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INNOVATING FOR TODAY WHILE INNOVATING FOR TOMORROW. A TEST OF INNOVATION AMBIDEXTERITY THEORY IN A LEADING TECHNOLOGY COMPANY

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Abstract

The theory of ambidextrous organisation in management and organisational studies latches onto the idea of simultaneous and equally high degrees of incremental innovation based on prior knowledge (exploitation) and discontinuous innovation based on experimentation and new knowledge (exploration). It claims that any organisation should be ambidextrous to succeed long term. This thesis research puts ambidexterity theory to test. Using the logic of falsification, I conduct an exploratory case study of the semiconductor IP designing company ARM to tests whether the central claims of ambidexterity apply in the empirical context of this successful technological company. The ARM is a leading-edge innovator and a successful company by any common sense criteria. I find that ARM used and banned the ambidexterity rationale because its underlying assumptions misrepresent the interactions between ARM and its Partners in the process of innovation across its vast Ecosystem. I find that ambidexterity assumptions break down in the context of the Ecosystem. Ambidexterity theory displays some serious limitations when applied to the company's innovation in System-on-a-Chip technology that powers ubiquitous computing and assembles an Ecosystem of Partners. The revealed limitations of ambidexterity thinking demand to reconsider the claim of ambidexterity's universal value and to reassess the fitness of ambidexterity assumptions for explaining innovation in the technology of the future.

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1 Introduction to the thesis

1.1 Innovating for today while innovating for tomorrow

This research has been ignited by a simple principle in management: any technology company has to engage in exploitation of the accumulated resources to ensure profitability for today, while, at the same time, exploring new opportunities to replace the old competences and enable profitability for tomorrow (O'Reilly and Tushman 2004). Innovation ambidexterity, similar to the human ability to use the right and the left hand equally skilfully, proclaims that firms should balance equal degrees of exploitation and exploration simultaneously to flourish over the long run (He and Wong 2004, Jensen et al. 2008, Lubatkin et al. 2006). Innovation ambidexterity theory has become a popular theory in management research because it seems to have pinpointed the key to firms' sustained growth and very survival. Technological change wipes out companies that fail to abandon obsolete technologies and organisational logic and reorganise to embrace innovation. Any organisation fails if it does not ensure the reliable delivery of its current products or services and, at the same time, responds to the constant changes in its environment. For those who manage to balance the tasks of exploitation and exploration, the effects of the balance will be positive and long-lasting, so the theory claims (O'Reilly and Tushman 2008). Organisational ambidexterity, underpinned by the exploitation-exploration framework, has become a popular theory to understand the elusive balance of efficiency for today and innovation for tomorrow and to offer prescription for organisational performance improvement, adaptation and survival.

These theorisations seem very promising and the theory of ambidexterity has been developed substantially in the attempt to get a deeper understanding of how the balance between exploitation and exploration can be achieved. Ambidexterity is a diffused and complex concept as I will show in the literature review that follows, but the central themes of the ambidexterity scholarship are the contest between trade-off (March 1991, Smith and Tushman 2005, Tushman and O'Reilly 1996) and cohesion of exploitation and exploration (Gibson and Birkinshaw 2004), their configuration (Lubatkin et al. 2006) and magnitude (Simsek 2009) and ultimately organisation and daily operation (Hughes 2017). The ambidexterity lens has been applied to interpret various tensions and processes

within and across organisations in a great variety of empirical contexts ranging from technological product innovation in business firms (Gibson and Birkinshaw 2004, Tushman and O'Reilly 1996), to financial services (Jansen et al. 2005), comic book publishing (Taylor and Greve 2006), clinical trials and new drug application stage (McNamara and Baden-Fuller 1999, 2007) and theatre productions (Voss and Voss 2013). Cumulating the diversity of generalisations about exploitation-exploration balance in a coherent theory has been problematic. The theory has become so encompassing that it seems to be applied to explain everything and so risks becoming a theory of nothing (Birkinshaw and Gupta 2013).

1.2 The aim of the study

The theory claims that ambidexterity is a universal tool for organisations to manage the challenges of adaptation and the ideal solution to sustaining long-term performance. In this explorative theory driven research I investigate how ambidexterity actually pans out in an empirical context of a cutting-edge innovative company. The classic ambidexterity case studies study old and obsolete technologies (Tushman and O'Reilly 1996, Tushman and O'Reilly III 1997) and their practical value in leading organisational change today is doubtful. *The aim of this study is to test whether ambidexterity propositions apply in the context of the modern technology-intensive innovative company?* I am going to use the semiconductor IP designing and licensing company ARM as an empirical site, because ARM is a company that has not only claimed to be ambidextrous, but it is also extremely successful by any common sense criteria. Its technological IP has come to underpin the design of 95% of all mobile phones and its microprocessor designs formed the basis of 60 billion chips that power what has become truly ubiquitous computing technology (ARM Holdings plc Strategic Report 2015).

1.3 Research design

The empirical analysis draws on Popper’s logic of falsification: theories must periodically be subject to risky tests (Popper 1952). Amounting additional positive evidence cannot prove a theory right, we need to seek contradictory evidence to try and disprove a theory – falsify it (Popper 1952). Falsification is, therefore, a more robust way to improve theory. Identification of discrepancies between theory’s core propositions and

empirical evidence is the basis for theory's revision. To falsify a theory, evidence from a single case is sufficient. The research is designed as a single case study of a technology-intensive company over 2011 – 2017 that rigorously test the enactment of ambidexterity principles. ARM provides a rich and promising context to test the theory, because the company designs complex System-on-a-Chip technologies and uses the distinct Ecosystem model to deploy its designs in billions of smart products without manufacturing any of its products at all. ARM's technological innovation in the modern semiconductor technology and the Partnership Ecosystem that helps ARM to deploy its designs in the plethora of cutting-edge digital devices are interesting aspects of the practice of innovation on which manifestations of innovation ambidexterity can be tested.

1.4 Contribution to theory

Empirical studies of ambidexterity are predominantly designed as gap-filling studies that are *"adding bricks"* to the ambidexterity "building" and *extend* our understanding of ambidexterity (Andriopoulos and Lewis 2009, Andriopoulos and Lewis 2010, Turner and Lee-Kelley 2012). They create new evidence and conceptualisations that explain particular aspects of ambidexterity that were unknown or problematic before. Classically, these studies conclude with identifying further gaps in the knowledge about ambidexterity and directions for further research. There are also studies designed as literature reviews that synthesise the ample and diverse evidence supplied by the gap filling studies (Gupta et al 2006, Raisch et al 2009, Simsek 2009, Lavie et al 2011, O'Reilly and Tushman 2013). They, too, classically conclude that ambiguities and contradictions continue to exist (Lavie and Rosenkopf 2006) and acknowledge that after 15 years of research on ambidexterity "there still remains some confusion about what precisely the term 'organizational ambidexterity' means" (O'Reilly and Tushman 2013, p.324). Innovation ambidexterity is experiencing the classical kuhnian paradigm crisis (Kuhn 1962), which I demonstrate in the next chapter "Innovation ambidexterity theory". As a consequence, we must revisit the very basics of the term "organisational ambidexterity" and our very thinking about the received assumptions of this frame of thinking, as well as its viability outside the contexts for which it was originally created 15 years ago. The anomalies of ambidexterity paradigm are not going to go away with an "adding a brick" exercise. We need to step back and review the theory's fundamental

assumptions and claims of the theory. This is the aim and the contribution of this doctoral dissertation.

1.5 Structure of the thesis

I begin my thesis by reviewing innovation ambidexterity theory (chapter 2 "Innovation ambidexterity theory"). In this theoretical chapter, I analyse the origin of the theory's central assumptions in the exploitation-exploration framework and examine how they have matured to form innovation ambidexterity theory. The purpose of the literature review is both descriptive and analytical: to extract the central assumptions and propositions of ambidexterity theory and to examine problems that have accumulated in the theory as the theory expanded. Here, I also explain how theoretical problems have motivated my research. Based on the analysis of the literature, I formulate my research aim, research questions and lay out the methodological tools with which I address them in chapter 3 "Research design and methodology".

After the research aim has been presented and the methodology and research design to achieve it have been explained, I begin my empirical examination. I first introduce the company that I have chosen to study: how it formed and acquired features that make it a peculiar and interesting case to study (chapter 4 "Setting the scene for the empirical investigation. Innovation that started ARM"). I proceed to carry out an in-depth investigation of how each of the central claims of the theory applies in the chosen context. Each of the empirical chapters progressively contributes to the test of exploitation (chapter 5 "Exploitation"), exploration (chapter 6 "Exploration") and the proposition about the implementation and benefit of ambidexterity (chapter 7 "Innovation ambidexterity"). In chapter 8 "Evaluating innovation ambidexterity theory: conclusions and discussion", I revisit the theory's assumptions and propositions in view of the presented empirical evidence and evaluate the usefulness of ambidexterity as a theory. Finally, I conclude my thesis by reflecting on the limitations of my research and proposing several areas for future research that emerged from my investigation and that seem to hold more answers to the questions of how organisations manage to create structures that both persist through and respond to change (chapter 9 "Limitations of the investigation and avenues for future research").

2 Innovation ambidexterity theory

This thesis is concerned with innovation ambidexterity theory or theory of ambidextrous organisation as it is also often called. This chapter reviews the body of knowledge about ambidextrous organising with the aim to extract core elements of ambidexterity generalisations that have accumulated into a theory. The literature review focuses on *the origin* of the theory's central assumptions and *their development* as the theory progressed. The chapter's function is both *descriptive* and *analytical*: by reviewing and extracting the core elements of the theory, I prepare the foundation for achieving the research aim - testing them in an empirical context. Given this task, I neither aim to produce an exhaustive overview of the main ambidexterity streams, structural or contextual, nor bring urgency to a particular research gap. The purpose here is to signal the accumulation of ambiguities, inconsistent interpretations and incoherent generalisations that result in the crisis of the paradigm of organisational ambidexterity.

The chapter begins with the examination of the origin of the assumptions in exploitation-exploration framework (March 1991) precursory to the concept of ambidextrous organisation (section 2.1). The central definitions, propositions and assumptions born with the exploitation-exploration conceptualisation are distilled in section 2.2 and reviewed in more detail in section 2.3. I proceed to examine innovation ambidexterity theory that was the heir to the exploitation-exploration framework in section 2.4 and formulate its definitions, central assumptions and propositions in sections 2.5 and 2.6. I review solutions that ambidexterity theory proposed to alleviate trade-offs between exploitation and exploration in section 2.7. In the rest of the chapter, I discuss central issues with the theory that emerged as it expanded into broader contexts (sections 2.8 - 2.9). The concluding section 2.10 explains motivation for this research.

2.1 Formation of the exploitation-exploration framework

The twin concepts of exploitation and exploration originated in the work of James March in the field of organisational learning to capture two distinct types of learning processes in an organisation: "exploitation of old certainties" and "exploration of new possibilities" (March 1991, p.71). March's classical definitions equate *exploitation*

activity with terms such as "refinement, choice, production, efficiency, selection, implementation, execution" and exploration activity with terms such as "search, variation, risk taking, experimentation, play, flexibility, discovery, innovation" (ibid.). It is important to emphasise that March used these descriptions in relation to the learning process in an organisation, i.e. ideas, knowledge and competences development. He defined the different types of knowledge producing activities through *opposites*, thus distinguishing *two distinct* types of learning and associated organisational behaviour. The argument that he then develops stresses that the organisation has to *adapt* these two opposing types of learning to each other so that the organisation neither misses out on future opportunities from the lack of exploration of new ideas, nor suffers suboptimal performance from the lack of exploitation of existing knowledge, technologies and competences (March 1991). March draws an important theoretical proposition that "adaptive systems" need to maintain "an appropriate balance between exploration and exploitation" as "a primary factor in system survival and prosperity" (March 1991, p. 71).

Learning, research and knowledge are vital for prosperity of any organisation. Above and beyond, they are, in the words of March, "profoundly important instruments of human well-being" (March 1991, p. 85). Adaptive processes between different types of learning, including those captured in the old-new knowledge duality, can be found in any human activity or system. Studies exist that focus on the tenacity of old decisions leading to social conservatism and the inability of society to adapt to changing conditions (Kuran 1988). Other studies investigate the implications of historical events and conventions for institutions (David 1994), analyse pressures to maintain compatibility and consistency of technical systems that lead to "lock-in" effects in technical development (Hughes 1987) and examine the role of technological trajectories in "creative incremental development" that is technological evolution (Andersen 1998, p. 5). The notion of path dependence as observed, for example, in economic processes and policies (Arthur 1994, David 2006) resonates with the idea that "our decisions tend to be sticky" (Kuran 1988, p. 143). Path dependence highlights the problem of vulnerability of the new, common to the exploitation-exploration duality and typically raised in all such studies (Benner and Tushman 2003, Levinthal and March 1993). In general, these studies converge on the argument about the *dominance of exploitation* saying that the change

directed and determined by *the established* trajectories, regimes or paradigms "is perhaps the most central regulating variable in society" (Andersen 1998, p. 5).

The exploration-exploitation framework originated to address the challenges of maintaining the input of the new to the established knowledge, processes and behaviour in organisations. It was formed to show the controversies of the alignment process of the newly brought individual knowledge and the established organisational code. For instance, it produced the counter-intuitive finding that fast learning and quick adaptation, either on the part of novice recruits or the organisation, is by far not always beneficial for the organisation. In fact, slow learners can benefit the organisation more because they will be able to preserve their individual knowledge and experience long enough for the organisation to fruitfully learn from them, rather than conforming them to the established organisational ways (March 1991). Additionally, the influx of the naïve and less knowledgeable new produces a more knowledgeable organisation, because it enables individuality and variability in the pool of knowledge. Ultimately, the exploitation-exploration framework provided the means to demonstrate that the conventional wisdoms about learning are not always true and that reaching a beneficial match of old and new knowledge is certainly a non-trivial, often counter-intuitive and never fully optimal process.

The universality and centrality of the old-new knowledge duality and its inherent challenges makes March's work on adaptive processes in organisational learning extremely pertinent for a number of contexts. This enabled extension of March's conceptualisations into the area of management studies (Benner and Tushman 2003, Gupta et al. 2006, He and Wong 2004, Hill and Birkinshaw 2014, Lavie et al. 2011, Lavie and Rosenkopf 2006, Lavie et al. 2010, Lee et al. 2017, Lin et al. 2012, Mom et al. 2007, Raisch et al. 2009). At the same time, the universality of the duality for different contexts and a vast amount of questions it raises does not make March's work unique. The interplay between established knowledge and technologies on the one hand, and "creative destruction" of innovation which re-arranges the existing economic order on the other, has been under a careful examination since the Schumpeter work in the first half of the twentieth century (Schumpeter 1943). From then on different fields abundantly addressed the complex interaction of established technologies and innovation (Abernathy and Utterback 1978, Anderson and Tushman 1990, Chandy et al. 2003, Christensen 1997,

Freeman 1994, Garcia and Calantone 2002, Henderson and Clark 1990). However, March's framework has taken prominence because it unified various types of knowledge and organisational behaviour associated with innovation in the intuitive notions of exploration and exploitation and parsimoniously conceptualised the complex interactions between them. The exploitation-exploration framework has transcended the original field of organisational learning and became an essential theoretical lens for examining a variety of processes and outcomes associated with innovation within and across organisations in the fields such as knowledge management, innovation, organisational design and strategic alliances.

