Architectural innovation and design evolution: strategic and organizational dynamics of industry platforms

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Abstract

The importance of understanding changes in the underlying architecture of complex systems has been well established, both in the academic and practitioner literature. Though existing research has made significant advances, important issues remain. Generally, existing research on architectural change has tended to overlook the interplay between environmental and firm-level drivers. In particular, relatively few studies have looked at the challenges firms face in making architectural design choices, and contingencies arising out of architectural change. As such, empirical evidence on this relationship is under-represented, even though its importance has been well established, for instance in the literature on organization design and contingency theory. Overall, this thesis emphasizes the interplay between environmental drivers and firm-level actions. In particular, it highlights the challenges firms face in dealing with environmental changes (e.g. new entrants, regulatory changes, standards setting), how this affects architectural design choices, and the underlying motivations driving these decisions.

The dissertation is built up as follows. Following an introductory chapter, Chapter 2 develops a conceptual framework to understand changes in industry modularity. It suggests that industry architectures become more modular based on dissemination of product interfaces and organizational practices, and highlights several moderating factors influencing this process. Chapter 3 analyzes changes in product and organizational architecture, highlighting the combined role of environmental and firm-level drivers in affecting this relationship. Tensions between collaboration and competition in particular complicate a firm’s decision making process regarding product and organization architecture design choices. Chapter 4 examines the product and industry level, focusing on which factors drive value appropriation and value creation in interdependent industry ecosystems. The chapter explores this through a study comparing the contrasting deployment of the i-mode mobile internet service, highlighting the importance of industry architectures to explain these differences.

Declaration of Originality:

I hereby declare that this work is my own and that all else is appropriately indicated, attributed and referenced.
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Chapter 1

Introduction: wholes, parts and their inter-connections

“Break a vase, and the love that reassembles the fragments is stronger than that love which took its symmetry for granted when it was whole.” ¹

Out of the many ways to interpret Derek Walcott’s quote above, one is its allusion to the efforts involved in the integration of individual parts comprising a wider system. As such, it might, beyond its broader insight, serve as a gentle introduction to the stream of work on complex systems and their underlying architecture.

1.1 Why study architectural change?

The importance of understanding changes in the underlying architecture of complex systems has been well established, both in the academic and practitioner oriented literature.² An oft-cited example involves the product architecture of the PC as defined by IBM, and its subsequent organization and industry level impact. In this setting, some firms (especially Microsoft and Intel) have thrived, whereas others (not least IBM) have been less fortunate (Ferguson and Morris, 1993). For different reasons, the automotive industry also serves as an important reminder of the importance of understanding architectural shifts. Here, it appears

² As elaborated on in Chapter 2, architecture generally refers to “an abstract description of the entities of a system and the relationships between those entities” (Whitney et al., 2004). Therefore, the phrase “architectural change” is used in a broader sense than related concepts such as “architectural innovation”, which generally refers to changes in the linkages between components in a given product architecture (Henderson and Clark, 1990). In this dissertation, architectural change encompasses both single-level (e.g. increase in modularity of product architecture) and multi-level changes (e.g. product -organization level interaction).
that some firms have misapplied strategies from the computer industry in an attempt to implement these in their sector, sometimes with unfortunate consequences (MacDuffie, 2006; Zirpoli and Becker, 2011). Furthermore, it is not just technology sectors where examining architectural change is important. In financial services for instance, research on changes in mortgage banking has highlighted how shifts in architecture may impact on firms’ capability development and a segment’s value generating logic (Jacobides, 2005; Jacobides and Winter, 2005). As a consequence, it may also prompt behavioral shifts, such as willingness to take risks, with far reaching socio-economic consequences (Jacobides and Winter, 2010). As such, a better understanding of architectural changes and the design choices these raise, appears of great value, both from an academic and practitioner point of view.

1.1.1 Background literature: a brief overview

Fortunately, besides the work mentioned already, extant research on this topic has provided important insights on architectural change. For example, existing work has shown how it can shape technological trajectories (Clark, 1985); affect firm survival and profitability (Henderson and Clark, 1990; Murmann and Frenken, 2006); influence knowledge trajectories, reinforcing the role of systems integrators (Brusoni, Prencipe and Pavitt, 2001; Prencipe, Hobday and Davies, 2003); induce the establishment of platform leaders (Gawer and Cusumano 2002, 2008; Gawer and Henderson, 2007); and affect sector-wide value appropriation (Jacobides, Knudsen and Augier, 2006; Pisano and Teece, 2007).

Many of these recent studies are, directly or indirectly, influenced by the work of Herbert Simon. Most relevant here is his research on the architecture of complexity, where he articulated his ideas on wholes, parts, and the relationships underlying them (Simon, 1962, 1996, 2002). Simon emphasized two characteristics of complex systems: hierarchy and near-
decomposability. In this context, *hierarchy* refers to the nested structure of systems, in that these are comprised of subsystems, which in turn are made up of further subsystems, until we reach a certain elementary level. Hierarchy is not only pervasive in natural systems (e.g. think of the nested structure of molecules, atoms etc), but also in symbolic ones (e.g. books and the subsequent breakdown into chapters, paragraphs, sentences etc). Most relevant to this dissertation, we also find it in other social systems, such as firms and their associated layers of subdivisions. *Near-decomposability* refers to the observation that, at each level in the hierarchy, interactions within components are greater than those between different components. Systems are nearly - as opposed to fully - decomposable when, as is often the case, interactions among subsystems are weak, but not negligible. Through examples spanning a variety of domains, Simon (1962, 1996, 2002) suggests that systems that are nearly decomposable display important evolutionary advantages.

Though Simon’s overall influence in and beyond the field of management is undisputed, it took several decades before the management literature began building on his work on complexity and architecture.\(^3\) Determining an exact starting point to the more recent wave is difficult, and probably unnecessary, but a list of influential studies should not exclude work on the architecture of products or organizations (Henderson and Clark, 1990; Ulrich, 1995), as well as research on modularity (Langlois and Robertson, 1992; Baldwin and Clark, 2000; for an edited collection of influential studies, see Garud, Kumaraswamy and Langlois, 2002).\(^4\)

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3 Individual exceptions notwithstanding, e.g. Starr (1965). Furthermore, though Simon, from my perspective, has been most influential to modularity scholars in the organization and management field, several scholars from other fields have also made important contributions, including Alexander (1964), Parnas (1972) and Holland (1995, 1999).

4 There appears to be some divergence of opinion on Simon’s position vis-à-vis the modularity concept. Particularly, Augier and Sarasvathy (2004) have argued that several of Simon’s key ideas, including near-decomposability, have been oversimplified, i.e. treated as synonymous to modularity. Further, as noted by Augier and Sarasvathy (2004), “a full text search of his entire oeuvre using the keyword ‘modul*’ failed to produce a single instance”. This claim however is incorrect: see Simon’s (1976: 519) usage of the phrase
1.1.2 Research gap

Though existing research has made significant advances to our understanding of architectural change, important issues remain. Generally, existing work on architectural change has tended to overlook the interplay between environmental and firm-level drivers. In particular, relatively few studies have looked at the challenges firms face in making architectural design choices, and contingencies arising out of architectural change. As such, empirical evidence on these relationships is under represented, even though its importance has been well established, e.g. in the classic literature on organizational design and contingency theory (March and Simon, 1958; Woodward, 1958; Burns and Stalker, 1961; Lawrence and Lorsch, 1967; Thompson, 1967; Child, 1972), as well as more recent conceptual work (e.g. Siggelkow and Rivkin, 2005). This thesis looks into the overall issue of the interplay between environmental and firm-level factors in the following ways.

First, it is unclear how environmental change relates to architectural decisions subsequently faced by firms, though several studies highlighted the importance of rapidly shifting environments (e.g. Brown and Eisenhardt, 1997; Siggelkow and Rivkin, 2005). Chapter 3 looks at this issue, focusing on the challenges firms face in adapting to environmental changes, and the role played by product and organizational architecture level choices.

Second, though an emerging line of work highlights the importance of industry architecture (Jacobides et al., 2006; Pisano and Teece, 2007), few studies have looked at the role of environmental factors such as standard setting and regulation (notwithstanding important exceptions that have addressed the role of regulation, in particular Jacobides (2005, 2008)).

“modularization”, referring to a computer program’s routines. Possible evidence of Simon’s support towards the modularity literature might be his sympathetic foreword for an edited collection on modularity and complex systems (see Callebaut and Rasskin-Gutman, 2005). Regardless of Simon’s personal position on particular terminology, it should be clear that he has had a major influence on a stream of work that, for better or worse, has often adopted the modularity label.
and Cacciatori and Jacobides (2005)). Chapter 4 looks into this issue, in particular to understand how they affect industry architecture and firm capabilities, and their subsequent impact on platform deployment.

Third, while existing research shows that architecture and modularity often relates to different levels of analysis (Brusoni and Prencipe, 2006; Colfer and Baldwin, 2010), there has been little work on their implications for understanding changes in industry architecture. Chapter 2 addresses this issue by developing a framework highlighting product and organizational level dynamics, highlighting several moderating factors that drive differences in industry modularity.

1.2 Data and Methodology

The findings reported in this dissertation have largely been based on qualitative methods, using case study analysis (Yin, 2003; Eisenhardt, 1989). I focused on qualitative methods as these are especially useful when trying to understand questions concerning “what is occurring” or “how is it occurring” (Lee, Mitchell and Sablynski, 1999; Pratt, 2009), as is relevant in this dissertation. They are not suitable to establish prevalence or generalizability, where variance-studies are appropriate (Lee et al., 1999). As such, the empirical data (described in more detail in the individual chapters) have been collected to better understand underlying mechanisms of architectural change, focusing in particular on the interaction between environmental and firm-level drivers.

1.2.1 Setting

The empirical chapters draw on data from the mobile telephony sector. I chose this sector for several reasons. First, mobile telephony constitutes a relatively young industry segment, yet
several instances of architectural change have taken place. These recent changes allowed me to get direct access to people that have been closely involved in the decision making process, thereby allowing me to not rely solely on secondary sources.\textsuperscript{5} One of the benefits of this is that it allows insights into motivations and other decision-making processes, which is not always present in secondary data. Second, in contrast to other settings (e.g. automotive or computing), mobile telephony also appears to be an area that has not often been studied in the context of architectural change. This might allow me to uncover dynamics that have not been highlighted elsewhere. As such, this choice of setting is an example of purposeful (as opposed to random) sampling; it was chosen on conceptual grounds, \textit{not} for representativeness (Miles and Huberman, 1994).

\subsection*{1.2.2 Levels of analysis}

I have collected data at different levels of analysis, as explained in more details in the individual chapters. Figure 1.1 provides a schematic overview of the different levels of analysis used in the different chapters, and how they relate.

\textbf{Figure 1.1:} Levels of analysis and inter-relationships by chapter

\textsuperscript{5} At the same time the high rate of change in this sector at times may also be a shortcoming. Though I have selected cases where changes in architecture are apparent, the relatively short history of the various segments sometimes preclude “definitive” statements regarding outcomes (this applies mainly to Chapter 3). While what constitutes a rapid or incremental rate of change is in some ways relative, it is important to point this out for this particular setting. On the other hand, selecting a case from sector that is “in flux” avoids the tendency of “sampling on the dependent variable”, i.e. bias towards successful cases only (Denrell, 2003)
The main levels of analysis I distinguish in this dissertation are the product, organization, and industry level. At the product level, I focus on the architecture of a technological system. Chapter 2 constitutes a conceptual study and provides a general discussion of product architecture. In the empirical studies presented in Chapters 3 and 4, product architecture refers to technological systems from the mobile telephony sector, respectively an operating system (Symbian) and a mobile internet service (I-mode). The organizational level includes both intra- and inter-firm organizations (e.g. an alliance or joint venture), further discussed in Chapters 3 and 4. At the industry level I focus on an entire “value chain” or sector, similar to Jacobides et al. (2006). This is further discussed conceptually in Chapter 2 and empirically in Chapter 4. Table 1.1 summarizes the ensuing chapters, in terms of research question, intended contribution, level of analysis and empirical setting.

Table 1.1: Overview of individual chapters

<table>
<thead>
<tr>
<th></th>
<th>Chapter 2</th>
<th>Chapter 3</th>
<th>Chapter 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title</strong></td>
<td>“Architectural change across levels: understanding drivers of industry modularity”</td>
<td>“Designing product and organization architecture in a dynamic environment: the combined impact of environmental and firm-level drivers”</td>
<td>“Industry architecture as a determinant of successful platform strategies: a case study of the i-mode mobile internet service”</td>
</tr>
<tr>
<td><strong>Research Question</strong></td>
<td>How do product and organizational architecture factors drive changes in modularity at the industry architecture level?</td>
<td>How do environmental changes and firm drivers impact on product and organizational architecture design choices?</td>
<td>What factors and processes drive value appropriation and value creation in interdependent industry ecosystems?</td>
</tr>
<tr>
<td><strong>Contribution</strong></td>
<td>Conceptual framework based on product and organizational processes to understand moderators affecting changes in industry modularity</td>
<td>Highlights the challenges firms face adapting to environmental changes, due to strategic and technological trade-offs complicating architectural design choices</td>
<td>Highlights how regional environmental differences shape industry architecture and firm knowledge, thereby affecting platform deployment</td>
</tr>
<tr>
<td><strong>Levels of analysis</strong></td>
<td>Product, organization, industry</td>
<td>Product and organization</td>
<td>Product and industry</td>
</tr>
<tr>
<td><strong>Setting</strong></td>
<td>General (conceptual study)</td>
<td>Symbian operating system for mobile phones</td>
<td>I-mode mobile internet service</td>
</tr>
</tbody>
</table>
1.3 Remaining chapters: a brief look ahead

Before moving on to the remaining chapters, a brief look at their individual contributions.

Chapter 2 develops a conceptual framework discussing architectural change at different levels to understand moderating factors that drive differences in industry modularity. It outlines how modularity increases at the product and organizational level, focusing on codification of standardized interfaces and stabilization of organizational practices. Industry modularity increases when product interfaces and organizational practices disseminate beyond the focal organization. Several moderating factors that influence this dissemination process are highlighted. At the product level I focus, first, on strategic considerations regarding standardization, and second on capability trajectories and firm specialization. At the organizational level I highlight informational mechanisms and convergence of cognitive frames, and the role of technological breakthroughs and its influence on the complexity and interaction of organizational practices. As such, the chapter presents a contingent perspective toward understanding changes in industry modularity.

Chapter 3 analyzes changes in product and organizational architecture, highlighting the combined role of environmental and firm-level drivers in affecting this relationship. Here, environmental drivers refer to changes in the competitive landscape (due to new entrants), while at the firm-level I focus on strategic and technological drivers. Based on a qualitative longitudinal study, the chapter emphasizes the challenges firms face in establishing product and organizational architecture. In this setting, the combined impact of environmental and firm-level drivers induces a set of partially conflicting demands. Tensions between collaboration and competition in particular complicate a firm’s decision making process regarding product and organization architecture design choices.
The fourth chapter focuses on the product and industry level. At the product level, this chapter focuses on a particular type of architecture, i.e. based around a platform (Baldwin and Woodard, 2009; Gawer 2009). It focuses on the question of which factors drive value appropriation and value creation in interdependent industry ecosystems (Iansiti and Levien, 2004; Adner and Kapoor, 2010). The chapter explores this issue through a study comparing the contrasting deployment of the i-mode mobile internet service in two regions. The comparison suggests that differences in the underlying industry architectures explain why similar strategies led to such different outcomes.

1.4 Concluding remarks

Besides hierarchy and near-decomposability, another property of a complex system is that the whole can add up to more than the sum of its parts (Simon, 1962). Similarly I hope that, though the chapters can be read independently, their combined value exceeds, if only slightly, the sum of the individual parts. Overall, the thesis highlights the challenges firms face in making architectural design choices, and contingencies arising out of architectural change. More specifically, I would like to highlight the following overarching threads.

Generally, the dissertation emphasizes the interplay between environmental drivers and a firm’s architectural design choices. Chapter 3, on Symbian, shows the challenges firms face in adapting to environmental changes (focusing on changes in the competitive landscape due to new entrants), and the role of organization and product architecture herein. This chapter highlights how the firm’s decision making process in relation to product and organizational architecture is complicated by competing trade-offs between strategic and technological

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6 Simon noted that he meant this in a pragmatic way (i.e. that one cannot easily infer the behavior of the whole by looking at individual parts), as opposed to a more meta-physical interpretation (Simon, 1962: 468); however, usage of this phrase has, at times, transcended the pragmatic meaning.
considerations. In Chapter 4, the study of i-mode points out the importance of environmental factors, focusing on standardization and regulatory processes, and how these subsequently shape industry architecture. These regional differences in industry architecture are shown to affect the scope and roles of the various firms involved, providing important implications for firm strategy.

Notwithstanding the influence of the broader environment on firm behavior, the chapters also emphasize how firms also attempt to shape the environment to their advantage. As Chapter 4 suggests, when platforms are implemented successfully, firms can consolidate and strengthen their position vis-à-vis partners such as suppliers and customers. Likewise, Chapter 3 shows how organizations might attempt to shape the environment to their benefit by adjusting patterns of collaboration. This case also shows the challenges that firms might face in doing so: here the firm was initially successful in its attempt to compete with outside challengers, but was unable to adapt to changes introduced by later entrants.

In sum, the dissertation emphasizes the interplay between environmental drivers and firm-level actions. In particular, it highlights the challenges firms face in dealing with environmental changes (e.g. new entrants, regulatory changes, standards setting), how this affects architectural design choices, and the underlying motivations driving these decisions.

1.4.1 Implications for practitioners

This dissertation also points to several implications for practitioners, both for managers and public policy makers. For managers, this work emphasizes the importance of being cognizant of architectural change, and the interplay between environmental changes and architectural design choices. For example, technological breakthroughs may have important implications
for product architecture decisions. This in turn may shape the types of collaboration the focal firm might be involved in, thereby affecting the organizational architecture. Finally, at the industry architecture level, it may further impact the overall distribution of profits among industry participants. As such, in situations where industry roles are uncertain, or may be redefined, firms might actively try to shape the segment to their advantage. This might not only involve lobbying policy makers, but also establishing strategic partnerships and influencing customer perception, in an attempt to act as a strategic “bottleneck” (cf. Jacobides et al., 2006).

Likewise, public policy makers need to be aware of the impact policy and regulatory decisions might have on architectural changes, to the extent that they aren’t already. Existing research in a variety of domains have shown how regulatory actions can have an important impact in shaping the architecture of products or services (see e.g. Jacobides, 2005; 2008; Cacciatori and Jacobides, 2005; see also Chapter 4). For instance, standard setting is an arena where issues such as public welfare, industry-wide benefits, and firm-specific interests coincide. As such, this is a highly complex area where a variety of interests need to be balanced. Explicit awareness of the architectural implications of policy actions might serve as one guideline to reconcile these competing interests. Regulation is another example where actions of policy makers can have wide-ranging and long-lasting impact. Current reforms in a variety of sectors show the real interests at stake here, which policy makers and regulators need to consider carefully.7

7 One illustration of this are recent discussions on health care reform and financial regulation in the U.S., and wider debates on telecommunications network reform and “net neutrality” (the latter being a rhetorical device itself).
1.4.2 Limitations and extensions

Like all dissertations, this work too knows several important limitations, above and beyond those noted in the individual chapters. The shortcomings of this dissertation could span several pages, but let me concentrate on those I consider most important.

First, my empirical evidence presented in Chapters 3 and 4 is, as noted earlier, limited to a single sector. Therefore, it is unclear to which extent the findings apply beyond the mobile telephony industry, in particular settings where the nature of interdependencies differs significantly. For example, existing work has shown that a concept such as modularity can take on different meanings, e.g. in the computer as compared to the automotive industry (Sako, 2003; MacDuffie and Helper, 2006). One aim of the conceptual framework developed in Chapter 2 is to provide a starting point towards understanding these differences. However, exploring the implications of these differences empirically and in more detail would be a fruitful area for further research, which can build on existing work that has started to examine sectoral differences (e.g. Whitney, 1996; Sako, 2003; MacDuffie, 2006; Luo, 2010).

Second, and partly related to the first point, the empirical work is based largely on qualitative data, aimed at understanding the drivers and mechanisms operating in this setting. In future work, additional quantitative data could be gathered to test the various results derived from the qualitative studies and shed more light on the generalizability of the findings reported here.\(^8\) Recent conceptual work has also highlighted the fit between qualitative case-based research and simulation methods (Davis, Bingham and Eisenhardt, 2007). As such, the propositions derived from the conceptual framework presented in Chapter 2 might be usefully combined with methods such as agent-based modeling.

\(^8\) A useful overview of examples of methods and representations to achieve this are summarized in Baldwin and Woodard (2009).
Third, the conceptual framework in chapter 2 focuses largely on *increases* in modularity. This choice should not be taken as evidence that increases in modularity are necessarily presumed to be beneficial. An unfortunate bias in many studies on modularity is the generally positive connotation of the term, i.e. “modular” is, more often than not, implicitly equated to be inherently desirable. The tendency to combine analysis with varying degrees of advocacy is not unique to the modularity literature, but has persisted despite several influential researchers pointing to the benefits and *costs* of modularity (e.g. Baldwin and Clark, 2000; Baldwin, 2008; Brusoni, Marengo, Prencipe and Valente, 2007). There are several exceptions, in particular work on systems integration (Brusoni et al., 2001; Prencipe et al., 2003; Hobday et al., 2005) as well as individual studies that have examined the modularity concept more critically (e.g. Sako, 2003; Fixson and Park, 2008; Zirpoli and Becker, 2011).

In this dissertation, Chapter 3 also points to circumstances where decreases in modularity might be useful or necessary. As such, one should be cautious in uncritically extrapolating the evolutionary benefits of near-decomposability (as highlighted by Simon) to the specific case of modularity. Therefore, future work might provide further contingencies when systems might *decrease* in modularity.
Chapter 2

"Architectural change across levels: understanding drivers of industry modularity"

2.1. Introduction

The growing literature on modularity and architectural change is grounded in Simon’s (1962) seminal work on the architecture of complex systems. Here he argued that these systems are characterized by hierarchical organization and “near decomposability”, emphasizing the evolutionary importance of compartmentalizing interdependencies within different subsystems. Building on this, the more recent literature on modularity has made important advances, including studies on the implications of modular product architectures (Ulrich, 1995); the role of knowledge regarding organizational architecture (Henderson and Clark, 1990; Sanchez and Mahoney, 1996; Brusoni and Prencipe, 2006); and the interaction between product architecture and changing industry patterns (Langlois and Robertson, 1992; Baldwin and Clark, 2000; Schilling, 2000; Baldwin, 2008).

Simon exemplifies his argument with the story of two watchmakers, Hora and Tempus. One makes watches sequentially, but needs to start the process again for every interruption. The other uses subassemblies to organize individual parts, thereby losing only the latest subassembly when interrupted. The latter would be an illustration of a more modular design, by containing parts in different subsystems.
Research on industry architecture (Jacobides et al., 2006; Pisano and Teece, 2007) emphasizes firms’ ability to shape the architecture to their advantage, contrasting with the traditional view of taking the structure of an industry as given. Recent advances in this area notwithstanding (e.g. Brusoni et al., 2009; Ferraro and Gurses, 2009; Dietl et al., 2009), we have comparatively little insight into what drives changes in industry architecture in terms of modularity. Drawing on a variety of existing work, this chapter looks at a number of determinants of changes in industry modularity. Relatedly, existing work shows that the modularity principle can be, and has been applied to multiple levels of analysis. However, few studies have analyzed architectural change across levels in more general terms, especially in relation to understanding shifts in industry architecture. This chapter attempts to address this gap by developing a conceptual framework that encompasses architectural change at multiple levels (product, organization and industry), highlighting moderating factors that affect differences in industry modularity.

