature has little to say on other factors that affect platform openness, and how they may relate to established innovation processes.

This article aims to fill such gaps in theory with empirical data from platforms in the mobile telecommunications industry (Pratt, 2008). It is proposed that platform openness can be discussed on two interfaces. There are additional non-technical factors that affect openness on each side, which in turn may be embraced by innovation processes in technological innovation systems. The dynamics of these familiar innovation processes can explain how platform openness affects innovation and growth, and also how and when closure is accepted in order to profit. Innovation processes can feed back into and change specific factors. Figure 2-2 presents a simplified model of these complex relationships.

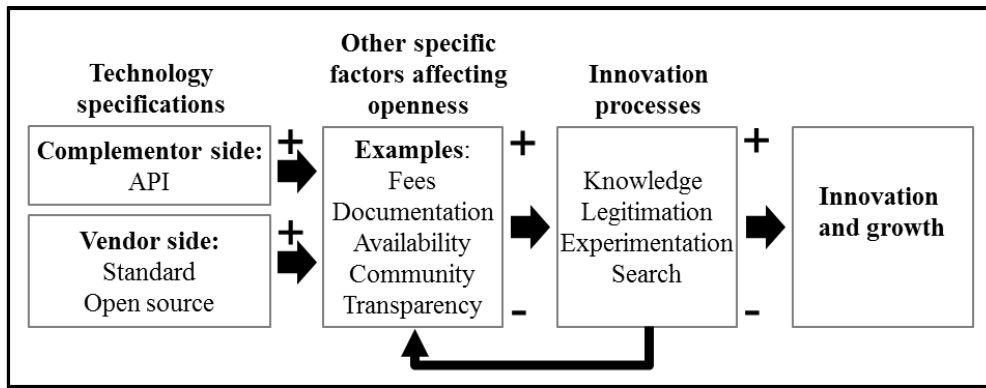


Figure 2-2 Factors affecting platform openness positively or negatively and in turn innovation and growth (+ indicating more openness, - indicating less openness)

3 Method

This article asks how and why platforms open their interfaces beyond technological specifications. As summarized in Table 3-1 and Figure 3-1, it is a multiple case study (Yin, 2014), aimed at uncovering the factors that affect platform openness and innovation processes, and in turn innovation and growth. Thus an explanation-building case study was appropriate, also suggesting a logical model for opening up previously black-boxed processes (Yin, 2014). The platform phenomenon is evident in the mobile telecommunications industry, offering a relevant context. The five units of analysis were influential standard-setting bodies and private platforms: 3GPP, IETF, W3C, Apple and Google – in this study, all referred to as “platforms” (Eisenmann et al., 2009; Gawer & Cusumano, 2014; NO-REST, 2005; West, 2007). 3GPP, W3C and IETF set standards for respectively mobile telecommunications, the Web and Internet; Apple and Google provide the iOS and Android platforms, respectively, for mobile devices and services. The platforms differ in their practices regarding platform interface openness and can thus shed light on a broad set of relevant aspects.

The analysis was conducted in several steps, as shown in Figure 3-1.

The first step involved exploring the specific concrete non-technical factors that affect openness, through a combination of evaluative and conceptual literature, and self-descriptions on platform websites. The accompanying interviews in one mobile operator were open-ended, but inspired by the platform ecosystem approach (Gawer & Cusumano, 2014); themes discussed were platform openness, innovation effects from openness, and assessment of platforms. The author is affiliated with the mobile operator in question and thus had direct access to informants. In this step, non-technical factors were identified, refined, and used for evaluating platforms and indicating relevance. Platform assessment in this step was based on

data from the platforms’ self-reporting on websites, and on interviews. The analysis distinguished the platforms from each other regarding openness, and indicated that two interfaces were important.

Table 3-1 Data sources

<i>Steps</i>	<i>Description of sources</i>	
Step one 2014-15	Interviews	Eight telecom experts in the incumbent Norwegian mobile operator: seniors involved in platform development, and working with research, research policy, standardization, technology strategy and trends
	Conceptual and evaluative documents	Sources are integrated in text
	Self-reporting on web-sites	The Web: w3c.org The Internet: ietf.org , Mobile network: 3gpp.org Apple: apple.com/about Google: google.com/about , android.com
Step two 2017	Interviews	Nine experts on platforms across Europe and the USA. Seniors involved in platform development, and working with research, technology strategy, development and trends
	White papers	Six white papers from major providers of management systems for APIs on the complementor interface: IBM, CA technologies, 3scale, Akana, WSO2, Apigee.

In the next step, the platform assessment served as the basis for discussing non-technical factors for platform openness with informants. These interviews were a more focused investigation. Informants were recruited through the international network of the experts in the incumbent mobile operator. In this step, informants were shown an illustration of the conceptual model and asked to elaborate on platform openness on two interfaces. This second step laid the foundations for the iteration with empirical data and theory (Yin, 2014).

All interviews were transcribed by the author. The interviews and white papers were coded and analyzed in NVivo. The coding was aimed at providing better insights into relationships, explanations, beliefs, judgements, and tensions (Saldaña, 2013); however, the platform ecosystem approach inspired the codes. The first cycle of coding coincided with the first step, and provided the basis for interviews with informants in the second step. An iterative process with second-cycle coding led to a match with existing theoretical constructs from the technological innovation systems approach (Bergek et al., 2008). Therefore, the data were re-organized according to the innovation functions of knowledge, legitimation, experimentation, and search. That made it possible to introduce a narrative and tables which accounted for

concrete factors, relationships and effects on innovation and growth. In this study, both the specific factors and the innovation processes are important results, whereas assessment of the platforms has a less prominent role.