March's work has become seminal because it began to shed light on the non-trivial task of *combining* different types of innovation activities and provided a theoretical foundation of the exploitation-exploration construct: the definitions, assumptions and propositions of the framework. Because it has become so fundamental and wide-spread, it is important to revisit the original definitions, examine the inherent assumptions and analyse the theoretical propositions of ambidexterity. The next section is dedicated to this purpose.

2.2 Definitions, assumptions and propositions of the exploitation-exploration framework

March made the first steps towards understanding management of distinct types of learning processes in an organisation and formulated a set of conceptualisations that captured the understanding in a theoretical way. Definitions have been introduced, assumptions have been laid down and theoretical propositions have been formulated. It is important to analyse how this occurred and critically examine the resulting theoretical constructs *because they shape our understanding* of the researched phenomena *and channel further thinking* about them in a particular direction. Additionally, definitions, assumptions and propositions are important to examine because they communicate the logical position of the author and form the foundation of theory that allows moving beyond description to explanation of phenomena. Here, I take a "constitutive" view on definitions, meaning clear and parsimonious description of content of theoretical constructs (Kerlinger and Lee 2000). By assumptions I understand self-evident statements, or axioms, that serve as points of departure to develop a theory and also

boundary points that restrict the theory's application (Bacharach 1989). Assumptions are also sometimes called postulates of a theory. Importantly, assumptions also concern definitions and contain implicit values of the theorist. Theoretical propositions are understood as verbal formulations that express relationships among theory's concepts (Mullins 1974). They are constructed by relating the terms observable in the empirical setting with the terms that appear in the theory's assumptions or postulates (Jasso 2001).

As discussed above, the definitions proposed by March categorised various possible types of learning through the relation of opposition creating two distinct categories. In general, the distinction that March draws is based on two criteria: the degree of newness of knowledge (new possibilities vs old certainties) and flexibility of associated organisational behaviour (e.g. play vs efficiency, discovery vs execution). Analogous conceptualisations have been made in relation to other manifestations of knowledge in the organisational realm. For example, scholars of technological innovation who asked the question "how do technologies differ?" also conclude that differences lie in the degree of innovativeness *and* in the potential to disrupt the existing order of things (markets and organisational processes), which in turn requires a higher degree of flexibility to adjust to the new order.

As a result, technology and organisation studies scholars highlight technical challenges of innovation as well as the challenges to the organisation's knowledge of the market and customers' needs through the concepts such as incremental and radical or discontinuous innovation (Anderson and Tushman 1990, Henderson and Clark 1990, Tushman and Rosenkopf 1992), sustaining and disruptive innovation (Christensen 1997, Danneels 2004, Govindarajan and Kopalle 2006) or competence destroying and competence enhancing innovations (Tushman and Anderson 1986). In the same vein, organisational design scholars identify the contradiction between improving core capabilities and developing new products and processes (Leonard-Barton 1992) and point to the opposition between maintaining and cannibalising the value of existing investments (Chandy and Tellis 1998). In evolutionary models, the distinction in technologies and organisational forms is framed in terms of variation and selection, evolutionary stability and revolutionary breakthroughs (Freeman 1991, Nelson 1994, Nelson and Winter 1982). These understandings of types of knowledge, technologies and innovation in general come from different fields, but they are similar to March's in the way that they

conceptualise the differences as opposing and base the distinction on the similar criteria of the degree of newness and the degree by which the two types of activities reconfigure the existing order in a system. This allowed the exploitation - exploration construct to embrace other notions and become a unifying framework for studying the inter-relation between the phenomena.

The theoretical proposition of the exploitation-exploration framework is that *exploitation and exploration have to be balanced* in order to enable sustained organisational performance (March 1991). The formulation stems from the logic of the qualities of exploitation and exploration and their inter-relation, which was later re-iterated by Levinthal and March in further studies of problems of organisational learning:

> "An organisation that engages exclusively in exploration will ordinarily suffer from the fact that it never gains the return of its knowledge. And organisation that engages exclusively in exploitation will ordinarily suffer from obsolescence. The basic problem confronting an organisation is to engage in sufficient exploitation to ensure its current viability and, at the same time, to devote enough energy to exploration to ensure its future viability. Survival requires a balance, and the precise mix of exploitation and exploration that is optimal is hard to specify" (Levinthal and March 1993, p. 105).

Duality and dialectic are the terms from philosophy that are sometimes evoked to understand the above made point (Benson 1977, Gupta et al. 2006, Smith and Tushman 2005). Duality states the existence of two fundamental categories of things in one domain. Dialectic conveys the disagreement between the dual points that has to be reconciled or reasoned. Dualism is pervasive in the definitions of the framework. Although other ways of describing forms of innovation exist, for example, OECD's class specific categorisation into product, process, market and organisational innovation (OECD 2005), or the identification of as many as fourteen distinct aspects of innovation pertaining to the degree of maturity of the new technology in practice-oriented literature (Moore 2008), the definition by means of duality is the predominant one in the management literature. This can be seen in the multiple dichotomical differentiations of innovation types (Kotsemir et al. 2013) in the academic research: evolutionary-revolutionary (Utterback 1996), radical-incremental (Atuahene-Gima 2005, Freeman 1994, Schumpeter 1934),

sustaining-disruptive (Christensen 1997), discontinuous-continuous (Anderson and Tushman 1990) and other. Dialectic conveys a certain type of the relationship between the dual structures of the construct. March's duality-based definitions and the dialectic-related rationale of the main theoretical proposition suggest a set of theoretical assumptions.

The first assumption of the exploitation-exploration framework, stemming from the definition, is that exploitation and exploration are *inherently contradictory* and, therefore, *challenging* to combine. Their adaptation is the process of continuous choice of one activity in favour of the other which subsequently evokes the notion of *trade-off*. According to March, "*It is clear* that exploration of new alternatives reduces the speed with which skills at existing ones are improved" (March 1991, p. 72, emphasis added). This statement is an axiomatic assumption of the framework. Further on, the dominance of exploitation over exploration is also assumed in the framework: "*It is also clear* that improvements in competence at existing procedures make experimentation with others less attractive" (ibid., emphasis added). In the organisational learning perspective, every effort to improve organisational performance through learning, innovation and technological change is viewed as an act of adaptation, which is affected by the characteristics of the context within which the learning occurs. The adaptation of exploitation and exploration is necessarily a trade-off, because the organisational resources are taken as finite, thus exploitation and exploration cannot be satisfied in full (March 1991). The limited resources factor is the necessary component in the trade-off conceptualisation, noted by March and organisational ecology scholars (Hannan and Freeman 1977). *Resource availability* for exploitation and exploration is *the decisive factor* for this type of relationship between them. Where resources are unlimited, as, for example, stock of externally available knowledge (Katila and Ahuja 2002), exploitation and exploration are viewed as non-competing. Organisational resources as well as environmental munificence and interaction with the environment are an important contextual factor for the type of the relationship between exploitation and exploration that has to be taken into account in the analysis of the theory.

The second assumption of the framework is that the two activities are *to be balanced*. The notion of balance is explicitly used to describe the nature of the adaptation processes in the theoretical proposition: "[…] maintaining an appropriate *balance*

between exploration and exploitation is a primary factor in system survival and prosperity" claims March (March 1991, p. 71, emphasis added). The commonly accepted notion of balance implies a state of equilibrium, equal distribution of weight or amount that creates harmony or symmetry. This assumption triggered several important implications, one of the most important of which is the subsequent idea of simultaneous and equal pursuit of exploitation and exploration activities that will become the subject of further extensive theorising (Birkinshaw and Gibson 2004, Gibson and Birkinshaw 2004, O'Reilly III and Tushman 2004, Tushman and O'Reilly 1996). At the same time, harmony or balance between opposites is hard to achieve. From this, it follows that organisations should *develop means* (structures, processes, decision rules as well as intangible capabilities such as culture) *to achieve balance* between the two contradictory but necessary forms of organisational behaviour.

The main proposition of the emergent framework is that *exploitation and exploration activities*, juxtaposed in the inherently contradictory nature, *need to be balanced for the benefit of optimal organisational performance*, even though such balance is very challenging to achieve (March 1991). Figure 1 below summarises the theoretical foundations of the exploitation-exploration framework that emerged from March's work.

Figure 1. Theoretical elements of exploitation-exploration framework (March 1991)

Field: Organisational learning (March 1991)	**Theoretical elements of exploitation - exploration framework**		
	Definitions	Assumptions	Propositions
	- Through opposites (two distinct types of learning activities) - Evoking the concept of duality and dialectic (unity and contradiction of the opposites)	- Exploitation and exploration are inherently contradictory - Type of adaptation: balance - Achieving balance is necessary, but it is a challenge	Exploitation and exploration need to be adapted to each other in order to ensure optimal performance outcomes

In his seminal paper, March (1991) is concerned with modelling two general situations in the organisational learning: how individuals and organisations learn from each other and how the organisation is using knowledge to position itself advantageously

in its competitive environment. His main theoretical conclusions are verbal formulations about optimal distribution of costs and returns of exploitation and exploration based on his modelling. March is more concerned with the task of analysing optimality between exploitation and exploration rather than empirically testing performance implications of the balance per se. The logic of the performance proposition is compelling enough for him to carry on with his task. A substantial fraction of subsequent research on ambidexterity also addressed the challenges of exploitation-exploration balance and means to resolve them. The next section is dedicated to an overview of this important part of the framework which eventually departs from March's fundamentals and expands to introduce a more complex problematic and a new theory to address it.

2.3 Challenges of exploitation-exploration balance

Following March's conceptualisations, balancing exploitation and exploration activities is necessarily a challenge. This is, first of all, due to their inherently opposing nature as discussed above. To evoke March's definitions once again: "The essence of exploitation is the refinement and extension of the existing competences, technologies, and paradigms. Its returns are positive, proximate, and predictable. The essence of exploration is experimentation with new alternatives. Its returns are uncertain, distant, and often negative" (March 1991, p. 85). This extends the understanding of the reasons for the challenge from the content of these two activities to their effects on the organisation.

March notes that *the returns* of exploitation and exploration activities vary in several aspects:

- Uncertainty and risk: returns on exploitation are more predictable and less risky, while returns on exploration are more uncertain and risky.
- Distribution in time: the outcomes of exploitation are more immediate (short-term), whereas the outcomes of exploration are distant (long-term).
- Pay-off: the returns of exploitation are positive albeit moderate, while the outcomes of experimentation and search are often negative, even though potentially more rewarding.

- Locus of action: exploitation takes place within the organisation, whereas exploration requires reaching beyond organisational boundaries and inviting input from the outside.

Making a decision regarding allocating resources to either exploitation or exploration involves making a decision on each of these trade-off dimensions. In other words, the challenge of exploitation-exploration balance comprises temporal, inter-institutional and financial trade-offs as well as risk preferences (March 1991). March notes that in addition to the trade-off challenge, the balance between exploitation and exploration is complicated by a system challenge, when each of the trade-offs occurs at every level of the organisational structure: individual, organisational and inter-organisational (March 1991).

Having analysed these challenges, March acknowledges that his theoretical conceptualisations and proposition offer some insights into balancing exploitation and exploration for the benefit of the organisation, but the complexity of the task of distributing the choices between exploitation and exploration is so high that the model is not exhaustive to specify the optimal balance and disentangle the relationship between the activities and their outcomes on different dimensions and organisational levels (March 1991).

The exploitation-exploration framework originated in the organisational learning context and had a narrow focus on the merits of new knowledge development versus refining existing knowledge. Subsequently, March's elaborations regarding the challenges and trade-offs of pursuing contradictory but necessary organisational activities have been found useful for understanding other manifestations of knowledge. Technological innovation predicates on discovery and specialisation and, along with organisational and individual knowledge, is aimed at improving organisational performance and strengthen competitive advantage. Values and norms are also associated with various types of knowledge and form organisational culture that can be conducive to exploitation or exploration. Interaction of people in the act of learning or innovation also impacts organisational performance, therefore, it is another aspect of ambidexterity. Application of the exploitation-exploration construct to organisational innovation has produced innovation ambidexterity theory.

2.4 Formation of innovation ambidexterity theory

The notion of *ambidexterity*, defined as an individual's propensity to use both hands with equal skill, has been introduced to various organisational contexts to denote the organisation's capability to "play two games at once": to focus on productivity and to innovate (Tushman and O'Reilly 1996, p. 10). The notion of the *ambidextrous organisation* was introduced in the early work of Duncan who suggested that organisations should implement dual structures to manage conflicting demands of efficiency and innovation (Duncan 1976). The idea of combining the two essential skills simultaneously and with equal proficiency got traction in organisational design and technology management research and manifested in *innovation ambidexterity theory.* The body of knowledge about ambidexterity has formed a theory as scholars worked to distil analytical concepts and the relationships between in a systematic way. As a result, the ideas about ambidexterity have accrued to *normative* generalisations and formulations, recorded in systematic literature reviews which is characteristic of theory formation (Mullins 1974). Scholars in the field conclude that "'ambidextrous organizations' theory can be characterized as rigorous and relevant (Durisin and Todorova 2012, p.53).

The work of Tushman and O'Reilly in the late 1990s, published in the practice oriented academic outlets, can be considered the birthplace of innovation ambidexterity (Tushman and O'Reilly 1996, Tushman and O'Reilly III 1997). However, their work builds upon previous organisation literature that highlights the idea of pursuing differentiation and integration activities simultaneously to deal with a variety of environmental contingencies but separating them in dedicated structures to avoid mutual interference (Galbraith 1982, Lawrence and Lorsch 1986, McDonough III and Leifer 1983). Tushman and O'Reilly promoted ambidexterity as the capability that would help firms to overcome comfortable reliance on incremental improvement and existing organisational alignment that fuel current success and achieve long-term success through more radical technology and renewed organisational structure (Tushman and O'Reilly 1996). Such conceptualisations imply that the best performing firms are those who act ambidextrously (He and Wong 2004, Raisch and Birkinshaw 2008, Raisch et al. 2009), maintaining both current efficiency and developing opportunities and capabilities for the future.