Drawing on the growing literature on modularity and architectural change, the key contributions of this chapter are as follows. First, the chapter underlines the role of product and organizational architecture in driving changes in industry modularity. The conceptual framework highlights processes at the product and organizational architecture, which serve as building blocks to understand differences in industry modularity. Drawing on processes related to increases in product and organizational modularity, the framework points to the role of dissemination to increase modularity at the industry architecture level. As such, this chapter builds on recent work that has examined modularity and architecture at different levels (e.g. Sako, 2003; Brusoni and Prencipe, 2006; Colfer and Baldwin, 2010) as well as studies analyzing changes in industry modularity (Langlois, 2002; Jacobides and Winter, 2005; Jacobides et al., 2006; Fixson and Park, 2008).
Second, the conceptual framework proposes several moderating factors that influence industry-wide diffusion. Regarding dissemination of product interfaces, these moderators are strategic factors related to standardization and capability trajectories. Concerning dissemination of organizational practices, moderating factors constitute informational mechanisms and complexity surrounding technological breakthroughs. As such, the framework presents a contingent perspective to understand differences in industry modularity. This ties into recent work that has examined how architectures at different levels are related, most explicitly in research examining “the mirroring hypothesis” (Colfer and Baldwin, 2010), and related empirical work addressing modularity at different levels (Brusoni and Prencipe, 2006). It adds to recent studies in this area (MacCormack et al., 2008; Cabigiuso and Camuffo, forthcoming) by highlighting contingencies that indicate how changes at the product and organizational architecture level relate to shifts in industry architecture.

Third, the contingent nature of the conceptual framework sheds light on recent debate in relation to the “vanishing hand” hypothesis, emphasized in particular by Langlois (2003; see also Sturgeon, 2002). Work in this area has pointed to the increasing prevalence of coordination via modular interfaces, as opposed to coordination through large organizations. The idea of the vanishing hand can be contrasted with other studies, in particular work on systems integration, which has suggested that these modular interfaces often pose an imperfect substitute for coordination. Therefore, firm coordination remains important, reflected in the role of systems integrators, whose primary purpose comprises the integration of different technological subsystems (Brusoni, Prencipe and Pavitt, 2001; 10)

10 The phrase “vanishing hand” responds to Chandler’s (1977) work on the “visible hand” and the role of large corporations vis-à-vis market-based exchanges.
Prencipe, Davies and Hobday, 2003; Hobday, Davies and Prencipe, 2005). The framework introduced in this chapter suggests why these phenomena need not be contradictory. For example, differences in degrees of product interface codification, or their dissemination across firms may explain heterogeneity of industry modularity across sectors.

This chapter is built up as follows. In the next section I examine background literature relating to the overall question of what drives changes in industry modularity, and the role of product and organizational architecture herein. I then move on to the conceptual framework, defining architecture and modularity generally, specifying how modularity might increase at different levels, and the role of industry-wide diffusion. After this, several moderating factors are highlighted that influence the dissemination process, followed by concluding remarks.

2.2. Background literature

Existing research on modularity and architectural change has often studied these concepts at multiple levels of analysis, examining e.g. the relation between products and organizations (Henderson and Clark, 1990; Sanchez and Mahoney, 1996) and how product and industry architecture interact (Baldwin and Clark, 2000; Sako, 2003; Fixson and Park, 2008). Building on emerging work that analyzes architectural change at different levels (Brusoni and Prencipe, 2006; Colfer and Baldwin, 2010), this chapter attempts to understand what drives changes in industry modularity, drawing on product and organization level dynamics.

Simon’s (1962) seminal work on the architecture of complex systems underlines the prevalence of hierarchical organization and near decomposability. In particular, he emphasizes that systems characterized by stronger interdependencies within, rather than across, subsystems appear to be more robust from an evolutionary perspective. Drawing on
this, research on modularity has used a variety of typologies to highlight different facets of modular systems. For example, in their influential work on design evolution and industry change, Baldwin and Clark (2000: 78) distinguish between modularity-in-use, modularity-in-production, and modularity-in-design, focusing on the latter and its associated task structures. Modularity-in-production allows firms to divide production into process modules, which may induce outsourcing. Modularity-in-use lets users and manufacturers mix and match independent modules into an overall system. Similarly, Takeishi and Fujimoto (2003: 254) distinguish modularization in product architecture, -production, and -interfirm system. Based on this typology, they refer to modularity in the automobile industry as “closed modularization”, which can be distinguished from “open modularity” observed in e.g. the personal computer industry. This distinction between open and closed organization is similar to work by Farrell, Hunter and Saloner (1998: 144) who use the terms components and systems organization.

Further conceptualizations of modularity include Langlois’ (2002) study of a modularity-based theory of the firm. Contrasting market-based from firm-based organizations, here he provides an illustration of how in the 1970s and 1980s vertically integrated firms produced personal computers in a non-modular (or internally modular) fashion. This can be constrained with the subsequent industry trajectory, characterized by external modularity. Similarly, Chesbrough (2003) distinguishes between internal modularity and market modularity. The former refers to modularity within the firm, whereas the latter refers to modularity at the industry level. He proposes that technological advance is marked by cycles of interdependence and modularity, which correspond with firm and market-based organizational form respectively.
### Table 2.1: Existing research: conceptualizing modularity at different levels of analysis

<table>
<thead>
<tr>
<th>Concept</th>
<th>Description</th>
<th>Applicable level(s) of analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modularity in design (Baldwin &amp; Clark, 2000)</td>
<td>Achieved by partitioning product design into visible and hidden information, and establishing design rules that determine how different modules work together</td>
<td>X</td>
</tr>
<tr>
<td>Internal modularity (Langlois, 2002; Chesbrough, 2003)</td>
<td>Refers to specification of interfaces that are limited to the organization, precluding supply via market transactions</td>
<td>X</td>
</tr>
<tr>
<td>Modularity in production (Baldwin &amp; Clark, 2000)</td>
<td>Achieved by simplifying production process by distinguishing organizational process modules and specifying their design ahead of production</td>
<td>X</td>
</tr>
<tr>
<td>Modularization of inter-firm systems (Takeishi &amp; Fujimoto, 2003)</td>
<td>Refers to inter-firm division of labor in development and production, and degree to which outside suppliers conduct and deliver subassemblies</td>
<td>X</td>
</tr>
<tr>
<td>Modularity in use (Baldwin &amp; Clark, 2000)</td>
<td>Allows users to mix and match modules from different firms, spurring innovation among firms who focus on specific modules</td>
<td>X</td>
</tr>
<tr>
<td>External modularity (Langlois, 2002); Market modularity (Chesbrough, 2003)</td>
<td>Refers to publicly disclosed product interfaces, allowing industry-wide supplier interaction via market transactions</td>
<td>X</td>
</tr>
</tbody>
</table>

As illustrated in Table 2.1, current work shows how existing conceptualizations of modularity can be applied to different levels of analysis. Further, existing studies display overlaps in conceptualizing modularity, different terms notwithstanding. For example, Takeishi and Fujimoto’s (2003) notion of closed and open modularity appears to be similar to what Langlois (2002) refers to as non-modular (or internally modular) vs. externally modular, and what Chesbrough distinguishes as internal vs. market modularity. However, these studies generally do not address what drives changes within or across these dimensions. The conceptual framework developed in this chapter distinguishes between architectural change at the product, organization, and industry level, which partially correspond to typologies
introduced by Baldwin and Clark (2000) and Takeishi and Fujimoto (2003). I expect that formulating a framework that more explicitly distinguishes between multiple levels can help better understand the processes underlying architectural change. Most importantly, I use the framework to highlight the role of changes in product and organization architecture and moderating factors that drive differences in industry modularity.

The framework builds on several recent studies that has focused on architectural change at or across different levels of analysis. In particular, recent work on the notion of the “mirroring hypothesis” (Colfer and Baldwin, 2010) examines existing work to understand when product and organizational architecture mirror each other. Woodard and West (2009) provide a framework to understand dualities between components and interfaces in the product and organizational domains. Further, Padgett's (2001) notion of “cross-domain rewirings” provides another important conceptual precursor of how different levels might interact. His study on the transformation of banking in Renaissance Florence, as well as related work by Padgett and Powell (2003), highlights the role of various network ties (e.g. relational or transactional) and their role across different types of domains (economic, family or political) in changing regimes. Adopting the conceptual apparatus of Padgett and Powell (2003), a study by Brusoni and Prencipe (2006) analyzes how different domains affect each other, focusing on changes in design rules. Their study, based on an in-depth examination of a firm’s tire design and manufacturing process, highlights the key role of knowledge, and how it mediates between the product-level (referred to as the technology domain) and the organizational level.

11 The point of specifying these particular levels is not that other levels of analysis (e.g. communities, institutions, geographic regions) are unimportant. For example, other researchers have specified modularity at a finer-grained level of analysis (e.g. modularity in intellectual property, cf. Henkel and Baldwin, 2009). Rather, I have chosen these particular levels as they appear most prevalent in current research.
Besides the role of knowledge, other authors have highlighted other contingencies. The notion that technology, among other factors, influences an organization’s architecture can be traced back to the contingency literature (Woodward, 1958; Lawrence and Lorsch, 1967; Burns and Stalker, 1961; Thompson, 1967). This line of work, responding to earlier research that presumed a singular optimal way of organizing, instead suggests that these depend on a variety of factors. While not drawing directly on contingency literature, several authors on modularity have similarly highlighted the importance of understanding contingencies that drive variation in organizational modularity. For example, Chesbrough and Kusunoki (2001)'s model of changes in modularity suggests the importance of achieving fit between the organizational configuration and the state of technological development, arguing that this fit will shift over time.

Finally, a number of studies have examined changes in industry modularity and their underlying drivers. Several authors have highlighted the interplay between transaction costs and capabilities as drivers of industry change (Jacobides and Winter, 2005; Langlois, 2006). Wolter and Veloso (2008) build on Henderson and Clark’s (1990) innovation typology to understand changes in industry structure. Baldwin (2008) synthesizes the literature on transaction costs, knowledge-based theories of the firm and modularity to understand the location of transactions. The study suggests that transactions will occur in locations characterized by “thin crossing points” (i.e. where interdependencies between modules are low), emphasizing the role of knowledge, strategies and technology in driving the modularization process.

Overall, existing research on modularity and architectural change shows that these concepts can be, and have been, applied at different levels of analysis. Drawing on existing typologies
of modularity, the product, organization, and industry levels appear to be most salient in existing work. However, few studies have addressed how changes across levels are related, in particular in relation to changes in industry modularity. Building on recent studies that have examined changes in industry modularity, I develop a conceptual framework that attempts to analyze what drives differences in industry modularity. To do so, I first describe processes underlying changes in modularity at the product and organizational level. Drawing on these processes, I then highlight several moderating factors that drive changes in industry modularity.

2.3. Conceptual framework

In this section I develop a conceptual framework to understand architectural change at different levels, in particular to understand differences in industry modularity. Due to variety in definitions of modularity and architecture, I will define relevant constructs upfront. First, architecture (or “systems architecture”) here refers to “an abstract description of the entities of a system and the relationships between those entities” (Whitney et al., 2004). Second, modularity is defined as a design principle that advocates designing structures based on minimizing interdependence between subsystems and maximizing interdependence within subsystems (Ethiraj and Levinthal, 2004). Drawing on existing work, I suggest that, at each level, knowledge about interdependencies is crucial to increase modularity. For product architecture I adopt Ulrich’s (1995) definition, i.e. “the scheme by which the function of a product is allocated to physical components”. Modularity of product architectures can increase as knowledge about interdependencies between functions and components accumulates. Organizational architecture is defined as “the scheme by which tasks are allocated to organizational units (…)” (Sako 2003: 235). Organizational modularity can increase as knowledge about interdependencies between tasks and organizational units
accumulates. *Industry architecture* has been defined as “templates that emerge in a sector and circumscribe the division of labor among a set of co-specialized firms” (Jacobides et al., 2006: 1201). This might be rephrased as “the scheme by which labor (i.e. bundles of tasks) is divided among industry participants (i.e. firms and other organizations).” Industry modularity can increase as knowledge about interdependencies between labor and industry participants accumulates. An overview of these concepts is given in Table 2.2.

### Table 2.2: Existing research: key concepts and definitions

<table>
<thead>
<tr>
<th>Concept</th>
<th>Description</th>
<th>Key references</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture</td>
<td>“An abstract description of the entities of a system and the relationships between those entities”</td>
<td>Simon, 1962; Whitney et al., 2004</td>
</tr>
<tr>
<td>Modularity</td>
<td>“A design principle that advocates designing structures based on minimizing interdependence between subsystems and maximizing interdependence within subsystems”</td>
<td>Baldwin &amp; Clark, 2000; Ethiraj &amp; Levinthal, 2004</td>
</tr>
<tr>
<td>Product architecture</td>
<td>“The scheme by which the function of a product is allocated to physical components”</td>
<td>Ulrich, 1995</td>
</tr>
<tr>
<td>Organization architecture</td>
<td>“The scheme by which tasks are allocated to organizational units”</td>
<td>Sako, 2003</td>
</tr>
<tr>
<td>Industry architecture</td>
<td>“The scheme by which labor (i.e. bundles of tasks) is divided among industry participants (firms and other organizations)”</td>
<td>Jacobides et al., 2006</td>
</tr>
</tbody>
</table>

### 2.3.1 Product architecture: increasing modularity through interface codification

This section shows how modularity of product architectures increases as knowledge about interdependencies between functions and components accumulates. I suggest that, at this level, a key mechanism towards increasing modularity is codification. Here, codification refers to the degree to which knowledge about function-to-component interdependencies (hereafter shortened to “functional interdependencies”) becomes stabilized in standardized interfaces. These interfaces can be defined when knowledge about relationships between functions and components increases. I distinguish three steps in this codification process:
functional partitioning, articulation of functional interdependencies, and interface standardization. Figure 2.1 provides a visual illustration of this process.\textsuperscript{12}

\begin{figure}
\centering
\begin{tikzpicture}
\node[draw,rectangle] (1) {Partitioning of functional interdependencies};
\node[draw,rectangle, right of=1] (2) {Articulation of functional interdependencies};
\node[draw,rectangle, right of=2] (3) {Codification into standardized interfaces};
\draw [->] (1) -- (2);
\draw [->] (2) -- (3);
\end{tikzpicture}
\end{figure}

**Figure 2.1:** CODIFICATION OF STANDARDIZED INTERFACES INCREASES PRODUCT MODULARITY

1A: **Partitioning of functional interdependencies**

The first step towards codifying functional interdependencies involves decomposition. Complex products are, by definition, characterized by various types of interdependencies (Thompson, 1967). One way to manage this complexity is decomposition (Simon, 1962), which involves specifying sub-functions, also referred to as task partitioning (Von Hippel, 1990). A key motivation in doing so is that partitioning can reduce the cognitive complexity associated with understanding the various functional interdependencies (Ulrich, 1995). Also, Simon (1962) has argued that systems, which are typically \textit{nearly-decomposable} as opposed to \textit{fully} decomposable, are more evolutionary robust when they are decomposed into subsystems.

Following our generic definition of modularity, the aim in this partitioning stage is to maximize functional interdependencies within subsystems, whilst minimizing interdependence between subsystems. Successful partitioning can usually be characterized as

\textsuperscript{12} In practice these stages will, of course, partly overlap. The feedback arrows in figures 2.1 and 2.2 highlight the iterative nature of this process.
a trial-and-error process (Nonaka, 1994), as initial ideas about how functions and components interact might be partially or wholly inaccurate (Bucciarelli, 1994). However, over time, the team or individual will typically develop a greater understanding of an appropriate partitioning.\textsuperscript{13} Also, due to heterogeneity in team size, competencies and so forth, functional partitioning may well vary depending on firm, even for the same product type. This will be reflected in differences in the way interdependencies between functions and components are specified, resulting in differences regarding performance, price and so forth.

\textit{IB: Articulation of functional interdependencies}

The next phase constitutes knowledge articulation. Accumulating knowledge of the relevant functional interdependencies involves articulation, as previously argued in the context of organizational learning. It is important to explicitly distinguish articulation before codification, since the latter cannot occur without the former (Kogut and Zander, 1992; Nonaka, 1994; Zollo and Winter, 2002).

Articulation involves specifying more explicitly how functional interdependencies play out, as opposed to tacit beliefs internal to the individual (or even internal to an organization, in the case of organizational norms or values). It is therefore likely that feedback loops will occur between articulation and decomposition. As knowledge about the relevant functional interdependencies accumulates, partitioning will be adjusted accordingly, which in turn may further affect the stock of knowledge of functional interdependencies. In the context of modular systems development, Chuma (2006) has referred to this process of knowledge accumulation as “interim modularity”. Here it is suggested that, in the case of product

\textsuperscript{13} We cannot assume a priori that partitioning will take place in the form of a project. However, in many firms, and certainly in most technologically complex systems, projects are the main way in which work is organized. See Prencipe and Tell (2001) on knowledge replication in projects; for analysis on project-based organizations in the context of capital-intensive complex systems (see Davies, 1997; Hobday, 1998, 2000; Gann and Salter, 2000; Brady and Davies, 2004; Davies and Hobday, 2005; Davies, Gann and Douglas, 2009).
innovations, knowledge about the relevant interdependencies can never be fully specified ex ante. Rather, they only become clear during the development of the innovation itself. Following existing work on the knowledge articulation process (Hakanson 2007), we can expect that the amount of knowledge about functional interdependencies an organization or individual possesses will be greater than the amount of knowledge that becomes codified. In other words, the tacit component surrounding certain functional interdependencies limit the degree to which these can be codified, elaborated on next.

**IC: Codification into standardized interfaces**

The final step towards increasing product architecture modularity constitutes standardization. In this context standardization focuses on codifying knowledge about functional interdependencies in standardized interfaces. A wide range of studies have emphasized the importance of standardized interfaces in enhancing product modularity (e.g. Langlois and Robertson, 1992; Ulrich, 1995; Chesbrough and Kusunoki, 1999; Baldwin and Clark, 2000; Schilling, 2000; Sturgeon, 2002; Chesbrough, 2003; Chesbrough and Prencipe, 2008). Generally, interfaces specify how subsystems “fit together, connect, and communicate” (Baldwin and Clark, 2000). In fact, it probably not much of an exaggeration to state that the importance of standardized interfaces provides one of the key axioms of the modularity literature. However, less emphasis has been given to the process of how these standardized interfaces might emerge. This framework suggests that codification plays a key role here.

In this context, codification involves the explication of knowledge about functional interdependencies that was previously tacit, i.e. embodied in the minds of the people involved
in understanding the various interdependencies. There are multiple ways in which knowledge can be codified. In the case of knowledge about functional interdependencies, it might take the form of e.g. manuals, databases, software, intellectual property (e.g. patents), knowledge management systems, and other repositories. Once knowledge about functional interdependencies has been codified, tools such as a Design Structure Matrix (DSM, see Eppinger, 1991; Baldwin and Clark, 2000; MacCormack, Rusnak and Baldwin, 2008) may be used to plot the various interdependencies.

Some authors have suggested that advances in information technology (IT) have eased the ability to codify knowledge (Arora and Gambardella, 1994) and may facilitate inter-firm exchanges (Chesbrough and Teece, 1996). At the same time, there may be ‘natural’ limits to the extent that relevant knowledge of interdependencies can be successfully codified. These might be related to the intrinsic nature of the system, such as the physical mechanics underlying the functional interdependencies, e.g. in the case of the automobile (Whitney, 1996; Sako, 2003; Gereffi, Humphrey and Sturgeon, 2005; MacDuffie, 2006; Luo, 2010). There might also be broader factors that limit codification. For example, in Dunbar, Garud and Kotha’s (1995) study on Steinway pianos, customer expectations regarding product “performance” (e.g. warmth of the sound, physical touch of the keys) set limits on the extent to which relevant interdependencies can be fully codified. In this case, a more modular design could likely be created but would lead to unacceptable performance limitations.

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14 For a broader discussion on the distinction between tacit and explicit knowledge, see Polayni (1966) and Winter (1987); further analysis on knowledge codification can be found in Prencipe and Tell (2001) and Zollo and Winter (2002).
2.3.2 Organizational architecture: increasing modularity through stabilization of organizational practices

This section discusses how organizational architectures become more modular. As specified earlier, modularity at this level focuses on knowledge of interdependencies between tasks and organizational units (i.e. task interdependencies). Here, this process consists of organizational partitioning (or divisionalization); build-up of systemic knowledge; and emergence of stabilized organizational practices. Overall, this process is referred to as “task stabilization”, which I argue is a key mechanism in increasing modularity at the organizational level. This process is visually illustrated in figure 2.2.

![Figure 2.2: task stabilization increases organizational modularity](image)

Figure 2.2: task stabilization increases organizational modularity

**2A: Organizational partitioning (e.g. divisionalization)**

In this context, organizational subsystems refer to teams, departments and other organizational units (Sako 2003). Here, the aim is to maximize task interdependencies within organizational units, and (where possible) minimize task interdependencies between units. The organization design literature has outlined various formal organizational structures to achieve this, including well known examples such as the multidivisional form (or M-form,

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15 In the case of inter-firm organizations (such as an alliance or joint venture), the units can also refer to entire firms (Schilling and Steensma, 2001).
cf. Chandler, 1962, 1977). Linking mechanisms include instruments such as matrix reporting and cross-unit liaisons (Nadler and Tushman, 1996).\textsuperscript{16} In organizational theory, finding a balance between independence and interdependence has been discussed in terms of different degrees of “coupling” (Weick, 1976; Orton and Weick, 1990). One way organizations might achieve effective coupling is to group units based on functional similarity. However, despite these advances, how exactly to divisionalize remains a complex process, as emphasized by e.g. Ethiraj and Levinthal (2004) and Jacobides (2006, 2007).\textsuperscript{17} Furthermore, similar to the product architecture level, there is no reason to expect equifinality in terms of decomposition. In fact, while technological and scientific boundaries enforce a degree of homogeneity at the product level, at the organizational these ‘natural’ limitations do not apply. Though institutional isomorphism (DiMaggio and Powell, 1983) might impose some limitations on decompositional variety, organization design is a design problem exactly because organizations have many degrees of freedom in setting up different organizational structures. Recent work on “landscape design” (Levinthal and Warglien, 1999) underpins this view, suggesting that task interdependencies are not just “discovered”, but that organizations can actively manipulate them.

Various studies have emphasized the importance of distinguishing between the formal and informal organization structure (e.g. Gulati and Puranam, 2009). In this context, we are agnostic as to whether it is the formal or informal organization design that best captures the actual organization, assuming that it will often be a combination of the two that determines the actual flows of information. What is more relevant in this context is that organizations (at

\textsuperscript{16} At the product level I noted that even though most complex systems will be developed by teams, there are also instances where complex systems are developed by individuals. Organizational partitioning of course only makes sense when the organization outnumbers a single individual.

\textsuperscript{17} Witness e.g. Jacobides’ (2007) intriguing study of the damaging consequences of how excessive divisionalization might drive behaviour that is understandable at the unit level, but highly undesirable at the aggregate level. See Knudsen and Levinthal (2007) for a discussion on the broader challenges of evaluating organizational alternatives.
least the formal structure) will periodically be redesigned, perhaps due to increasing insight into a more appropriate organizational partitioning.

2B: Accumulation of systemic knowledge

As organizations gain experience in decomposition, they build their stock of systemic knowledge i.e. “the underlying patterns of interdependence between tasks” (Puranam and Jacobides, 2006; see also Sako, 2003; Brusoni and Prencipe, 2001, 2006). Systemic knowledge allows the organization to divide tasks based on standardized procedures, as opposed to having to rely on rich, ongoing coordination, e.g. via continuous communication. Creating systemic knowledge may require an initial stage of rich communication (Puranam and Jacobides, 2006), also referred to as integrated problem solving (Von Hippel, 1998) or technical dialog (Monteverde, 1995).

Complementing the notion of systemic knowledge is the concept of common ground, defined as “the sum of their mutual, common or joint knowledge, beliefs and suppositions” (Clark, 1996). Common ground can be regarded as both a by-product of accumulating systemic knowledge and a pre-requisite for coordination. In particular, several studies by Srikanth and Puranam (2008, 2010, 2011) have shown the importance of establishing and maintaining common ground when organizational units rely on standardized practices. In their work on software services offshoring, they demonstrate that various ICT based tools can help to establish and maintain such common ground. Based on an extensive and insightful literature review, Colfer and Baldwin’s (2010) notion of “actionable transparency” also emphasizes the importance of such tools to facilitate coordination across organizational boundaries.
It is likely that there will be feedback loops between the organizational partitioning stage and build-up of systemic knowledge. As organizations learn, through trial and error, about which divisionalization works best (Ethiraj and Levinthal, 2004), their stock of systemic knowledge accumulates and certain practices stabilize (Fujimoto, 2007). This in turn will affect organizational divisionalization, which influences accumulation of systemic knowledge.