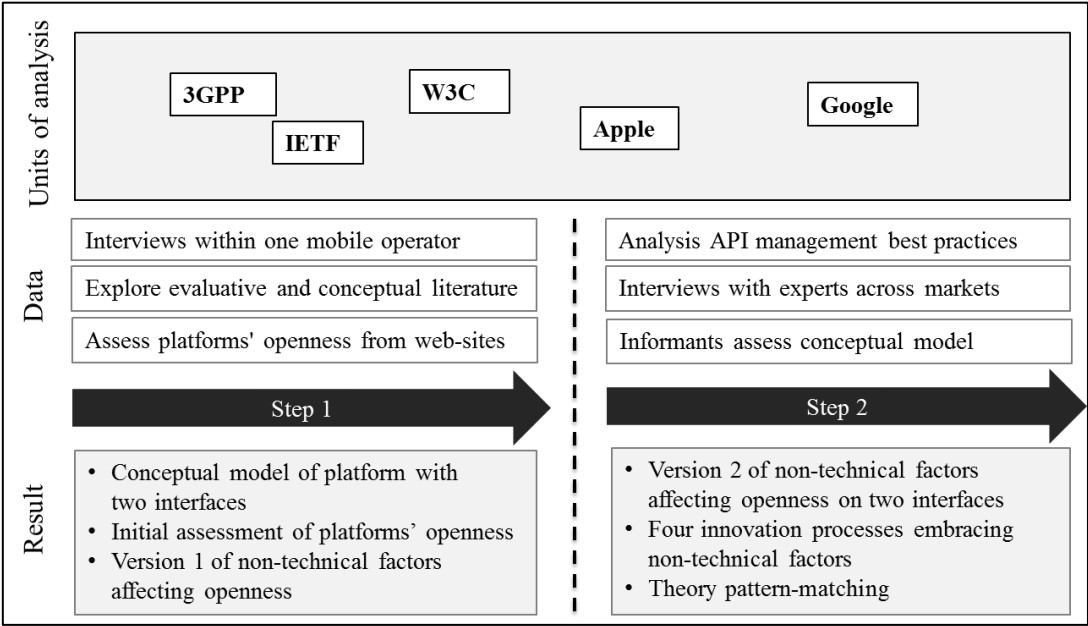


Figure 3-1 Research approach

About half of the experts agreed to be interviewed under conditions of anonymity; however, the quotes provided here are representative across the range of experts consulted. However, that experts were selected through a snowballing technique that benefitted from the researcher's role in one mobile operator is one possible source of a skewed perspective; drawing on the website self-presentations of the standard-setting organizations is another. These limitations were mitigated mainly by the use of multiple sources, multiple perspectives and practices, and ready access to experts. Also the chain of evidence (see Figure 3-1) was aimed at increasing construct validity. Research validity was further increased by informants' responses to the conceptual model, the use of theoretical pattern-matching and a logic model.

4 Results

The iteration with theory and empirical data in this study converged into four innovation processes that can extend our understanding on the opening of platforms, and how this in turn affects innovation and growth. These processes shape the presentation of the results in the following. First, a short assessment of the five platforms' openness is presented, to be expanded, refined and commented in the subsequent results section. Second, how informants related to idea of governing openness on two platform interfaces is presented. And finally, the

analyses of platform openness on the vendor and the complementor interfaces are presented, including tables showing the broad set of non-technical factors affecting openness, with discussion of how these factors serve as elements in innovation processes.

4.1 Platform assessment

Five influential platforms in the mobile telecommunications industry were studied: 3GPP, W3C, IETF, Google and Apple. These are either standard-setting organizations or private platforms that provide standards (West, 2007).

These platforms differ in governance and financing, in who can participate and decide, and what participants have to pay. They differ in mission and purpose, and regarding transparency and access to processes, documentation, and platform resources.

The initial assessment, reported in Appendix 1, indicated the platforms W3C and IETF as being open, letting everyone participate and take part in decisions, and with easy access to existing code. 3GPP and Google are less open – still not fully closed on the vendor side, controlling financing, participation and decision processes. 3GPP was assessed as being closed towards complementors, not giving ready access to platform resources; by contrast, Google was open and inviting, with a large community using platform resources and a smoothly functioning extension market. Apple was assessed as being open towards complementors, but as closed on the vendor side, which featured proprietary and fully controlled technologies.

This assessment provided a broad set of evaluation criteria in the form of non-technical factors affecting openness. In addition, the assessment offered a basis for discussing these non-technical factors in further detail with the informants, as they could use the various platforms as examples in their own explanations.

4.2 Platform vendor and complementor interface

The model of a platform with two interfaces was presented to informants in the second step of this study. They responded positively to the model, finding it a good way to organize the discussion. “The model seems a quite good way to exemplify some of the issues we have across different standard bodies,” said one expert; another added, “in many respects, this picture is correct”. Throughout the discussion, the model made it possible for them to move back and forth, commenting on the significance of being able to participate in developing or using APIs, standards and open source.

However, informants also noted that real life is much more complex with “multiple layers within the stack where open interfaces play a role and where open source might play a role”. They further indicated the practice and need for all actors to be able to access the core platform and add or refine existing code, so as to ensure and refine interoperability; for instance, being able to add new APIs can be important. Thus, openness is not only about being able to use a platform: it can also involve being allowed to develop it further. In the following, both the use and the development of standards and open source are topics on the vendor side, while on the complementor side the prime concern is the use of APIs.

4.3 Vendor interface openness

The following presents how informants explain the relationship between concrete non-technical factors and platform openness, systemized according to familiar innovation processes. The four innovation processes from the technological innovation systems approach that embrace the non-technical factors are: knowledge generation and diffusion; legitimation; entrepreneurial experimentation; and guidance to the search. Table 4-1 summarizes the broad set of specific non-technical factors identified, indicating how they all are related to the various innovation processes. References to the assessment of the platforms are made in terms of the accounts given by informants.

4.3.1 Knowledge generation and diffusion

Knowledge sharing was recognized as important for platform openness on the vendor side. The technology in question is fast-moving and complex, and builds tacit knowledge. As one expert explained, the people involved in standard specifications can be “extremely knowledgeable,” making it hard for generalists to keep up. Another expert said: “some of the very big projects out there – like Open Stack, or Linux itself – have become so complex that just taking the code is not enough. You need the skills and the expertise to translate what you receive into something useful for your company, your job, or what you want to sell as added value to the market.” Having many small actors may be counterproductive to reaching consensus on the way forward; having large participants can be an advantage for progress.

The experts emphasized that administrative routines are important for openness and thus knowledge development. GitHub.com is a highly appreciated software platform for code development and “at least with W3C and IETF is extremely important”, according to one expert. “GitHub makes it easy to develop specifications,” said one expert. In contrast,

tiresome forms of organizing the work with bureaucratic routines and long hours can have an excluding effect, and deter knowledge sharing.

Membership rules may limit participation in knowledge development and sharing. Together with high fees, this was seen as an effective tool for including financially strong actors, and excluding small and financially vulnerable ones. As one expert explained: “IETF has a very open way of including people. There are no prerequisites. If you want to be a part of the community, you can be.” By contrast, in W3C it is not the individual but the company that is a member, paying a high fee. In a setting where you are “desperate to get people to come work on your stuff” this reduces the pool from which you are recruiting. Also the platform 3GPP was recognized as having a more closed paid membership model, involving companies recruited from stakeholders such as ETSI – implicitly hindering participation in standard development.