2.5 Definitions

Early ambidexterity theory conceptualisations were quite discursive and the central theoretical proposition that ambidexterity enables sustained organisational performance was supported by anecdotal evidence about the fates of selected firms (Benner and Tushman 2003, Birkinshaw and Gibson 2004, Tushman and O'Reilly 1996). Definitions of ambidexterity were fluid, intermingling terminology from different disciplines, and pertained to different domains such as technology, competition, customers, regulations and strategies. For example, in their formative paper, Tushman and O'Reilly express their idea of ambidexterity through statements such as "incremental and revolutionary change" (Tushman and O'Reilly 1996, p.8), "effective defenders of […] old technologies" and "effective attackers with new technologies" (Foster 1986, quoted from Tushman and O'Reilly 1996, p.10), "increasing the alignment or fit among strategy, structure, culture, and processes, while simultaneously preparing for inevitable revolutions" (ibid, p.11), "managers must continuously readjust their strategies and realign their organisations to reflect the underlying dynamics of technological change in their markets" (ibid, p.17), "diagnose and actively shape organizational cultures to both execute today's strategies and create the capabilities to innovate for tomorrow's competitive demands" (ibid, p.20). Finally, Tushman and O'Reilly define ambidexterity as "the ability to simultaneously pursue both incremental and discontinuous innovation […] hosting multiple contradictory structures, processes, and cultures within the same firm" (ibid, p. 24).

As the idea of an ambidextrous organisation gained popularity, definitions proliferated in the attempt to illuminate different aspects of the new concept. Some definitions were more descriptive : "to move quickly to new opportunities, to adjust to volatile markets and to avoid complacency" as well as "exploiting the value of […] proprietary assets, rolling out existing business models quickly, and taking the costs out of existing operations" (Birkinshaw and Gibson 2004, p. 47). Other were more conceptually loaded: "adaptability" to the changes in the wider industrial environment and "alignment" within the internal business context (Birkinshaw and Gibson 2004). Metaphors were often brought in to aid understanding of the emergent theory. Tushman and O'Reilly speak of ambidexterity as "a juggling act" and refer to the metaphor of a "symphony conductor rather than a general" to describe the ambidextrous manager (Tushman and O'Reilly 1996, p.18). Gibson and Birkinshaw also employ the metaphor

of the juggler to depict the ambidextrous leader and characterise them as an individual "comfortable wearing more than one hat" (Birkinshaw and Gibson 2004, p. 49).

Ample ambidexterity definitions aimed at capturing various aspects of ambidextrous behaviour in the organisation. As more and more authors addressed the topic, the rationale of ambidexterity distilled exploitation and exploration features in the analysed contexts. The diversity of descriptive definitions ultimately converged on the concise, and already conveniently existing, exploitation-exploration terminology. The exploitation-exploration lens was merged into innovation ambidexterity theory, lending it not only its terminology, but also theoretical conclusions about the relationship between the exploitation and exploration activities. Incorporating the exploitation-exploration framework in ambidexterity theory took the framework beyond the context of knowledge management to various other domains: technology, products, individuals, organisation and markets. O'Reilly and Tushman provide a renewed concise definition of ambidexterity as "the ability of a firm to simultaneously explore and exploit" (O'Reilly III and Tushman 2008, p. 185). Having been incorporated into organisational ambidexterity theory, exploitation has since been broadly associated with notions such as focus, efficiency, experience and variance reduction and exploration with organisational diversity, experimentation and flexibility.

2.6 Central assumptions and propositions of ambidexterity theory

March's conceptualisations within the exploitation-exploration framework entered innovation ambidexterity theory. Namely, the assumption about the conflicting relationship between exploitation and exploration, the necessary trade-off between them and the need to balance them have all been inherited at the origin of ambidexterity theory. Early innovation ambidexterity theses are quite compact and fully reflect March's ideas. The notion of ambidexterity, however, added more assumptions about the inter-relation of exploitation and exploration. I will now extract the central elements of the theory for a further empirical test.

The conflicting nature of exploitation and exploration is derived from three main factors: (1) different locus of outcome (short-term versus long-term), fundamentally divergent frames of thinking and (3) limited resources. Contrary to exploration, exploitation produces returns which are more certain, more proximate in time and more

similar to the organisation's knowledge base. By extension, exploitation is associated with reliability and short-term productivity from leveraging currently available knowledge. In turn, exploration is associated with future viability from developing new technologies, acquiring new skills and searching for new business opportunities. Therefore, *the main rationale of innovation ambidexterity theory inherited from exploitation-exploration framework is that sufficient levels of exploitation and exploration in the firm would enable the firm's immediate profitability while at the same time ensure continuity of technology and capability development for future prosperity*. The proposition to balance exploitation with exploration put forward by March in the original framework comes to the forefront in innovation ambidexterity theory with an even stronger assumption about the balance, since the notion of ambidexterity dictates more concrete ideas about what the balance should look like. *Innovation ambidexterity formulations converge on the central idea that simultaneous and equal amount of both exploitation and exploration activity should be balanced in a firm in order to sustain renewal and long-term success. Ambidexterity also implies that exploitation and exploration are done skilfully, i.e. they are of equally high quality*.

The central assumptions and proposition of innovation ambidexterity are thus:

1. *The definition assumption*: exploitation and exploration are distinct organisational modes, opposing in nature and in a trade-off relationship organisationally.
2. *The balance assumption* that ambidexterity is a simultaneous pursuit of an equally high degree of exploitation and exploration.
3. *The proposition that implementing ambidexterity is essential* to ensure the firm's renewal and long-term success.

2.6.1 Trade-off between exploitation and exploration

Exploitation and exploration activities are essential for a firm, but resource constraints compel firms to choose one type of activity over the other. Resource allocation decisions are, therefore, where the opposing nature of the exploitation and exploration tangibly manifests. In addition, there is a less tangible opposition in behaviour when one is exploiting and exploring (refinement vs discovery, search vs selection, play vs execution). The trade-off assumption follows. By allocating resources to refining existing

capabilities rather than developing new skills and putting new processes in place, the firm trades off long-term innovation for short-term productivity. Conversely, by over-emphasising search for new knowledge, the firm trades off immediate needs for uncertain future opportunities. At a more general level, the problem of balancing exploitation with exploration becomes a bigger question of "whether the present should be hedged for the future" (Lavie et al. 2010, p.116).

Another aspect of the trade-off concerns the choice between stability and flexibility. The tendency of organisations to favour stability and resist to change due to the organisation's size, complexity of interdependent processes and dedication to the established premium paying markets lead to cultural and structural inertia (Christensen 1997, Tushman and O'Reilly 1996). Such inertias have been promptly called "organisational equivalent of high cholesterol" (Tushman and O'Reilly 1996, p.18) that confines the firm to the things already known making it difficult to experiment and prepare for inevitable changes in the environment. The opposite risk is incessant innovation with the failure to reduce variety of innovative ideas and stabilise organisational processes around the innovations. Exploitation and exploration are self-reinforcing: organisations that are disproportionately focused on exploitation face major challenges when attempting exploration (Sørensen and Stuart 2000), organisations that commit to too much or too radical change risk organisational chaos (Huy 2002). Although both exploitation and exploration can create path dependencies for organisations, entrenchment in exploitation is more likely and organisations tend to do more of the same than more of the new due to organisational inertia and lower risk and uncertainty (O'Reilly III and Tushman 2011).

The different elements of organisational ambidexterity and the trade-off inter-relation between them have been the cornerstone of innovation ambidexterity theory. Even though the initial interest in the theory has been inspired by the theory's promise of sustained performance and long-term success for firms, much of the body of innovation ambidexterity theory has been dedicated to understanding trade-offs (Jansen et al. 2006, Nerkar 2003, Uotila et al. 2009) and elaborating solutions to relax the tensions between exploitation and exploration (Andriopoulos and Lewis 2009, Birkinshaw and Gibson 2004, Gibson and Birkinshaw 2004, Lee et al. 2017, Lubatkin et al. 2006, O'Reilly III and Tushman 2008). As the theory advanced, additional scholarly attention has been paid

to the empirical testing of the performance benefits hypothesis with quantitative data (Cao et al. 2009, He and Wong 2004, Lavie et al. 2011, Lubatkin et al. 2006, Venkatraman et al. 2007).

A vast part of the effort to advance innovation ambidexterity theory consisted in identifying key factors that promote ambidexterity – antecedents of ambidexterity (Chang et al. 2011, Gibson and Birkinshaw 2004, Jansen et al. 2006, Raisch and Birkinshaw 2008, Rogan and Mors 2012, Simsek et al. 2009). Similarly, a lot of work was done to analyse outcomes of simultaneous exploitation and exploration in a qualitative (O'Reilly III et al. 2009, O'Reilly III and Tushman 2004, Tushman et al. 2011) as well as quantitative way (Cao et al. 2009, Gibson and Birkinshaw 2004, He and Wong 2004, Lee et al. 2017, Lubatkin 2006). This comprised a vast and diverse body of literature. Scholars have also begun to summarise and systematise the findings and reflect on the differences in conceptualisations that appeared as more and more contributions came in (Gupta et al. 2006, Lavie et al. 2010, Raisch and Birkinshaw 2008, Raisch et al. 2009, Simsek 2009, O'Reilly and Tushman 2013). The formalisation of the ambidexterity scholarship in such reviews is an indicator of ambidexterity becoming a theory (Mullins 1974).

Further research concentrated on organisational solutions that would allow to alleviate trade-offs between exploitation and exploration. I will review the central ambidexterity solutions below.

2.7 Central solutions to resolve ambidexterity trade-offs

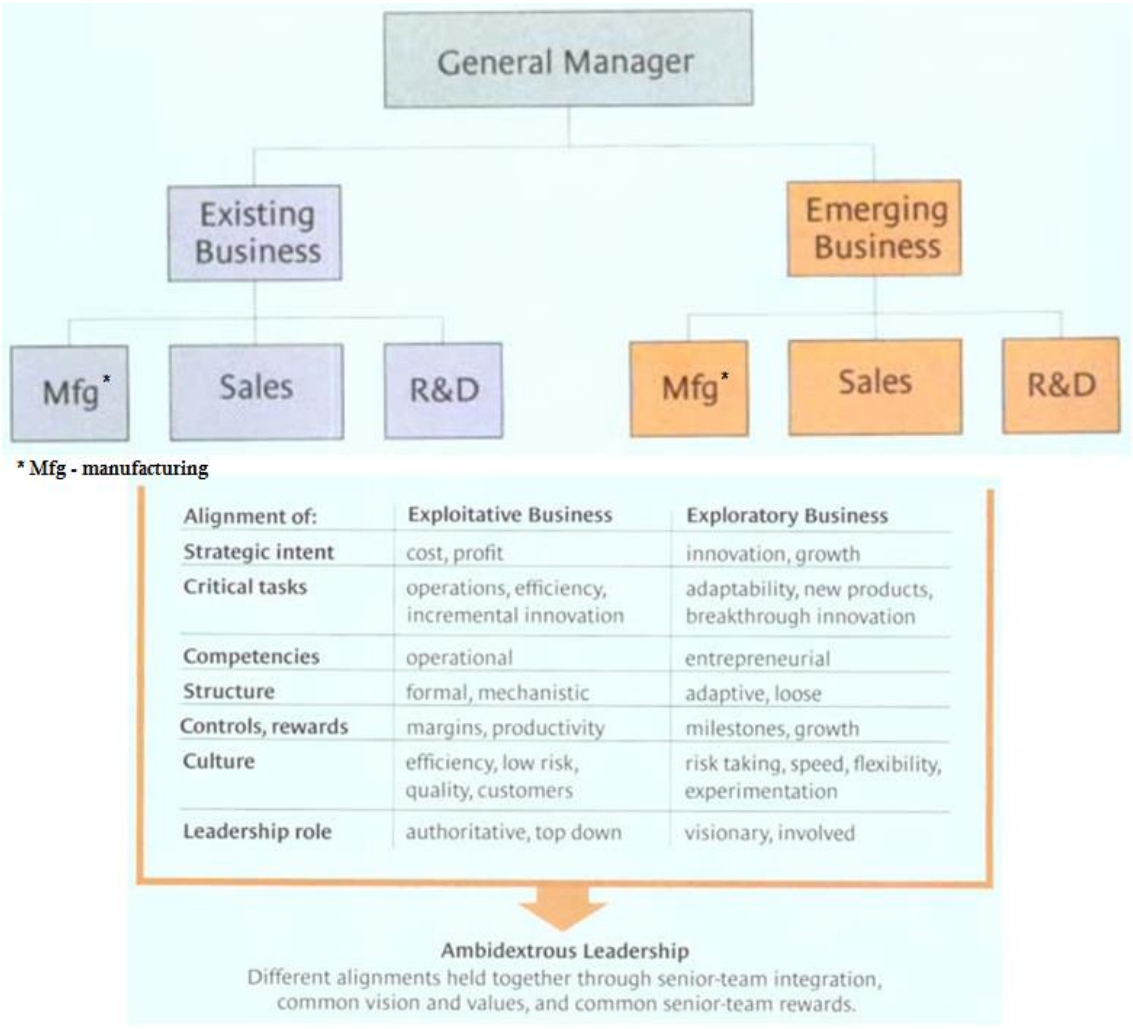
Researchers have come to recognise that although an optimal balance between exploitation and exploration activities is hardly attainable, firms can take actions to relax inherent tensions between exploitation and exploration and become ambidextrous. A number of ambidexterity solutions have been proposed. The gradual shift in thinking about the relationship between exploitation and exploration as an insurmountable trade-off to paradoxical mutual reinforcement has been important for further development of ambidexterity thinking. Several solutions that would alleviate the trade-off problem and allow achieving the beneficial ambidexterity have been put forward. All of them are in line with the central ambidexterity assumption that the firm should *simultaneously* pursue activities focused on improvement of efficiency and activities focused on innovation.

Innovation ambidexterity theory

It must be noted that balancing mechanisms advocating engagement of the organisation in only one activity at a time has been proposed before March and has been studied henceforth (Burgelman 2002, Mudambi and Swift 2011, Romanelli and Tushman 1994, Siggelkow and Levinthal 2003, Tushman and Romanelli 1985). I discuss them at the end of the chapter, since, under the simultaneity definition, they are not ambidexterity solutions proper (and this is problematic again, because definitions vary). For structuring purposes, I begin with the discussion of ambidexterity solution proper.

Tushman and O'Reilly, following their initial ambidexterity conceptualisations, proposed *structural ambidexterity*, which advocates the spatial separation of profoundly different exploitation and exploration activities into dedicated business structures, each having their own processes, strategies and cultures, with integration at the top management level (Figure 2) (O'Reilly III and Tushman 2004).

Figure 2. Structural ambidexterity (O'Reilly III and Tushman 2004, p.10-11)



The structural solution has been based on the theory's early assumption that exploitation and exploration activities are irreconcilable and need to be buffered from one another in separate business units (Tushman and O'Reilly 1996). The role of the structures is to preserve autonomy and quality of the respective activities. The role of ambidextrous leaders is to mediate the structures by setting a common vision, instilling culture and norms critical for both efficiency and innovation, ensuring timely interaction between the structures and reviewing performance. Pursuit of exploitation and exploration in highly differentiated but weakly integrated units allows avoiding conflicts over organisational resources, attention of managers and different approaches to doing things, such as reward systems, incentives and measurement of performance.