2C: Emergence of stabilized organizational practices

The final step towards increasing organizational modularity involves standardization. In this context standardization refers to the establishment of stabilized operating procedures (March and Simon, 1958; Cyert and March 1963), or standardized practices. In this context, these practices can be regarded as codified procedural knowledge (Argyris 1991). Various studies have argued that organizations become more modular when they interact based on simple, standardized exchanges (Schilling and Steensma, 2001; Galunic and Eisenhardt, 2001). In these situations, organizational units are specialized and operate with a narrow focus (Ulrich 1995). To achieve this, organizations need to formulate standard operating procedures, which might be articulated in design rules, plans or schedules which specify what each unit has to do to achieve coordination, as argued in the classic organization design literature (Tushman and Nadler, 1978; Galbraith, 1977). These standardized practices act as the organizational equivalent of interfaces (Woodard and West, 2009). Importantly, once these are formulated, they minimize the need for ongoing communication, as well as the amount of knowledge that needs to be shared among organizational units. However, organizations need not only select a particular operating procedure, they also need to maintain and enforce them, as otherwise the interface might be compromised (Srikanth and Puranam, 2010).

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18 Therefore, in this paper, these practices refers to a specific subset of organizational routines, as coined by Nelson and Winter (1982); for a review on organizational routines in the general sense, see Becker (2004).
An important consequence of this non-technical standardization\textsuperscript{19} is that it regularizes expectations among organizational actors (Langlois and Savage 2000). This notion of task stabilization is similar to the analysis of Padgett and Powell (2003), in their study of Renaissance Florence, of how socially standardized models or protocols induce reproduction across levels. A further effect is that it allows a coherent division of labor to be established (Narduzzo, Rocco and Warglien, 2000). It is likely that only a subset of knowledge on task interdependencies becomes standardized, given e.g. complexity or degree of unpredictability of tasks, or the costs associated with effective standardization (Hakanson, 2007).

\textbf{2.3.3 Industry architecture: increasing modularity via dissemination}

The previous section discussed how product and organizational architecture increase in modularity, focusing respectively on codification of product interfaces, and stabilization of organizational practices. However, while these processes are necessary for increasing modularity at the industry level, they are not sufficient. The final level I distinguish is the industry architecture (see Jacobides et al., 2006; Pisano and Teece, 2007; Dietl et al., 2009; Brusoni, Jacobides and Prencipe, 2009). At this level, modularity increases when knowledge about interdependencies between labor (i.e. bundles of tasks) and industry participants (i.e. firms and other organizations) accumulates. I suggest a key mechanism for increasing industry modularity is \textit{dissemination} of intra-firm product interfaces and organizational practices. An important question then, is which factors influence this dissemination process?

Drawing on existing work, I highlight the following moderating factors: 1) strategic considerations; 2) capability trajectories and firm specialization; 3) informational mechanisms and convergence of cognitive frames; and 4) technological breakthroughs, complexity and interaction of organizational practices. Below I discuss these moderating

\textsuperscript{19} As opposed to technical interface standards (David, 1987; Shapiro and Varian, 1998), further discussed below.
factors in more detail, and formulate several propositions. Table 2.3 summarizes the
moderating factors and their effect on industry modularity.

**Table 2.3: Conceptual framework: moderating variables and effect on industry modularity**

<table>
<thead>
<tr>
<th>Moderator factor</th>
<th>Underlying process</th>
<th>Effect on industry modularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissemination of product interfaces</td>
<td>Strategic factors (in particular value and control of subsystems) moderate standardization of product interfaces, either promoting or inhibiting dissemination across firms</td>
<td>Product interfaces may or may not disseminate, either increasing or decreasing industry modularity (net effect unclear)</td>
</tr>
<tr>
<td>1: Strategic considerations concerning standardization</td>
<td>If capability trajectories induce firm specialization, demand for standardized product interfaces across firms increases</td>
<td>Product interfaces disseminate beyond focal organization, increasing industry modularity</td>
</tr>
<tr>
<td>Dissemination of organizational practices</td>
<td>Informational mechanisms (e.g. shared board memberships, industry consortiums) and convergence of cognitive frames promote dissemination of standardized organizational practices across firms over time</td>
<td>Organizational practices disseminate across firms, increasing industry modularity</td>
</tr>
<tr>
<td>3: Informational mechanisms and convergence of cognitive frames</td>
<td>Technological breakthroughs, and complexity and interaction among procedures, inhibit diffusion of organizational practices across firms</td>
<td>Dissemination of organizational practices to other firms is limited, inhibiting industry modularity</td>
</tr>
</tbody>
</table>

**Moderator 1: Strategic factors concerning standardization**

The first moderating factor constitutes strategic aspects of standardization, in particular the trade-off between value capture and control. As highlighted by e.g. Langlois and Robertson (1992), Macher and Mowery (2004) and Jacobides et al. (2006), standards can have important implications for the way industry-wide value is appropriated among individual firms. Also, Schilling and Steensma’s (2001) analysis suggests that when industry standards are present (combined with high heterogeneity of inputs and demands) industry modularity increases. An important question therefore is what drives the dissemination of these standards. A variety of literatures has looked at the process of standards establishment and dissemination (e.g. David, 1987; Shapiro and Varian, 1998). The type of standard most relevant here are “technical interface standards”, i.e. the collection of explicit rules that permit components and
subsystems to be assembled in larger systems (Greenstein and David 1990). Furthermore, there are a number of varieties of interface standard setting. A key distinction involves standards created by publicly controlled standards organizations (de jure standards) or market based standards (de facto standards) (Funk and Methe, 2001; Steinmueller, 2003).

While in some contexts the extra-organizational standardization of product interfaces is relatively straightforward (as in Argyres’ (1999) study of standardizing interfaces in a public defence sector project), more frequently this process can be highly strategic, as shown in several in-depth studies (Gawer and Cusumano, 2002; Gawer and Henderson, 2007; Ballon, 2009). Generally, firms resist adoption of industry standards to maintain control over their current suppliers. For example, in the automobile industry, interface standards for electronic data interchange have purposefully been made specific to assemblers, so that firms retain control over this process (Markus et al., 2006). Likewise Sako’s (2003) analysis of the automobile industry highlights how, for strategic reasons (e.g. when the subsystem is considered to be differentiating, and therefore of high value to the firm) interfaces remain proprietary to the manufacturer. Further, interface standards might also be kept proprietary, or remain less codified to prevent imitation (Langlois, 2002). On the other hand, standards may be used by firms to shape the industry architecture to their advantage. In particular, firms may attempt to control key parts of the value chain (i.e. a “bottleneck”), to enhance value appropriation (Jacobides et al., 2006; Baldwin, 2010). Similarly, Gawer and Cusumano (2002, 2008) have observed this dynamic in the behavior of platform leaders, i.e. firms that successfully control industry platforms. These firms benefit from inducing competition in

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20 Other types of standards, as noted by Steinmueller (2003: 134) include reference standards (e.g. the definition of a unit of electrical resistance) and quality standards (related to e.g. health or safety).

21 This chapter focuses on de facto standards, since “diffusion” beyond the focal organization of de jure standards does not apply in this context. De facto standards may emerge through processes of market leadership, design and problem solving within organizations, or between organizations that lead to ‘privately held’ technical compatibility standards (Steinmueller, 2003).
complementor markets. Dissemination of interface standards may also be involuntary, exemplified in IBM’s development of the personal computer.\footnote{IBM’s decision to use standards from external suppliers for several key subsystems (particularly the operating system and microprocessor, sourced from Microsoft and Intel respectively), had long term implications on the subsequent trajectory of the PC industry. Whilst IBM thought it was able to maintain control over these subsystems via its proprietary BIOS, reverse engineering of this technology by new entrants, loosened IBM’s control of the technology and diminished its ability to capture value (Baldwin and Woodard 2009).}

In sum, when deciding whether to disseminate interface standards beyond the focal organization, firms generally trade-off their ability to capture value with control considerations. This trade-off (which, as the IBM case illustrates, may be based on incomplete or inaccurate perceptions) leads to increases in dissemination of interface standards when the benefits of dissemination are higher than the benefits of maintaining proprietary control. Further, systems might also revert back to private (i.e. proprietary) interfaces, as a result of performance considerations or strategic factors (Fixson and Park, 2008). More generally, strategic considerations may influence whether or not interfaces will be shared with other firms, or where exactly the boundaries will be set (Sako, 2003; Zirpoli and Camuffo, 2009). Overall, these findings lead to the following proposition:

**Proposition 1**: Firms will promote dissemination of product interface standards when perceived value capture benefits exceed proprietary control considerations, increasing industry modularity.

**Moderator 2: Capability trajectories and firm specialization**

The modularity literature has used various ways to conceptualize the distinction between intra and inter-firm product interfaces; they include internal as opposed to external standardization (Ulrich, 1995), internal vs. external modularity (Langlois, 2002), and open vs. closed architecture (Fujimoto, 2007). However, as mentioned earlier, existing conceptual studies
have generally paid little attention to the mechanisms by which firm-specific interfaces exceed the firm boundary. By contrast, several empirical studies have focused on the mechanisms that influence the transition from intra- to inter-firm product interfaces.

In particular, Jacobides (2005) argues that motivating factors to standardize information across firm boundaries include gains from trade, based on an in-depth study on changes in mortgage banking. A result of this standardization is that the transactions become “simple, transmissible, universally understood”, allowing transactions with other firms (Jacobides, 2005; see also Baldwin 2008). Other studies have looked at a variety of domains (e.g. the bicycle and electronics industries) and argue that gains from specialization, in particular to enhance capability development, constitute an important factor (Sturgeon, 2002; Gereffi et al., 2005; Jacobides and Winter, 2005). Langlois and Robertson (1992) further highlight supply and demand-side benefits of a modular production system. Focusing on the stereo systems and micro computer industries, they identify dissimilarity in firm capabilities along stages of production as a driver towards more modular industry architectures. Finally, Sako (2003) also emphasizes how an industry’s existing distribution of capabilities affects if and how product interfaces cross firm boundaries. Overall, these findings suggest the following proposition:

Proposition 2: When capability trajectories induce firms to specialize, dissemination of standardized product interfaces is promoted, increasing industry modularity.

Increasing industry modularity via dissemination of organizational practices
This section focuses on how organizational practices might disseminate beyond the focal firm, thereby increasing modularity at the industry level. Standardized product interfaces are
of limited use when organizations do not have suitable partners to transact with. For example, Chesbrough (2003) has emphasized the importance of being able to rely on a credible supplier base. This is further emphasized in a study by Jacobides (2008), who highlights the importance of “institutional modularity”. His study demonstrates the importance of differences or similarities in the way activities are partitioned along the value chain. Differences between countries are particularly relevant for firms embarking on international expansion. Below I highlight moderating factors that influence the dissemination process from intra-firm to inter-firm practices. Here I will focus on informational mechanisms and convergence of cognitive frames, and complexity surrounding technological breakthroughs.

**Moderator 3: Informational mechanisms and convergence of cognitive frames**

The third moderating factor concerns informational mechanisms that spread organizational practices, which may be reinforced by convergence of cognitive frames. The notion of common ground discussed earlier plays an important role here too. Several studies have underlined the importance of repeated interactions to develop common ground, which might subsequently be codified in organizational systems based on a shared ‘grammar’ (Argyres, 1999) or contracts (Mayer and Argyres, 2004). This accumulated knowledge allows organizations to codify roles and responsibilities in more detail (Argyres, Bercovitz and Mayer, 2007). More generally, stabilized practices can be considered as a kind of “public routine”, which helps organizations coordinate among what previously constituted “private” practices, as Langlois and Savage (2000) demonstrate in an in-depth study of standardization in the field of medical practice. Dissemination of practices may also be promoted by industry associations and other inter-firm consortia (Zenger and Hesterly, 1997). Information about successful practices may also spread through consulting firms, industry associations, and other informational mechanisms, such as employee mobility and shared board memberships.
(Shanley and Peteraf, 2004). Institutional isomorphism, the pressure for organizations facing similar environments to adopt similar practices (DiMaggio and Powell, 1983), may also promote dissemination of organizational practices.

Relatedly work on organizational learning has highlighted how cognitive frames shape organizational practices (Gavetti and Tripsas, 2000; Benner and Tripsas, 2011). Actors, both individually and collectively, are assumed to be boundedly rational (Simon, 1991), hence do not have complete knowledge of the optimal organizational decomposition. Still, through trial and error, knowledge of appropriate practices increases, and over time cognitive frames stabilize, leading to convergence in terms of organizational practices. Problem solving can be conceptualized as a search for (near) optimal solutions (Levinthal, 1997). This search process often involves cognitive reframing, in order to arrive at more powerful representations of both the problem and associated solution (Dosi, Hobday and Marengo, 2003; Gavetti and Levinthal, 2000). A key role of management is to articulate and promote these cognitive frames across the organization (Marengo, 1996; Dosi et al., 2003). Further, conceptual work on technological change proposes that cognitive frames tend to converge over time, thereby disseminating across different organizations (Kaplan and Tripsas, 2008). These findings lead to the following propositions:

**Proposition 3:**

3a) Informational mechanisms promote dissemination of organizational practices, increasing industry modularity over time.

3b) When technology stabilizes cognitive frames converge, promoting dissemination of standardized practices, thereby increasing industry modularity.
Moderator 4: Technological breakthroughs, complexity and interaction of organizational practices

The fourth moderating factor that influences industry-wide dissemination of stabilized practices relate to technological breakthroughs, and its effect on the complexity and interaction of practices. In line with the literature on organizational routines (Simon and March, 1958; Cyert and March, 1963; Nelson and Winter 1982; Dosi et al., 2003) firms and other organizations can be conceptualized as a collection, or bundle, of practices. Building on this stream of work, the literature on dynamic capabilities (Teece et al. 1997; Eisenhardt and Martin, 2000; Helfat and Peteraf, 2003) suggests that a firm’s competitive advantage may partly be driven by its ability to change its capabilities in turbulent environments.

One feature of turbulent environments are technological breakthroughs, driven by new combinations of knowledge (Galunic and Rodan, 1998). Initially, organizational practices will be limited and idiosyncratic to individual firms. However, once the technology life cycle (Anderson and Tushman, 1990) reaches a more stable phase, knowledge of organizational practices may spread to other firms. If gains from trade are present, the value of specialization increases, promoting dissemination of modular practices (Christensen et al., 2002; Chesbrough, 2003; Jacobides, 2005). However, successful execution of practices may depend on a high degree tacit knowledge, which by definition does not disseminate easily. Further, certain practices may only work in combination (Murmann et al., 2003; Marengo and Dosi, 2005). As such, the complexity of a combination of practices (or specific interactions between them) may hamper successful dissemination (Rivkin, 2000).

Finally, gains from transacting with extra-organizational divisions constitute another factor prompting dissemination of practices outside of firm boundaries. Jacobides (2005), in his study of mortgage banking, illustrates how practices that organizational units initially applied
to other divisions subsequently were used to deal with organizations outside the firm boundary. Likewise, MacDuffie (2006) has highlighted the difficulty to contain transactions within a single organization once the practices have become more modular inside an organization. Overall, these findings suggest the following propositions:

**Proposition 4:**

4a) Technological breakthroughs characterized by high complexity or interactions hamper dissemination of standardized practices, inhibiting industry modularity.

4b) When technological breakthroughs stabilize, gains from trade promote dissemination of standardized practices, increasing industry modularity.

**4. Concluding remarks**

This chapter has developed a conceptual framework to understand architectural change at different levels, focusing in particular on moderating factors driving changes in industry modularity. To do so, I first outlined how modularity increases at the product and organizational level, focusing on codification of standardized interfaces and stabilization of organizational practices. I then argued that industry modularity increases when product interfaces and organizational practices disseminate beyond the focal organization. Next, I highlighted several moderating factors that influence this dissemination process. At the product level I focused, first, on strategic considerations regarding standardization, and second on capability trajectories and firm specialization. At the organizational level I highlighted informational mechanisms and convergence of cognitive frames, and the role of technological breakthroughs and its influence on the complexity and interaction of organizational practices. The overall framework is visualized in Figure 2.3.
Intra-firm product interfaces

Main mechanism increasing product modularity: codification of product interfaces

Organization architecture level

Main mechanism increasing organizational modularity: stabilization of organizational practices

Moderator 1 (+/-)
strategic considerations (value and control) for standardization

Moderator 2 (+)
Capability trajectories and firm specialization

Moderator 3 (+)
Informational mechanisms and convergence of cognitive frames

Moderator 4 (-)
Complexity of technological breakthroughs

Inter-firm product interfaces

Industry architecture level

Main mechanism for increasing industry modularity: dissemination of codified product interfaces and standardized practices

Figure 2.3: Overall conceptual framework

Overall, the key contributions of this chapter can be summarized as follows. First, the framework highlights processes at the product and organizational architecture level, which serve as building blocks to understand changes in industry architecture. Second, the conceptual framework suggests how industry architectures become more modular through dissemination of interfaces and practices, and proposes several moderating factors that influence this diffusion process. Third, the contingent perspective developed in the framework may reconcile diverging perspectives on the role of modularity and inter-firm coordination. As such, the chapter complements recent work that has examined changes in industry modularity, focusing on e.g. the interplay between firm capabilities and transaction
costs (Jacobides and Winter, 2005; Langlois, 2006) and the role of technological innovations (Wolter and Veloso, 2008). Further, the framework builds on existing work that has analyzed how modularity at different levels is related. For example, research on the “mirroring hypothesis” (Colfer and Baldwin, 2010; Cabigiosu and Camuffo, forthcoming) has investigated how architecture at the product and organizational relate. Work by Brusoni and Prencipe (2006), drawing on Padgett (2001) and Padgett and Powell (2003), investigate different domains (knowledge, technology and organization), emphasizing the role of changing knowledge bases in affecting how organizations change over time. Drawing on these studies, this chapter emphasizes architectural change at different levels (i.e. product and organization), and their relation to changes in industry modularity.

Several implications can be derived from the framework. At the product level, characteristics of the artefact, as well as broader factors (e.g. usage patterns) affect the extent to which the product can be modularized (i.e. the extent to which knowledge of functional interdependencies can be codified). Likewise, at the organizational level, the extent to which practices can be standardized will differ depending on the system in question. Given heterogeneity in size, resources etc., different firms might choose alternative organizational partitions. Further, the chapter has highlighted several moderating factors that influence the extent to which industries become more or less modular. As such, the framework may also shed light on the debate on the impact of modularity in relation inter-firm coordination. Here, several authors have stressed how modular interfaces may substitute for organizational coordination (Sanchez and Mahoney, 1996; Sturgeon, 2002), further exemplified in the “vanishing hand” hypothesis forwarded by Langlois (2003). This can be contrasted with other

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23 Notwithstanding the overall costs of codification (Hakanson, 2007), increasing pervasiveness of ICT’s may lower these costs, though its effects across sectors is mixed (Steinmueller, 2000; Brusoni, Marsili and Salter, 2005). At the same time, recent advances in visualization and simulation impact on the way firms innovate, and may enhance the degree to which knowledge can be codified (Dodgson, Gann and Salter, 2005, 2007). However, the extent to which this will impact on product modularity needs to be further explored.
studies that have emphasized the ongoing importance of firms that need to coordinate disparate knowledge bases and technological subsystems (Pavitt, 2003), in particular in research on the role of systems integrators (Brusoni et al., 2001; Hobday et al., 2005). The framework developed in this chapter instead proposes a contingent perspective: both perspectives might be true at the same time, and may depend on product or industry related characteristics. For example, industries marked by higher degree of interface codification (e.g. information-based industries and electronics-based products such as stereo components) have often been the focus of research underlining increases in modularity (e.g. Langlois and Robertson, 1992; Sturgeon, 2002). This contrasts sharply with settings characterized by lower degrees of both interface codification and stabilized practices, such as the aerospace and automotive sectors, settings investigated in research on systems integration (Prencipe et al., 2003). In these latter cases, mechanical interdependencies - as opposed to informational - also play a key role (see also Luo, 2010).

This chapter has several implications for practitioners. While many practitioners may intuitively grasp that there are important sectoral differences in modularity, the framework might give theoretical grounding to understand these industry differences, and predict when (and when not!) these might change. The misapplication of the modularity metaphor in the automobile industry (see MacDuffie, 2006 for an insightful account) might serve as a reminder of misappropriation of theoretical concepts across sectoral boundaries. Likewise, policy makers may also take into consideration that modular changes might differ per industry.

As always, there are limitations to this study, and similar boundary conditions apply to the framework introduced in this chapter. First, though we know some of the firm-specific
benefits associated with modularity, existing work has also highlighted the costs firms face in achieving modularity, in particular in relation to the product and organizational level (e.g. Brusoni, Marengo, Prencipe and Valente, 2007; Srikanth and Puranam, 2011). Chapter 3 further expands on some of the challenges firms might face in making architectural design choices. Future work might further expand on these issues, for example to understand the extent to which increasing product and organizational modularity is beneficial in changing environments. Second, the framework has largely ignored public policy and socio-economic implications of modularization. For example, an underlying motivation for increasing modularity at the product or organizational level might be to facilitate outsourcing or offshoring to lower wage countries, which may lead to employee resistance. For example, as noted by Sako (2003), the term modularity was met with great resistance in the automotive industry, since it was perceived by labor unions as a euphemism for offshoring. Further, Pisano and Shih (2009) observed that offshoring may have longer-term implications for the innovative potential of regional clusters, further highlighting potential macro-level policy questions.

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24 However, firms might also modularize organizational processes without relying on external suppliers (Hoetker, 2006).
Chapter 3

"Designing Product and Organization Architecture in a Dynamic Environment: the combined impact of environmental and firm-level drivers"

3.1 Introduction

Influenced by Simon’s work on the architecture of complex systems (1962, 2002), research on modularity has, among a wider range of issue, examined the relationship between product and organization architecture. Here, influential work on design rules (Baldwin and Clark, 2000) and architectural innovation (Henderson and Clark, 1990) implicitly assumed that product and organization architectures are isomorphic. Going further, Sanchez and Mahoney (1996) suggested a causal direction in this relationship, proposing that “products design organizations”. Recent work has questioned whether product and organization architecture are necessarily isomorphic. In particular, Colfer and Baldwin’s (2010) study, invoking the term “mirroring hypothesis”, reveals that the extent and prevalence of mirroring varies, suggesting the need for a more contingent perspective. Likewise, other research has highlighted how factors such as knowledge (Brusoni and Prencipe, 2001, 2006; Tiwana,
2008) and strategic considerations (Sako, 2003; Fixson and Park, 2008) might affect the way product and organization architecture relate.

Though existing work has made important advances in understanding the relationship between product and organization architecture, important gaps remain. In particular, we have comparatively little insight as to how environmental factors influence this relationship, though existing literature, in particular contingency theory (Lawrence and Lorsch, 1967; Burns and Stalker, 1961; Thompson, 1967) has emphasized its importance. This paper expands on existing work by developing a process oriented framework, highlighting the combined impact of environmental and firm-level drivers on architectural design choices.

In this chapter, product architecture refers to the different subsystems comprising the overall technological system. Here I focus on changes in the way subsystems are partitioned, particularly how subsystem boundaries are drawn. Organization architecture comprises ownership structure and development, which can change through arrangements such as joint ventures or acquisitions. Empirically, I examine the development of Symbian, an operating system for mobile phones. As such, the main unit of analysis is the overall technological system, which guides the empirical analysis. What varies over time are the organizational arrangements by which this system is developed and the demarcation of the various technological subsystems. Given the types of organizational changes, I focus on the inter-firm (as opposed to intra-firm) level of development.