4.3.2 Legitimation

Experts mentioned that decisionmaking rules and practices can affect the legitimacy of the platform, and thus its openness. In 3GPP, the process of making and dealing with suggestions is more formalized and connected to membership status, whereas in W3C any participants can suggest and engage others in their projects. One telecom expert gave little credit to Apple when commenting on its decisionmaking: “Apple – their iOS – they make the decisions. Full stop. It’s all proprietary.”

3GPP, IETF and W3C all have a consensus-based decision model which can favor influential and affluent actors, in turn blocking decisions among other stakeholders. Regarding decisions in 3GPP one telecom expert commented: “In the end, size is important. Who are you? If you’re a small actor in the world market you are less influential, even though you in theory should be equal to all the others.” One expert explained why larger firms become more dominant in IETF: “If you are an Internet provider, you are a larger organization, and that means you have more cash you can use to get people into working in standards in IETF.” Although IETF is very open to participation, it admits that these principles are challenged by the concentration of influence and larger firms’ higher financial allowances for participation (Davies, 2004).

Transparency was held to be important for legitimacy throughout the whole process: from administrative systems for development, approval processes and decisions, to access to and good documentation of complete standards and code. To be able to trace back such data is

vital: for instance, who developed the code, where is it available, what was last updated, which forums were involved, etc. Also in this respect GitHub has played an important role, according to one expert: “...you can find not only the official developer documentation, you can also trace back, see who developed it, and its development on GitHub. You can see when it was last revised, see how quickly they are dealing with issues, you can get the issues list and the actual technologies and the actual services that are being developed.” This in turn “affects trust – transparency can help drive trust”.

A system like GitHub also enables the decisionmaking process and allows remote participation – a means of improving platform legitimacy among smaller self-financing actors. At the other extreme of transparency is Apple – to the frustration of experts: “Apple have been unapologetically closed, completely. They participate in W3C – people moan about it: ‘we know how you work’. They do not tell what they are doing. They are very privacy conscious about their work and their users.”

The various platform missions differ greatly, and build legitimacy in different ways. IETF focuses on technological performance; W3C provides standards on a highly idealistic basis with open innovation to the best of society, with technical merit and sharing as important values. Even though some large actors seem to contribute to IETF for commercial reasons, there is considerable personal engagement when individuals choose to participate. One expert explained how communities have emerged: “There are groups of developers and systems engineers who meet up to work on IETF work collaboratively – or just for fun, really.”

3GPP’s message is that it ensures progress and backward compatibility. Backward compatibility is held to be rooted in technological functionality. Nevertheless, it signals a high level of continued commercial success for 3GPP and its stakeholders, and high degree of self-imposed self-reinforcing. One telecom expert explained how there is a tension between technical and commercial arguments in 3GPP: “You cannot sit there and argue that you have hundreds of millions of subscribers. Arguments must be based on technologically reasonable solutions. That means that in discussions you have technical arguments, but there are always underlying commercial arguments.”

One guiding principle for achieving legitimacy was to ensure good end-user experience through interoperability: “as a user, I want my Internet services providers to be working for me. I want my user experience on my devices to be clean,” said one expert.

4.3.3 Entrepreneurial experimentation

To access code cheap and easily for testing and experimentation was regarded as a sign of openness. Google – its Android system – used to be a system with which developers could do “whatever you want,” according to one expert. It was as negative that Google “gradually, over the last five years, they’ve started to shrink down the amount of flexibility in the platform.”

4.3.4 Guidance of the search

The experts interviewed for this study recognized that economic incentives are necessary, and described openness and closure primarily as complementary, not competitive forces. In this respect, IPR and patents create closure of a platform, whereas royalty-free code and open licensing open it up. They also agreed that platform openness is a growing phenomenon, and that proprietary solutions and IPR obstruct innovation. One expert elaborated on drawing the line between open and closed: “So I guess it is about that line, where you put that line. We do not put it up – it happens organically. And there’s a constant tussle between openness and closed in various quarters.”

The balance between the need for closure and open standards for respectively profit and innovation is reflected in what one expert said: “The goal with standards is to achieve a minimum for things to function [...] Things have to be interoperable. But you have to open for competition – otherwise all are identical, and there’s no more business, right?” For instance, IETF and W3C policies are clearly royalty-free licensing, however, with guidelines for handling IPR issues. This is important for openness, according to one expert: “Because of the open license for standards – that enables you to build the open source. It’s much harder to build open source when you have royalty-encumbered standards. Or ... specific standards issues.”

Overall, openness is seen as advantageous because it fuels innovation and growth of the ecosystem. One expert explained how large patent holders find it worthwhile to invest in basic functionality in order to harvest in a different part of the ecosystem. They “choose to participate in open standards – royalty-free open standards – that allow them to set a baseline of technology which will be open and where they are happy to contribute with their intellectual property. Because they know that it creates a kind of market for services that delivers more value in the end, than if they simply sat on their patents and tried to cross-license. The development of this kind of open infrastructure layer, open layer on top of open source stuff, enables all these services to be done – that brings them much more value.”

Another telecom expert said that platform openness in turn affects end-user costs through scale: “Global markets provide the opportunity to build mass market with economies of scale. We get lower prices for the operators and users. It also gives service compatibility across countries.”

One expert explained how interests and expectations are signaled at conferences and workshops; the point can be to identify a group that shares the same interests, or consortia and alliances to join. The formation of expectations can also be directed specifically towards smaller vendors by showing willingness to work with them. To be predictable – to give vendors signals about if and who they can hire – is important in legitimizing the platform and providing incentives for investing.

The experts also gave examples of how and when openness is complemented by closure, and when closure is perceived as a legitimate way to extract profit. First, secrets and proprietary recipes could be black-boxed in architecture modules. Openness – they explained – is by definition about interfaces; that implies that IPR and proprietary solutions on interfaces represent acts of closing the platform to extract profit. Second, profitable closure could involve proprietary code on top of open source code – for instance, there are many proprietary versions on top of open Linux code. Third, knowledge advantages about open but still complex systems imply closure; such knowledge could be transformed into profitable services. Fourth, open source software could be populated with proprietary data that are attractive and profitable.

In addition, some of the experts interviewed argued that closure can be necessary in order to control resources and enable better and more predictable system performance.