Differentiation is a key element of structural ambidexterity: he contrasting and incompatible exploitation and exploration units must be physically and culturally

separated from one another in the units best configured to achieve their respective distinct goals. At the same time, the paradox of ambidexterity is that exploitation and exploration are two different facets of organisational learning and adaptation and need to be combined to generate interactive outcomes. Integration, therefore, is another key aspect of structural ambidexterity: exploitation and exploration pursued internally in separate units must be strategically integrated by senior managers with a strong shared corporate culture. Culture should contain both tight and loose aspects and promote the values of autonomy and innovation, teamwork and initiative, accountability and innovation. Ambidextrous leaders embody the culture and serve as the point of integration of exploitation and exploration, promoting efficiency and constantly striving to renew their organisations (Tushman and O'Reilly 1996). The essence of the structural ambidexterity solution is differentiation at the organisational level into dedicated internal structures for exploitation and exploration and integration at the individual level of top managers who steer new and existing processes, structures, strategies and cultures.

Departing from the claim of absolute incompatibility of exploitation and exploration, researchers have moved to a proposition that the competing frames can co-exist in one context so long as the context is properly managed. *Contextual ambidexterity* has been proposed as a behavioural rather than structural capability of the organisation to pursue alignment and adaptability simultaneously in a single organisational context (Birkinshaw and Gibson 2004, Gibson and Birkinshaw 2004). The role of the human aspect of the organisation, rather than organisational structures, is emphasised in this solution: ambidextrous contexts are created and maintained by ambidextrous individuals – employees at various levels in the organisation "who make choices between alignment-oriented and adaptation-oriented activities in the context of their day-to-day work" (Birkinshaw and Gibson 2004, p.49). Unlike structural ambidexterity where exploitation and exploration are integrated at the senior management level, the locus of strategic integration of alignment and adaptability in contextual ambidexterity is lower: all individuals are expected to create a business context supportive of ambidexterity and judge for themselves how to best divide their time between the conflicting demands of exploitation and exploration. Ambidextrous individuals are thus the key source of ambidexterity in this solution. What is important is that the role of ambidextrous individuals powering ambidexterity is neither equated with charismatic leadership by

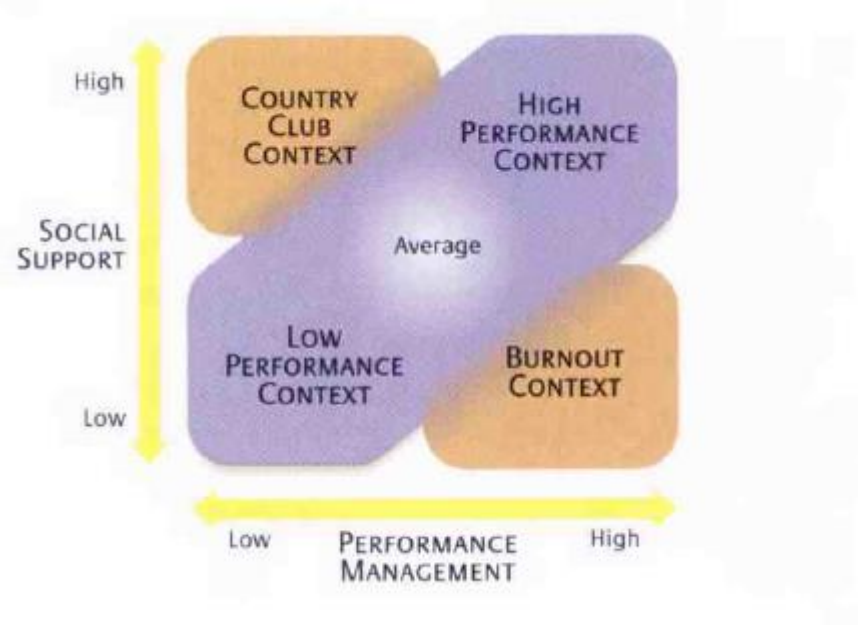
some individuals, nor with a strong organisational culture (Gibson and Birkinshaw 2004). Contextual ambidexterity advocates the creation of a behavioural context for all individuals at every level of the organisation to take agency to integrate exploitation and exploration.

Because organisational conditions can facilitate or inhibit an individual's ability to act ambidextrously, contextual ambidexterity is considered an organisational, as well as an individual capability. According to Birkinshaw and Gibson, "at the organisational level contextual ambidexterity can be defined as the collective orientation of the employees toward the simultaneous pursuit of alignment and adaptability" (Birkinshaw and Gibson 2004, p.50). Referring to both organisational and individual level capabilities, the notion of organisational context has important similarities to the notions of organisational structure and culture. Birkinshaw and Gibson define organisational context as "the systems, processes, and beliefs that shape individual-level behaviors in an organisation" (Gibson and Birkinshaw 2004, p.212). They also draw a more tacit characterisation of organisational context as "often invisible set of stimuli and pressures that motivate people to act in a certain way" (Birkinshaw and Gibson 2004, p.51) from the earlier work of Ghoshal and Bartlett about organisations that fit people (Ghoshal and Bartlett 1997). The idea of ambidextrous context has thus elements of structure and culture manifested in people's behaviour.

Building on these ideas, Gibson and Birkinshaw argue that four organisational qualities facilitate contextual ambidexterity: stretch, discipline, support and trust, and that different degrees of these combine to define an organisational context (Birkinshaw and Gibson 2004). Discipline and stretch are the hard elements of the context. They are concerned with motivating people to work efficiently and reach for high quality results. They comprise the "Performance Management" dimension of the organisational context (see Figure 3). Support and trust are the soft elements of the context that comprise the "Social Support" dimension. They are concerned with providing guidance and help and the sense of fairness and appreciation that people need to perform well. Combination of different levels of performance management and social support qualities produces a matrix of four types of organisational contexts of which the high-performance context combining high levels of social support with strong performance management gives rise to an ambidextrous organisation. Three other contexts: low performance, country club

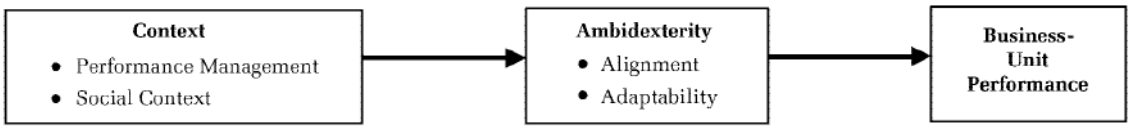
and burn-out context display an imbalance where one or both dimensions of organisational contexts is poor.

Figure 3 Four types of organisational context (Birkinshaw and Gibson 2004, p. 51)



Contextual ambidexterity, therefore, presupposes not only *simultaneous presence* but also a *high level* of equally important attributes that would facilitate the processes of alignment and adaptability across the organisation (Birkinshaw and Gibson 2004). Importantly, the four attributes per se do not imply specific actions or guarantee superior organisational outcomes. Rather, the attributes of a context are creating a *capacity* for contextual ambidexterity: the more they are present in the organisation, the higher is the level of ambidexterity, which in turn influences organisational performance. Ambidexterity, is a meta-capability that mediates the relationship between the qualities of organisational context and subsequent performance (Figure 4). Ambidexterity, according to Gibson and Birkinshaw, is "a carefully selected set of systems and processes that collectively define a context that allows the meta-capabilities of alignment and adaptability to simultaneously flourish, and thereby sustain business unit performance" (Gibson and Birkinshaw 2004, p.210).

Figure 4 Performance relationships between context, ambidexterity and business unit performance (Gibson and Birkinshaw 2004, p.210)



The behavioural qualities of discipline, stretch, support and trust manifest in actions of individuals, which in turn concern all functions and levels in the organisation. If these actions bear high level qualities to create ambidexterity, ambidexterity is then deployed throughout the whole organisation. Conceptualised this way, contextual ambidexterity is argued to be more conducive to sustainable performance because it simultaneously permeates the whole organisation through the effort of ambidextrous individuals at every level without creating a polarity of exploitation and exploration (Gibson and Birkinshaw 2004). Importantly, the contextual ambidexterity approach also transcends the perception of exploitation and exploration as confrontational. Instead, it views them as intertwined and mutually reinforcing. In more metaphoric terms of Ghoshal and Barlett whose thinking influenced Gibson and Birkinshaw, exploitation and exploration are not mutually exclusive but "the yin and yang of continuous self-renewal" (Ghoshal and Bartlett 1997, p.151).

The structural and contextual ambidexterity conceptualisations have some similarities and overlapping points. They both include an individual dimension and emphasise the strategic role of ambidextrous individuals, either senior managers or regular employees who become critical enablers of organisational ambidexterity. Proponents of both the structural and contextual view agree that achieving ambidexterity is not simply a matter of installing respective organisational structures or contextual attributes. Ambidexterity is predicated on the agency of individuals who put in place an overarching vision, values and culture and actively integrate exploitation and exploration activities in their daily work. Researchers also propose that the two ambidexterity solutions should be viewed as mutually supportive because firms use a combination of structures and behavioural capabilities to deliver simultaneously on the needs of exploitation and exploration (Chang and Hughes 2012).

Innovation ambidexterity theory

The emphasis on the crucial role of individuals in structural and contextual ambidexterity has been extended into the third solution of ambidexterity problem, *the leadership solution* (O'Reilly III and Tushman 2008, Smith and Tushman 2005, Tushman et al. 2011). Following Tushman and O'Reilly's idea of the integrative role of the top management team in the original ambidexterity conceptualisation (Tushman and O'Reilly 1996), researchers have proposed that ambidextrous agency per se may be an critical factor in enabling innovation ambidexterity (Lubatkin et al. 2006, Mom et al. 2007). In other words, flexible managers, supportive leaders and an aligned top management team are important antecedents of any form of ambidexterity. Leaders are essential for ambidextrous orientation of the firm not only because leadership processes make ambidextrous structures and contexts effective (O'Reilly III and Tushman 2008), but also because leaders provide "behavioral integration" of disparate demands of exploitation and exploration (Lubatkin et al. 2006). They unify formal rules and informal social codes such as values, norms and culture, deal with the paradoxical demands of concurrent divergent processes (Atuahene-Gima 2005, Smith and Tushman 2005) and ensure consensus around the decisions about coordination of exploitation and exploration at different levels of the organisation (Floyd and Lane 2000).

The leadership solution to ambidexterity problem marks an overlap between organisational and individual factors in enabling ambidexterity. Scholars have become aware that structural, contextual and leadership conditions should be explored together to understand how firms might balance the contradictory demands of exploitation and exploration. On the one hand, this complicated the hitherto existing understanding of *what* ambidexterity is. On the other hand, it signalled a transition to a new phase of research offering a more detailed scrutiny of *how* ambidexterity can be achieved. More studies started to analyse a variety of antecedents and environmental conditions of organisational ambidexterity (Jansen et al. 2005, 2006), identify potential moderating effects (Kyriakopoulos and Moorman 2004, Rogan and Mors 2012, Rothaermel and Alexandre 2009) and examine more complex relationships between exploration and exploitation.

Maintaining the trade-off assumption between exploitation and exploration, ambidexterity scholars realised that firms can resolve the trade-offs by pursuing the opposing activities across different organisational domains or across organisational

boundaries (Lavie et al. 2011, Lavie and Rosenkopf 2006, Lavie et al. 2010). Ambidexterity research moved to study organisation's alliances, as well as mergers and acquisitions (Stettner and Lavie 2014).

Merging individual, organisational and inter-organisational ambidexterity conditions meant that theoretical understanding of more complex ways of organising was needed. This motivated increasing contributions from additional research strands such as organisational adaptation, strategic management, marketing and leadership theory (Raisch and Birkinshaw 2008). The initially focused debate on organisational ambidexterity became complex and fragmented, with different contributions bringing in their own terminology and conclusions about the relationships between ambidexterity concepts in their particular context. Researchers called for more research to clarify the problematic incoherence in the scholarship. Efforts continued to consolidate the large body of literature into a comprehensive theoretical framework, promoting a systematised understanding of the notion of ambidexterity and the twin concepts of exploration and exploitation (Lavie et al. 2010, Simsek 2009).

2.8 Central tensions within innovation ambidexterity theory

The continuing effort to systematise definitions, conceptualisations and measures of organisational ambidexterity revealed serious issues within the body of knowledge about organisational ambidexterity. Gupta and colleagues have been among the first to raise concerns about inconsistencies of ambidexterity theorisations. In their review paper, the researchers systematised the theory's problems in what they termed four "central questions": the question of *definitions and connotations*, of *orthogonality versus continuity*, of *ambidexterity versus punctuated equilibrium* and *duality versus specialisation* (Gupta et al. 2006). Raisch and colleagues offered their list of four "central tensions" which echoed those already identified: the tension between *differentiation and integration* pathways to ambidexterity, the question whether ambidexterity manifests at the *individual or organisational level*, *static versus dynamic* perspective on ambidexterity and the question of whether *internal or external* processes constitute organisational ambidexterity (Raisch et al. 2009). Lavie and colleagues offer another in-depth overview of the state-of-art of ambidexterity theory only to reconfirm that the main issues persist and that a number of more nuanced problems obstruct coherent theorisation across

multiple organisational levels and domains (Lavie et al. 2010). Importantly, the re-iteration that fundamental contradictions continue to exist and the explicit call to address them before further advancement is made have signalled a broader paradigmatic crisis of ambidexterity theory. In summary, the issues identified by the scholars converged on the following problematic points:

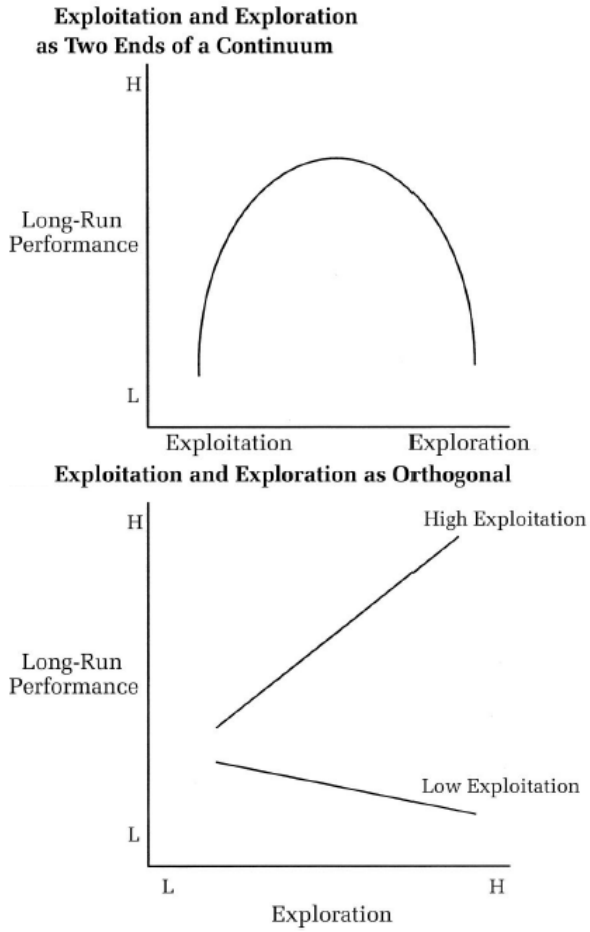
Definitions and connotations of exploitation and exploration activities. Are incremental knowledge gain, local knowledge search and learning along the existing trajectory a case of exploitation? Or is new learning, however minimal, a case of exploration? Where does the quantitative distinction between these two lie, to which phenomena do they apply and from whose standpoint are they assessed? To clarify this, the terms have been defined and operationalised for particular contexts where they acquire a more precise meaning and a measure. For example, Rosenkopf and Nerkar in their study of patenting activity use the term "exploration" for all activities involving learning, even for the most localised knowledge search, and reserve the term "exploitation" for refinement of an existing technology when no moving down any kind of learning trajectory occurs (Rosenkopf and Nerkar 2001). While this may be a fair operationalisation in the study of the impact of knowledge search on the quality of resulting patents, the demarcation between exploitation and exploration on the basis of absence versus presence of learning seems quite extreme. Reuse of old knowledge, improvement of established technologies and replication of existing routines is never devoid of some degree of novelty and learning. It is, therefore, argued that exploitation and exploration represent different types of learning and should be differentiated by the type and degree of new knowledge, rather than presence versus absence of it.