Based on a qualitative longitudinal study tracking changes in product and organizational architecture, I develop a framework that highlights the combined role of environmental and firm-level drivers in affecting this relationship. Here, environmental drivers refer to changes
in the competitive landscape (due to new entrants), while at the firm-level I focus on strategic and technological drivers. The framework emphasizes in particular the challenges firms face in establishing product and organizational architecture. In this setting, the combined impact of environmental and firm-level drivers induces a set of partially conflicting demands. Tensions between collaboration and competition in particular complicate a firm’s decision making process regarding product and organization architecture design choices.

Overall, this process is marked by an ongoing search for an appropriate set of “design rules” (an overarching set of principles that codify how components are connected, cf. Baldwin and Clark, 2000; Brusoni and Prencipe, 2006), characterized by mutual adjustment between organization and product architecture. This setting shows that when these design rules are not clearly specified, or applied inconsistently, that coordination costs might increase, in spite of modular system designs. As such, these findings extend recent work that has argued that modular designs decrease the need for ongoing coordination (Sanchez and Mahoney, 1996; Tiwana, 2008) and the role of knowledge in drawing subsystem boundaries (Brusoni and Prencipe, 2001, 2006; Takeishi, 2002; Baldwin, 2008). This chapter points to a particular set of challenges when establishing technological subsystem boundaries, especially when environmental and firm-level drivers exercise diverging demands, thereby complicating architectural design choices.

This chapter proceeds as follows. The following section discusses relevant background literature. I then describe the data collection process and subsequently present my empirical data. This is followed by a discussion of the empirical findings in light of existing literature. The final section concludes, highlights limitations, and suggests areas for further research.
3.2 Background literature

Drawing on Simon’s (1962, 2002) work on hierarchy and near decomposability of complex systems, a system’s architecture refers to the way individual elements in a given system are connected (Whitney et al., 2004). As such, architecture is a general system property and can be distinguished at multiple levels of analysis (see also Chapter 2). The wider importance of changes in architecture has been shown in a variety of studies, including its impact on problem solving ability (Simon, 1962; Brusoni, Marengo, Prencipe and Valente, 2007), technological trajectories (Clark, 1985), and firm survival and profitability (Henderson and Clark, 1990; Baldwin and Clark, 2000; Murmann and Frenken, 2006). The impact of architectural change has been examined most explicitly in the modularity literature (Baldwin and Clark, 2000; Schilling, 2000; Langlois and Robertson, 1992; Ulrich, 1995; see Garud et al., 2002 for an overview). Existing work has provided multiple definitions of modularity (see e.g. Salvador, 2007; Campagnolo and Camuffo, 2010); an overarching theme is that a system’s modularity increases when interdependencies are higher within than between subsystems. At the organizational level, the notion of “loose coupling” (Weick, 1976; Orton and Weick, 1990) provides a similar conceptualization of subsystem interdependency.

Among a range of issues, research on modularity has examined how changes in product architecture relate to changes in organizational architecture. Initially, several prominent studies assumed that the relationship between product and organization architecture is isomorphic. For example, Henderson and Clark’s (1990: 27) influential study on architectural innovation and its potential impact on firm survival concludes as follows: “We have assumed that organizations are boundedly rational and, hence, that their knowledge and information-processing structure come to mirror the internal structure of the product they are
designing." Subsequent studies have questioned the assumption of isomorphism, examining when this “mirroring hypothesis” holds (MacCormack, Rusnak and Baldwin, 2008; Colfer and Baldwin, 2010).

Research on systems integrators, i.e. firms that possess the relevant knowledge to integrate the various subsystems produced by the firm and its partners, has also examined the relationship between product and organizational architecture (Prencipe et al., 2003; Hobday, Davies and Prencipe, 2005). This work has looked into drivers affecting which tasks firms maintain in-house and which ones are outsourced. Here, the role of firm-level differences in knowledge accumulation or sector-specific rates of technological development are emphasized, explaining why firms “know more than they make” (Brusoni, Prencipe and Pavitt, 2001). Related work has further highlighted the role of knowledge in creating design rules, emphasizing how firms’ knowledge bases mediate between the organizational and technological domain (Brusoni and Prencipe, 2001, 2006). Extending this, a study by Tiwana (2008) focusing on alliances, suggests that increasing inter-firm modularity decreases the need for inter-firm knowledge sharing. Discussing different dimensions of integration, Jaspers and Van den Ende (2006) further distinguish between ownership, coordination, task, and knowledge integration, to analyze different types of organizational configurations.

Besides the role of knowledge, existing research has also emphasized how strategy influences the relationship between product and organizational architecture. For example, a study by

Likewise, Baldwin and Clark’s (2000: 358) seminal work on the creation of design rules of IBM’s Systems 360, discusses the issue of isomorphism as follows: “Each workgroup is fundamentally – isomorphically – involved in carrying out the tasks of design or production, or both, for a specific module experiment. In this fashion, the modular form of the artifact begins to be visible in the form of organizations that design and produce it. The artifact’s task structure, in effect, determines industry structure up through the level of workgroups.” Similarly, Sanchez and Mahoney (1996: 64) in their widely-cited study on knowledge and organization design, propose that “although organizations ostensibly design products, it can also be argued that products design organizations, because the coordination tasks implicit in specific product designs largely determine the feasible organization designs for developing and producing those products” (emphasis in original).
Sako (2003) emphasizes how strategic considerations influence differences in modularity, highlighting different historical trajectories in the automobile and PC industry. Further emphasizing strategic choices, Fixson and Park (2008) provide an in-depth study of the drivetrain subsystem in the bicycle industry, analyzing how a firm might decrease product modularity to gain competitive advantage. As such, these lines of work, pointing to knowledge and strategic factors, underscore the need for a more contingent perspective to mirroring.

Notwithstanding the value of existing contributions, they have generally overlooked the role of the environmental drivers, e.g. in terms of changes in the competitive landscape. However, existing research, in particular work on contingency theory, has emphasized the importance of the environment in relation to the structure or architecture of an organization. Contingency theory suggests that organizations need to achieve fit with the nature of the environment, depending on whether this is e.g. more dynamic or static (Lawrence and Lorsch, 1967; Thompson, 1967). More recent work has also highlighted the importance of organizational fit and adaptation to changing environments (e.g. Brown and Eisenhardt, 1997; Siggelkow and Rivkin, 2005). Related work has further expanded how this might impact on organizational boundaries (e.g. Santos and Eisenhardt, 2005, 2009) and the role of coordination costs (Gulati and Singh, 1998). Reconciling divergent views on organizations’ (in)ability to change, Grandori and Prencipe (2008) focus on organizational variants and invariants to understand organizational change and environmental fit. However, more emphasis is given here to the *choices* firms have in adapting to the environment, moving away from the static and deterministic perspective found in some contingency research (see also Sinha and Van de Ven, 2005).

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26 This literature has also identified other factors that determine how an organization should be structured, such as task uncertainty (Burns and Stalker, 1961) and operational technology (Woodward, 1958). See Donaldson (2001) for an overview of the contingency literature.
The notion that firms are not entirely passive in relation to the environment has also been recognized in the emerging literature on industry architecture (Jacobides et al., 2006; Pisano and Teece, 2007), which highlight how firms might shape the environment to their advantage. Strategies to do so have further been investigated in research on platforms (Gawer and Cusumano, 2002, 2008; Gawer, 2009). More generally, the dynamic capabilities literature (Teece et al. 1997; Eisenhardt and Martin, 2000; Helfat and Peteraf, 2003) also recognizes the importance of firms’ resources in adapting to changing environments. As such, while we anticipate that environmental changes will impact on product and organizational architecture, firm-level choices are expected to play a role as well.

In sum, the existing literature points to a number of factors with regards to the way product and organizational architecture relate. The modularity literature, building on initial assumptions of isomorphism between product and organizational architecture, has further examined this relationship. Here, later work has emphasized the complex relationship between product and organizational architecture, and highlighted mediating factors such as knowledge and strategic considerations. More generally, the need for a more contingent view has been emphasized. However, it is unclear from existing work how changes in the environment might influence the relationship between product and organizational architecture. Therefore, this study examines a setting characterized by environmental changes, focusing on changes in the competitive landscape due to new entrants. In doing so, I attempt to shed more light on the process of how environmental and firm-level drivers impact on product and organizational architecture design choices.
3.3 Data collection and methodology

This chapter follows a case study approach (Yin, 2003; Eisenhardt, 1989), frequently iterating between my initial propositions and the empirical data. An approach such as this is particularly appropriate to understand the processes operating in this setting (Pettigrew, 1990, 1992; Van de Ven and Poole, 1995; Van de Ven, 2007). The importance of process studies has also been underlined in recent work on inter-firm collaboration, which has emphasized the need for case studies as a way to better understand how these organizations develop over time (Khanna, 1998; Noorderhaven, 2005; Beamish and Lupton 2009).

This study followed a single-case design in order to track in detail the drivers underlying changes of the main constructs, i.e. organization and product architecture. The data cover a period of over ten years, from the start of Symbian in 1998 (including the decision process leading up to its founding) up to the inception of the open source foundation starting in 2008. I collected both primary data (in particular through interviews) and also made use of archival data. Table 3.1 provides an overview of the various data sources used in this study.

The overall setting in which the case is situated, the mobile telephony sector, appears to be particularly suited to understand the relation between product and organization architecture. Generally, the mobile telephony industry represents a rapidly evolving sector, marked by various instances of change in product and organizational architecture. The particular case of Symbian was chosen for two reasons. First, the technology dates back to the late 1990s and has witnessed several instances of change. Secondly, it has also witnessed several organizational transformations, making it a well suited case to analyze these variations against a general background of environmental shifts.
3.3.1 Data sources

Interviews were conducted with informants from several firms, the majority being done with Symbian (32 out of 48), but also other relevant firms including handset makers, network operators, and application developers (for a more detailed breakdown, see Table 3.1). The interviews followed a semi-structured protocol: common among each interview was identification of background and role of interviewee vis-à-vis Symbian. Topical scope differed depending on the specific role of the interviewee (the Appendix provides a more detailed description of the interview topics). To reduce the role of (retrospective) bias, every key topic that emerged was discussed with at least two informants. Where relevant, I tried to gain multiple perspectives by discussing key issues with informants from different organizations. The interviews lasted on average one hour (ranging from 30 minutes up to 2 hours, with the average length being 1 hour). In terms of functional role, interviewees ranged from top level (CEO, CTO level) to middle management and operational roles. I applied the following selection criteria with regard to interviewees. First, informants needed to have been involved in decisions regarding aspects of the product and/or organizational architecture of Symbian. Second, I selected interviewees based on their tenure, identifying people who had been involved with Symbian from the start. At the same time, to avoid getting information solely from “veterans”, I also interviewed people that had joined later, as well as those that had since left the company.

Secondary sources include industry publications, press releases, developer handbooks and annual reports. I was given access to several internal documents, including presentations on the internal structure of Symbian and various versions of the systems model that represent the product architecture of the Symbian OS. I was also given access to a pre-release (“beta”) version of the Symbian Foundation website, which provides a forum and repository for the
Symbian developer community. Finally, I also attended a workshop (“bootcamp”) organized by Symbian and a mobile network operator, to get a better understanding of the motivations of developers to contribute to the system. Overall, the combination of primary and secondary sources was used to obtain both a broad understanding of the relevant competitive dynamics of the setting, and to gain an in-depth understanding of the various motivations underlying these processes.

Table 3.1: Sources of evidence

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<tr>
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<tbody>
<tr>
<td><strong>Objectives</strong></td>
<td>Explore general industry dynamics in smartphone market (Symbian, Java, Windows Mobile) Understand relation between OS, UI and middleware subsystems</td>
<td>Explore interaction product and organization architecture and boundary setting Understand transition of Symbian Software to Symbian Foundation</td>
<td>Finalize data collection Resolve conflicting accounts Check accuracy of initial case summary</td>
</tr>
<tr>
<td><strong>Interviews</strong></td>
<td>Interviews (total 18) Symbian (5): Symbian Software Ltd (2), Symbian licensees (3) Other (13): application developers (6), specialist consulting firms (5), mobile network operators (2)</td>
<td>Interviews (total 21) Symbian (18): Symbian Software Ltd (15), Symbian Foundation (2), Nokia (1) Other: application developers (2), specialist consulting firms (1)</td>
<td>Interviews (total 9) Symbian (9): Symbian Software Ltd (2), Symbian Foundation (2), Nokia (5)</td>
</tr>
<tr>
<td><strong>Secondary sources</strong></td>
<td>Business press Analyst reports Research papers and books on mobile telephony industry</td>
<td>Business press Internal documents Analyst reports Developer handbooks System architecture models</td>
<td>Business press Internal documents Analyst reports Developer handbooks System architecture models</td>
</tr>
<tr>
<td><strong>Events</strong></td>
<td>n/a</td>
<td>Attend developer workshop (“Bootcamp”) organized by Symbian Foundation and mobile network operator Help test Beta developer website Symbian Foundation</td>
<td>Present initial case summary to 2 key informants (Symbian Foundation, Nokia)</td>
</tr>
</tbody>
</table>

3.3.2 Data gathering stages

Data collection proceeded in three stages. First, an exploratory round of interviews was held in 2004, followed by a second and third round in 2009. These periods precede and follow several key transitions, further described in section 3.4. The main objective in the first round
was to explore the general industry dynamics in the then upcoming smartphone market. The aim was to establish the general competitive context, including technologies competing with Symbian. During this stage the interviews focused in particular on the relationship between the OS, UI and middleware subsystems. In the second interview round, the aim was to explore interactions between product and organization architecture, in particular to understand how stakeholders engaged in the process of boundary setting. More generally, I also wanted to examine wider changes associated with the transition of Nokia’s acquisition of Symbian Software and the role of the Symbian Foundation. Finally, in a third round of interviews, I aimed to resolve any remaining discrepancies and other conflicting accounts. I developed a case summary to check for factual accuracy and gain feedback from several key informants. This case summary and quotes from informants provided input for the empirical section.

The majority of interviews were held face-to-face (44 out of 48), normally at the site of the informant. Three were done via telephone when a personal meeting was not possible; one respondent preferred to conduct the interview via email. In the second and third round of interviews I held several interviews in a short period of time at Symbian Foundation and Nokia, and was given a flexible work-space to be able to make notes in between interviews. This also allowed me to get more informal contact with several informants, e.g. during coffee breaks, and may have been useful to create a more open setting during some of the interviews. At the start of the interview I notified each informant that their anonymity would be preserved when using individual quotes.
3.3.3. Data analysis

As an inductive study, there were ongoing adjustments between the data collection and my analytical framework. I approached the interviews with general working assumptions about the setting, which evolved and were refined in the course of the data collection process. Interview round 1 mainly served to get a better understanding of the general setting. Extensive notes were made during and after each interview. Subsequently, all interviews in rounds 2 and 3, constituting the core of my interview data, were recorded, transcribed, and coded.

Following Strauss (1987), this coding process consisted of three stages: open, axial, and selective coding. Starting with open coding, in this stage a broad number of codes were assigned, without great concern regarding prioritization, links between codes or hierarchical relationships. Next, during axial coding, I revisited the initial codes to form general and subcategories and explore their relation. Finally, I used selective coding to decide on key categories and further outline how general and subcategories of codes are systematically linked. The latter two stages also allowed me to distinguish four temporally distinct episodes (Van de Ven and Poole, 1995), on which I elaborate in the next section. I used NVivo software to help with the coding process. (See Appendix 2 for an illustration of the codes used in these three stages).

3.4 Case description: Symbian

This section provides a longitudinal analysis of Symbian’s development, focusing on changes in product and organizational architecture. For each of these episodes I highlight both environmental and firm-level drivers of change. At the organizational level, I focus on ownership structure (i.e. single or shared ownership) and development (centralized or
distributed). At the product level, I concentrate on where the subsystem boundaries are drawn, and whether this is more consolidated or separated.

Before going into the particulars of the case study, a brief description of the setting might be useful. Smartphones are usually defined as mobile telephones that allow end-users to install third-party applications. Apple’s iPhone provides one of the more prominent contemporary examples. Like all mobile phones, smartphones run on a particular operating system (OS). These operating systems are either developed in-house (such as Apple’s iOS) or developed by specialized organizations and subsequently licensed to mobile phone makers (e.g. in the case of Windows Phone, Android, and Symbian, each of which is licensed to a variety of phone makers). An operating system is important as it impacts on a range of functionality, including battery life, hardware requirements, third-party applications, and overall performance. In this study, a key subsystem is the User Interface (UI), which provides the overall visual navigation experience and is directly visible to the end-user.

3.4.1 Overview of key events

Symbian was founded as an independent company in June 1998 by mobile handset manufacturers Nokia and Ericsson and PDA maker Psion. A key reason for collaboration amongst the then dominant handset makers was to set a standard for a new class of mobile

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27 Schilling and Steensma (2001) use a related operationalization using the label “modular organizations”; Santos et al. (2006) similarly focus on ownership issues in relation to organizational modularity. This operationalization also partly follows Jacobides (2006), who notes division of labor (albeit at the intra-firm level) as one element of organization architecture, also recognizing the imprecise definition of the organizational architecture concept (Jacobides, 2006: 160).

28 I avoid the terms “modular” or “integral”, as these typically refer to the degree of interdependency within a subsystem. By contrast, here I focus on where the product subsystem boundaries are drawn, which does not necessarily coincide with the degree of interdependency (Yayavaram and Ahuja, 2008). Also, I do not focus directly on connections to subsystems external to Symbian, such as middleware (e.g. Java) or third-party applications.

29 Installation of third party applications refers to “native” applications, i.e. written specifically for the operating system. This contrasts with “interpreted” applications that run on middleware technology such as Java, which have more limited capabilities compared to native applications.

30 “Symbian” refers both to the company (Symbian Software Ltd) and the technology (Symbian OS). For readability I generally use “Symbian”, distinguishing explicitly only where necessary.
phones, later referred to as “smartphones”. Over time, ownership of the joint venture expanded to 7 firms, and was eventually owned solely by handset makers (see Figure 3.1 for an overview of the various shareholders of Symbian over time).

![Figure 3.1: Equity distribution in Symbian Software Ltd (SSL)](image)

The initial plan was that Symbian would provide the complete system based on “Device Family Reference Designs” (DFRD’s), which would allow handset makers to provide customers different types of form factors and user experiences. However, this changed, when in 2001 it was decided that Symbian would only focus on developing the core subsystems; other firms would develop the User Interface (UI), the part of the system directly visible to the end-user.

In the first 10 years of its lifetime, Symbian had largely achieved its key objectives: it managed to prevent a reoccurrence of Microsoft’s dominance in the PC industry, instead constituting the market leading smartphone system itself. Subsequently, however, other entrants to the mobile industry (in particular RIM and Apple, both more vertically integrated
in terms of hardware and software) were increasingly considered to be a danger to Symbian’s dominant market share. This was a threat in particular to Nokia, who had emerged as the market leader amongst Symbian phones, as well as the wider mobile phone market. In response, Nokia eventually decided to acquire Symbian outright, announced in June 2008, exactly 10 years after the initial formation.

The announcement of the acquisition was complemented by another transition, namely that Symbian would become available under an open source license, responding to the emergence of the Android OS led by Google. Various royalty-free, open source alternatives had been available in the course of Symbian’s lifetime. However, few of these managed to gain significant market share. However, the announcement of Android, another Linux based open-source system, was taken more seriously, given Google’s strong involvement in the initiative. Further, both network operators and handset makers appeared to be highly interested in the technology. To enable Symbian’s move towards open source, Nokia, joined by various other firms, established the Symbian Foundation. In February 2011, Nokia announced its decision to adopt Microsoft’s Windows Phone system, indicating a planned two year phase out and transition to the new technology. As such, Symbian’s overall track record is mixed: on the one hand it reached its initial goal in preventing a firm outside the telecoms industry (Microsoft) to dominate the smartphone market; on the other hand, it was unable to successfully compete with later entrants such as Google and Apple. Figure 3.2 gives a schematic overview of these events, analyzed in more detail next.

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31 The Symbian Foundation was active with the overall governance of the platform from April 2009 until November 2010, after which Nokia regained control of this process. The latter event exceeds the data collection stage and is largely beyond the scope of the analysis.

**Episode 1: 1996 - 2001**
- Environment: Microsoft’s entry into mobile device (PDA) market
- Firm: Mobile handset maker’s desire to share OS development
- Design choices: Shared ownership: Symbian Software Ltd (SSL), Centralized development: Complete system developed by Symbian, differentiation based on DFRD’s
- Outcomes: Form factor ambiguity in “nascent market” spurs divergent interface designs among stakeholders.

**Episode 2: 2001 - 2004**
- Environment: Firm, Rivalry and imbalances complicate standardization
- Design choices: Shared ownership: Symbian JV expanded with other shareholders Distributed development: amongst OS (SSL) and UI firms (Nokia, NTT Docomo, UIQ)
- Outcomes: Challenges defining the boundaries between OS and UI Tacit knowledge complicates licensing of UI to other firms.

**Episode 3: 2004 onwards**
- Environment: Emergence of new entrants (Apple, RIM)
- Firm: Gain operational control by remaining Symbian licensee Nokia
- Design choices: Single ownership: acquisition of Symbian Software Ltd by Nokia, Centralized development: single firm (Nokia)
- Outcomes: Consolidated: OS and UI components unified

**Episode 4: 2008 onwards**
- Environment: Emergence of credible OSS solutions (Android/Google)
- Firm: Facilitate external contributions
- Design choices: Shared ownership: Symbian Foundation (SF), Distributed development: amongst SF members (284 members, chief contributor Nokia)
- Outcomes: Re-partitioned: system re-partitioned into approximately 100 software packages

**Figure 3.2:** Case description: overview of key changes at Symbian

### 3.4.2 Case description: Examining Symbian’s transitions and their underlying drivers

This section provides an in-depth description of several key transitions that have taken place at Symbian, focusing on changes in product and organizational architecture. I look at both environmental drivers (i.e. changes in the competitive landscape due to new entrants) and firm-level drivers of change (i.e. strategic and technological considerations). In the ensuing empirical analysis, I distinguish 4 episodes. Episode 1 and 2 are temporally sequential, but are characterized by one organizational form (i.e. the Symbian joint venture). Episode 3 and 4 are temporally, as well as organizationally distinct, but were driven by a common underlying decision. Though the decisions underlying episodes 3 and 4 are partly intertwined, these episodes are separated to facilitate exposition. Table 3.2 provides an overview of key drivers and illustrative quotes underlying these events, further described in more detail below.
<table>
<thead>
<tr>
<th>Driver</th>
<th>Description</th>
<th>Illustrative quote(s)</th>
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<tbody>
<tr>
<td><strong>Episode 1 (1998 – 2001): Symbian’s formation</strong></td>
<td><strong>Environmental driver: External threat</strong></td>
<td>Common external threat (Microsoft) spurs collaboration among incumbent handset makers to define standard</td>
</tr>
<tr>
<td>Firm driver: Product ambiguity</td>
<td>Form factor ambiguity in “nascent market” spurs divergent interface designs among stakeholders</td>
<td>“But there wasn’t agreement on the form factor. And there were these DFRDs, and they were called after crystals, ‘Emerald’ and so on […] So people came up with these design concepts which were fragmenting the platform, which we recognize now. And it led to combinatorial explosion so to speak of software configurations, which were called DFRDs. And it was completely mad in retrospect.”</td>
</tr>
<tr>
<td><strong>Episode 2 (2001 – 2008): Growth and internal rivalry</strong></td>
<td>Firm driver: Shareholder interaction</td>
<td>Rivalry and shareholder imbalances complicate aim to create shared standard</td>
</tr>
<tr>
<td>Firm driver: Subsystem separation</td>
<td>Ongoing difficulty to consistently define boundaries between OS and UI subsystems</td>
<td>“In reality, software is often the UI and the software coupled together. Even though the desire is to separate the UI and the logic, but in reality it’s not really physically possible to do.”</td>
</tr>
<tr>
<td>Tacit knowledge complicates licensing of UI subsystem to other firms</td>
<td>“There’s a lot of tacit knowledge associated with the in-house stack. Whereas in effect S60 was an in-house stack that Nokia had a lot of inside knowledge in. The amount of inside knowledge [required to implement the UI] was underestimated.”</td>
<td></td>
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<tr>
<td><strong>Episode 3 (2008-2009): Symbian’s acquisition by Nokia</strong></td>
<td>Environmental driver: entry of integrated competitors</td>
<td>New entrants (especially RIM and Apple) gain marketshare based on novel interface designs</td>
</tr>
<tr>
<td>Firm driver: Licensing issues</td>
<td>Symbian licensing model spurs take-over by remaining dominant Symbian licensee (Nokia)</td>
<td>“This was really the only choice Nokia had. Otherwise it may as well for every £10 just email £5 to everybody else. That's really what they were doing to themselves. And that's a crazy situation for any company to be in.”</td>
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</table>
| Firm driver: Coordination challenges | Reduce duplication of efforts, and improve coordination between organizationally dispersed subsystems | “In comparison to Symbian OS, it [S60] does feel like quite an over-developed UI. Too much effort [had] gone into make into doing all the things it needs to, and there not being enough kind of deprecation, there's too much fat, should we say, in the UI. And I think one of the first things, really, when they started integrating the teams, was the Symbian engineers were very quickly able to help some of
“So the problem we had there is because we were always creating an operating system for other vendors, is Symbian had to, whilst Nokia would say, ‘You don't need to do this, because we've already done it’, we would still have maybe Fujitsu and Sharp saying, ‘We need this technology in Symbian OS because MOAP-S (an alternative UI) won't have that.’”