In contrast to this acceptance of closure, the experts elaborated on instances where closure in order to profit is not legitimate. Firstly, closure should not violate the end-user experience. One elaborated on the balance: “if you try to end that line too far down towards the end-user, you end up limiting user choice.” Secondly, it was seen as negative if actors were obstructed from being involved in the use and development of platforms because of elements like membership rules, high fees, or decision hierarchy.

The above accounts have presented how non-technical factors may affect platform openness in the context of innovation processes. Table 4-1 systemizes all the non-technical factors identified, indicates how they may vary, and how they may affect innovation processes.

Table 4-1 Detailed factors for platform openness on the vendor interface

<i>Description of openness factor</i>	<i>How this factor affects platform openness</i>	<i>Factor variance</i>	<i>Innovation processes affected</i>
Rules for membership and participation	Membership rules and recruitment of individuals affect who can be a member of working groups developing standards.	Totally open – Strict membership and recruiting policy	All
Membership fee	Size of fee affects who can afford to become a member and contribute to development.	Totally free – High fee	All
Participation by large and small actors	Large commercial actors may dominate and choose their preferred solutions. Other actors are deterred from using the standard.	Independent contributors – Large dominating actors	Legitimation Search
Numbers of actors involved	High number of actors increases process complexity and stalls decisions (contradicts dominant actor)	One firm in control – Many contributors	Knowledge
Backward compatibility/path dependency	Path dependency affects openness positively and negatively: 1) ensures scale, critical mass, deep insight, and efficiency; 2) favors existing implementation and may lead to inertia.	Lean, technical functionality – Full backwards compatibility	Knowledge Experimentation Search
Decisions about standards: initiative, governance, voting	Governance and voting can be exclusive, unpredictable, and bureaucratic stalling development and diffusion.	Predictable and democratic – Fuzzy and unfair	Legitimation
Availability of standards and access to code in documents and libraries	Low availability of standards and code (also in reference implementations) affects possibilities for knowledge sharing, search and experimentation.	More available – Less available	Knowledge Experimentation Search
Administrative routines: decisions, versions, documentation	Routines that are not user-friendly, efficient or transparent hinder transparency, participation and knowledge sharing.	Efficient and user-friendly – Not efficient or user-friendly	All
Communities and projects for development and implementation	Ability to engage and involve many in development and implementation enable efficient knowledge sharing.	Large and engaged community – Small community	Legitimation Knowledge Experimentation
Financing of platform	Financial interests may skew actions and decisions about development and diffusion.	Small and idealistic – Large commercial interests	Legitimation
Mission statement, overall motivation	The mission may be social and inviting to innovation, or it may stall innovation with commercial goals for stakeholders.	Idealistic; technical orientation – Commercial	Legitimation Search
Transparency with regards to elements in this list	Lack of transparency obstructs external inquiry and evaluation; it hinders access to experimenting with standards for opportunities.	Transparent – Not transparent	Legitimation Experimentation
IPR and patents held by private parties	IPR and high costs decrease the accessibility of specifications and hinder implementation.	Royalty-free via FRAND – High secrecy	All

4.4 Complementor interface openness

The following presents informants' input on non-technical factors affecting platform openness on the complementor interface, categorized in terms of the four innovation processes from the technological innovation systems approach. Table 4-2 shows the broad set of non-technical factors affecting openness, and how they relate to innovation processes. The presentation here includes an analysis of industrial best-practice reports; references to the assessment of the different platforms are made throughout the informants' accounts.

4.4.1 Knowledge generation and diffusion

Administrative routines can affect platform openness by providing more, or less, simplicity and flexibility in knowledge understanding, and how to use share and use it. An open developer portal should be efficient and comprehensive with regard to documentation of technology as well as authentication, security, software development kits, analytics, support systems, and self-service. Experts emphasized that, on the complementor side, openness is affected by how easy it is to start developing applications with the software developer kit. The expression “developer journey” was used by one expert in describing platforms that were “a great success because they made that developer journey so easy and gave them exactly what they wanted.”

Experts explained that among community members there are competing “schools of thought” about the best tools, libraries, script and testing approaches. This implies that tacit knowledge may close a platform. It can lead to a “higher cognitive load” said one expert, and thereby to knowledge barriers.

On the complementor side, communities commonly used for building and sharing tacit knowledge about the technology itself, and how to use the platform tools. Communities are supported by platforms in social settings such as hackathons, developer events or one-to-one sessions. As one expert commented, “it is another hygiene factor actually – that if you’ve got an API – if you have a developer program – you have to have people that are out there talking about your program. Not just talking about the program but helping developers – whether there are one-to-one sessions, hackathons or events.”

4.4.2 Legitimation

A community is not only a way of enabling knowledge diffusion: it also involves earning legitimacy and thus opening or closing the platform. Developers and complementors may be

driven by idealism and fun, and building communities is a legitimate way to publish and market APIs. “Evangelizing” about a platform is a well-established practice – but the evangelist must strike the right note among complementors, whether from the technical or communication departments.

One expert emphasized that developers are customers: “a well-functioning dialogue is something – an element that induces trust.” This expert went on to explain that, for newcomers, “the only way to increase trust is to have really an open dialogue with your anticipated and, you hope, future customers”.

Transparency ensures access to knowledge, but also gives legitimacy to the platform. Also on the complementor side, insight into and how decision processes are practiced affects legitimacy. In general, having rules that complementors must follow creates tension: rules for forking and uploading were mentioned specifically. Apple’s review process for new apps have always been tight and were not highly regarded; they were contrasted with Google, which only recently added manual assessment of acceptable content to its automatic acceptance processes. W3C is completely free to use, with no authorities required to assess and accept new applications.

One expert explained the tight relationship between good administrative routines, transparency, and trust. For instance, reputation can be ruined by late payments, time issues, and ill-functioning problem handling, and implementation failures.

4.4.3 Entrepreneurial experimentation

Compared to the vendor side, the significance of entrepreneurial experimentation was noted more explicitly on the complementor side. An open platform simplifies experimentation. Readily available APIs enable complementors to search for, identify, and experiment. “It should be so easy to get somebody to start making something for your platform or making something for the APIs.” one expert said, adding: “It is – this isn’t so much about technical stuff anymore.” Another expert explained how easy Apple has made their developer journey: “If I wanted to build for Apple – it is very simple. I go to the developer side on Apple, I pay my 99 dollars, I get the programming language, I get the KIT, I go through all the videos, they tell me exactly how to do it, and then I start building it.”