This seems the furthest the theoretical definitions of exploitation and exploration can go: a more precise general definition is difficult to produce. A point of view or level of analysis also plays a role: an individual employee might consider their work inventive and explorative but it may be advancing her organisation along the existing trajectory and amount to exploitation for the organisation. Conversely, various incremental improvements coming from different individuals might set the organisation on a new path and amount to exploration. Definitions and operationalisations for concrete contexts can be empirically helpful. At the same time, operationalising the notions of exploitation and exploration for the purposes of a particular study creates divergence across existing

formulations and can potentially change the conceptual meaning of the terms, which is problematic for the theory. For example, in the study of how firms search for new products, Katila and Ahuja operationalise exploitation as search depth, i.e. how frequently the firm reuses its existing knowledge, and exploration as search scope, i.e. how widely the firm explores new knowledge (Katila and Ahuja 2002). This has taken exploitation and exploration from a unidimensional search spectrum from local to distant, as originally conceptualised and illustrated above in Rosenkopf and Nerkar (2001), to two distinct non-overlapping dimensions: search scope and depth (Katila and Ahuja 2002). Katila and Ahuja emphasise that "exploitation is a more comprehensive concept that it is considered to be" (ibid. p.1191), where firms also differ in the extent to which they master old knowledge. This complicates the conceptualisation of the duality of exploitation and exploration even more and leads to the next problematic conceptual point of the theory.

Continuity versus orthogonality of exploitation and exploration is the issue pertaining to the nature of the relationship between exploitation and exploration. In March's original understanding, exploitation and exploration are in a trade-off relationship (March 1991). They tend to crowd out one another in competition for scarce organisational resources, attention of managers and organisational processes. This led to the conceptualisation of exploitation and exploration as two ends of a continuum where exploration is inversely related to exploitation at any given time (Lavie and Rosenkopf 2006). Furthermore, the interrelation has been expressed as an inverted U-shape relationship, where performance benefits of moving along the curve from exploitation to exploration decline past a certain point of the exploitation-exploration balance (Gupta et al. 2006). However, this key assumption has been challenged. Empirical studies that measured exploitation and exploration separately produced mixed results, reporting a confusing array of findings from negative correlation between exploitation and exploration (Park et al. 2002, Van Deusen and Mueller 1999), to no significant association (Jansen et al. 2006), to positive correlations and complementarity between exploitation and exploration (Katila and Ahuja 2002, Knott 2002). The latter led to the possibility of conceptualising of exploitation and exploration as non-contradictory orthogonal activities (Figure 5).

Figure 5 Conceptualisation of exploration and exploitation as two ends of a continuum and as orthogonal activities (Gupta et al. 2006)



It is argued that orthogonality is the case when resources required for exploitation and exploration are infinite or fundamentally different not to create a conflict or can be easily leveraged from a munificent environment. For example, Baum et al. conceptualised exploitation as an organisation's learning from its own experience and exploration as learning from others, both of which are potentially unlimited and thus, orthogonal (Baum et al. 2000). In the already mentioned study, Katila and Ahuja stipulated that the number of patents an organisation may cite and the frequency it can cite any particular patent is unlimited, thus, exploration and exploitation activities do not necessarily suffer from resource constraints or compete with each other for resources (Katila and Ahuja 2002).

It has also been demonstrated that high levels of both exploitation and exploration may coexist when they are distributed among individuals or across different

organisational domains and beyond the organisation (Lavie and Rosenkopf 2006, Lavie et al. 2010a). It may be extremely difficult for a single individual to multitask or switch between creativity of exploration and efficiency of exploitation, but with the division of labour between several individuals in different units this task may be not as hard. It is also easier to switch when efficient change routines are in place and the change is supported by the management. Exploitation and exploration across different and loosely coupled domains makes these activities orthogonal such that high levels of exploitation in one domain may coexist with high level of exploration in another.

Innovation ambidexterity theory encompasses both positive and negative associations between exploitation and exploration which creates inconsistency within the body of knowledge and leads to ambiguity of conceptualisations. These problems are caused by elements of the research designs such as the level of analysis, operationalisation and measure of exploitation and exploration. The theoretical problems somewhat found a resolution in an observation by Lavie and colleagues who argued that a positive association between exploitation and exploration comes not from their complementarity or orthogonality, but is enabled by managers who resolve trade-offs through domain separation, change routines and leveraging external resources (Lavie et al., 2010). This argument is in line with the ambidexterity's central ideas and allows to relax the theoretical inconsistency. The fact that organisations can take actions to resolve trade-offs does not negate the existence of trade-offs while at the same time suggests complementarity. The complementarity between exploitation and exploration is desirable as well as possible precisely because there can be a positive temporal spill over between exploitation and exploration, opposing as they are. For example, exploitation can create revenue that afford exploration and exploration generates opportunities that later can be exploited. The trade-offs do not rule out the temporal reinforcing association between exploitation and exploration over time (Lavie et al, 2010). The discussion about the temporal interplay between exploitation and exploration is the next important issue of the theory.

The adoption of time as a research lens has been an important development in innovation ambidexterity theory. As already mentioned, researchers proposed that the balance between exploitation and exploration can also be achieved through *temporal separation* of exploitation and exploration activities in an organisation. Punctuated

equilibrium, where long periods of exploration are punctuated by short periods of exploration, was noted as an alternative mode of balancing the two activities that allowed to avoid the conflicts of simultaneous exploitation and exploration (Burgelman 2002, Mudambi and Swift 2011, Siggelkow and Levinthal 2003). The issue of *ambidexterity versus punctuated equilibrium* challenged one of the main premises the innovation ambidexterity - *simultaneity* of exploitation and exploration.

It has been argued that the punctuated equilibrium is an appropriate adaptation mechanism for an organisation when exploitation and exploration take place in a single domain and are viewed as two ends of a continuum (Gupta et al. 2006). Additionally, an organisational design is possible where the organisation is split into two loosely coupled sub-systems: A and B, where at time t1 A pursues exploitation and B pursues exploration, whereas at time t2 A switches to exploring new opportunities and B switches to exploiting the idea it has explored at time t1 (see Figure 6). The units would each exemplify the punctuated equilibrium, but at the level of the organisation they would together amount to ambidexterity. Ambidexterity may, therefore, arise both from simultaneous and sequential attention to exploitation and exploration. Consequently, temporal as well as structural separation of exploitation and exploration activities was claimed to be an ambidexterity solution.

Figure 6. Punctuated equilibrium in units, ambidexterity at organisational level (Gupta et al. 2006)

	Time 1	**Time 2**
Unit A	exploitation	exploration
Unit B	exploration	exploitation

In the punctuated equilibrium solution, exploitation and exploration are not pursued simultaneously by the same individual or organisational unit. They are buffered in a time period dedicated for that activity. This allows a single unit or tightly coupled organisation to relax tensions between the conflicting needs of exploitation and exploration. The researchers who conceptualised this, accept time separation as an ambidexterity solution, whereas others hold to the original thesis of ambidexterity and underscore the importance of "simultaneous capacities for alignment and adaptability" (Gibson and Birkinshaw

2004, p. 223). Here, the theory suffers the ambiguity problem of whether ambidexterity refers to any mechanism so long as it ensures the presence of exploitation and exploration and relieves the tensions between them, or whether ambidexterity is only one approach, namely, simultaneous exploiting and exploring within the boundaries of the firm.

To complicate things further, specialisation in either exploitation or exploration has been argued to be an entirely viable option for some organisations. It is easy to imagine a niche organisation doing either exploitation or exploration. For example, a design consultancy may do very little exploitation because what it is paid for is to explore. Alternatively, an organisation may be tasked with executing ideas as, for example, a university spin-out company would exploit ideas developed at the university department. March (1991) and later Benner and Tushman (2003) noted that under well-specified conditions, specialisation in either exploitation or exploration may be entirely viable. The specialisation argument was iterated by Gupta and colleagues (2006) who stated that "individual organizations may justifiably focus solely on exploration or exploitation while delegating the task of achieving a balance between the two to the social system" (Gupta 2006, p. 699). They also specify a number of conditions under which an organisation A may successfully exploit and organisation B be successful only exploring, such as when they control mutually complementary resources and interface at the shared marketplace. It is easy to see that "such a scenario is nothing other than the logic of ambidexterity extended and generalized from the context of single organizations to the context of the broader social system." (Gupta et al. 2006, p.699). This signalled the important theoretical problematic of ambidexterity, that of its boundaries: how far one can look till it stops being ambidexterity?

Whereas the initial studies of ambidexterity considered balancing exploitation and exploration within organisational boundaries, later studies suggested that organisations can balance exploitation and exploration across organisational boundaries (Lavie and Rosenkopf 2006). *External versus internal perspective on ambidexterity* has become an issue in the research on organisational ambidexterity. The original notion of ambidexterity focused on how organisations address exploitation and exploration internally. But further research showed that the balance between exploitation and exploration may also be achieved across various organisational domains. Exploration often implies moving beyond the existing organisational and technological frontiers and

externally acquired knowledge has the most impact on subsequent technological development of the firm (Rosenkopf and Nerkar 2001). Combining new knowledge from the outside with existing knowledge allows greater opportunities for recombination in organisational learning. Indeed, organisations often acquire and synthesise knowledge across boundaries. They also externalise one or another type of activities to resolve the paradoxical requirements of exploitation and exploration by outsourcing, corporate venturing (Hill and Birkinshaw 2008) or establishing alliances (Lavie et al. 2011, Lavie and Rosenkopf 2006, Lavie et al. 2010, Rothaermel and Deeds 2004, Stettner and Lavie 2014). However, concerns have been raised that *organisational separation* of exploitation and exploration activities may harm strategic integration of the activities for the firm (Benner and Tushman 2003). The emphasis on the external locus of opportunity means that organisations have to develop additional skills and routines such as, for example, brokering capabilities, external social relations and the ability to pull resources from broad contexts together. To be useful, externally sourced knowledge also has to be absorbed and integrated with internal elements (Cohen and Levinthal 1990, Kogut and Zander 1993). The notion of ambidexterity broadened to incorporate the ability of firms to access new knowledge from the outside and to integrate the knowledge flexibly across boundaries within the organisation. The theory of innovation ambidexterity had to absorb a new mechanism of balancing exploitation and exploration and conceptualise the processes that would enable integration of external exploration with internal exploitation, or vice versa.

The option of separating exploitation and exploration across organisational boundaries and outsourcing either of the activities to specialised actors brought up the issue of *duality versus specialisation* as a form of pursuing exploitation and exploration activities. As discussed above, organisational separation of exploitation and exploration activities brought into question March's argument regarding the need for every organisation to pursue both exploitation and exploration (March 1991). Research on ambidexterity shifted in focus from individual firms to the broader social system across which ambidexterity can be enacted. It has been argued that ambidexterity can manifest at the level of the organisational environment or industry (Stettner and Lavie 2014). Expanding the boundaries of theory's application has complicated ambidexterity theory and introduced the problem of inconsistent generalisations supplied by different levels of

analysis. Exploitation and exploration across multiple organisational levels is difficult to generalise and the interactive ambidexterity effect of the two activities at every level of a nested organisational system is difficult to pinpoint. These complications notwithstanding, ambidexterity theory continued to develop.

2.9 Success and crisis of ambidexterity

The ambidexterity lens has been applied to interpret various tensions and processes within and across organisations in a great variety of empirical contexts ranging from technological product innovation in business firms (Gibson and Birkinshaw 2004, Tushman and O'Reilly 1996), to financial services (Jansen et al. 2005), to comic book publishing (Taylor and Greve 2006) and theatre productions (Voss and Voss 2013). Ambidexterity research is plentiful, but the use of the terms exploration, exploitation and innovation or organisational ambidexterity in the literature has not been matched by a smilarly substantial consideration of appropriateness of the terms in the new areas into which the theory is so rapidly expanding.

In its infancy, innovation ambidexterity was a fairly compact set of ideas that described the organisational forms and transformation processes of companies that were engaged in technological innovation (Tushman and O'Reilly 1996). Ambidexterity rationale made sense and the theory expanded beyond technological innovation. It became applied to domains such as knowledge management, strategy (Jansen et al. 2008, Lubatkin et al. 2006, Smith and Tushman 2005, Venkatraman et al. 2007), marketing (Atuahene-Gima 2005, Hughes et al. 2010, Kyriakopoulos and Moorman 2004), organisational behaviour (Birkinshaw and Gibson 2004) and organisational design (Tushman and O'Reilly 2011). The theory developed further to interpret firms' learning across organisational boundaries such as strategic partnerships, alliances and acquisitions (Lavie et al. 2011, Lavie and Rosenkopf 2006, Lavie et al. 2010, Stettner and Lavie 2014).

The *analytical toolkit* of organisational ambidexterity has also changed from *intra-organisational structures, processes, strategies and structures* for enabling a balance between exploitation and exploration to *the organisational ability to implement both static and dynamic components in its design* to deal with conflicting priorities *at different organisational levels and domains*. Innovation ambidexterity has transformed to a more general theory of ambidextrous organisation that was applicable to any complex adaptive

social system seeking solutions to enable efficiency and flexibility for system survival (Siggelkow and Levinthal 2003).