“Sometimes features were purposely not disclosed by vendors. For example, when Nokia did their first cameraphone, that feature was kept secret also to Symbian, to avoid the chance of that information being leaked to rivals. These things complicated overall development of the system.”

<table>
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<tr>
<th>Firm driver: Knowledge sharing</th>
<th>Remove obstacles preventing knowledge sharing between cooperating teams</th>
<th>“[…] We had to be very clear all the time as to who would end up owning the intellectual property. Because the systems were so closely linked.”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental driver: entry of Google</td>
<td>Google’s entry to the smartphone market, through its open-source based Android operating system</td>
<td>“So there was external pressure from Android. But instead of responding with just a proprietary ‘Nokia OS’, instead it chose what I think is the correct competitive answer, going with an open strategy, a really open strategy with the Symbian Foundation”</td>
</tr>
<tr>
<td>Firm driver: Licensee concerns</td>
<td>Address licensees’ desire to reduce dependency on single firm (i.e. Symbian Ltd)</td>
<td>“[…] Being dependent on a single technology was not an issue, as long as multiple firms were involved. So that favored open sourcing.”</td>
</tr>
<tr>
<td>Firm driver: Moving towards open source</td>
<td>Combination of anticipation and internal resistance moving towards open source</td>
<td>“So, really, for us to move towards a completely open platform was just kind of the next step in thinking.” “There was certainly resistance to change within the company, you know, ‘turkeys don’t vote for Christmas’”</td>
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This episode looks at Symbian’s initial years, focusing on two issues. First, I focus on environmental drivers by examining the underlying motivations that drove the establishment of the joint venture. Second, in terms of firm-level drivers, I discuss how contemporaneous uncertainty surrounding the “smartphone” category subsequently influenced product development.
Founding Symbian: common threat spurs collaboration among incumbent handset makers

In terms of environmental drivers, Symbian’s initial establishment was primarily a response to Microsoft’s entry into the PDA and mobile telecommunications market. In doing so, Microsoft repurposed technology it had earlier used in the PDA market (Windows CE), which it attempted to license to various PDA and handset manufacturers (later called Pocket PC, Windows Mobile, and finally Windows Phone). Anticipating this development, the then-dominant mobile handset makers decided to set up an alternative technology. The initiative was driven in particular by Nokia and Ericsson, firms which had a long-standing history of cooperation in mobile telephony (typically in standards consortia), including development of several successful network standards.32

An additional motivation underlying this collaboration was to share development costs, as competing with incompatible systems was considered to be unattractive to each of the top tier handset makers. In turn, Psion, a successful but relatively small company, became increasingly concerned about the possibility of having to compete with much larger firms entering the PDA market. Teaming up with better resourced handset makers allowed them to exploit their recently developed EPOC OS on a much larger scale. As illustrated by one interviewee, initially at Psion and later at Symbian and Nokia:

“[…] Thoughts at the time were that Microsoft smartphones would happen unless we do this [or] we’d be in the same position as laptop makers, where all laptops are made in Taiwan and there are no R&D people. […] And we’d rather as incumbents, Motorola, Ericsson, Nokia, would like to define our own standard and we’re going to acquire Psion’s software to do that […] I think that was the strategy at the time.”

32 Motorola, at that time also one of the “big three” handset makers, each of which had around 20% marketshare, was invited to join at the last moment, and, as indicated by several interviewees, was given circa 24 hours notice whether to join the initiative.
As such, the incumbent handset makers’ plans matched well with Psion, which had recently decided to look for customers for its PDA operating system. As one interviewee recalls:

“So, before there was Symbian, there was a precursor of Symbian, which was called Psion Software. So, Psion had been divisionalized in 1996. So this was Psion Software, which was created with a mission to make the software used by other people, and not just by Psion. So, the arguments that had been raging in 1994, '95, '96, was, ‘Will Psion die like Apple or will Psion die like IBM?’ And, some of the arguments went, ‘Well, if it remains proprietary, it's bound to die. You know, it's going to be too hard to survive, and so it has to go open.’ And so that's why Psion software was formed, to go in search of other customers.”

Product ambiguity spurs divergent interface designs

Like any emerging technology, it was unclear at the outset in which direction the market would evolve. Therefore, it is important to recognize the uncertain environment in which these firms were operating around 1998. One informant reflects on this as follows:

“And so a smartphone, it’s almost like a horseless carriage, you know, in the sense that you’ve got that vision of a car, as being just, something that doesn’t have a horse in front. There’s that aspect of it, and the idea of a camera being part of a smartphone and multimedia wasn’t in the air. […] People thought of a smartphone as a PDA that could do voice, rather than ‘what you can do when you put a decent OS in a phone?’.”

As such, while these handset makers were united in their goal to establish their own standard to pre-empt Microsoft from dominating this newly emerging market, each shareholder had their own conceptualization of what smartphones (initially referred to by Symbian as “Wireless Information Devices”) would look like. To allow differentiation among competing handset makers, Symbian distinguished several “Device Family Reference Designs”
(DFRD’s). One DFRD made use of a small QWERTY keyboard; another focused on touch input using a stylus; a third was suitable for one-handed operation, similar to a conventional mobile phones with a numeric keypad. Figure 3.3 provides a visual illustration of the various DFRD form factors.

![Figure 3.3: Illustration of “Device Family Reference Design” (DFRD) form factors](image)

However, the DFRD strategy raised several challenges, and led, as recalled by one interviewee to a “combinatorial explosion of software configurations” (see Table 3.2). As highlighted by another interviewee involved with Symbian from the outset:

“[…] there were six reference designs which were in principle in the planning. So that was what the founders signed off to. […] Let's take Sapphire, the so-called […] one-handed smartphone. […] Motorola said ‘Well, we like that, but we'd like to make sure that it’s pen-enabled as well.’ So then, well how do you actually go forward? Do we create two reference designs or do we just have one reference design? […] So we said: ‘Let's have Blue Sapphire, which will be suitable for the needs of Nokia without touch, and Red Sapphire, which will be suitable for the needs of Motorola with touch’. Then we said, ‘My goodness, this is too hard.’ So then we said, ‘Let's split them off’.”
As a result, given the difficulties of collaborating on DFRD’s, this model was changed. Instead, Symbian would focus on development of the core subsystems of the OS, and Symbian’s licensees would separately develop the UI subsystem on top of this.

**Episode 2 (2001 – 2008): Growth and internal rivalry**

The second episode looks at Symbian’s growth following the decision to re-partition the system and allow licensees develop the UI subsystem. In this stage, the environment largely remains unchanged: as expected, Microsoft entered the smartphone segment, but did not constitute a serious threat to the incumbent handset makers. As such, this episode focuses on firm-level drivers, highlighting two issues. First, rivalry and imbalances between the various shareholders made it difficult to achieve one of the original goals of the joint venture, to create a standard used by all shareholders. The second point involves the separation between the OS and UI subsystems, the antecedents of which were described in the previous section. This separation had a number of consequences: ongoing difficulty to consistently define boundaries between OS and UI; and licensing complications of the UI to other firms.

**Shareholder interaction: rivalry and imbalances complicate standardization**

When Symbian was established, the three then dominant handset makers each had a market share of around 20%. However, from 2001 onwards, Nokia grew rapidly, both in the overall mobile telephony market, and also in the smartphone segment. This destabilized the alliance, and derailed plans to create a common standard. One interviewee reflects on these developments as follows:

“[When Symbian was formed] Ericsson was the biggest with 23%, Motorola had 21%, and Nokia had 19%. And people forget all of that now. But that was very important because the whole joint venture depended on those three players being in equal balance to each other and
[to] Psion, because that kept them at bay as a cooperating group. [...] It got unaligned, and Nokia grew too big. And that destroyed the dynamic of power sharing. [...] Because Nokia, by becoming the biggest customer, then it became whatever Nokia wanted, essentially, Symbian had to do."

As each of the Symbian shareholders (with the exception of Psion) were direct competitors, rivalry and lack of trust was another area of concern. Many interviewees pointed in particular to Motorola, especially after their defection from the consortium in 2003 and their subsequent adoption of Microsoft’s Windows Mobile technology. A former Nokia employee reflects on this as follows:

“A view that one can have of all of Symbian was that it was all along a way for the others to slow down Nokia. So by licensing and discussing and requiring, the others would slow down Nokia’s progress. And I have the strongest feeling that that was the tactic that Motorola deployed, that they were there to stall and slow down. But whether that’s true or not, I have no real evidence of it.”

On the other hand, another founding member of Symbian, previously at Psion Software with no allegiance to any of the handset makers, has an alternative view, emphasizing that Motorola did initially take an active role in Symbian:

“They did throw themselves into it. There were people involved in projects almost straightaway. [...] They tried to collaborate. They did have people working on both these projects. I would not say that they stood back. They tried to make it work.”
Subsystem separation: challenges defining subsystem boundaries

Having decided that Symbian would not develop User Interfaces (UIs) itself, a division of labor had to take place between Symbian and the UI makers. Symbian would develop the core functionality of the OS, and Symbian licensees could develop their own UI. However, setting a clear boundary between the OS and UI subsystems was an ongoing concern, manifesting itself in several ways. One interview, who had been closely involved in managing Symbian’s architecture, makes the following observation:

“I think it’s fair to say that the line [between the OS and UIs] wasn’t drawn. So I used to joke that, you know, even numbered modules would go to Nokia, and odd numbered modules would go to Symbian [would have been a more efficient process]. [...] So in truth, Nokia were rich, and they could invest in anything they want. And so anything that a team in Nokia wanted to, they could just do. And so Symbian would be in a position where they’d say: ‘we can do this’, and then Nokia would say, ‘we need it a bit faster, we’ll do it ourselves’.

Another interviewee, closely involved with the architecture of Nokia’s S60 UI, observes:

“[...] it was difficult to draw a line where the functionality starts and where the UI stops. And that split was built and created in a way by operating system theorists, who were of the opinion that functionality, in those days, [that] it could be split.”

While the malleable nature of software allows flexibility, this flexibility can also create costs and complexity in the long term. Symbian licensees, in particular well-funded ones like Nokia, were able to complement and replace parts of the base OS with their own technology. As one interviewee recounts:

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33 In that light, Symbian’s headquarter address (on a street named Boundary Row) seems unexpectedly appropriate in retrospect.
“Nokia could use as much, or as little, from the OS as they wanted to. And so, instead of having a well architected line between an upper and lower layer of the stack, you’d have a jaggy line. And that added to the cost and complexity of making the whole Symbian ecosystem.”

Another informant, working on intellectual property for Symbian, further illustrates the malleable nature of the boundaries surrounding the OS. When asked on the possibility to leave out particular features, the response was as follows:

“[…] That was when we often relied then on our technical consulting. So what we would sometimes say to the other companies, especially if it was a small request that was, say, only for Japan, is we'd say, ‘That won’t be part of our project. We feel it’s outside the operating system. However if you talk to technical consulting, they will happily engineer this for you and deliver to you as a complete solution’” [emphasis added].

One interviewee with experience both at Nokia and later at the Symbian Foundation views the decision to separate the OS from the UI as a key point, with potentially fatal consequences:

“And it, to this day, may be the death knell of the entire ecosystem. [If] we don’t succeed this will be one of the primary reasons. Because the stakeholders and parties midway through the life of Symbian decided to enable this level of fragmentation and control point practice.”

By contrast, a former employee of a Symbian licensee emphasizes that development of large complex systems such as an operating system raises inherent challenges:
“I don’t think this split model was such an important issue; you know, without naming names, I can think of plenty dysfunctional UIs that have been developed under the umbrella of a single firm”

UI subsystem licensing: tacit knowledge complicates external development

Besides difficulties to cooperate amongst the various Symbian shareholders, there were further issues that complicated Symbian’s adoption. For example, Nokia had made its S60 UI available for licensing, an opportunity taken up both by new entrants (Sendo, later acquired by Motorola) and other Symbian shareholders such as Siemens and Samsung. However, using a competitor’s technology proved difficult in practice:

“And so it didn’t start off as Series60 (S60). It was one phone; it was the 7650 which was codenamed Calypso. So they [Nokia] did it as just an individual phone. And it was only later there was more emphasis on, ‘Well let's make this reusable. Let's make it available for other companies to license.’ So in fact it was designed with a whole lot of Nokia specific stuff in it and that made it difficult actually to turn it into something that other companies could use.”


The third episode examines Nokia’s decision to acquire Symbian, focusing on the underlying motivations driving this. Here, the ownership structure moved from shared to single ownership, given Nokia’s acquisition of Symbian and all of its assets. Instead of the split model described before, the software developers previously working for Symbian now became part of Nokia’s handset group. Here, Nokia consolidated the previously separate OS and UI subsystems. In doing so, it countered the fragmentation of UI’s that had occurred earlier, using Nokia’s S60 UI as the primary UI for the newly formed system. However, this move towards single ownership and product consolidation mainly functioned as a transition
step. As further described in the following episode, Nokia subsequently complemented this model by founding an organization marked by shared ownership and a re-partitioned product architecture.

Nokia’s acquisition of Symbian can in part be considered a response to further changes in the competitive environment, in particular the emergence of more integrated competitors, such as RIM and Apple. First, RIM’s Blackberry smartphones started to gain marketshare, initially in the corporate sector and later also among individual consumers. Apple introduced its first iPhone handset in 2007 among widespread publicity and rapid growth rates. As one interviewee suggests:

“Of course, Symbian was jointly owned, so there were competing interest, and tensions over the direction. This slowed down innovation, and also adoption of the platform. However, this was basically OK; until there were no credible competitors, there was no impetus to change. External pressure, especially from Apple, changed all this.” (emphasis added)

Beyond these environmental drivers, there were other motivations underlying the acquisition. First, there were financial considerations, in particular licensing costs. Second, there were issues related to product development, including duplication of efforts and legal complexities.

Licensing issues: competitive concerns and cost reductions

From Nokia’s point of view, there were further reasons as well to acquire Symbian and consolidate the various subsystems. In particular, for each Symbian handset it shipped, Nokia was indirectly paying its competitors, some of which had since exited the handset market. Acquiring Symbian could avoid these licensing costs. A former Symbian employee describes this situation as follows:
“Let's be honest, the majority of our [Symbian’s] business, probably 80% of our profits was coming from Nokia. But Nokia only had 47% ownership, and [was] now literally paying money to everybody else in the joint venture.”

On the other hand, another informant closely involved with the acquisition notes the following:

“It would be a mistake to focus just on the cost side of things. If it were merely costs, there would have been other things Nokia could have done, and quite easily [they] could have renegotiated the license fee. So it’s not just costs, there were other motivations as well.”

While the extent to which costs played a part in Nokia’s decision making is not entirely clear (and may well have been a combination of financial and strategic considerations), further drivers to consolidate the various subsystems can be identified, described in more detail below.

**Coordination challenges: improving collaboration between organizationally dispersed subsystems**

Given its shared ownership structure, Symbian’s collective decision making process was most damaging to Nokia, which as mentioned earlier had emerged as the most successful Symbian licensee. However, Symbian’s decision making process complicated rapid development. One Symbian employee shares the following observation:

“So, you know the architectural, the requirements process, said well, there’s a requirement to get into the OS, it comes up to TechCom (Technological Committee), and everyone at TechCom votes. Who’s on TechCom? There’s a representative from every product management group within Symbian, and representatives from all the licensees. But if you’re
Nokia and you’re paying 2/3rds of the wage bill, and you have got a product that required feature X, and all the other licensees, some of whom are barely committed to the thing anyway. So you got Panasonic there or whoever, they have a vote. They may not actually have made a phone for a year. And Nokia made ten. And they all have equal say, and that feature, that’s mission critical to Nokia, may or may not get in. And they did that throughout...

Duplication of efforts was another issue, given divergent requirements among the various licensees.

A former Symbian employee illustrates this as follows:

“I think, you know, there was quite often, as I said, the effort would be doubled up. So, I mean, we would often have, you know, certainly around multimedia, we would have camera technology and things that were integrated at the OS level. We would then sell our software to Nokia and find that Nokia already had exactly the same third-party vendor solution tied into S60. So they had to unplug ours, plug in theirs, re-attach it all, and you can imagine the kind of re-engineering efforts they were constantly having to make. And I think, for Nokia, that was probably why, in some ways, they ended up being one of the slowest handset vendors in terms of time to market.”

Knowledge sharing: facilitating inter-organizational communication

The organizational model also added complexity to coordinate development of the different subsystems. For example, Symbian’s ownership and development structure created a legal separation between OS and UI development, leading to additional challenges. For example, discussions about technological issues sometimes raised concerns about ownership of
intellectual property. A former Symbian employee working on legal issues relates this as follows:

“You know, when you're sitting there talking about know-how and processes and how to engineer things you have to be very careful that you're not giving away confidential information that one party would then patent, which then could cost more money for the other party. Because the licensing model whereby Symbian licensed to Nokia was quite restricted in many ways, because it had to be the same license to all our OEMs (i.e. handset makers), in the interest of treating them fairly. We had to be quite careful about the information we gave them. [...] You would find that engineers wanted to be so helpful that they would end up giving things to Nokia that we really couldn't afford to give them. Our whole regime would mean we would have to give it to everybody, and then we were kind of undermining our own business really. So you ended up in this awkward situation, where you'd end up with lawyers in a room who really didn't belong there.”


Finally, the fourth episode focuses on the establishment of the Symbian Foundation and its underlying motivations. In this stage, Nokia’s single ownership was subsequently complemented by shared ownership, with a cross-section of telecom firms joining the foundation’s governing board.34 Further, product development evolved from a single firm to a potentially much broader community of contributors. The Symbian Foundation focused on managing external contributions, as it did not have the resources to develop the various subsystems itself.35 Following the consolidation of the OS and UI, the system was

34 The foundation’s initial board members (each of which had a single governing seat) were AT&T, Nokia, NTT Docomo, Samsung, Sony Ericsson, ST-Ericsson, Texas Instruments and Vodafone, later joined by Qualcomm and Fujitsu.
35 The Symbian Foundation was a relatively small organization (with an approximate headcount of around 200) that had been set up to facilitate community development, rather than develop the code itself. The initial key
repartitioned into subsystems based around the concept of “software packages”. These subsystems were managed by a package owner, overseeing development of that particular subsystem. This partitioning is crucial for a system based around distributed development, as the various contributors were typically based at different locations and different companies.

A key environmental driver toward open sourcing Symbian was the emergence of Android, an operating system led by Google. As an open-source initiative, Android could be licensed free of charge, with the technology largely developed by Google. In contrast to open-source initiatives introduced earlier by other organizations (e.g. the Limo Foundation), Android was taken up rapidly by handset makers and mobile network operators. One interviewee reflects on this as follows:

“So there was external pressure from Android. But instead of responding with just a proprietary ‘Nokia OS’, instead it chose what I think is the correct competitive answer, going with an open strategy, a really open strategy with the Symbian Foundation”

Before establishing the Symbian Foundation, Nokia had gained experience with open source software development. Already in 2006, it had made use of open source development for its S60 web browser. It had also developed an alternative OS based on Linux called Maemo. Besides the emergence of Android and Nokia’s familiarity with open source, there were other drivers, expanded on below.

Licensee concerns: address single firm dependency

One issue for Symbian was that among some of its licensees, take-up of the technology had reached a glass ceiling. Especially in Japan, some handset makers used Symbian for entire

contributor was Nokia, which retained the majority of software engineers previously employed by Symbian Software Limited (original headcount circa 2000).
product lines. Other licensees were also increasingly uncomfortable being reliant on a single supplier for a technology that became more important strategically. As a former Symbian employee recalls:

“Towards the end of Symbian, the Japanese licensees and Nokia were becoming uncomfortable on being dependent on a single company. [This applied to] one of the Japanese licensees in particular, [who] had once missed a ‘season’ because of problems with one of their suppliers. So they were reluctant to become more and more dependent on a single firm. On the other hand, being dependent on a single technology was not an issue, as long as multiple firms were involved. So that favored open sourcing.”

Moving towards open source: anticipation and internal resistance

With respect to the move towards open sourcing, some interviewees emphasized that Symbian already had plans to partially move to an open-source type model. One interviewee recalls:

“[...] There had been a strategic project set up about a year before the announcement [that Symbian would be open sourced]. And that was looking at a closed source community whereby we were going to have a gated system that would use a modified version of the Apache license to look after all the non-differentiating software in Symbian OS. [...] So, really, for us to move towards a completely open platform was just kind of the next step in thinking. We hadn't thought that most people were ready, so we'd gone for this kind of mid-term level of closed source. It turns out that Nokia were far more ready than we thought.”

On the other hand, there were certainly signs of resistance among Symbian’s leadership team:
“Some members of Symbian Software’s leadership team were very opposed to changing the licensing deal. They thought, ‘this is the best deal we could ever get, we’d be crazy to undermine it’. So they were much opposed to the open source model.”

Summing up, a combination of environmental and firm-level changes drove adjustments in product and organizational architecture. In particular, the drivers highlight how architectural design choices were complicated by competing tensions around collaboration and competition. The next section discusses these findings in light of existing literature.

3.5 Discussion

Though existing research on organization and product architecture has made important progress, several issues remain. In examining the role of environmental and firm-level drivers over time, this study has attempted to address one of these gaps. In particular, it has focused on the ways in which firms respond to environmental changes and the architectural design challenges these raise. I would like to highlight in particular the following points. First, the study analyzes the role of strategic considerations and its impact on collaboration and competition. Second, I emphasize the tension in balancing commonality and differentiation, and its implications for mirroring. Third, the study points to the importance of examining the combined influence of environmental and firm-level drivers, and how they might require mutual adjustment between product and organization architecture. Figure 3.4 provides a visual overview of this process, showing how environmental and firm drivers shape product and organization architecture decisions, and subsequent environmental and firm-level outcomes.
Overview of episodes
[The visual representation of architectural design choices is meant to illustrate relative differences]
Episode 1: Environmental change shapes strategic and technological firm-level considerations, driving collaboration on product and organizational architecture based on common threats and benefits.
Episode 2: Firm level considerations (especially rivalry) drive product architecture differentiation, while maintaining organizational collaboration.
Episode 3: Environmental change and firm-level challenges (e.g. coordination, duplication of efforts) drive organizational centralization and product consolidation.
Episode 4: Environmental change drives separated product repartitioning and collaboration based on shared open source development.

Figure 3.4: Process framework highlighting combined impact of environmental and firm drivers on organizational and product architecture decisions

Strategic considerations and its impact on collaboration and competition
In this setting, architectural choices are shaped by both environmental and firm-level drivers, though strategic concerns might complicate this process. In line with Gulati and Singh (1998), organizational architecture decisions are characterized by a tension between collaboration and competition. On the one hand, common benefits or common threats drive collaboration, resulting in shared ownership. On the other hand, existing rivalry drives the need to control differentiating parts of the technology. This tension surfaces in particular in episodes 1 and 2. In episode 1, each of the incumbent handset makers shared the potential
threat of a dominant new entrant (Microsoft), driving the establishment of the Symbian joint venture. Besides responding to environmental changes, firm-level drivers also play a role in establishing organizational architecture. For example, unwillingness to share differentiating parts of the system (in particular the User Interface) created an organizational split between Symbian and its licensees, as witnessed in episode 2.