Table 4-2 Detailed factors for platform openness on complementor interface

<i>Description of openness factor</i>	<i>How this factor affects platform openness</i>	<i>Factor variance</i>	<i>Innovation processes affected</i>
Decisions	How reviews and decisions about new applications are made can affect complementors' willingness to use resources.	More transparent and predictable - Less transparent and predictable	Legitimation
Availability of APIs and code for testing and experimenting	Low and costly availability of code decreases ability for initial search and experimentation.	Easily available - Hardly available	Knowledge Experimentation Search
Administrative routines: Developer portal routines giving access to API	How developer portal is managed affects how inviting and open platforms are: access rules, authentication, documentation, analytics reports, software developer kit, approval decisions, and security.	Easy to access and use - Difficult to access and use	All
Community: Complementor engagement and developer programs through e.g. blogs, hackathons, workshops	Platforms can seek to build a community with complementors to diffuse knowledge, and create engagement.	Large and engaged community - Small community	Knowledge Legitimation Experimentation
Mission statement, overall motivation	The mission can be social and inviting to innovation on technical bases, or it may stall innovation with commercial goals for stakeholders.	Idealistic; technical orientation - Commercial	Legitimation Search
Transparency with regard to elements on this list	Lack of transparency obstructs external inquiry and evaluation, and affects trust-building.	More transparent - Less transparent	Legitimation Experimentation
Models for monetization and revenue sharing for complementors	Models that are disadvantageous or unpredictable for complementors affect their willingness to experiment and innovate with the platform.	More favorable - Less favorable	Legitimation Search
Extension markets that enable access to and purchases of complements	End-users' purchases through extensions markets reduce risk and increase demand for complementors' products and services.	Easier and cheaper to join - Less easy and cheap to join	Legitimation Search
Versioning and backward compatibility	Lack of backward compatibility for substantial platform improvements: 1) limits existing complementors' access to new platform versions; 2) new complementors find platform less attractive due to weaker network effects.	Full compatibility - No backward compatibility	Legitimation Search
Exclusivity to platforms	Exclusivity for some complementors can deter the adoption of others.	Giving no exclusive rights - Extensive exclusive rights	Legitimation Search
Absorption risk	Risk of losing future profits because of absorption by platform may deter complementors from using it.	Active absorption - Nurture sustainable ecosystem	Legitimation Search
Cross-platform interoperability of API when platform controlled by multiple actors	Restriction of API: too few platform actors deter complementors from the platform because not all end-users are reached.	Shared API across all actors - API across few actors	Legitimation Search

One expert explained that the importance of allowing complementors to experiment for free, so they can identify good business cases: “It’s not only technical. You need a lot of marketing, trust, business models to make it work.” When experimentation is allowed, according to one expert, there is “an amazing explosion of innovation around services, simply because of that openness.”

4.4.4 Guidance of the search

One expert elaborated on how ease of experimentation also builds belief in business opportunities for the complementors; it is “very important to give this type of experimentation freedom to complementors – they’re the ones that implement applications and services for the platform – so that they can find out themselves whether this is good business or not.”

In addition, there are factors that can increase belief in, or deter economic incentives for complementors. An efficient app-store where complementors can earn money is positive, whereas lock-in and exclusivity issues may be risk factors.

Table 4-2 sums up the various non-technical factors indicated as affecting platform openness on the complementor interface, showing how specific factors vary and affect innovation processes. Also on the complementor side all potential relationships are indicated, while informants’ accounts report on these relationships in greater detail.

5 Discussion and conclusions

This article has asked: How and why do platforms open their interfaces beyond technological specifications? The study has showed that platform openness is not only about APIs, standards, or open source code: it also concerns the tools, means, and practices that are used in interaction between platforms and stakeholders. This has been systemized in comprehensive lists of non-technical factors affecting openness in Table 4-1 and Table 4-2. The chain of factors involved in opening platform interfaces is seen as following the logic modelled in Figure 2-2. First, it is a necessary condition that the platform uses API, standard or open source to open up interfaces. Second, and in focus in this study, are the non-technical factors important for openness in addition to the technological specifications. These are specific to each of the platform interfaces, and may be positive or negative for openness. Third, specific non-technical factors affect innovation processes, acting as inducing or blocking mechanisms for further innovation and growth. Fourth, innovation and growth of the platform are affected, positively or negatively. By introducing innovation processes as

intermediate variables between non-technical factors and innovation, processes previously hidden in a black box (Yin, 2014) have now been revealed.

However, the model in Figure 2-2 forces complex relationships into a linear model that is far from reality (Hekkert et al., 2007). Table 5-1 offers a more comprehensive summary of the complex relationships between non-technical factors and innovation processes, cutting across the differences between vendor and complementor interfaces. This cross-interface summary reveals that there are more instrumental factors affecting innovation processes, but also that social processes such as communities can have significant effects. Thus, it makes sense to distinguish between a complementor and vendor side, although real life is far more complex. Moreover, platform openness is shown to involve not only having access to a platform, but being able to develop and refine it.

According to innovation processes, being able to develop and diffuse *knowledge* so as to cater for variety is critical for further innovation and growth (Hekkert et al., 2007). For platforms, the technologies in question are fast-moving and complex, difficult to codify fully, and involve features of tacit knowledge (Lundvall & Johnson, 1994). For experts seeking to develop and use such knowledge it is challenging to acquire all the necessary knowledge; for those developing the platform, it is important to get access to the available brainpower to make the best technology possible. Table 5-1 shows how actual availability for use, administrative routines, and community building are non-technical factors that affect knowledge development and diffusion, and in turn platform openness. Availability concerns every aspect of providing easy access to using the platform resources. This is taken further by administrative routines involving every aspect of documenting and making the knowledge easy to absorb, and eliminating any administrative hurdles to getting access: in short, providing good developer journeys. Thirdly, community building acknowledges that social interaction is an important way of sharing tacit knowledge.

These aspects about *knowledge* concern primarily the *use* of APIs, standards or open source code. For vendors, practices concerning participation in the *development* of standards and code may represent additional hurdles to openness (West, 2007) – be it strict participation rules, high costs and fees, dominance of large actors, or chaos with too many small ones. On the vendor side, these aspects also affect legitimacy, experimentation and search guidance, as indicated in Table 5-1.