The rapid growth of the field, with scholars working in an increasing variety of research domains, has been both a sign of the theory's success and its emerging epistemological weakness. The versatility of empirical studies that have contributed conclusions about ambidextrous organising is as impressive as problematic. Contexts of comic books publishing (Taylor and Greve 2006) and theatre productions (Voss and Voss 2013) are offering insights about ambidexterity alongside technology management research (Benner and Tushman 2002, Smith and Tushman 2005). Assembling and distilling the dominant relationships between the central ambidexterity concepts from the exploding number of contributions in the course of this research has been a challenge in itself. However, above and beyond the challenge of distilling the core theoretical elements of ambidexterity theory, the spread of organisational ambidexterity theory is problematic on the epistemological grounds. It has been noticed that ambidexterity has become so wide-spread that it risks becoming an all-purpose framework to interpret any organisational situation that involves combining competing priorities (Raisch and Birkinshaw 2008). Being applied to too many things, ambidexterity loses the value of the original construct and runs an additional danger that an ambidexterity perspective *can be manufactured* to explain almost any types of distinct activities competing. Having become theory of everything, it risks becoming theory of nothing (Birkinshaw and Gupta 2013).

Organisational challenges are often caused by an inter-play of conflicting forces of some kind, which is why there is a strong temptation to apply the already popular theory to every such context and compartmentalise multiple forces acting on the organisation in the two archetypes. This also leads to the tenuous assumption that any such tension, paradox, or conflicting organisational forces must be reconciled regardless of the logic of doing so. For organisations, this may mean misdiagnosing the problem and applying the wrong tool to understand and resolve it. The lack of boundary conditions makes the theory epistemologically problematic: terms get diluted because they cannot retain the same conceptual load across different context. Empirically established logical connections between theoretical concepts break down when the concepts get transferred

across a very wide variety of contexts. The theory's robustness weakens because generalisations become difficult to sustain.

The proliferation of studies on the topic has created disjointed silos of knowledge about ambidexterity. The resulting ambidexterity theory has failed to diminish the complexity of the empirical world into a coherent, systematised generalisation. The theory is not cumulative and contributions from the different research strands remain inconsistent. Some of key ambidexterity scholars highlight the alarming examples of evidence that is outright conflicting. Lavie and Rosenkopf give an example of the studies of external industry forces as antecedents of exploitation and exploration that conclude "that turbulence and market uncertainty may generate either exploitation (Beckman, Haunschild, & Phillips, 2004; Rothaermel, 2001b), exploration (Rowley, Behrens, & Krackhardt, 2000), or both (Koza & Lewin, 1998)" (Lavie and Rosenkopf 2006, p.797). Such example is a work by Birkinshaw and Gupta (2013) that eschew the trade-off assumption set by March (1991) with no sufficient reasoning.

Despite the frequent and substantial efforts to critique and systematise the intellectual structure of the burgeoning field (Gupta et al. 2006, Lavie et al. 2010, Nosella et al. 2012, Raisch and Birkinshaw 2008, Simsek 2009), ambidexterity theory seems to remain a collection of research sub-fields that illuminate ambidexterity at different organisational levels and in different subject areas. The findings are appropriate for specific empirical contexts where they originated, but they do not add up to a consistent and robust body of knowledge. By virtue of their research designs, scholars inevitably focus on a particular ambidexterity phenomenon in a particular context, rely on definitions, operationalisations and measures of ambidexterity tailored to that context and assume a certain literature stream as a theoretical lens. As a result, they produce low-dimensional studies idiosyncratic to their research designs that yield conflicting results and support a variety of inconsistent propositions. This has been repeatedly signalled by some scholars in the field (Lavie and Rosenkopf 2006, Lavie et al. 2010).

Another epistemological problem, relating to the problem of generalisability, is the problem of practical applicability. A theory that does not produce consistent generalisations and, therefore, does not allow managers to locate knowledge appropriate for their contexts, has a questionable value. Very often, the rich but inconsistent knowledge of ambidexterity does not seem to usefully transfer to empirical contexts,

precisely because of its disjointed nature. It is difficult for an organisation to locate relevant theoretical insights and judge on the applicability of these to their practical context. All these problems began as intra-paradigmatic incoherencies that eventually accumulated to signal the theory's paradigmatic weakness.

2.10 Motivation for the research

The illuminated anomalies will not go away by doing the "filling the gap" research and can only be resolved when the very foundations and the nature of knowledge of organisation ambidexterity theory are reconsidered. This need has motivated my research. If we are to use ambidexterity theory as a robust analytical framework, rather than a rhetoric device, and provide constructive contribution to managerial practice, we need to re-examine the theory's very assumptions, fix confusion in the theorisations and define boundaries of the theory's empirical application.

3 Research design and methodology

A scientific investigation is a "puzzle-solving activity" that traditionally aims at extending the scope and precision of knowledge and results in uncovering an unsuspected novelty of fact or theory in more special cases (Kuhn 1962). Such activity is guided by a set of research questions that specify what is to be examined about a phenomenon. It relies on a structure and techniques that allow explicating and capturing the studied matter in the best way possible. Every scientific enquiry also presupposes a philosophical position ─ a reflection on the possibility of knowing and the limitations of knowing ─ although the degree of explicitness of the philosophical position will vary from investigation to investigation (Crotty 2009).

This chapter discusses the core elements of the research. It presents aims and objectives of the research (section 3.1), specifies research questions (section 3.2), presents a philosophical basis for the research, explains the Popperian logic of falsification used in the design of the research (section 3.3) and lays out a research design and methods used to address the research questions (section 3.3.2). While the ontological and epistemological positions form a philosophical basis of the research concerned with what is possible to learn about the researched topic and how, the research design is concerned with accessing relevant types of evidence and providing a logical structure to the enquiry. Research methods are subsidiary to the research design and are techniques for gathering compelling evidence that is necessary to answer the research questions. Together, the philosophical position, research design and research methods help to produce meaningful answers to the research questions.

3.1 Research aims and objectives

This thesis is concerned with understanding the value of theorisations of ambidexterity theory. As the act of balancing exploitation and exploration activities by the firm, innovation ambidexterity is lauded in the management and organisational studies for the promise to enable continuous technological innovation and sustained organisational performance. In the literature review above, we have seen that ample research has captured structures, processes and agency necessary to create an

ambidextrous organisation. It has examined challenges as well as benefits of instilling ambidexterity in organisations. We have also seen that paradigmatic issues emerged in the theory as it expanded to new contexts and struggled to cumulate finings coming from a variety of research streams. Ambidexterity research is plentiful and ambidexterity constructs have been helpful, but we need to address the paradigmatic problems that emerged and check the theory's robustness.

The aim of this thesis is to test whether the central assumptions and propositions of ambidexterity theory apply in the context of an innovative company to make conclusions about robustness and value of ambidexterity theorisations.

For the purpose of clarity of research design and discussion, I distinguish between the research aim and research objectives. The former is defined as the fundamental purpose of research, which is achieved by answering research questions. The latter is understood as stages or steps in the research process that must be taken to achieve the research aim successively. The aim of the thesis research has been given above. The research objectives of the thesis are:

1. To examine fundamental ambidexterity constructs, extract central assumptions and propositions of ambidexterity theory and make explicit paradigmatic problems with the theory.
2. To examine the empirical context in order to identify practices that do and do not accord with the central assumptions and propositions of innovation ambidexterity.
3. To re-evaluate ambidexterity theory in view of the empirical evidence.

The research objectives 1 and 2 are being addressed in the theory chapter 2 "Innovation ambidexterity theory". Objective 2 is achieved through the analysis of the empirical case in chapter 5 "Exploitation", chapter 6 "Exploration" and chapter 7 "Innovation ambidexterity". Objective 3 is fulfilled in the concluding discussion chapter 8 "Evaluating innovation ambidexterity theory: conclusions and discussion".

3.2 Research questions

The research seeks *to test* innovation ambidexterity theory by asking the following question:

Does innovation ambidexterity theory apply in the business context of the successful technology-intensive firm in the semiconductor industry?

The research question is formulated to check whether the central claims of innovation ambidexterity, namely - that any successful firm should engage in an equal degree of exploitation and exploration, and that exploitation and exploration are distinct and conflicting activities that need to be reconciled - hold in the context of the chosen firm. This is a theory-testing, exploratory study that aims to question ambidexterity thinking and implementation. This is a study according to the falsification logic: no new knowledge is sought here[1], but old, existing knowledge is subjected to test. As mentioned in the literature review, this is a rare exercise in the field with only one visible study (Durisin and Todorova 2012) that questions if ambidexterity thinking is at all implemented in firms in the way the theory claims.

To perform the test of ambidexterity's core propositions in line with the falsification logic, the following set of sub-questions has been formulated to try and explicate the assumptions and assess whether these are found in the studied firm:

1. What organisational processes are associated with exploitation, exploration and ambidexterity in the given firm?
2. How do these processes manifest themselves across the firm?
3. Where does the agency to initiate change lie in the organisational environment and who makes the decision?
4. How do industrial and organisational circumstances of the firm shape innovation adaptability in the studied firm?
5. What implications does the test of ambidexterity have on our understanding of structures and processes of technological and organisational innovation?

[1] Not of the "filling the gap" kind. The novelty here is in reassessing our received believes and understanding of organisational ambidexterity.

6. What are the consequences of the test for the usefulness of innovation ambidexterity framework?

The sub-questions are a mixture of "what", "how", "where" and "who" questions that indicate the exploratory nature of the research. The sub-questions also structure and organise the analysis of the collected empirical material and relate to the extracted theoretical concepts of ambidexterity in a systematic way. These questions will help to generate a rich qualitative description of innovation activities in the studied firm and use it as evidence to question the accepted assumptions of innovation ambidexterity theory. It will also serve as a basis to re-examine and evaluate ambidexterity thinking.

3.3 Philosophical basis

As stated above, this research is driven by theory and theory improvement is one of the implicit aims of this doctoral thesis. It is, therefore, necessary to consider the nature of knowledge that constitutes the theory in question, specify the kind of evidence that would be a valid contribution to the theory and understand the limitations of obtained knowledge. A set of ideas regarding the existence of objects and phenomena of the natural and social word, the relationships between them and their general features represents the ontological position of the researcher. A set of views on whether and how the true knowledge about the subject in question can be achieved constitutes the researcher's epistemological position (Crotty 2009). The ontological and epistemological positions combine to form a philosophical basis of a scientific enquiry.

Traditionally, a social science enquiry has often been expected to provide a clearer articulation of the philosophical position than a natural science investigation because of the need to acknowledge subjective, meaningful and voluntarisic components of human behaviour as opposed to deterministic inter-relation of inanimate objects of the physical world (Suppes 1970). The versatility of social phenomena makes it necessary to justify methodological ideas that the researcher applies to gain rigorous knowledge about human world and social phenomena (Crotty 2009).

The philosophical basis, or "methodological philosophy" (Hammersley 2013), adopted by the researcher, shapes the process and outcomes of their research. The methodological philosophy will determine what expectations the researcher has about the

knowability of the object of enquiry, how they collect legitimate evidence and justify conclusions. Additionally, the philosophical position presupposes approaching a topic with a set of values, following a certain process and using a certain style of language (Creswell 2007). These aspects are also important in qualitative research because they influence and characterise the practice of qualitative research. The narrative employs a specific personal language with terms evolving during the research process. To begin to tackle a topic, the researcher assumes a particular philosophical stance.

3.3.1 Constructivism and social constructivism

As a researcher, I locate my work within the constructivism paradigm. In this thesis, I take a meso-perspective on innovation and understand it as interaction of individual actors in the act of innovation within a broad context of the firm. Innovation is conceived and led by individuals, but it is shaped, on the one hand, by macro phenomena, such as the historical, geographic and socio-technological context in which the organisation is embedded and, on the other hand, the micro phenomena such as the organisational legacy and culture. Innovating is difficult, grasping the complex contextual combination of decisions and actions that make it a success or failure is even more challenging. Innovation is often tacit and difficult to pinpoint. It is a confluence of social activities such as science, technology, art, business and entrepreneurship, powered by human ingenuity and contingent upon broader, often unforeseeable, circumstances. In my view, the methodological philosophy of constructivism offers meaningful ways to understand the complex social phenomenon of innovation because it puts its socially constructed nature to the forefront.

The primary idea of constructivism is that the reality is not objective and external to humans, but socially constructed. The meaning of the experienced reality is produced by humans and is also socially constructed (Berger and Luckmann 1967, Easterby-Smith et al. 2012). Objects and phenomena of the world are not directly reflected in our cognition, but our cultural norms, social circumstances and our language actively shaped our perception and understanding (Hammersley 2013). What is important for this thesis is that constructivism underscores social dimensions of knowledge as a process and outcome. This means that the way we access the intrinsic features of objects and phenomena of the world and our understanding of them will inevitably, and even perhaps

to an overwhelming extent, bear the social characteristics of the research context. This will include features and dispositions of the researcher, norms and values of the scientific community in which they are located, as well as the broader social circumstances of the research. In the context of the social science research, this means that studying human interactions and social phenomena is itself a socially constructed process. The social constructivist paradigm helps to instil reflective awareness towards both the object and the process of social research.

A more complex philosophical paradigm of social constructivism emphasises that the construction of the social world and our knowledge about it occurs not so much through individual perception and cognition, but through shared socio-cultural processes of communication and interaction (Hammersley 2013). In general, social constructivism captures the idea that human interactions produce distinctive forms of discourse which are parts of distinct social worlds.

The implications of assuming the philosophy of social constructivism for this thesis research are both promising and challenging for the following reasons. First, the philosophical position influences the expectations of what can be learned about innovation, to what extent the research questions can be answered and how rigorous knowledge can be achieved. Social constructivism is promising in shedding light on interactions of individuals which innovation is. It also guides the research design and the choice of research methods which I discuss later in the chapter. Second, studying practices and processes though which people construct their collective worlds is itself a practice and a process generating a particular discourse. This turns the notion of construction back onto the researcher and the scientific enquiry. In its most radical form, social constructivism does not grant a research project epistemological privilege over other types of methodological philosophies (Hammersley 2013). On the other hand, the socially constructed, rather than the "natural" character of human endeavours, remains the main and the most powerful rationale that this research borrows from the social constructivism. It provides ground for contesting the dominant positivist way of thinking about the research area - the practice and content of innovation.

3.3.2 Popperian logic and the principle of falsification

Theory improvement is an implicit aim of this thesis. Here, I will articulate and argue for the logic that I adopted to improve the theory in question.

Improving our understanding of social phenomena be can achieved by bringing in additional relevant evidence. However, philosophers of science have noted that obtaining additional evidence to corroborate theory does not make the theory more true (Popper 1959). In other words, the probability of a scientific proposition or hypothesis being true remains the same no matter how much evidence is collected to support it (Russell 1998). Popper (1959) argued that a scientific theory can never be verified, i.e. conclusively proved as true. Instead, the best a researcher can do to test theory is to seek to falsify it, i.e. to look for evidence that would disprove and challenge the theory (Popper 1959). If a deliberate search for disconfirmatory evidence has brought no results then the theory is accepted as true, if only provisionally until new evidence is presented. Falsification as opposed to verification has, therefore, been proposed as a more rigorous method for evaluating theory, which increases its scientific robustness and, ultimately, demarcates scientific theory from other systems of knowledge (Popper 1959). According to Popper, theories should be regularly exposed to falsification in order to refine facts, propositions and premises that they contain and safely cover increasing data (Popper 1959).