As such, these dynamics extend earlier work on the underlying drivers of cooperation. In particular, Gulati and Singh (1998) have emphasized the role of coordination and appropriation costs in determining governance and ownership boundaries. Related work on vertical relationships (Jaspers and Van den Ende, 2006) has further addressed this topic by distinguishing between ownership, coordination, task, and knowledge integration. Building on these works, this setting provides an additional viewpoint: that appropriation concerns might drive technological boundary setting, such that differentiation among shareholders is maintained. Yet, this choice further might further impact on coordination costs, which will increase given interdependence among subsystems. Therefore, strategic considerations may complicate organizational architecture decisions, in that coordination costs between different firms may increase, despite having a modular system design. As such, the role of strategic concerns might differ depending on the domain: here, at the environmental level, due to threats by new entrants, it can induce collaboration. However, at the firm-level, such collaboration might be complicated by other strategic considerations (e.g. rivalry among collaborators).

Technological considerations: balancing commonality and differentiation

Similar to strategic concerns highlighted previously, decisions driven by technological considerations are characterized by a tension between commonality and differentiation. In
particular, rivalry considerations may compromise product architecture, to the extent that subsystem boundaries are drawn sub-optimally, at least from a technological perspective. In addition, changes in organizational architecture may further prompt changes in product architecture, most clearly observable in episodes 3 and 4. In these stages, decisions regarding ownership and task structure (distributed vs. centralized) and subsystem partitioning (separated vs. consolidated) are interconnected. To a certain extent, this is in accordance with existing work on “mirroring”, as we observe a degree of isomorphism between product and organizational architecture.

On the other hand, it departs from existing work in a number of ways. First, existing empirical studies of “mirroring” have focused on measures related to coupling, i.e. degree of interdependence of subsystems (e.g. MacCormack et al., 2008). By contrast, this study has focused on how subsystem boundaries are drawn, which do not necessarily coincide with coupling measures. Second, this study highlights when organizations might change these boundaries, as opposed to some existing conceptualizations that implicitly treat mirroring as a one-off decision (i.e. either the levels mirror each other or not). Further, it is important to recognize the role firm actions play with regard to these architectural decisions; at least in this case, technological drivers are secondary to strategic firm-level considerations. This contrasts with previous research that has mostly emphasized technological factors (Sanchez and Mahoney, 1996) or has provided a more deterministic perspective on how organizations are influenced by e.g. changes in demand (see e.g. Schilling and Steensma, 2001).

Furthermore, extant research has emphasized that the decision to modularize products do not necessarily coincide with the decision to move the activity out of hierarchy, i.e. change ownership structure (Hoetker, 2006). This study highlights a related issue: the ongoing
challenges of partitioning product architecture when changing ownership structure. As highlighted in this setting, firm-level drivers, in particular strategic considerations, can severely complicate the modularization process at the product level, since technologically optimal subsystem boundaries do not necessarily coincide with strategic logic.

The combined impact of environmental and firm-level drivers: mutual adjustment between product and organization architecture

Overall, these findings extend recent studies that have explored organizational boundaries from a broader perspective (Santos and Eisenhardt 2005, 2009; Jacobides 2005; Jacobides and Winter, 2005; Jacobides and Billinger 2006; Baldwin, 2008). Complementing recent work on nascent markets (Santos and Eisenhardt 2009), this study highlights the combined impact of environmental and firm-level drivers and the challenges these raise in establishing, and re-establishing, organizational and product architecture.

In particular, the study highlights how the search for an appropriate set of “design rules” requires mutual adjustment between organizational and product architecture. At least in this setting, this process can, in particular at the product level, be characterized as an ongoing “negotiation” process. This process is complicated due to trade-offs between what is desirable strategically and technologically. Therefore product architecture changes might in turn affect organization architecture decisions (and vice versa), showing a reciprocal relationship. As such, this complements existing work that has emphasized the role of knowledge and the open ended and evolving nature of the organization design process (Brusoni and Prencipe, 2006). Previous studies have shown that, in some settings, knowledge boundaries and ownership boundaries do not coincide (Brusoni et al., 2001), and have emphasized the key role of knowledge in creating design rules of technological subsystems
(Brusoni and Prencipe, 2001, 2006; Takeishi, 2002). By contrast, this study has investigated how product and organizational architecture might shift over time, emphasizing how, beyond knowledge, the combined influence of environmental and firm-level drivers might further induce change.

3.6 Concluding remarks

This study has examined how environmental and firm-level drivers impact on product and organization architecture. In particular it has focused on changes in the competitive landscape through new entrants, as well as firm-level drivers, focusing on strategic and technological considerations. Based on a longitudinal study, the data highlight how the combined impact of environmental and firm-level drivers may provide challenges to the way firms establish (and re-establish) product and organizational architecture. Here, product architecture focused on partitioning of technological subsystems; organization architecture examined changes in ownership structure and development. Overall, the findings suggest a reciprocal relationship between product and organization architecture, requiring mutual adjustment to balance diverging demands, in particular collaboration and competition. Presenting a process oriented framework to analyze these changes over time, the study highlights the joint impact of these drivers, and the resulting tensions and trade-offs they might impose, in particular when strategic and technological rationales diverge.

More generally, the study adds to more recent work on architecture and modularity that has highlighted some of the challenges to how these concepts apply empirically (e.g. Sako, 2003; Staudenmayer et al., 2005; Brusoni and Prencipe, 2006; Brusoni et al., 2007; Fixson and Park, 2008; Zirpoli and Becker, 2011; Baldwin, 2008; Srikant and Puranam, 2008). Initial work on modularity mostly emphasized its potential benefits, e.g. in terms of flexibility and
adaptability. Not denying the potential benefits that modular architectures can provide, it is equally important to address some of the challenges that might emerge.

There are several limitations to the current study. First, it is important to keep in mind the limitations of a single case study. In particular, caution should be taken with regard to generalization to other settings: this setting was chosen on conceptual motivations, not for representativeness. As such, one important boundary condition might be the particular nature of the focal sector, i.e. software development. For example, particular properties of software (e.g. relatively high degree of codification and malleability) might make the product more flexible than the architecture of e.g. mechanical systems (Whitney, 1996; Woodard and West, 2009; Luo, 2010). Second, the relatively recent nature of the various changes precludes definitive statements about outcomes, e.g. regarding performance or longer-term relation to market share. On the other hand, a particular strength of process research, as attempted in this study, is the opportunity (and challenge) to “catch reality in flight” (Pettigrew, 1990, 1992).36

Though Nokia’s decision to phase out Symbian provides a strong indication of its diminished strategic relevance, Symbian’s overall status as a “success” or “failure” is somewhat ambiguous. It was successful in terms of establishing a technology that became dominant in the initial stages of the smartphone market. It also kept Microsoft at bay, one of the primary goals of the initiative. However, the technology failed to be widely adopted beyond the dominant Symbian licensee, Nokia. Further, following the rise of new entrants (most importantly Google and Apple), Symbian’s global market share has fallen from a market

36 The tendency to “sample on the dependent variable” (i.e. high emphasis on cases that generated successful outcomes) may not be limited to management research, but nonetheless colors the collective pool of studies that comprise the field (Denrell, 2003). From that perspective, avoiding this tendency towards selecting a clear-cut case of “success” partly redresses that bias.
leading 71% in 2006 to 22% in 2011 (third behind Google’s Android and Apple’s iOS). As a final twist, Nokia decided to license Microsoft’s Windows Phone operating system (and phase out Symbian, as well as Nokia’s alternative operating system Meego), the very firm perceived as the key threat to the handset makers, spurring Symbian’s founding. The decision to adopt an alternative technology provides the clearest indication of Symbian’s inability to compete with the systems offered by new entrants. Interestingly, these rivals include both firms that are more integrated (Apple, RIM), as well as organizations that chose a licensing model (Google’s Android operating system).

As mentioned, it is difficult to make conclusive statements regarding competitive outcomes given the rapid rate of change in this industry segment. Therefore, the managerial implications that might be derived from this setting are not straightforward. However, regardless of how the market will unfold, what the developments from this study do make clear are the challenges firms face in making architectural decisions. These design choices are particularly complicated when, as was the case here, there are tensions between what is desirable technologically, as opposed to strategically. Therefore, it is important that firms are aware of the additional architectural challenges that might arise in the development of complex technological systems, such as a mobile operating system. While eliminating these tensions entirely might not be realistic, identifying where possible tensions might arise, and deciding how the organization intends to deal with them, might mitigate the efficiency and effectiveness issues that plagued Symbian.

Future research might expand on this study in a number of ways. First, examining current findings in light of the literature on fit and configuration of interdependent elements of

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37 Marketshare data comes from Gartner.com
subsystems (Miller, 1996; Levinthal, 1997; Siggelkow and Rivkin, 2005) could be of interest. E.g. Siggelkow’s (2002) analysis of coherence among reinforcing or complementary elements could be applied to analyze fit, either within or between product and organizational architecture level. Second, follow-up work could test these findings in other settings. In particular, future studies could provide further verification of the role of environmental and firm-level drivers, and their subsequent impact on product and organization architecture. Cabigiosu and Camuffo’s (forthcoming) study provides one example of how to quantitatively operationalize the latter two measures. Finally, as briefly mentioned earlier, the case appears to provide pathways to the literature on platforms (Gawer and Cusumano, 2002, 2008; Gawer and Henderson, 2007; Gawer, 2009; West, 2003) and industry architecture (Jacobides, Knudsen and Augier, 2006; Pisano and Teece, 2007). In particular, given the current emphasis on subsystem demarcation, as opposed to e.g. connections to external subsystems of complementors, further studies could examine the impact of these interface choices.
Chapter 4

Industry architecture as a determinant of successful platform strategies: a case study of the i-mode mobile internet service
(co-authored with Annabelle Gawer) 38

4.1 Introduction

To analyze firms’ strategy and performance in their industrial context, management scholars have long represented relationships between firms in a given industry as a set of sequential, linear, supplier–buyer relationships, often referred to as a ‘supply chain’. Observation of today’s complex high-tech industries, however, has brought to the fore the idea that in many cases, industries can be better analyzed as networks of interconnected firms or ‘industry ecosystems’ (Iansiti and Levien, 2004), to try to capture the multidimensionality and the complexity of firms’ relationships. In this context, an important question is: What factors and processes drive value appropriation and value creation in interdependent industry ecosystems?

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38 This chapter is based on Tee and Gawer (2009); reprinted with permission. Earlier versions of this chapter were presented at the LBS Trans-Atlantic Doctoral Conference 2009 and the DRUID Summer Conference 2009. Thanks to all participants for useful feedback.
This chapter explores this issue through a case study of i-mode, a mobile internet service created by Japanese mobile network operator NTT Docomo. I-mode provides a favourable context to explore this question, for three reasons. First, i-mode’s setting constitutes an industry ecosystem, because i-mode was an innovation that was functionally dependent on a set of products, technologies and services developed by other firms. Second, i-mode is a platform, (Gawer and Cusumano, 2002, 2008), and as such, value creation and value capture are related in predictable ways: in particular, we know that platform firms cannot capture value without stimulating value creation by other members of the ecosystem. Third, the i-mode case presents us with a rich case of success and failure. I-mode was a striking success in Japan, but subsequent attempts to commercialize it in Europe resulted in stark failure (Funk, 2001; Fransman, 2002; Steinbock, 2003; Haas, 2005; O’Brien, 2007).

We analyze the deployment and commercialization of i-mode, and explore the reasons behind these contrasting outcomes, focusing on Japan and the Netherlands. I-mode’s failure is particularly surprising considering that NTT Docomo had taken a 15% equity stake in KPN, the Dutch network operator deploying i-mode. KPN benefited from information sharing on i-mode technology and had privileged access to the original Japanese strategy.

The platform leadership literature (Gawer and Cusumano 2002, 2008), has explained the reasons behind i-mode’s success in Japan, by positing that NTT Docomo had successfully pursued platform strategy aiming to stimulate and orchestrate ecosystem innovation. However, this literature does not explain why the same platform leadership strategy failed in the Netherlands. Our analysis suggests that the structural differences between Japan and the Netherlands in the rules and roles of industry actors, – in other words, differences in ‘industry architecture’ (Jacobides et al., 2006), – were fundamental.

39 To illustrate, whereas in Japan i-mode has an active user rate of 89%, in subsequent European deployments this percentage ranged from 0.2% up to 21%. Most European providers have since phased out the service.
The architecture of the mobile telecom industry in the Netherlands constrained the capacity of the incumbent network operator to influence other key players in the industry ecosystem to provide essential complements such as i-mode-specific handsets and i-mode-compatible applications – thus reducing i-mode’s attractiveness to end-users. We therefore suggest that KPN failed in its attempt to achieve platform leadership because of differences in underlying industry architectures. Thus, our findings suggest that combining a platform approach with an industry architecture perspective offers useful insights for firms seeking platform leadership, and for scholars aiming to develop theory in these areas. The success of NTT Docomo as a platform leader was predicated on the successful integration of mobile phone technology and content, which were combined in an innovative business model that sustained its ecosystem of software developers, handsets manufacturers, and customers in a virtuous cycle. Compelling content (developed by external developers) attracted customers who in turn increased the installed base and therefore attracted more developers to the i-mode ecosystem, and also gave NTT Docomo the bargaining power to set specifications to handsets manufacturers. Ultimately, KPN was unable to replicate this strategy successfully.

Our data suggest that the processes of industry regulation and deregulation and the emergence of industry standards played out differently in these two countries, and as a result the industries evolved differently. The industrial configurations in Japan and the Netherlands entailed different firms’ scopes, which held different relationships with other firms, leading to different sets of firms’ capabilities and degrees of bargaining power (this process is visually represented in Figure 4.1). The combination of these factors fit well with the way Jacobides et al. (2006) conceptualize industry architecture.
Figure 4.1: Platform - Industry architecture interaction framework

Although we are aware of the limitations of our study, which, given the nature of our data, can only offer exploratory results, this chapter is, to our knowledge, the first empirical study to attempt to explore the interaction between industry architecture and industry platforms. The chapter is structured as follows. Following this introduction, we outline the concepts of platforms and industry architecture. Next, we briefly describe the methods we used and the type of data we gathered for the study. We subsequently describe the case evidence of i-mode’s rollout in the context of the competitive dynamics of mobile telecom in Japan and the Netherlands. The following section offers our interpretation of the evidence. We conclude by presenting a discussion of our findings, indicate limitations of our study and point to directions for future research.
4.2 Background literature

The empirical puzzle of i-mode’s contrasting fortunes is connected to the broader theoretical issue of the dynamics of value appropriation and value creation in the context of interdependent economic systems. There is a rich literature exploring the factors driving firms’ ability to benefit from innovation. Teece (1986) and the stream of innovation and strategy research his work inspired (such as Tripsas, 1997), have generally examined this question at the level of the dyad between firms, examining the competitive dynamics between innovators and their followers, or incumbents vs new entrants. Although a useful simplification, in reality, the context within which value is created and distributed often consists of network of interdependent actors. On the other hand, research that has focused at the industry level, such as work on industry evolution (see for example, Klepper and Graddy, 1990; Klepper and Thompson, 2006) often takes a more structural approach, and tends to obscure the competitive dynamics associated with changing the logic of value creation and appropriation (see McGahan (2004) for an exception). In recent years, two theoretical perspectives, industry architectures and platforms, have attempted to explicitly address the issue of how value is created as well as captured in the context of interdependent systems of firms and institutions.

4.2.1 Industry platforms

Industry platforms are technological building blocks that act as a foundation upon which an array of firms, organized in a set of interdependent firms (sometimes called industry ‘ecosystem’), develop a set of interrelated products, technologies, and services (Gawer, 2009a, b). Platforms provide an essential, or ‘core’, function to an encompassing system-of-use. They are subject to so-called network effects, which tend to reinforce in a cumulative manner early-gained advantages such as an installed base of users, or the existence of
complementary products (Eisenmann et al., 2006). These platforms typically emerge in the context of modular industries (Baldwin and Clark, 2000; Baldwin and Woodard, 2009) or industry ecosystems (Iansiti and Levien, 2004).

Research on industry platforms (Gawer and Cusumano, 2002, 2008) and ecosystems (Iansiti and Levien, 2004) builds on earlier research on technology evolution and technological dominance (Utterback and Abernathy, 1975; Tushman and Anderson, 1986; Suarez, 2004; Murmann and Frenken, 2006), as well as literature on standards and network externalities (Katz and Shapiro, 1985; Shapiro and Varian, 1998). It also draws on literature on engineering design, product architecture and modularity (Ulrich, 1995; Baldwin and Clark, 2000; Schilling, 2000), and research on new forms of industry dynamics mixing competition and cooperation (coined as ‘co-opetition’, see Brandenburger and Nalebuff, 1996) which highlight the importance of ‘complementors’ – developers of complementary products and services.

Gawer and Cusumano (2002, 2004, 2008) have formulated strategies to allow firms to achieve platform leadership. ‘Platform leaders’ (Cusumano and Gawer, 2002; Gawer and Cusumano, 2002) are organizations that manage to successfully establish their product, service or technology as an industry platform. Platform leaders tend to drive industry-wide innovation in a trajectory that allows them to exert architectural control over the overall system, as well as derive large profits and erect barriers to entry in their own market.

Platform leaders are highly dependent on innovations developed by other firms, but, at the same time, aim to ensure the overall long-term technical integrity of the evolving technology platform (Gawer and Cusumano, 2002). Platform leaders aim to create innovation in
complementary products and services, which in turn increase the value of their own product or service. At the same time, they wish to preserve or increase competition among complementor firms, thereby maintaining their bargaining power over complementors. Platform leadership is therefore always accompanied by some degree of architectural control. Further, the momentum created by the network effects between the platform and its complementary products or services can often erect a barrier to entry from potential platform competitors. As such, establishing an industry platform requires not only technical efforts to increase value creation opportunities for the ecosystem participants, but also establishing a business model that is sustainable for ecosystem participants.

4.2.2 Industry architectures

Complementary to the research on platforms, a new strand of work centred on the notion of ‘industry architecture’ (Jacobides et al., 2006) has emerged. It focuses on the ways in which activities along the value chain get divided among industry participants, paying particular attention to firm roles, interdependencies, and the ways in which organizations attempt to shape the industry’s division of labour. The concept of industry architecture (Jacobides et al., 2006) defines the ways in which roles are distributed among interacting firms. Industries have fairly well-established rules about what activities each party undertakes, as well as roles played by industry players. Industry architecture defines both the division of labour between firms and the division of surplus in industries, and provide the template for both ‘who does what’ and ‘who gets what’. Industry architectures are characterized the distinct ways in which industries follow particular rules and how firms’ scope, roles, and relationships, account for the ways in which value gets both created and appropriated. Therefore, the concept of industry architecture echoes insights derived from institutional theory, invoking the informal ‘rules of the game’ as well as the formal legal framework that industry participants need to
adhere to. As such, an industry’s intellectual property (IP) regime can have an important effect on industry architecture (Pisano and Teece, 2007). Further, industry architecture has implications for the way firm capabilities are distributed within a particular industry (Jacobides and Winter, 2005). Environmental shocks, such as changes in regulation, can lead to significant changes in the way an industry organizes itself, with important implications for control or profitability of particular types of firms (Cacciatori and Jacobides, 2005; Jacobides, 2005).

Depending on the structure of the industry architecture, certain types of firms can capture more value than others. Jacobides et al. (2006) suggest that this ‘architectural advantage’ depends on two factors: complementarity and mobility of assets. Complementarity refers to the combined returns from the combination of two or more assets, with some combinations resulting in higher value creation than other combinations. Mobility concerns the number of assets that can potentially be combined to create such combinations, and switching costs of these assets should not be significant. Firms enjoy an architectural advantage when both factors are high. Recent contributions to the industry architecture literature include work by Ozcan and Eisenhardt (2009), who focus on network ties in relation to industry architecture formation; and Cowhey et al. (2008), who analyze the historical trajectories of technological networks in relation to industry architecture and public policy. As such, existing research on platforms and industry architecture has started to contribute to understanding how organizations influence the way work is divided among industry participants and its impact on value creation and value appropriation.
4.2.3 Industry architecture and platforms: impact on value creation and value capture

Research on industry platforms has highlighted the need to understand both the technological and business actions required to successfully establish a platform. It has highlighted the trade-offs between value creation and value appropriation resulting from product design choices such as those regarding opening or closing elements of the platform, as well as choices with regard to ecosystem governance. However, research in this area has largely been limited to the platform ecosystem itself, or to the interactions between different platform ecosystems. By contrast, research on industry architectures, which has emphasized how different actors’ roles along the value chain affect the overall distribution of value, has not specifically focused on platform structures or ecosystem interactions; as such, it may offer insights that extend beyond the platform ecosystem. Furthermore, research in this area has investigated the underlying drivers affecting the distribution of these roles. Therefore, it may be suggested that industry architectures provide the broader conditions in which industry participants, including potential platform leaders and complementors, operate. In turn, these participants may have the ability to shape the industry architecture to their advantage. However, it is unclear how exactly platforms play a role in this process and if and how the industry architecture affects the ability of players to successfully implement well-formulated platform strategies.

The complementarity between the industry architecture perspective and the platform approach should not come as a complete surprise. Research on platforms and on industry architecture share common themes, as they both aim to contribute to understanding how organizations influence the way labour is divided among industry participants and its impact on value creation and value appropriation. Another common theme is the central role of the notion of ‘architectural control’, also referred to as a ‘bottleneck’ in the literature on industry
architecture (Jacobides et al., 2006). As such, both research strands explore how different structural positions of firms affect value creation, profit, and value distribution. They cover similar territories but approach them from different angles. While research on platform strategies has focused on the rewards associated with managerial action (some of these rewards having to do with establishing architectural control, leading to an ability to extract superior profits), the concept of industry architecture lends itself towards the examination of how embedded and sometimes implicit structures may limit the scope for managerial action. Research on industry architecture, however, also suggests that such architectures can be manipulated by deliberate, forward-looking firms (and in this case, these behaviours much resemble firms’ attempts to establish platform leadership). At a more fundamental level, both platform literature and industry architecture literature grapple with the interaction between action and structure.

4.3 Data and methods

This chapter followed a case-study methodology, testing, and revising hypotheses throughout our data collection process (Eisenhardt, 1989; Yin, 2003). We collected data from written publications (industry publications, books, and articles) and interviews, aiming to get a better understanding of (1) the process of designing and deploying the platform; and (2) the various actors and roles in the industry architecture, where we focused on understanding the vertical scope of the actors and their relationships to other actors. To ensure that we obtained multiple perspectives of our phenomenon of interest, we interviewed representatives from all relevant actors. We carried out 50 interviews in three different periods (2002, 2004, and 2009), carrying out 21 interviews in Japan and 29 in Europe. The interviews followed a semi-

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40 During the first stage (2002) of our research, we tried to understand differences in success between the Japanese and European deployment of mobile internet services; in the second stage (2004), we focused on the development of several mobile platforms in the European mobile industry. As it became clear that industry architecture plays an important role in the development of these platforms, we focused our attention on the
structured protocol and lasted on average for an hour. The first two sets of interviews were conducted face-to-face, whereas the last set was done via telephone. Interview reports were submitted to interviewees for verification. One of the authors presented intermediate findings at a conference targeted at industry and public policymakers, organized by one of the European i-mode operators, providing feedback on our initial findings. We tried to ensure triangulation of our data using these different sources of evidence.