Only when formal and informal rules are considered appropriate and legitimate will actors make the effort to mobilize resources to innovate (Bergek et al., 2008); *low legitimacy* closes

the platform and is an obstacle to innovation and growth. Many specific factors will affect the legitimacy of a platform, as shown in Table 5-1. Again, administrative routines and community building are influential. On the complementor side, poor handling of issues, payment and delays can destroy a reputation. Platforms establish and engage stakeholders in platform communities to build and nourish legitimacy; here it is important to use the right competence and backgrounds, to be able to “evangelize” convincingly to community members. How decisions are made – in developing APIs, standards and open source, but also in their use and implementation – may have major effects on legitimacy. The actors behind the platforms, and the mission signaled, evoke and address varying emotions and beliefs among stakeholders, and the degree of transparency will affect whether they trust the messages conveyed.

Table 5-1 Specific factors and innovation processes combined; grey color indicates that specific factors affect innovation processes

		<i>Innovation processes</i>			
		Knowledge	Legitimation	Experimentation	Search
Vendor interface	Development process: • Rules for participation • Cost for participation • Large/small actors	✓	✓	✓	✓
	Backward compatibility	✓		✓	✓
Both interfaces	Decisions		✓		
	Availability for use	✓		✓	✓
	Administrative routines	✓	✓	✓	✓
	Community building	✓	✓	✓	
	Mission/Financing actor		✓		✓
	Transparency		✓	✓	
	Monetization/IPR		✓		✓
Complementor interface	Signals from platform: • Versioning • Exclusivity • Absorption risk • Cross-platform interoperability		✓		✓

A technological innovation system – and thus platform ecosystems – will be subject to high uncertainty. That in turn can obstruct the mobilization of other actors to start innovating with

the platform. One way to handle this uncertainty is to enable probing into new technologies and applications through efficient *experimentation*. Without experimentation, a platform will not grow (Bergek et al., 2008). Availability, administrative routines, and community building are important for experimentation, for many of the reasons mentioned above. Every tool that makes it easier to start making something for a given platform serves to fuel experimentation; any cost or hurdle will be a drawback. Transparency is helpful, as regards having full access to knowledge, former and ongoing projects, and experts.

Financial incentives are important for an actor to start *searching* for business opportunities for further proliferation, and then fueling the further innovation and growth of the platform (Hekkert et al., 2007). Availability and administrative routines, as well as the mission signaled from the platform, will affect stakeholder beliefs in business opportunities. On the complementor side, the financial opportunities are often determined by the revenue split between the platform and complementors. Other signals from the platform affect complementors' beliefs (Eisenmann et al., 2009) concerning, for example, the risk of being absorbed by the platform, and lack of interoperability. On the vendor side, platform openness is recognized as good for growth and innovation, whereas proprietary solutions and IPR can be obstacles. However, openness and closure must be balanced in order to enable both innovation and profit.

Two innovation processes appear particularly important for closure (and thus profit) in an otherwise open context: legitimation, and knowledge development and sharing. The dividing line between open and closed will differ from one platform to another, and will have been subject to a legitimation process determining where and how it is acceptable to extract profit (Ghazawneh & Henfridsson, 2013). Some issues may prove devastating for legitimacy – like closure that violates end-user experience or excludes participation in development on the vendor side. Second, taking advantage of tacit knowledge and developing this into services appears to be a legitimate way of extracting profit. It is also deemed legitimate to conceal secret knowledge in modules, to administer private data with open systems, and to build closed code on top of the public. However, the dividing line between what is kept closed and what is open is undergoing continual change (Eaton et al., 2015). Previous tacit knowledge may become commoditized with time (West, 2007), and a platform's actual shared knowledge base can evolve. That also means that new tacit knowledge that can lay the ground for new profit must develop continuously.

Many of the non-technical factors that affect platform openness can be found in other technological innovation systems as well. The factor here labeled “communities” caters for increasing the density in social networks in the platform’s innovation system (Bergek et al., 2008; Hekkert et al., 2007) and inter-expert relationships where tacit knowledge is exchanged and built. A software platform like GitHub offers new significance. This type of software addresses many of the non-technical factors that affect openness – availability, documentation, transparency, and participation costs. In addition, it can support the building of communities through its potential social media features.

5.1 Theory contribution

The study fills a gap in theories on platform openness through operationalizing and detailing factors influential for platform openness (Gawer, 2014). Especially important is how the matching with well-established innovation processes (Bergek et al., 2008; Hekkert et al., 2007) extends our understanding of how APIs and other non-technical factors can lead to growth and innovation. Arguably, the association between an API and innovation is somewhat more complex than often communicated. The use of already familiar innovation processes for studying platforms is in accordance with the call for applying literature on institutions and legitimacy to explain the constitution of platforms and platform openness (Gawer & Cusumano, 2014). This article has also addressed the unresolved trade-off between openness and closure (Laursen & Salter, 2014) with concrete and legitimate ways of extracting profit: knowledge can be tacit and act as profit-enabling closure in the case of APIs, standards, and open source, while also subject to commoditizing (West, 2007).

For technological innovation system approaches (Bergek et al., 2008; Hekkert et al., 2007), this study introduces the platform ecosystem as an increasingly widespread phenomenon. Platform ecosystems are complex systems where opening of platforms is used strategically to affect innovation and growth. The study finds support for the relevance of the technological innovation systems approach in a telecommunications sector characterized by a high degree of bilateral technological complementarities, as well as potential bottlenecks due to incompatibility – or lack of APIs, standards, or open source (Markard & Hoffmann, 2016).

Further, this study extends how technological compatibility and interface openness are treated in technological innovation systems (Markard & Erlinghagen, 2017). First, technology specifications (like APIs, standards, and open source) are presented as initial strategic necessities to build complex technological systems such as platform ecosystems; this is

different from seeing standards solely as a policy response to bottlenecks (Markard & Hoffmann, 2016), or the result of an ongoing struggle (Markard & Erlinghagen, 2017). Second, well-established constructs for innovation processes have served to explain the role of compatibility and openness on an interface. Third, entrepreneurial experimentation has been identified as a core innovation process (Hekkert et al., 2007) but has not been explored as fully as have institutions and legitimation (Bergek, Jacobsson & Sandén, 2008; Markard et al., 2016). Recognition of the significance of entrepreneurial experimentation for engaging and motivating platform stakeholders revitalizes it as a fundamental force in further evolution. Fourth, software systems such as GitHub appear to play a central role, affecting many well-known innovation processes and adding to the factors that deserve attention in technological innovation systems.