Popperian ideas and principles stemmed out from logical positivism and have been initially applied, though not without controversy, to natural sciences. The Popperian logic and the principle of falsification have been more problematic in application to social scientific theory, in part because its social dimension renders it inevitably more complex in nature and form than natural science. However, the idea of falsificationism remains attractive because it enforces strict evaluation of theories and rigorous scientific standards relevant for both natural and social science endeavours. Whilst the Popperian logic has been predominantly associated with the positive epistemology and hard sciences domain, it is still relevant to a social constructionist philosophy because it calls on social constructionist researchers to question their beliefs and observations and "look for evidence that might confirm or contradict what one currently believes to be true" (Easterby-Smith et al. 2012, p. 68). In the same vein, Benton and Craib (2001) propose to approach science by specifying theoretical expectations or suggesting a set of explanations of what is observed, which researchers then set out to study on the basis that

they can prove them false (Benton and Craib 2001). A social researcher should aim to systematically check for, or at least to be alert to, adverse evidence that could undermine their theory. These are appealing principles to use to examine ambidexterity theory, whose advancement so far was propelled by gathering additional evidence, but which confused rather than improved ambidexterity theory. In this sense, improving theory by subjecting it to scrutiny as proposed by Popper seems to be a more promising and more original way.

My research borrows on the rationale of falsificationism to the extent that it provides logical grounds to embrace the conflicting empirical evidence, review theory in view of new evidence and generate conclusions to inform or reform the theory. The falsification logic drives to expose and analyse phenomena at play in the firm that have not yet been processed by the theory. This research is designed to look for the type of evidence that would challenge the core propositions of the innovation ambidexterity framework and analyse this evidence in a way that would make it more robust, i.e. improve it. The empirical setting of a single case study is used to provide evidence to falsify, or test, the premises of innovation ambidexterity theory.

3.4 Research design

The purpose of a research design is to provide a structure and logic for a scientific investigation that would enable collecting the type of evidence that would help to answer research questions in the most unambiguous and compelling way. The primary structuring factor of the research design is, therefore, the research question. The main question of this thesis research is *whether innovation ambidexterity theory apply in the business context of a successful technology-intensive firm in the semiconductor industry*? The research sub-questions collectively ask what mechanisms does the firm employs in the pursuit of the two-fold goal: improving the existing products and refining the underpinning competences to maintain business viability today and gearing towards distinct new possibilities outside the existing corporate scope for future viability.

To answer these questions, we need to obtain rich descriptions of the processes of refinement and variation that the firm employs to innovate and to manage organisational change associated with the innovation. This need motivates the choice of a qualitative study. Qualitative research is used when a problem or issue needs to be explored, when

"we need a complex, detailed understanding of the issue" (Creswell 2007, p.39-40) and when we need to enhance theories "when partial or inadequate theories exist […] or existing theories do not adequately capture the complexity of the problem we are examining (Creswell 2007, p.40). In this study, I need to answer the "if", the "what" and the "how" questions for which purpose quantitative and statistical analyses simply do not fit. Quantitative research deals with gathering numerical data to explain a particular phenomenon, and quantitative methods in social science emphasise the statistical, mathematical, or numerical analysis of data collected through polls, questionnaires and surveys to determine a relationship between predefined variables (Babbie 2010).

3.4.1 Qualitative research

Qualitative research methodology has been advocated when answering research questions requires granulated, contextual knowledge about a researched phenomenon. Understanding how particular ambidexterity balancing mechanisms function in concrete empirical situations is a research problem well suited for a qualitative study. The qualitative research takes advantage of the rich empirical data collected in various contexts of the innovative firm to test theoretical propositions derived from innovation ambidexterity theory and develop inductive constructs that would refine and extend it. The innovation ambidexterity framework, thus, serves as a theoretical lens of the study and the research design encompasses deductive and inductive logic. In the tradition of qualitative research, the design of this doctoral study has been emergent rather than strictly predefined from the beginning (Creswell 2007, Marshall and Rossman 2011). Research procedures have been evolving and changing throughout the study because getting to know the empirical setting of the innovative firm has been important in order to understand it and start producing accounts and conclusions useful for the theory.

At the same time, some main elements of the research have been established from the outset. Central literature on innovation ambidexterity has been examined. The core issues regarding innovation ambidexterity have been identified. Research themes have been drafted. An empirical context for exploring the issues and themes has been chosen. In this research, the literature was reviewed ahead of the field work and an a priori theory of innovation ambidexterity was used extensively. In this relation, Creswell's definition of

qualitative research is helpful because it captures the traditional components of qualitative research in their logical development:

> "Qualitative research begins with *assumptions*, a worldview, the possible *use of a theoretical lens*, and the study of *research problems inquiring into the meaning* the individuals or groups ascribe to a *social or human problem*. To study this problem, qualitative researchers use an *emerging qualitative approach* to inquiry, *the collection of data in a natural setting* sensitive to the people and places under study, and *data analysis* that is *inductive* and *establishes patterns or themes. The final written report* or presentation includes the voices of participants, the reflexivity of the researcher, and *a complex description* and *interpretation* of the problem, and it *extends the literature* or signals a call for action" (Creswell 2007, p. 37, emphasis added).

On the one hand, the process of this study has followed the traditional qualitative research design stages and reflected the inductive logic characteristic of qualitative research. On the other hand, iteration between theory and data has been a crucial design principle and the research design has been fundamentally based on deductive logic that initiated the recursive, cyclic investigation in the first place. The research design has thus been comprised of deductive logic that puts theoretical propositions of innovation ambidexterity theory through the test of actual evidence collected from a "natural" and "sensitive" empirical setting (Creswell 2007, p. 37) and inductive logic that completes the cycle by using the rich data to establish new analytical categories and detail theoretical propositions to relate them back to the theory and thereby, refine and extend it. Deductive theory testing in a qualitative study by means of detailed qualitative accounts cannot, and does not, aim to compete for a statistical robustness of a quantitative research strategy. The logic of the test with qualitative data is the logic of falsification which has been discussed above.

3.4.2 Case-study approach and selection of the case

Following the Popperian logic in testing ambidexterity theory, the research has been designed as a single case study. The logic of the test is to take one context governed by theory and subject it to a risky and rigorous examination: to scrutinise the case of

ARM for evidence contradictory to the established theoretical assumptions about organisational ambidexterity. The search for disproving evidence in a context governed by theory – falsification – has been argued to be a more rigorous test of theory than an examination upholding the framework of existing assumptions and propositions (Popper 1959). No amount of positive evidence can prove a theory right. Identification of anomalies in theory, if only in a single case, is the basis for theory revision (Popper 1959). Review of theory in the face of contradicting evidence would increase the theory's robustness.

The choice of ARM as a test site for testing ambidexterity theory was both opportunistic and purposeful. ARM was suggested to me by a senior academic following my presentation of the initial ideas for my doctoral research. After getting to know more about ARM's cutting-edge semiconductor technology, innovative IP business model and the Ecosystem organisation, it became clear that the company would be a representative case for ambidexterity phenomena. Ambidexterity theory claims that any successful company exercises some form of ambidexterity (O'Reilly III et al. 2009). Moreover, any technology-based company should be ambidextrous to ensure continuous innovation and renewal of its technology base (Hill and Birkinshaw 2008, O'Reilly III and Tushman 2008, Tushman and O'Reilly III 1997).

ARM's work is high-tech innovation as it is tasked with designing semiconductor IP in the knowledge-intensive semiconductor industry. ARM's designs go on to underpin digital devices in the vast scope of industries from automotive, manufacturing, enterprise networking solutions and consumer electronics to agriculture, wearables, smart homes and medical. ARM works closely with each of these industry to ensure that they design product that fit their needs. ARM is an ideal setting to test ambidexterity as it *should* demonstrate both exploiting current capabilities while at the same time exploring possibilities to develop innovative IP products, new competencies and new areas to apply their technology. We *should expect* exploitation to entail "supporting repeat clients' need for incremental innovation" and "improving on previous product designs to satisfy rising expectations of both the client and the client's customer" (Andriopoulos and Lewis 2010, p.106). We *should expect* exploration to be a distinctly different activity that "on the other hand, denotes much more disruptive or radical innovation, those 'blue sky' projects for

either new or repeat customers to satisfy rising expectations of both the client and the clients' customer (ibid, p.106).

ARM *should* also be good at exploitation and exploration, i.e. ambidextrous, because ARM is a very successful company by any common sense criteria. ARM's designs are in 95% of mobile phones. It is a global company with 400 licensees, which are all of the semiconductor companies in the world. It produced Reduced Instruction Set Computing architecture and propelled it to become one of the two global microprocessor standards. It determines the next generation microprocessor architecture to be used in the next generation computing devices. Its IP formed basis of billions of microprocessors that power a plethora of digital devices from sensors to servers. ARM has been a major player in the dynamic semiconductor industry for 27 years. The case of ARM as the test site for ambidexterity is also multi-layered because innovation in ARM concerns the technological, business and organisational domains. ARM, therefore, is a rich case that should vividly exemplify ambidexterity processes. Its technological, business model and organisational innovation are interesting aspects on which manifestations of innovation ambidexterity can be tested.

In the case study of ARM, I take a meso-perspective at the company and focus my analysis on technological and organisational innovation processes at the intra- and inter-organisational levels. Embracing both of these levels is vital: ARM is a supplier of intellectual property for the semiconductor industry, so no innovation is created internally in isolation from the ARM's Ecosystem Partners. The unit of analysis is, therefore, the innovation processes within the company and its interactions over innovation with the Ecosystem Partners. This is in line with my philosophical stance of social constructivism where I see innovation as *interaction* of individual actors in the act of innovation *within a broad context* of the firm.

3.4.3 Data collection. Longitudinal perspective

Qualitative data enables answering the main research question of whether innovation ambidexterity principles can be found in the empirical context of ARM. Data were collected through multiple sources of information: documents, including audio-visual materials and web sources, interviews and nonparticipant observation. Data collection was carried out between September 2011 and September 2014. The fieldwork

for this research spanned several UK locations[1] and one European office of ARM[2]. Interviews and observations allowed to collect real-time data, while documents yielded both real-time and retrospective data. The writing-up of the thesis was carried out in two phases over September 2013 – May 2015 and May 2016 – August 2017. Additional analysis of contemporary documents was done over the entire process of writing-up up until August 2017. Thus, the study encompassed organisational and innovation processes in ARM over the period between 2011 and 2017.

The period of time up until writing-up in 2017 affords a longitudinal *perspective* on the organisational transformation of the company. In the social sciences, "longitudinal" is a broad term where several types of data may be regarded as longitudinal and methods for the analysis of temporal data may also vary substantially (Menard 1991). What makes a study longitudinal is the collection and analysis of data over time (ibid), which is a more suitable method of assessing organisational processes and change than the study of a social context at just one point in time. The continuous recording of data and data analysis over the years 2011 – 2017, sans the formal measurement of change with a variable frequently employed by social sciences, but instead *the description of transformations and shifts of organisational patterns over time* affords this study a longitudinal perspective. The longitudinal perspective has the benefit of adding insights into ambidexterity processes and structural arrangements, because it shows *a number* of organisational transformations *over time*. It adds an opportunity to compare old organisational structures and practices to new, to comment on the dynamism of organisational transformation and analyse the pattern of change in terms of variation in exploitation and exploration.

The longitudinal perspective tracks the following aspects:

1. Formal changes in the organisational structure: creating new and reorganising existing organisational divisions. This also includes rethinking employee roles and tasks for existing divisions.

[1] ARM headquarters in Cambridge as well as sites across the UK where ARM employees appeared at events (London, Manchester, Liverpool, Nottingham and other venues in Cambridge).

[2] ARM Sweden in Lund.

2. Executives' decisions prioritising exploitative and explorative innovation, motivation behind the decisions and their subsequent implementation.
3. Changes in how engagement with Partners is managed. This allows to observe the dynamism in the broader organisational form of the company – the Ecosystem of Partners.
4. Transformation in the values upheld in the company and promoted from above (by the human resources department and the executive team). In order to contribute to business strength, values and culture must be deeply embedded in the ways employees work, act and think. Once established, organisational culture is difficult to change, yet fine-tuning organisational culture to facilitate innovation is typical for high-tech industry (Tushman and O'Reilly 1996). The longitudinal perspective helps to pinpoint these important elements of organisational change as well.

All of these aspects will help to trace "ambidexterity in action", the "what is" (Friedman 1953) of ambidexterity in ARM in my analysis. The longitudinal perspective will also transfer a chronological structure upon the empirical enquiry and help to shape evidence that comes from the breadth of organisational contexts.

3.4.4 Data sources

The collected empirical data are of three types: interviews, documents and participant observation. The use of several different methods of data collection and comparison of data from the multiple sources allows for triangulation of evidence to strengthen the emerging interpretations (Yin 2009). The data collection strategy that engages a wide number of stakeholders accessed through interviews, various types of the company's documents, external analytics as well as observation of the company's activities in different contexts has also been intended to minimise researcher bias and increase accuracy of findings.

Documents have formed the largest source of empirical data, followed by interviews, followed by observation that accompanied the interviews or constituted separate instances. Documents and interviews were equally important sources of data, although they differed substantially in terms of volume (in pages) and to some extent in the topics they covered. Documentary sources provided extensive descriptions of ARM

products, explained their application and customer innovation around them. Documents were also the source of detailed information about ARM's business performance and partner relationships. Documents provided rich historical accounts about the company's origins and the evolution of its products. The setting the scene chapter 4 about the historical origins of ARM, for example, has been almost entirely based on the analysis of documentary and multimedia sources. Interviews did not allow time to go into details of ARM's history, only some such information was revealed through some of the interviews. Interviews, on the other hand, were an invaluable source of data about actual organisational processes as experienced by the individuals in the company. Interviews gave the opportunity to ask targeted questions pertained to the research question, allowing to solicit accounts of organisational ambidexterity processes in the spot-light of this research. They also allowed to fill the gaps where no formal documentary records on a certain topic existed. Where they did, interviews enabled clarification or interpretation of the existing records by human respondents.