4.3.1 Choice of country comparator

Following the success of i-mode in Japan, the service was deployed in over a dozen countries outside of Japan. (Table 4.1 gives an overview of the European countries where the service was introduced.) The choice of the Dutch context for i-mode’s commercialization was predicated upon its structural similarity with Japan, to the extent that the respective i-mode champions KPN and NTT Docomo were both market leaders, network operators, and incumbents. It might have been preferable, given the size of the domestic Japanese market, to have sought a comparison with the wider European market – but a single European market does not yet exist in telecommunications, as telecom regulations are still largely determined nationally and not at the European level. Further, KPN was the first operator after NTT Docomo to introduce i-mode. As such, this comparison decreases the time difference of the introductions. Secondly, KPN, like NTT Docomo, was the incumbent operator and crucially, market leader when i-mode was introduced. This contrasts with the majority of other European i-mode operators, most of which were challengers. Third, among the various i-mode deployments outside of Japan, cooperation between NTT Docomo and KPN was

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interplay between platforms and industry architectures, revisiting and expanding our initial data collection. Finally, in 2009 we held additional interviews to get further reflection, particularly on the deployment process in the Netherlands.

arguably strongest, given the timing of the introduction and the financial stake NTT Docomo held in KPN at that time. As such, this choice reduces the influence of differences in, for example, strategy that may have otherwise impacted on the deployment of the service.

<table>
<thead>
<tr>
<th>Country</th>
<th>Operator</th>
<th>I-mode introduction</th>
<th>I-mode subscribers millions - (total subs) - i-mode users %</th>
<th>Current status</th>
<th>Handsets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>NTT Docomo</td>
<td>Feb 99</td>
<td>48 (54) – 89%</td>
<td>Active</td>
<td>Casio, Fujitsu, Hitachi, Kyocera, Mitsubishi, NEC, Panasonic, Sanyo, Sharp, SonyEricsson, Toshiba; HTC, LG, Motorola, Nokia, Pantech/ Curitel, RIM, Samsung</td>
</tr>
<tr>
<td>Germany</td>
<td>E-Plus</td>
<td>Mar 02</td>
<td>1.1 (7.8) – 14%</td>
<td>Phased out Apr 08</td>
<td>NEC, Toshiba, Panasonic, Mitsubishi, Samsung</td>
</tr>
<tr>
<td>Netherlands</td>
<td>KPN</td>
<td>Apr 02</td>
<td>0.8 (4.9) – 16%</td>
<td>Phased out Jul 07</td>
<td>NEC, Toshiba, Panasonic, Mitsubishi, Samsung</td>
</tr>
<tr>
<td>Belgium</td>
<td>BASE</td>
<td>Oct 02</td>
<td>0.3 (1.4) – 21%</td>
<td>Handset procurement cancelled</td>
<td>NEC, Toshiba, Panasonic, Mitsubishi, Samsung</td>
</tr>
<tr>
<td>France</td>
<td>Bouygues</td>
<td>Nov 02</td>
<td>1.1 (7.2) – 15%</td>
<td>Handset procurement cancelled</td>
<td>NEC, Toshiba</td>
</tr>
<tr>
<td>Spain</td>
<td>Telefonica</td>
<td>Jun 03</td>
<td>1.1 (19) – 6%</td>
<td>Handset procurement cancelled</td>
<td>NEC</td>
</tr>
<tr>
<td>Italy</td>
<td>Wind</td>
<td>Nov 03</td>
<td>0.7 (14) – 5%</td>
<td>Handset procurement cancelled</td>
<td>NEC</td>
</tr>
<tr>
<td>Greece</td>
<td>Cosmote</td>
<td>Jun 04</td>
<td>0.5 (4.2) – 12%</td>
<td>Handset procurement cancelled</td>
<td>NEC, Panasonic</td>
</tr>
<tr>
<td>Russia</td>
<td>MTS</td>
<td>Sep 05</td>
<td>0.1 (48) – 0.2%</td>
<td>Phased out Jul 06</td>
<td>NEC</td>
</tr>
<tr>
<td>UK</td>
<td>O2</td>
<td>Oct 05</td>
<td>0.25 (14.2) – 2%</td>
<td>Phase out planned Mid 09</td>
<td>NEC, Samsung</td>
</tr>
<tr>
<td>Ireland</td>
<td>O2</td>
<td>Oct 05</td>
<td>n/a (1.5)</td>
<td>Phase out planned Mid 09</td>
<td>NEC, Samsung</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>Globul</td>
<td>Sep 06</td>
<td>n/a (1.3)</td>
<td>Active</td>
<td>Samsung, Motorola</td>
</tr>
<tr>
<td>Romania</td>
<td>Cosmote</td>
<td>May 07</td>
<td>n/a (2.0)</td>
<td>Active</td>
<td>Sony Ericsson, Samsung, LG, Sagem</td>
</tr>
<tr>
<td>Germany</td>
<td>O2</td>
<td>Introduction cancelled (Mar06)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.1: Deployment of i-mode in Japan and various European countries
We did not choose to compare Japan with larger European countries (e.g. Germany, UK, France, Italy) for a number of country-specific reasons. In Germany, i-mode operator E-plus was a challenger; this also applies to Bouygues in France and WIND in Italy. In the UK, O2 might have been considered, though it was no longer the market leader when it licensed i-mode, and crucially, introduced the service more than 6 years after NTT Docomo. As such, choosing a mid-sized operator and market leader like KPN appears to be the most suitable choice. Of course important disparities between both countries remain, including population size, cultural differences, degree of internet penetration, etc. While recognizing the limitations introduced by these variations, we will argue that the overall patterns observed in the Netherlands can to a large extent also be applied to other European i-mode deployments, given similarities in industry architecture roles and conditions.

4.3.2 Case evidence: i-mode rollout and industry dynamics

This section presents evidence on i-mode’s rollout in Japan and in the Netherlands, and provides background on industry dynamics, including regulation and standardization. I-mode is an example of a mobile internet service, operating among a wider spectrum of offerings. In Europe, most network operators focused on delivering mobile internet services via standard protocols, in particular Wireless Application Protocol (WAP) and Multimedia Messaging Service (Sigurdson, 2001; Steinbock, 2003). Later, i-mode came to encapsulate these standards into its offering. As such, i-mode provides a richer service than competing standards-based mobile internet services (e.g., providing push e-mail and instant messaging) – albeit at the cost of providing a narrower range of handsets. More recently, mobile internet solutions have been provided as specialized e-mail solutions (e.g., RIM’s BlackBerry devices) or through mobile web browsers that make use of larger touch screen displays (popularized in Apple’s iPhone). I-mode requires a network operator who needs to
orchestrate the relevant content and services and make sure the mobile devices are aligned to these services. I-mode can therefore be construed as an operator-centric solution to providing mobile internet services. This might be contrasted with more recent business models, such as device-centric models exemplified by Apple’s iPhone (Ballon, 2009).

I-mode was introduced in Japan in February 1999 and its subsequent success has been well documented (see Funk, 2001; Fransman, 2002; Gawer and Cusumano, 2002; Steinbock, 2003). In 2007, 48 million users out of NTT Docomo’s 54 million subscribers used i-mode, 89% of their user base. I-mode’s deployment outside of Japan has been very different. As of 2007, 5 years after the European rollout started, initial i-mode providers have phased out the service. Compared to NTT Docomo, the difference in i-mode subscribers is especially striking, with no European operator having been able to reach more than 21% of their user base. Table 4.1 compares i-mode’s Japanese deployment to Europe, identifying the time of introduction, number of subscribers, status of the service, and i-mode handset suppliers. In the following section, we describe deployment process in more detail.

4.3.3 I-mode’s rollout in Japan

From i-mode inception in 1997, NTT Docomo made several decisions regarding its technical design as well as its business model, including its approach to content, handsets specifications, and pricing. It used a revenue-sharing agreement to induce content provision and implemented a micropayment system where users were billed for the data they consumed. NTT Docomo would charge a 9% transaction fee for monthly user fees, with the remaining 91% going to the content provider. The micropayment system could only be used by official i-mode content providers, who were linked from the i-mode home menu. These approved content providers needed to adhere to several rules, such as a limit on the monthly fee, and
types of content. Handset makers were enlisted to design i-mode handsets, focusing on a uniform user interface, menu, and dedicated i-mode and mail buttons.

At the launch, only one i-mode handset was available, with 67 content providers having signed up. Three additional i-mode handsets were introduced soon after, while NTT Docomo continued to improve the platform’s functionality. In contrast to expectations, entertainment (ringtones and screensavers) initially proved most popular, rather than more functional usage such as mobile banking or news (Funk, 2001). However, as the design of the platform facilitated fast and accurate feedback, the range of content could quickly be adjusted and rapid entry of additional content providers ensued. Following the success of i-mode, NTT Docomo subsequently made i-mode available via its 3G service FOMA, and later expanded into other services including mobile payments (FeliCa), mobile television (1seg), and music downloads.

4.3.4 I-mode’s rollout in the Netherlands
KPN introduced i-mode in the Netherlands in April 2002, phasing out the service 5 years later. Discussions between NTT Docomo and KPN regarding cooperation started in the summer of 1999, about half a year after the Japanese launch. The companies were looking for ways to cooperate on mobile multimedia services. KPN organized several senior management level visits to Japan, as well as a visit of potential end-users to assess customer response. Given positive reception from both constituencies, KPN decided to pursue the opportunity. In May 2000, NTT Docomo took a 15% share in KPN mobile; in September 2000, the firms issued a licensing agreement to introduce ‘i-mode like’ services.\(^{42}\)

\(^{42}\) The phrasing in the press release was deliberately vague because negotiations about the license were still ongoing.
NTT Docomo played an important role in KPN’s launch of i-mode. For example, the Japanese firm trained and hired additional people so that they were able to cooperate effectively in English. It also made a number of considerable technical investments: for instance, since Japan used a different network standard than Europe, NTT Docomo decided to build a customized test network (based on the European GPRS standard) to be able to test and prototype handsets and services in Japan. NTT Docomo also helped with negotiating handsets, and was instrumental in acquiring the first Global System for Mobile communications (GSM)-based i-mode phone. Subsequent handsets, such as models from Samsung, were also procured with the assistance of NTT Docomo. Also, KPN and NTT Docomo worked together to attract other operators to license i-mode. Finally, NTT Docomo located its European i-mode headquarters in the Netherlands. Concurrently, the KPN team worked on the design of the service. One important decision was which standards to include in translating NTT Docomo’s Japanese i-mode specifications, in particular, with regard to e-mail and browsing functionality. Whereas NTT Docomo was used to being able to essentially prescribe its standards to handset makers (Funk, 2001), KPN felt it needed to adjust the specifications to the context of the GSM market. This meant that it tried to base content delivery specifications around WAP–OMA standards, so that handsets would be easier to customize to i-mode’s requirements. Further, it was expected that the convergence towards a single 3G standard would also facilitate procurement of future Japanese 3G i-mode handsets.

In the buildup to the launch, a select group of pilot users responded largely positively to both the handset and the range of services. The accompanying handset was developed by NEC, an experienced Japanese handset maker, – but an entrant to the GSM market. Further, KPN had enlisted over 50 i-mode content providers, covering a wide spectrum of well-known firms, including major newspapers, banks, and entertainment providers. Media interest in i-mode
was high. Still, in spite of high initial visibility and expectations, i-mode adoption was slower than expected. KPN had set a target of 1 million users by the end of 2003 – but failed to attain this (Van Impe, 2003).

One reason for i-mode’s slow adoption, in contrast to Japan, was that procurement of i-mode handsets proved to be more difficult than anticipated. At the outset, no major GSM handset maker was willing to develop a customized i-mode handset. As a result, KPN was initially dependent on Japanese handset makers who, with the help of NTT Docomo, were willing to develop customized i-mode handsets. However, their inexperience in developing handsets for the GSM market negatively affected the quality of the initial handsets (in terms of size, battery life etc.). Further, KPN’s expectation that Japanese 3G handsets might be procured more easily would not materialize. The differences between Japanese and European 3G handsets proved to be substantial, as handsets still required support for the different underlying 2G networks.

When faced with the lack of commitment from GSM vendors, KPN decided to loosen the i-mode specifications for handset makers. In contrast to the strict ways in which NTT Docomo was able to prescribe handset specifications in Japan, KPN introduced an additional class of handsets, which did not offer full i-mode functionality (e.g., in terms of e-mail functionality), but were largely compatible with i-mode sites. Second, KPN and NTT Docomo also tried to address the issue of lack of volume by enlisting other operators to license i-mode. This group of operators joined forces in the i-mode alliance, sharing best practice, negotiating with content or marketing partners, and developing technical specifications. However, the most important goal was to increase bargaining power vis-à-vis leading handset makers, in

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43 One example of a collective marketing endeavor was i-mode’s sponsorship of Renault’s Formula 1 team in 2004.
particular the market leader Nokia. Even as the i-mode alliance expanded, the service would not reach the required scale to convince Nokia to develop dedicated i-mode handsets. NTT Docomo’s leverage in Japan eventually persuaded Samsung and Sony Ericsson to release a number of i-mode-compatible handsets. Still, none of these models were developed exclusively for i-mode. The only exclusive i-mode handsets were developed by Japanese manufacturers, which had low brand recognition to European end-users.

In terms of content and applications, KPN continued to expand the number of i-mode sites, totalling around 250 providers before the service would be phased out in 2007. Meanwhile, even though it had put significant amount of resources in i-mode, it still needed to support mobile internet services based around the WAP protocol, as the large majority of KPN’s handsets comprised non-i-mode models.\textsuperscript{44} In May 2006, KPN decided to make a selection of i-mode sites (50) available via WAP, hoping to attract more users to the complete i-mode service. Still, the strategy of selectively disclosing i-mode content would have no significant impact on the success of the service. Finally, in July 2007 KPN announced its decision to phase out the service.

4.3.5 Regulation and deregulation processes: comparison between Japan and the Netherlands

Regulation plays a crucial role in defining market conditions in mobile telephony, as they allocate the radio spectrum licenses that provide the conduit for transmitting data wirelessly – as such, regulators can shape the nature of competition (Kushida, 2007). In Japan, the regulatory framework shaped competition to the advantage of the network operator. In particular, it strengthened the position of NTT Docomo by weakening outside competition

\textsuperscript{44} We would like to thank an anonymous reviewer for prompting this issue.
and also increased its bargaining power over local handset makers, who were largely confined to the Japanese market.\footnote{In Japan, the two key regulatory actors are the Ministry of Internal affairs and Communication, formed in 2004 and the Japan Fair Trade Commission. Prior to the formation of MIC, telecoms regulation was part of the Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT), formed in 1999. In turn, before that regulation was responsibility of the Ministry of Post and Telecommunications, which was later subsumed into the MPHPT (ITU, 2002; Kushida, 2007).}

By contrast, in the Netherlands, the regulatory framework in the Netherlands has resulted in strong competition for incumbent operator KPN.\footnote{Dutch telecom regulation is managed jointly by the national regulator Independent post and telecommunications authority (OPTA) and the relevant European Union (EU) bodies. Telecommunications policy is the responsibility of Directorate- General for Energy and Telecom (DGET) (formely Directorate- General for Telecom and Post (DGTP)), a directorate of the Ministry of Economic Affairs. Allocation of the 3G licenses was done by the Ministry of Transport who, advised by OPTA and Nederlandse Mededingingsautoriteit (NMa) (the national competitions authority), decided to distribute these via a competitive auction. Also, EU directives typically inform national policy and regulation.} Combined with standardization dynamics, expanded upon in the next section, this has had a strong influence on KPN’s (and other GSM operators’) capability development. In 1994, partial privatization of KPN was initiated. The next year a mobile license was granted to challenger Libertel (later acquired by Vodafone). Additional 2G licenses were made available in 1998, resulting in competition among four (initially five) competitors. Though its market share has decreased over time, KPN has always retained its market leader position.

Overall, the Dutch telecommunications market is considered to be one of the most competitive in Europe. For example, in 2007 the European Competitive Telecommunications Association, an organization of new entrant telecoms operators, ranked the Netherlands second in terms of competitiveness after the UK. As such, it may be argued that KPN has faced a tougher competitive environment compared to NTT Docomo. For example, in 1999 OPTA further encouraged competition by designating KPN and Libertel as holding significant market power. Further, mobile number portability was introduced in 1999, making it, together with the UK, among the first countries in Europe to do so (Buehler and Haucap,
Furthermore, in contrast to the Japanese ‘beauty contests’, many national regulators in Europe, including the Netherlands, awarded 3G licenses via competitive bidding auctions. As a result, some of these licenses, especially those auctioned at the height of the dotcom bubble, were auctioned at very high costs, putting additional financial pressure on many network operators. In the Netherlands too, 3G license costs were substantial and would initially constitute one-third of KPN’s total debt (The Economist, 2001).

4.3.6 Standardization dynamics in Japan and in the Netherlands

Standardization dynamics followed different paths in Japan and in the Netherlands, with important implications for firms’ capabilities and relative bargaining power. In Japan, the lack of global uptake of the Japanese Personal Digital Cellular (PDC) network standard had important repercussions for both the intensity of competition among operators, and set limits on the expansion of handset makers. By contrast, in Europe, the success of the GSM standard had the reverse effect: the standard intensified competition for incumbent operators, while expanding opportunities for handset makers.

The confinement of the PDC standard to Japan had important repercussions for the Japanese market. In particular, it constituted an advantage for NTT Docomo, since it dissuaded outside competitors from entering the market. Following the liberalization of the handset market, consolidation of network operators led to a situation where 13 handset makers (only two of which, Nokia and Motorola, were non-Japanese) were supplying three operators (Haas, 2005). The dependency of Japanese handset makers on their local market was further exacerbated by their difficulties to enter more lucrative GSM markets; prohibitive licensing

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47 MNP became mandated in Europe only in 2003, as part of the EU’s Universal Service Directive.
48 For example in the UK, total licensing costs amounted to £ 22.47 billion and in Germany to € 51 billion (see Binmore and Klemperer (2002) for background information on the 3G auctions).
costs for non-IP holders were an initial impediment here (Bekkers et al., 2002). Furthermore, attempts to enter foreign markets by cooperating with European i-mode providers were, as mentioned, largely unsuccessful.

In the Netherlands, by contrast, standardization benefited handset and equipment providers more than network operators. In particular, the success of the GSM standard allowed a number of handset and equipment providers (in particular Nokia and Ericsson, prior to that largely confined to their small national markets) to expand, establishing themselves as multinational players (Steinbock, 2003). Spurred by rapid growth and global expansion, their underlying knowledge base and capabilities developed accordingly. A handful of GSM handset makers would come to dominate the market, targeting their handsets and equipment to more than 200 network operators in over 100 countries. As such, during the global expansion of GSM in the mid to late 1990s major manufacturers had strong incentives to prevent fragmentation and therefore refused to produce customized handsets (Haas, 2005). Meanwhile, incumbent network operators such as KPN were primarily engaged in fending off competition, emanating from new entrants as well as incumbent providers expanding abroad. In this process, the technical knowledge and ‘R&D engines’ of the mobile telecommunications industry had steadily moved from the research laboratories of incumbent operators into the domain of specialized equipment manufacturers (Hommenen and Manninen, 2003). Focusing on their core capabilities allowed some new entrants (e.g., Vodafone) to expand globally; collectively, however, GSM network operators increasingly ceded technological control to the specialized handset and equipment providers. Operators recognized this and responded through individual initiatives such as i-mode and Vodafone Live. In addition, network operators, including KPN, united in the M-services initiative, an attempt to specify a minimum set of requirements to handset makers, recognizing the mutual
benefits for all operators. However, this collective initiative also failed to catch on, due to coordination problems among operators, lack of technological competencies and bargaining power (Haas, 2005).

The development of WAP provides another illustration of the difference between Japan and Europe. WAP was part of the first attempt to offer mobile internet services in GSM markets. These services failed to rouse much interest from application developers and end-users. The approach differed fundamentally from solutions such as i-mode, in that WAP was set up by handset makers to act essentially as a standardized protocol for data delivery. As such, WAP had not been designed to include any of the features of i-mode such as revenue sharing, micropayments, and initially not even the standard HyperText Markup Language (HTML) language, which would have made a difference for application developers. Rather, WAP used Wireless Markup Language, a new markup language that made it more cumbersome for application developers to develop WAP-based services (as opposed to i-mode which was based around Compact HTML (cHTML) from the start). In short, the handset makers, who had taken the technological lead in WAP, did not create or protect incentives for complementary developers (such as application developers). European operators, because of their diminished capabilities, largely lacked the capabilities to knowledge to specify handsets requirements, and to set up the billing or micropayment systems which would have incentivized application developers.⁴⁹ So, from the perspective of the ecosystem, WAP failed to protect the incentives of all required complementors. In contrast, i-mode, with its reliance on cHTML (an easy language for application programmers) and its revenue-sharing model using the micropayment method (which allowed application developers to make money

⁴⁹ As a further illustration, when Austrian network operator Mobilkom announced the launch of its 3G network service, it could not offer customers a single 3G handset, being dependent on timelines of handset manufacturers (Poropudas, 2002).
easily on their applications) was a more compelling proposition for a wide class of complementors.

4.4 Interpretation: differences in industry architecture account for different outcomes when implementing platform leadership strategies

This section presents our interpretation of the case evidence, with the view to explain the puzzle mentioned at the outset of the article (success of i-mode in Japan, failure in the Netherlands). We interpret the differences in context (in particular, different outcomes of the deregulation process as well as the emergence in Europe of dominant handset makers associated with the GSM standard) as leading to differences in industry architectures with, in particular, in European operators’ diminished capabilities and bargaining power over handset makers. These, in turn strongly affected the chances of success of operators such as KPN, despite its attempt to replicate in its geography what had been a successful strategy in Japan.

4.4.1 Firms’ scope, relationships, capabilities and bargaining power

Differences between Japan and Europe in regulation and standardization led to a different set of firms’ scope, knowledge base and capabilities, relationships, and ultimately bargaining power vis-à-vis other firms. The Japanese rollout of i-mode suggests that NTT Docomo possessed, or could successfully acquire, the relevant knowledge and capabilities to successfully coordinate the service. These include building the necessary billing and micropayment systems, setting up revenue-sharing arrangements and providing various network adjustments. As such, the platform successfully incentivized content providers and handset makers. Most importantly, NTT Docomo had the ability to specify handset requirements to ensure seamless integration between the handset and the service. By contrast, no European network operator possessed comparable knowledge or capabilities at the time.
NTT Docomo introduced i-mode: as mentioned, European mobile internet services were initially based on WAP, a network protocol where handset providers, not network providers, took the lead (Sigurdson, 2001). Tables 4.2 and 4.3 describe the key actors and the roles they fulfil. The structure of relationships is visually illustrated in Figures 4.2 and 4.3.