5.2 Management implications

Several implications can be drawn for managers' governance of platforms and platform openness. First, the strategic focus of a platform should be on the innovation processes that concern knowledge generation and sharing, legitimation, entrepreneurial experimentation, and guidance of the search – so as not to lose sight of the fundamental motivation for opening up a platform. Second, this study provides a framework of specific non-technical factors that can be used to govern openness. Regarding when closure is legitimate in order to profit, the chief message is that the end-user experience must be ensured. The platform and other profit-seeking actors are allowed and expected to find ways of combining the open pool of knowledge with tacit and thus closed knowledge. There is no final rule, except to find the right balance between openness and closure.

As regards other stakeholders, this article has argued why platforms should open up interfaces and create more attractive conditions for all parties. All actors should expect to keep searching for the legitimate balance between open and closed, and together form the ruling institutions. For policymakers, the main implication is an expanded understanding of the forces affecting innovation and competition in a context where strong platform ecosystems may evolve or already exist, and where innovation must be spurred while competition is also regulated.

5.3 Limitations and further work

This study cannot fully capture the complexity of the phenomenon of platform openness. Still, it marks one important step in increasing our understanding of what such openness is, and how it affects innovation. Future studies could use the proposed framework to assess other

platforms more systematically. That would test the applicability of the framework, and extend, refine, and weight the factors and relationships indicated in this article.

6 References

- Andersen, P., 2008. *Evaluation of ten standard setting organizations with regard to open standards*, Copenhagen: IDC.
- Baldwin, C. & Clark, K., 2000. *Design rules. Volume 1. The power of modularity*. Cambridge, MA: The MIT Press.
- Baldwin, C. & Woodard, J., 2009. The architecture of platforms: a unified view. In: A. Gawer, ed. *Platforms, markets and innovation*. Cheltenham: Edward Elgar, pp. 19–44.
- Benlian, A., Hilkert, D. & Hess, T., 2015. How open is this platform? The meaning of and measurement of platform openness from the complementors' perspective. *Journal of Information Technology*, 30(3), pp. 209–228.
- Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. & Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy*, Volume 37, pp. 407–429.
- Bergek, A., Jacobsson, S. & Sandén, B., 2008. "Legitimation" and "development of positive externalities": two key processes in the formation phase of technological innovation systems. *Technology Analysis & Strategic Management*, 20(5), pp. 575–592.
- Castellacci, F., 2008. Innovation and the competitiveness of industries: comparing the mainstream and evolutionary approaches. *Technological Forecasting and Social Change*, 75(7), pp. 984–1006.
- Cowan, R., 2004. *Network models of innovation and knowledge diffusion*, Maastricht: MERIT - Infonomics Research Memorandum series.
- Davies, E., 2004. *Request for comment: 3774. IETF Problem Statement*. [Online] Available at: <https://tools.ietf.org/html/rfc3774> [Accessed 13 April 2016].
- Eaton, B., Elaluf-Calderwood, S., Sørensen, C. & Yoo, Y., 2015. Distributed tuning of boundary resources: the case of Apple's iOS service system. *MIS Quarterly*, 39(1), pp. 217–234.

- Edquist, C. (ed), 2003. *The Internet and mobile telecommunication system of innovation. Developments in equipment, access and content*. Cheltenham: Edward Elgar.
- Eisenmann, T., Parker, G. & Alstyne, M. V., 2009. Opening platforms: how, when and why?. In: A. Gawer, ed. *Platforms, markets and innovation*. Cheltenham: Edward Elgar, pp. 131–162.
- Farrell, J. & Simcoe, T., 2012. Four paths to compatibility. In: M. Peitz & J. Waldfogel, eds. *Oxford handbook of the digital economy*. New York: Oxford University Press, pp. 34–58.
- Frenken, K. & Mendritzki, S., 2012. Optimal modularity: a demonstration of the evolutionary advantage of modular architectures. *Journal of Evolutionary Economics*, 22(5), pp. 935–956.
- Funk, J. & Methe, D., 2001. Market- and committee-based mechanisms in the creation and diffusion of global industry standards: the case of mobile communication. *Research Policy*, 30(1), pp. 589–610.
- Gawer, A., 2009. Platform dynamics and strategies: from products to services. In: A. Gawer, ed. *Platforms, markets and innovation*. Cheltenham: Edward Elgar, pp. 45–76.
- Gawer, A., 2014. Bridging different perspectives on technological platforms: toward an integrative framework. *Research Policy*, 43(7), pp. 1239–1249.
- Gawer, A. & Cusumano, M. A., 2014. Industry platforms and ecosystem innovation. *Journal of product innovation management*, 31(3), pp. 417–433.
- Ghazawneh, A. & Henfridsson, O., 2013. Balancing platform control and external contribution in third party development: the boundary resources model. *Information Systems Journal*, 23(2), pp. 173–192.
- Ghazawneh, A. & Henfridsson, O., 2015. A paradigmatic analysis of digital application marketplaces. *Journal of Information Technology*, 30(3), pp. 198–208.
- Greenstein, S. & Stango, V., 2007. *Standards and public policy*. Cambridge: Cambridge University Press.
- GSMA, 2014. *Mobile Economy Europe 2013*, s.l.: GSMA.

- Hekkert, M., Suurs, R., Negro, S., Kuhlman, S. & Smits, R., 2007. Functions of innovation systems: a new approach for analysing technological change. *Technological Forecasting and Social Change*, 74(4), pp. 413–432.
- Henkel, J., Baldwin, C. Y. & Shih, W., 2013. IP modularity: Profiting from innovation by aligning product architecture with intellectual property. *California Management Review*, 55(4), pp. 65–82.
- Henkel, J., Schöberl, S. & Alexy, O., 2014. The emergence of openness: how and why firms adopt selective revealing in open innovation. *Research Policy*, 43(5), pp. 879–890.
- Iansiti, M. & Levien, R., 2004. *The keystone advantage. What the new dynamics of business ecosystems mean for strategy, innovation and sustainability*. Cambridge, MA: Harvard Business School Press.
- IFI Claims Patent services, 2014. *IFI CLAIMS 2013 Top 50 US Patent Assignees*. [Online] Available at: http://www.ificlaims.com/index.php?page=misc_top_50_2013 [Accessed 11 August 2014].
- Jansen, S. & Cusumano, M., 2013. Defining software ecosystems: a survey of software platforms and business network governance. In: S. Jansen, S. Brinkkemper & M. Cusumano, eds. *Software ecosystems*. Cheltenham: Edward Elgar, pp. 13–28.
- Jarschel, M., Zinner, T., Hossfeld, T., Tran-Gia, P. & Kellerer, W., 2014. Interfaces, attributes, and use cases: a compass for SDN. *IEEE Communications Magazine*, June, 52(6), pp. 210–217.
- Laffan, L., 2011. *Open governance index - Measuring the true openness of open source projects from Android to WebKit*, London: Visionmobile.
- Langlois, R. & Robertson, P., 1992. Networks and innovation in a modular system: Lessons from the microcomputer and stereo component industries. *Research Policy*, 21(4), pp. 297–313.
- Laursen, K. & Salter, A., 2014. The paradox of openness: appropriability, external search and collaboration. *Research Policy*, 43(5), pp. 867–878.
- Lundvall, B.-Å. & Johnson, B., 1994. The learning economy. *Journal of Industry Studies*, 1(2), pp. 23–42.