<table>
<thead>
<tr>
<th>Actor</th>
<th>Roles</th>
<th>Relationships to other actors</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Infrastructure equipment provider</td>
<td>Develop network infrastructure equipment (base stations, switches etc)</td>
<td>Supplier to all network operators, adapted to network standard (PDC-WCDMA or CDMA/CDMA2000)</td>
</tr>
<tr>
<td>(2) Mobile handset provider</td>
<td>Develop handset, customized to network operators' requirements</td>
<td>Supplier to all network operators, adapted to network standard (PDC-WCDMA or CDMA/CDMA2000); operators require exclusivity</td>
</tr>
<tr>
<td>(3) Network operator</td>
<td>Provide network service Specify functionality and brand handset Manage voice and data (inc third party content) billing</td>
<td>Buyer from handset providers, requires exclusivity Supplies to all independent retailers Regulates content and applications provider</td>
</tr>
<tr>
<td>(4) Content provider</td>
<td>Create content (e.g. news, entertainment info) and applications (e.g. games)</td>
<td>Supplier to network operator via proprietary network service</td>
</tr>
<tr>
<td>(5) Independent retailer</td>
<td>Sell handsets Sell network subscriptions</td>
<td>Buyer of handsets and network subscriptions from all network operators Supplier of handsets and network subscriptions to end-users</td>
</tr>
<tr>
<td>(6) End-user</td>
<td>Purchase handset and mobile service</td>
<td>Buys handsets and network service from independent retailers</td>
</tr>
</tbody>
</table>

Table 4.2: Actors and roles in the Japanese mobile industry
<table>
<thead>
<tr>
<th>Actor</th>
<th>Roles</th>
<th>Relationships to other actors</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Infrastructure equipment provider</td>
<td>Develop network infrastructure equipment (base stations, switches etc)</td>
<td>Supplier to all network operators using GSM standard</td>
</tr>
<tr>
<td>(2) Mobile handset provider</td>
<td>Specify handset features and design Brand handset Sell handset</td>
<td>Supplier to all network operators*, retailers, or end-users</td>
</tr>
<tr>
<td>(3) Network operator</td>
<td>Procure handsets Provide network service Manage voice and data billing Sell network service and handset</td>
<td>Buyer from all handset providers. Supplier to all independent retailers, or directly to end-users</td>
</tr>
<tr>
<td>(4) Content provider</td>
<td>Create content (e.g. news, entertainment info) and applications (e.g. games)</td>
<td>Supplier of content and applications directly to end-user via standard protocol (e.g. WAP, SMS)</td>
</tr>
<tr>
<td>(5) Independent retailer</td>
<td>Sell handsets Sell network services</td>
<td>Buyer from all handset makers and all network operators Supplier to all end-users</td>
</tr>
<tr>
<td>(6) End-user</td>
<td>Purchase handset and mobile service</td>
<td>Buyer from all handset makers and network operators. Can mix and match network and handset type via independent retailer *</td>
</tr>
</tbody>
</table>

**Table 4.3:** Actors and roles in the European-Netherlands mobile industry

* Exceptions are (1) mobile phones (typically low-end) exclusively procured from “ODM” handset makers and branded by the network operator, and (2) “premium” handsets such as the Apple iPhone which in some countries are supplied exclusively; however, in the second case, this form of exclusive tying is not allowed in some countries because of the regulatory framework.
Figure 4.2: Relationship structure mobile industry in Japan

Figure 4.3: Relationship structure mobile industry in the Netherlands
For i-mode to provide an architectural advantage or a ‘bottlenecks’ for KPN (in other words, for KPN to achieve platform leadership with i-mode), KPN would have needed to successfully induce both competition and innovation at the level of complementary products (such as handsets and applications). It failed on both accounts. It was not able to provide the right incentives to handsets makers to create i-mode-specific handsets (complementarity). And it was not able to muster a compelling enough business model that would incentivize its complementors (handset makers and application developers).

Fransman’s (2002) account of the mobile industry provides further explanation of the observed differences in knowledge and capabilities, analyzing how European network providers have increasingly become reliant on specialist equipment providers more actively engaged in R&D. In fact, European operators have an R&D intensity comparable to sectors typically not considered to be hightech, for example beverages and personal care (Fransman, 2002). Crucially, NTT Docomo provides the key exception here. Specifically, in 1999, the year both i-mode and WAP were introduced, the R&D expenses as a percentage of sales of NTT (NTT Docomo’s parent company) are approximately twice as large as its main competitors (AT&T, BT, Deutsche Telekom, and France Telecom), and the R&D expenses per employee are approximately five times as large (Fransman, 2002).

It is important to be precise about the role of R&D. Although NTT Docomo’s strong commitment to R&D has often been remarked (see, e.g., ITU, (2002)), and should not be underestimated, we should also note that NTT Docomo’s main competitors, KDDI and Softbank, also have the relevant orchestrating capabilities – despite lacking the size of NTT
Docomo’s R&D budget. As such, we interpret the distribution of R&D expenses in this context as follows: on the one hand, it provides an indication of the rise of handset vendors in Europe. On the other hand, in the Japanese case, it also illustrates the importance of maintaining these capabilities. However, given the relatively high R&D expenses of globally dominant operator Vodafone, R&D expenses by themselves appear not to be a sufficient explanation. The regulatory framework and standardization, expanded upon earlier, have also played an important role. As such, simply increasing R&D expenses would probably not restore the operator’s position in Europe, given the way the industry architecture has emerged as a path-dependent, historically shaped process. Therefore, overall, it is the historically developed structure of the relationships that is key here and NTT Docomo’s initial capabilities may have been a prerequisite to establish the current Japanese industry architecture.

In Japan, these capability differences are subsequently reflected in the type of actor that provides the main brand to the end-user. NTT Docomo’s informal agreements to delay handset shipments (Funk, 2003) was particularly harmful to competing operators, though it also impacted on handset makers. There were incentives for handset makers to cooperate with these exclusivity arrangements: it gave them access to information ahead of their rivals; it reduced competitive pressure as only a small number of manufacturers could join the arrangement; and it guaranteed sales volume as the operator committed itself to purchase a first batch of models (Haas, 2005). At the same time, it made it more difficult for handset makers to establish their brand to consumers. As a result, in Japan the ‘guarantor of quality’ (Jacobides et al., 2006) function is taken up by the network operator. In Japan, i-mode has

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50 As an illustration, in 2007, Docomo’s R&D budget totalled ¥ 99,315 million ($845 million); by contrast KDDI’s R&D budget in the same year was ¥ 2283 million ($23.8 million), and Softbank’s ¥ 833 million ($ 8.8 million); for the GSM operators, Vodafone’s R&D budget in 2007 was € 222 million and KPN’s € 16 million (source: annual reports).
enabled NTT Docomo to further strengthen its position in the industry architecture: it has enhanced its brand, and expanded its scope to payment services, music downloads, and mobile television. By contrast, when European operators decided to introduce i-mode – effectively an attempt to reshape the industry architecture – they were too late. In Europe, handset makers had firmly established themselves as guarantors of quality (ITU, 2002) and also possessed the relevant capabilities to consolidate and expand this role, in particular market leader Nokia. Efforts of European operators to counter this can be witnessed in attempts to either co-brand handsets or reduce the visibility of the handset maker altogether in the case of handsets by Original Design Manufacturer (ODM) suppliers. Yet, handset makers, especially top tier vendors, also realized it was not in their interest to diminish their brand by allowing another actor (the operator) to co-brand.

4.4.2 Japan and the Netherlands: different industry architectures

For historical reasons that relate to regulation and standardization processes, the European and Japanese contexts differed in several respects. As a result, the respective industries differed not only in which firm(s) were the main sources of innovation (i.e., who created value) in the industry, but also how value was captured and appropriated in the industry (i.e., who held bargaining power over other actors in the ecosystem – or network of co-specialized assets). Both the capacity to create value and the ability to hold bargaining power were underpinned by specific firms’ capabilities, as we explained earlier in this section. While in Japan the incumbent operator was both the repository of capabilities and the holder of bargaining power over the other actors of the ecosystem, in the Netherlands the operator held

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51 Examples of this include music platforms (Nokia ComesWith- Music) that bypasses the mobile operator and are sold directly by retailers or by Nokia itself; another example is Nokia’s Ovi platform, which acts as portal to personal content (e.g. contacts, photos, music) as well as third party services.

52 Examples of this include Vodafone’s attempts to introduce handsets exclusively branded with the Vodafone label (Steinbock, 2005), as well as other European operators (e.g., Orange or Three) that often co-brand their handsets with the operator logo.
neither. In Japan, bargaining power as well as innovation lay with the operator NTT Docomo. The enduring and embedded structure of relationships between economic players, combined with the firms’ distinct respective abilities to create value by innovation as well as to appropriate value due to their bargaining power, constrained the network operators’ ability to achieve similar outcomes from replicating the platform strategy that worked in Japan.

Taken together, these variables (firm’s scope, bargaining power, capabilities, and relationships with other firms), correspond well to what Jacobides et al. (2006) refer to as industry architectures. Let us recall that in their definition, industry architectures are the templates that define the nature of co-specialization, as well as the way surplus is divided between the co-specialized players. More precisely, they provide two templates, each comprising a set of rules: (1) a template defining the division of labour, that is who can do what; and (2) a template defining the division of surplus, or revenue, that is who gets what.

In our setting, a more accurate description of the challenge that KPN faced with i-mode is that, in contrast to Japan where i-mode was the first platform in mobile telephony, in GSM markets there was already an incumbent industry platform with its own ecosystem, – and that platform was constituted by GSM-compatible handsets from players such as Nokia. That platform existed, albeit in a different layer of the industry architecture than the layer where the operators were competing. It is possible (and a fascinating area of research ahead) that, as both NTT Docomo and KPN were operators as opposed to handset makers, they both did not quite anticipate the contrarian effect on their plans coming from the ranks of handset makers. With the benefit of hindsight, it is quite easy to see how dominant handset makers would have no interest in facilitating i-mode’s success in Europe. Handset makers like Nokia not only held bargaining power vis-à-vis operators, but also vis-à-vis application developers, and
vis-à-vis end-users (with their strong brand, fuelled by significant investment in advertising). In fact, dominant handset makers already acted as platform leaders, and, as Gawer and Cusumano (2008) point out, this means that they were benefiting from lots of competition between poorly differentiated complementors (which included operators). Therefore, it was in the interest of European handset makers to keep operators’ offering as undifferentiated as possible, and in this regard, operator driven i-mode was presenting a threat to their continued superior bargaining power. I-mode, an innovative offering coming from the ranks of operators, did not appear as a winning proposition to handset makers – and, as the handset makers had greater bargaining power in Europe, used it to prevent i-mode from succeeding.

Further, the lack of compelling content played a role in i-mode’s failure, as it led to an inferior offering, and a poor value proposition for the end-user. While ‘lack of content’ is part of what the platforms literature would already warn us to pay attention to as an explanation for success or failure, we still believe that to uncover the reasons why KPN failed to stimulate content, it is useful to look at the situation from an industry architecture perspective. The reasons behind the lack of compelling content are well explained by an analysis of the industry architecture, such as the European operators’ diminished scope, and capabilities (when compared to NTT Docomo) and their relationships with developers.

KPN, with its restricted scope and capabilities, was not in a position to usefully influence the specifications of mobile standards such as WAP, which specified essential programming tools for application developers to create mobile applications. Operators like KPN also lacked the bargaining power to convince most application developers to create i-mode-specific content, as in Europe developers expected to create applications that would not be operator specific. In the European context, where handset makers were the dominant players (over and
above network operators), developers had come to expect that applications would work on any network. As a consequence, it was usually not in their interest to develop for an operator-specific service, as this would imply they would have to redevelop their applications for other networks. To application developers, investing in operator-specific services was to invest in a co-specialized asset with one telecom operator only, with unconvincing appeal to a large user base. Further, as operators had not introduced technical features such as micropayment capabilities and a billing system, developers lacked business incentives to create and innovate on a stream of compelling i-mode applications.

4.4.3 Alternative explanations

Let us consider alternative explanations that might explain differences in the outcome of i-mode’s commercialization. One explanation, put forward ever since the first success of i-mode became clear, emphasizes cultural differences between Japan and other countries (see, e.g., Barnes and Huff (2003); Ishii (2004)). Specifically, it is suggested that, compared to Europe, Japan might be more disposed towards ‘electronic gadgets’. Although this might be true for specific examples, we would suggest that this does not apply to the case of mobile internet services. In particular, more recent trends such as the strong growth of smartphones (e.g., Apple’s iPhone) and other mobile internet initiatives (e.g., RIM’s BlackBerry line of wireless e-mail solutions) appear to point to a latent demand for mobile internet services in markets outside of Japan (The Financial Times, 2009). As such, we think these recent developments illustrate that the specific form through which mobile internet services are offered is key – and may need to be adjusted to the local industry conditions.

Another explanation that has been suggested is Japan’s low fixed internet penetration at the time of introduction of i-mode. Although Japan’s initial internet penetration may indeed have
been lower than other advanced economies, the premise underlying this explanation does not seem to hold. Namely, this explanation appears to assume that fixed and mobile internet services are substitutes; instead, empirical data suggest that they are largely complementary. For example, in Japan demand for broadband internet has been very high (currently one of the leading countries in broadband penetration), and has not come at the expense of mobile internet usage (ITU, 2003; Henten et al., 2004). Of course, given the nature of the data we cannot fully rule out alternative explanations. However, recent developments in both Japan and Europe appear to counter explanations that have focused on cultural or infrastructural differences to explain differences in i-mode commercialization outcomes.

In conclusion, in Japan, NTT Docomo had the market influence and systems knowledge to orchestrate an extensive ecosystem around its i-mode service. However, a combination of deep historical differences in standards, regulation and market structure reduced the bargaining power of European operators and their subsequent ability to act as platform leader. As a result, while in Japan the industry architecture was shaped by NTT Docomo’s successful platform establishment, platform leadership itself was circumscribed and bounded by the European industry architecture.

4.5 Discussion and conclusion

Our study’s main finding is that the underlying industry architecture prevented a firm (KPN) to successfully achieve platform leadership, despite the fact that it was replicating a successful platform strategy in a different geographical context, all the while benefiting from the support of the very firm (NTT Docomo) that had been spectacularly successful in the original context. Attempts to apply similar platform strategies in two different contexts, – characterized by two distinct industry architectures – led to radically different outcomes:
success on the one hand, failure on the other. Our study therefore suggests that underlying industry architectures, if not properly taken into account, can thwart the effect of what appear to be well-formulated strategies. We therefore suggest that the industry architecture concept can be usefully combined with platform theories.

As a corollary to our main finding, our analysis also suggests that platforms and industry architectures may require a ‘fit’. The European operator did not match the roles of its Japanese equivalent, in particular, in terms of vertical scope and resulting differences in bargaining power. This clearly negatively affected deployment of the platform in Europe. Therefore, this case suggests that the deployment of a platform to a different type of industry architecture may prove elusive, or that the platform may need to be adapted in such a way that a better fit with the existing architecture is reached. This observation falls in line with existing research on the co-evolution between the existing distribution of capabilities and transaction costs (see Jacobides and Winter, 2005). They also underline the importance of taking into account a firm’s ‘design capabilities’ (Gawer, 2009b), that is whether or not actors should fulfil the role of systems integrator (Brusoni et al., 2001; Prencipe et al., 2003; Hobday et al., 2005) or component supplier.

Overall, our study extends and confirms existing research on industry architectures and platforms. In particular, platforms and industry architectures appear to provide complementary perspectives. The chapter contributes to the literature on industry architecture by unpacking interactions between evolutionary processes, industry architecture, and business strategies. It also contributes to the platforms literature, by positing that firms’ ability to successfully pursue platform strategies depends on industry architecture. The case suggests that differences in roles across industry architectures affect the likelihood for
platform strategies to be successfully implemented. Further, we have seen how different knowledge bases, in part a function of regulatory frameworks and standardization dynamics, might shape these roles.

We suggest therefore that theories of industry architecture are useful to refine and complement platform theories. Part of a tradition of theories of strategy, platform theories (which are still in their early days) have tended to focus on ‘action’, on the strategic moves that managers should do to transform their product into a platform. This chapter suggests that these theories may not have paid enough attention to the structural reasons why these strategic moves are not always possible. This chapter makes the case for paying careful attention to industry architecture as potentially limiting the scope for action in some areas. A finer understanding of industry architecture, combined with recent findings from platform research should allow more accurate strategic recommendations.

Focusing on actors and differences in their roles can help us understand why platforms might show differences in regional take-up. From a technological perspective it is indeed true for both regions that handset makers provide handsets and network operators provide network service. However, when we focus on the subsequent definition of that role, interesting distinctions and tensions come to light. Yes, handset makers provide handsets, but (in Europe) they increasingly also provide services that traditionally would be beyond their boundaries. Likewise, network operators, in Japan as well as Europe, attempt to shape their boundaries to increase control and value appropriation.

In Japan, the local set of regulations mostly favoured the incumbent network operator vis-à-vis handset providers as well as competing network operators. Here, network operators, in
particular the incumbent, were able to maintain their knowledge base and preserve control over branding and overall development of the system. By contrast, the European regulatory framework increased competition for incumbent network operators, and in the wider context of GSM standardization allowed handset and equipment providers to expand their business globally, enhancing their capabilities in that process. As a result, European operators relinquished technological control to specialist handset and equipment providers. In that process, some of these were able to capture a significant part of the value by becoming the guarantor of quality, manifested, for example, in branding and marketing towards end-users.

That said, given the exploratory nature of this study and the limited setting that compares only two firms in two geographies, we would suggest that our finding should be taken as preliminary. It would be worthwhile to investigate this further, treating our finding as a proposition and designing further studies aimed at testing it rigorously, by using a combination of supplementary case studies in different industries, and eventually through the means of a deductive study, using data obtained from a larger sample.

4.5.1 Limitations and directions for future research

This study knows several limitations, pointing to ways in which our results might be extended in future work. First, the lack of successful foreign expansion of Japanese telecoms firms (both operators and handset makers) appears to reaffirm what has been referred to as the ‘paradox of Japanese info-communication companies’ (Fransman, 1995, 1999). Though both Japanese mobile network operators and handset makers are at the forefront technologically, they have mostly been unable to replicate this success in other regions – in sharp contrast to other industries such as automobiles and consumer electronics. As such, it emphasizes the importance of the institutional structure of value chains in international
expansion, confirming the observation that differences herein can be most pronounced in service-based industries, given the greater room for difference in terms of structuring the industry architecture (Jacobides, 2008; Jacobides and Kudina, 2009). The problem of architectural change also appears to be related to the broader concept of business models (Amit and Zott, 2001; Chesbrough and Rosenbloom, 2002; Ballon, 2009). As mentioned by Ferraro and Gurses (2009), innovation in business models might constitute a necessary, though not sufficient condition for establishing shifts in industry architecture. This study has not focused on these issues, which may constitute a fruitful area for further research.

A second area for further research could attempt to analyze whether and to which extent industry architecture could be strategically manipulated. This chapter has proposed that industry architectures, when not properly taken into account in the formulation of business strategies, can prevent strategies’ successful implementation and limit the effect of deliberate managerial action. Our chapter therefore takes largely the view that industry architectures are structures that are hard to manipulate. However, Jacobides et al. (2006) also suggest that, although structural, industry architectures can be manipulated by industry actors. To some extent, NTT Docomo did this in Japan, and a straightforward interpretation of platform leadership strategies is to construe them as an attempt to create ‘architectural advantage’ (as has been noted by Jacobides et al., 2006). We find particularly intriguing the hypothesis from Jacobides et al. (2006) that posits that assets ‘complementarity’ and ‘mobility’ determines the extent to which actors can shape industry architecture. Recent empirical papers such as Ferraro and Gurses (2009) provide evidence of how players in the US motion picture industry successfully shaped the industry architecture.
At the same time though, our chapter highlights the effect of regulation, as well as the process of standardization on the development of firms’ capabilities and bargaining power over other actors – which can in turn affect firms’ ability to create but also to appropriate value. As such, we should indicate that the study also highlights the unpredictable nature of these processes, and therefore, the difficulty for firms to manipulate them to achieve strategic advantage. In the context of our case study, several actions that were taken had consequences that were probably not foreseen. For example, it is quite likely that the cumulative impact of a combination of a historically strong PTT in terms of R&D capabilities (NTT), a network standard that would remain localized to Japan, consolidation among network operators, and liberalization of the equipment market, were not foreseen by the various actors involved. Equally, it is unlikely that the impact of various measures in Europe, in particular the global success of the GSM network standard, de-regulation of infrastructure, and considerable financial strains due to disproportionately high licensing costs, were anticipated. This unpredictability suggests the need for firms to be cautious about their own expectations about how much they can shape the industry context (including the industry architecture) in which they operate. On the one hand, individual actors obviously have the ability to influence specific lines of action, including, for example, the properties of standards. Likewise, through lobbying firms may also shape the regulatory framework in ways that advance their individual or collective interests. On the other hand, our case also suggest that the cumulative result of individual decisions, which may lead to unpredictable results due to interactions between individual actions, are beyond the immediate influence of even the most farsighted actors.

In addition, our study has focused on a ‘macro’ level of analysis; as such we have largely ignored the design process of the various artefacts that make up the system, for example
particular network or interface standards. A micro-level analysis of such a design process of such a standard could shed more light on the various strategic trade-offs involved in this process. For example, Camuffo and Zirpoli (2009) shed more light on such a design process in their comparative study of a subsystem in the automobile industry. Importantly, they highlight the pragmatic and often political approach surrounding the way the division of labour is shaped. In our context, it would also be of interest to investigate the repercussions of particular design choices, for example characteristics of the standards subsumed in the i-mode platform or the design choices of particular network or messaging standards.

Finally, in terms of empirical scope, i-mode constitutes only one of several platforms operating in the mobile industry; there are platforms directly competing (e.g., Vodafone Live) as well as ones located at different parts of the value chain (e.g., the Symbian operating system). Therefore, we focused on only one platform that is part of a wider competitive landscape. Future work taking a broader scope may be able to focus on dynamics between platforms at different levels, in an attempt to understand competitive dynamics at the overall industry level.\textsuperscript{53} Such an analysis would be particularly worthwhile for this industry, given the key role of bottlenecks – or, using telecoms industry parlance, ‘control points’ – in the migration of control and value. For example, in the mobile industry, platforms at the level of the operating system are increasingly being commoditized (cf. recent initiatives by Google and Nokia to provide royalty free platforms based on open source licensing). This makes it difficult for actors that might wish to establish a bottleneck at this level (e.g., Microsoft). Likewise, industry actors appear to be increasingly cognizant of the way value might be appropriated at different parts of the value chain. This is reflected, for example, in music download initiatives by Apple and Nokia that bypass the infrastructure of the network.

\textsuperscript{53} Examples of such studies are Ballon (2009) who studies several mobile platforms in relation to business models, and Boudreau (2005) who compares the development of several mobile operating systems platforms.
operator. In turn, network operators try to maintain control not only through services like i-mode, but also by offering competing music platforms and, in Japan, broadening their portfolio to a range of other services such as mobile payments; highlighting an increasing tendency for firms to integrate downstream into services (Davies, 2004; Chesbrough and Davies, 2009). Given the state of flux the industry is currently in, such an analysis would certainly be challenging. Nevertheless, it seems likely that work in this area could achieve much to further our understanding of how changes in the nature of bottlenecks provide a reflection of the way value migrates across different parts of the value chain.
Appendix 1

Symbian interview protocol

Interviews followed a semi-structured protocol, using a combination of open-ended and focused questions. All interviewees agreed to being recorded. Ahead of the interview, I sent out a short description of my research project and a list of topics I intended to cover. Depending on the background of the interviewee (e.g. functional role and tenure) more weight was given to technological issues (e.g. development of the different subsystems) or strategic and organizational questions (e.g. motivations as to why particular architectural choices were made).

Below is a list of exemplary interview questions:

*Can you provide a brief background on your role(s) in relation to Symbian Software Ltd (SSL) and/or Symbian Foundation (SF)?*

*Can you comment on your experience in the founding of SSL and/or SF?*

*What has been your experience on the relationships between the various partners and competitors vis-à-vis SSL and SF?*

*Can you comment on the changes in organizational scope of SSL and SF – e.g. changes in OS and UI development?*

*Can you elaborate on the advantages and disadvantages of separating UI/OS development? (from perspective SSL and UI owner)*

*Can you comment on the decision making process that drove the separation of OS and UI development?*

*Can you elaborate on the various technical dependencies between UI and OS? (e.g. viability to build a new OS underneath an existing UI?)*

*Can you elaborate on the transition period from SSL to SF and the various decisions that were made?*
Appendix 2

Overview of coding process

<table>
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<tr>
<th>Open coding</th>
<th>Axial coding</th>
<th>Selective coding</th>
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<tbody>
<tr>
<td>Founding SSL</td>
<td>Founding SSL</td>
<td>Episode 1: Microsoft threat</td>
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<tr>
<td>Nokia acquisition</td>
<td>Nokia acquisition</td>
<td>Form factor ambiguity</td>
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<tr>
<td>Founding SF</td>
<td>Founding SF</td>
<td>Episode 2: Rivalry, imbalances</td>
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<td>Microsoft entry</td>
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<td>Subsystem separation</td>
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<td>Apple, Android entry</td>
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<td>Episode 3: Emergence of new entrants</td>
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<td>Alliance dynamics</td>
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<td>Motivations for acquisition</td>
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<td>IPO</td>
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<td>Episode 4: Reduce supplier dependency</td>
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<td>Role of Nokia</td>
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<td>OSS transition</td>
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<td>Role of Psion</td>
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<td>Firm level drivers:</td>
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<td>Fragmentation</td>
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<td>Strategic and organizational considerations</td>
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<td>Third party developers</td>
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<td>Mirroring</td>
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