- MacCormack, A. & Iansiti, M., 2009. Intellectual property, architecture, and the management of technological transitions: evidence from Microsoft Corporation. *The Journal of Product Innovation Management*, May, 26(3), pp. 248–263.
- Markard, J. & Erlinghagen, S., 2017. Technology users and standardization: game changing strategies in the field of smart meter technology. *Technological Forecasting and Social Change*, Volume 118, pp. 226–235.
- Markard, J. & Hoffmann, V., 2016. Analysis of complementarities: framework and examples from the energy transition. *Technological Forecasting and Social Change*, Volume 111, pp. 63–75.
- Markard, J., Wirth, S. & Truffer, B., 2016. Institutional dynamics and technology legitimacy - a framework and a case study on biogas technology. *Research Policy*, 45(1), pp. 330–344.
- Martin, B., 2016. Twenty challenges for innovation studies. *Science and Public Policy*, 10 April, pp. 1–19.
- NO-REST, 2005. *Report on demand factors and on the supply side for standards for networked organizations - D05/06*, Brussels: European Commission. Networked Organisations - Research into standards and standardisation.
- Pratt, M., 2008. Fitting oval pegs into round holes. Tensions in evaluating and publishing qualitative research in top-tier North American journals. *Organizational Research Methods*, 11(3), pp. 481–509.
- Ritala, P., Golnam, A. & Wegmann, A., 2014. Coopetition-based business models: the case of Amazon.com. *Industrial Marketing Management*, 43(2), pp. 236–249.
- Ruutu, S., Casey, T. & Kotovirta, V., 2017. Development and competition of digital service platforms: a system dynamics approach. *Technological Forecasting and Social Change*, Volume 117, pp. 119–130.
- Saldaña, J., 2013. *The Coding Manual for Qualitative Researchers*. London: Sage.
- Schmidt, S. & Werle, R., 1997. *Coordinating technology: studies in the international standardization of telecommunications*. Cambridge, MA: The MIT Press.

- Takanashi, C. & Lee, K.-J., 2013. Standard development by committees and communities: a comparative case study of IEEE1394 and USB. *Technology Analysis & Strategic Management*, 25(1), pp. 91–105.
- Thomas, P. & Breitzman, A., 2013. *www.ieee.org*. [Online]
Available at: <http://spectrum.ieee.org/at-work/innovation/patent-power-2013>
[Accessed 11 August 2014].
- Tidd, J., Bessant, J. & Pavitt, K., 2005. *Managing innovation. Integrating technological, market and organizational change*. Hoboken, NJ: John Wiley & Sons.
- Tiwana, A., 2014. *Platform ecosystems. Aligning architecture, governance and strategy*. London: Elsevier.
- Tiwana, A., Konsynski, B. & Bush, A. A., 2010. Platform evolution: coevolution of platform architecture, governance, and environmental dynamics. *Information Systems Research*, 21(4), pp. 675–687.
- Weber, M. & Truffer, B., 2017. Moving innovation systems research to the next level: towards an integrative agenda. *Oxford Review of Economic Policy*, 33(1), pp. 101–121.
- West, J., 2003. How open is open enough? Melding proprietary and open source platform strategies. *Research Policy*, 32(7), pp. 1259–1285.
- West, J., 2007. The economic realities of open standards: black, white and many shades of grey. In: S. Greenstein & V. Stango, eds. *Standards and Public Policy*. Cambridge: Cambridge University Press, pp. 87–122.
- West, J. & Dedrick, J., 2000. Innovation and control in standards architectures: The rise and fall of Japan's PC-98. *Information Systems Research*, 11(2), pp. 197–216.
- West, J. & O'Mahony, S., 2009. The role of participation architecture in growing sponsored open source communities. *Industry and Innovation*, 15(2), pp. 145–168.
- Yin, R. K., 2014. *Case Study Research*. 5 ed. Thousand Oaks, CA: Sage.

Appendix 1

Table 6-1 Initial platform assessment

<i>Units of analysis</i>	<i>W3C</i>	<i>IETF</i>	<i>3GPP</i>	<i>Google</i>	<i>Apple</i>
What is this?	Web	Internet	Mobile cellular networks	Android – operating system for mobile devices	iOS– operating system for mobile devices
Mission	Innovation to the best of society	Technology concerns. Running code.	Industry-led, commercial goals on behalf of members	Commercial missions	Commercial missions
Financing of platform	Membership fees >50%. Funders and donors	Funded by Internet society	Membership organizations, e.g. ETSI.	Privately financed. Contributors to code finance themselves.	Privately financed
Participation in development	Individual Organizations must apply for individual membership	Individual Completely open. One may not participate on behalf of an organization	Seven partner members assign individual contributors	Private Open-source project highly controlled by Google.	Private Some open source in Mac OS X.
Membership fee conditions	Organizations pay fee, dependent on size, type and country	No membership fee; fee for participating in meetings	Membership organization pay, e.g. ETSI	No membership fee required for contributing code	Private
IPR	Prefer royalty-free standards	Prefer royalty-free standards.	Accept patents on terms that are Fair, Reasonable and Non-Discriminatory ³	All rights go to the Android open source project. In general Google uses patents actively to protect technology ⁴ .	Use patents actively to protect technology ³ .
Complementor community	Large	Large	Small	Large	Large
Advanced extension markets	Quite inviting	No	No	Yes	Yes

³ The electronic and hardware industries that provide components to the telecommunications market – for instance. Samsung, Sony, Qualcomm, LG, Intel, Ericsson, and AT&T – hold many US patents (IFI Claims Patent services, 2014).

⁴ Google and Apple score high on several assessments of their patent activity, regarding patent power (Thomas Breitzman, 2013) and number of US patents (IFI Claims Patent services, 2014).