Observation and information conversations with ARM employees and partners complemented the interviews by giving additional insights into the processes of exploratory and exploitative innovation in ARM's vast and complex Ecosystem. The amount of interviews and observation has been influenced by the circumstances of access to the company. I was brought in contact with ARM by a senior academic at Nottingham University who asked his contact in ARM, a top executive, to facilitate me with my research project. The top executive welcomed my interest to study the company and helped to arrange several initial interviews. As I started my research, I made an important and somewhat unexpected clarification to my first interviewees that the research project was doctoral research. The ARM executive mentioned that no research of such scale had been done on ARM before and that "it was not a bad thing" (ARM senior manager, interviewee 1, 2011). This did not create problems with continuing the study, but involved a discussion around publication of the research, both intermediate and final, which was agreed. While access to the company's headquarters had to be coordinated with ARM, there was no such barrier to meeting ARM executives, senior managers and engineers at various external events where ARM participated. Overall, the access to the company was not cumbersome to arrange. The combination of researching at the company's premises and external venues where ARM participate regularly and

characteristically, gave an advantage of yielding data that describes ARM as an entity as well as a broad Ecosystem. I will detail the scope and use of each source of data in the respective sections below.

3.4.4.1 Documentary sources

Documentary sources have been used extensively in this thesis research and have been an important source of empirical data in addition to interviews. Large amount of analytical coverage of ARM's business as well as technical specifications of the semiconductor products that it developed over the years meant that a certain structuring approach was needed for selecting and organising the documentary sources. Also, a definition would be useful as to what was regarded a valuable and credible documentary source. Documentary sources have been defined as text, audio and video records concerning ARM's business, engineering and partnership activities that have been generated throughout the course of the company's operation by various parties, including the company itself, where authorship and credibility of the source could be established.

The documentary sources used for the analysis can be distinguished into two types based on the source of the record and into three types based on the medium of the record. The former categorisation is superior to the latter in terms of analytic value, because the source and authorship of a document is more relevant for the judgement about its content quality than the type of medium by which it is disseminated (printed/digital text, audio or video). Modern social media platforms such as YouTube, Vimeo, Facebook and Twitter are increasingly used by companies for professional communication and offer a plethora of quality video and audio material, which made these platforms valuable source of information that was incorporated into data analysis (ARM Company Facebook page, ARMflix Youtube channel, ARM Community Twitter Account). Some sources, particularly Internet web pages, contain a mix of media which would make grouping documentary records by the medium type cumbersome and essentially not relevant. Therefore, categorisation according to the source of a recorded document has been given the priority and discussed in more detail here.

The first group, thus, consisted of the sources with ARM's authorship: the company's own records and statements made publicly available in the first instance through the company's main web page (ARM Holdings web page), dedicated Infocenter web page

(Infocenter ARM Holdings) and Twitter account (ARM Community Twitter AccountARM Community). ARM web page offered an abundance of information about the company that spans a comprehensive overview of the company's products, support resources for technical issues, ARM Connected Community area and market information, through to the company's profile including milestones, investor information, annual reports, presentations, results centre, press releases and an events calendar, concluding with a career section. ARM Infocenter contains all ARM non-confidential technical information including ARM architecture reference manuals, technical reference manuals for a number of microprocessor cores, technical support articles and documentation, developer guides, technical research papers and other developer support sources.

The value of documentation from these sources is particularly emphasised here. They provided first-hand accounts of the company's activity and, in this respect, offered the most accurate factual information. For this reason, these sources were sought in the first instance to complement, verify and detail factual data yielded though interviews and observation. Additionally, white papers, webinar and hang-out recordings, presentations, keynotes and speeches at business and technology fora, technology demonstrations and interviews of ARM employees made available by parties other than ARM, have been also included into this group.

The second group was comprised of third party coverage and analysis of ARM's various activities. This group included academic articles and studies focusing on ARM, expert publications about ARM's technology by ARM's former and current partners and professional bodies such as Electrical and Electronic Engineering Institute, external analytic coverage of ARM's business in specialised media sources such as Bloomberg Businessweek, Forbes, Business Weekly as well as technology coverage by professionals in specialised on-line magazines such as Wired, ExtremeTech, MIT Technology Review, Tech Design Forum, Anand Technology, ChipEstimate TV and other. The purpose of the documents in this group has been to expand the pool of information about ARM as well as to complement data from ARM's original sources. Both historical and contemporary documentary records have been used in the research.

These documentary sources offered rich information about various aspects of ARM. However, to utilise this *information* as valuable empirical *data*, some guiding principles were needed to navigate through it and select relevant pieces for the analysis. The first

guiding principle for selecting information has been, as mentioned above, identifiable and credible source or clearly attributable authorship of a document. As in the case with other data collection methods employed in the research, the aim of documentary records has been to yield information that was both *factual* (launch of products, development of technology features and components, facts and terms of acquisitions, financial metrics, etc.) and *witness* (comments on market position, analysis of future growth strategy, innovation priorities, etc.). Both types of information had to be of high quality to be used as data and so the second criterion for selecting information suitable for the analysis was quality.

Making judgement about information quality and quality attributes such as objectivity, credibility, reliability and relevance is notoriously problematic (Wang and Strong 1996). Occasionally, information in a source as an Internet article may appear anonymous and difficult to verify, raising concerns about its quality and usability for the analysis. Such information was avoided as a basis for conclusions, but it could still prove helpful by ways of initiating a search toward an ARM original source that would verify factual information or toward a more credible specialised source that would present a validated view. For the practical purposes of this research, the following quality traits of information have been identified: intrinsic attributes of believability, accuracy, objectivity and reputation as well as contextual attributes of completeness, relevancy, appropriate amount and "fitness for use", i.e. information's value for elucidating the research questions (Wang and Strong 1996, p.6). Information sourced from documentary sources that has met the above listed criteria has been considered data.

Once the documentary data have been evaluated and structured, they have been coded for empirical analysis that related them to ambidexterity concepts. Documents have been essential to elucidate topics that are best covered in recorded documentation rather than in observation or interviews, such as history of the company and evolution of the microprocessor technology. For example, section 4.1 "Origin of ARM's technology" relies almost exclusively on documentary sources. The history of ARM Holdings and the evolution of the microprocessor technology it has been promoting are documented in a large number of online technology and business articles (Business Insider 2010, Reconfigutable and Embedded Digital Systems 2005, The Telegraph 2011, Bloomberg Businessweek 2014). These have been the most important sources for writing this section

that provided a wealth of information about the company's development. The online historical records, however, have at times been fragmented, lacked detail and provided insufficient amount of data, in which case complementary information was sought in a few available research papers about ARM Holdings (Williamson et al. 2009, Williamson and Meyer 2012) and a commissioned study about ARM's Ecosystem (Moore 2013). Lacking details were followed up in interviews. Using multiple sources and methods of collecting data helped to draw a fuller picture of the history of the company and the technology it developed.

Validation

3.4.4.2 Interviews

Interviews have been an important source of empirical material for this study. Although document analysis (plus observation of events, industry presentations, etc.) is a fundamental part of the method, interviews have been essential, because they have provided contextually interpreted empirical data about the researched themes. Interviews are a crucial, and sometimes the only, source of information, because document analysis and observation often require clarification and tend to raise additional questions - the need that interviews provide for. The inherent quality of interviews is that they provide the researcher with insights that would be hardly obtainable by other means, because they are personal and contextualised (Dingwal 1997, Hammersley 2013). Sociology has long recognised the importance of personal accounts for explanation of social behaviour and social events (Orbuch 1997), although there are obvious concern associated with interviews' objectivity (Dingwall 1997). Nonetheless, personal accounts are important because "we can use what people say as evidence about their perspectives" (Hammersley and Atkinson 1995, p.125). Soliciting insiders' accounts has been instrumental for achieving the goals of the thesis. The conducted interviews have offered personal interpretations of organisational processes associated with innovation ambidexterity as they are understood within the firm and have been helpful to identify managerially interesting processes and behaviour not suggested by organisational ambidexterity theory.

The purpose of interviews in this study has been two-fold: to collect *witness information* about the social context: interesting aspects of organisational dynamics that

the interviewees have observed, managerial decisions and innovation processes they are familiar with; and to extend and contextualise *factual information* about the company's technical expertise and business sourced from document analysis and observations. Sometimes, the distinction between these two types of information has been difficult to make in practice and combined evidence from interviews was related to the information obtained from document analysis and observation to provide *ground for analysis.*

In total, 19 formal semi-structured interviews were conducted with 17 people. The first interview took place in September 2011 and the last one in July 2014. Additionally, several informal, unstructured discussions took place with the company's engineers, managers and administrative staff during my visits to the company, as well with partners at external events. The recruitment of the interviewees has been influenced by two factors: availability of informants and an ambition to approach a representative sample. Coordinated access to the research site and interviewees through scheduling the meetings has been a factor limiting opportunities for data collection. Sometimes, individuals recommended for an interview were difficult to schedule due to extensive travelling and a busy schedule. This, to some extent, was compensated by the availability of vast amount of on-line multimedia interviews and talks produced by ARM. In addition, multiple informal conversations with ARM staff at opportunities such as external events, follow-up telephone discussions, and indeed informal conversations following or preceding the very interview have also served a source of data. The interviewees included the ARM top executives, vice-presidents, senior and middle managers, senior engineers, business development directors, a director of strategy, an executive assistant, former engineering staff, ARM's Partners and managers at ARM acquired companies.

I recruited my interviewees using the "snowball" sampling technique where I asked the interviewees to nominate others for the interview. I stopped interviewing additional informants when the in-coming data stabilised (Hammersley 2013). I started to recognise patters in the interviewees' accounts and no new patters regarding the researched topic continued to emerge. The interviewed group was heterogeneous enough to supply rich accounts, but having approached about 12 interviews, additional interviews started to confirm what I started to discern in my analysis. The interviews, together with the documentary material, has supplied data that was at odds with the ambidexterity claims. The patterns emergent from the interviews contradicted the central assumptions of

ambidexterity giving the confidence that these were the sought falsification data with which the theory could be challenged. The research was designed to yield disconfirmatory data. Unlike positive data that needs to be vast to build generalisations, a minimum amount of rich targeted disconfirmatory evidence suffices to challenge theory. The conducted interviews, along with the additional data sources, have sufficed to yield such evidence.

All interviews have been digitally recorded and transcribed verbatim for further analysis. It is with the understanding that careful and complete transcription allows a deeper familiarity with data and more comprehensive insight into the message of the interviewee that the interviews have been transcribed fully and personally. Although time consuming, producing verbatim transcripts has had the benefit of creating a more intimate connection with the interview material and longer periods of reflection as well as enabling the use of direct quotes throughout the thesis.

The interviews have been conducted according to the semi-structured model, where open-ended questions were asked to address the research themes and stimulate the interviewees to reflect on the proposed issues in their own manner. Interviewees have also been encouraged to talk freely on the pertinent issues and share anecdotal examples when they saw appropriate in relation to the outlined themes regarding innovation in the company. The questionnaire guide has been devised to set direction to the interviews and explore the following main research themes:

1. Organisational change and significant internal and external change forces in the company
2. Redeployment of resources and initiating innovation
3. Innovation strategy: clarity of direction and role of individuals
4. Organisational structures, processes, managerial decisions and individual practices associated with innovation (exploration, exploitation and innovation ambidexterity) in the company
5. External and internal contexts in which the above phenomena manifest themselves
6. Role of organisational culture and values in innovation
7. Understanding of incremental and radical innovation (exploitative and explorative activities) across different contexts in the firm

8. Enactment of two-fold goals of innovation ambidexterity: focus on the core business in the short-term and pursue of innovation for the future

Specific questions have been varied from interview to interview to relate best to the informant's expertise. Semi-structured interviews were employed where more factual information was needed in interviews with engineering and managerial staff. The unstructured model was prevalent in interviews with top executives and senior managers, where storytelling and personal reflection on a set of directing themes were sought. Examples of interview questions that were selectively used to comprise interview guides for the semi-structured and unstructured interviews can be found in Appendix 2.

In the tradition of the qualitative research methodology, the interview guide for both semi-structured and unstructured interview model has been transforming as the data collection progressed to reflect the changing understanding of the research problems and address new information and emerging issues (Creswell 2007). This allowed not only addressing the research questions in the deductive way, but also being perceptive to various emerging issues and collecting information for inductive analysis (Eisenhardt and Graebner 2007).

While personal accounts and subjective story telling were explicitly sought in the interviews to detail and contextualise innovation processes in the firm, subjectivity of interviews and the attached social and political agenda are also their recognised weakness (Hammersley 2013). This is methodologically problematic as well as unavoidable. In the ontological and epistemological sense, no raw information exists and no tool can produce pure knowledge, more so within the adopted social constructivism paradigm, which highlights the inevitability of construction of the observed reality through human interpretation. Human communication is always "a narration and a performance" (Law 2000, p. 20), which means that information delivered by the interview informant is necessarily shaped by their subjective preferences as well as the features of the interview context. Same applies to the information consumed by the interviewer. Various degrees of misinterpretation or distortion of information are, therefore, an intrinsic and inevitable quality of the interview. The point, however, is that although performativity of the interview process is not to be entirely overcome, we can understand how it is being

produced and derive meanings on which to base conclusion about the researched phenomena.

Narrative analysis, or narratology, provides a framework for collecting and analysing recounted stories of human experience (Patton 2015). It provides a methodological grounding for accessing meaning of interviewees' accounts. It borrows on the phenomenological study of human experience (Sokolowsky 2000) and hermeneutic interpretations (May 2001) and has its focus on the content and performativity of experience being told. From the narratology's perspective, creation of meaning about a phenomenon or event takes place in several instances: when the story is told by the informant as it is recorded, when it is presented in its finalised form by the author and when it is finally perceived by the recipient. Meaning is, therefore, "fluid and contextual" (Kohler Reissmann 1993, p.15). It manifests itself differently in each instance and gets modified as instances add up, meaning that a narrated testimony can never achieve a complete stringency with respect to meaning. On the basis of this understanding, the advantages and qualities of interview accounts can be used constructively. Namely, informants' reports have been treated as a particularly rich source of information about organisational events and processes and aided document analysis by providing links and contextual interpretations through personal explanations.

The methodological aim of the research has been to recruit heterogeneous interviewees representing various parts of the organisation to ensure that the research themes are commented from different professional and personal perspectives. However, selection and availability of interviewees have been another methodological issue. Researching a business company has an important practical implication that access to the company's premises, staff and information is regulated for external individuals for reasons of potential confidentiality and commercial sensitivity of corporate information. This inevitably limited the opportunities for interviewing and observation and necessitated another routes for data collection, namely analysis of data sources such as the firm's non-confidential publicly available documents, archival reports, press releases, media announcements and analytics as well as business and technical presentations and interviews with the company's staff available online.

The initial contact with the company was established through a personal contact with a "gatekeeper", an executive in a key position. Subsequent interviews have been arranged

thanks to the goodwill and considerable openness of the company to an external inquiry, given the commercial purpose of the organisation and associated confidentiality issues. While openness to input from the outside and participation in research, business and public fora are customary for the company and are part of its value of non-complacency, consenting to be a subject of a close investigation in doctoral research is something more than that. Met with consent and goodwill on part of the company's employees, this investigation has been reliant on personal contacts with the company's staff and predicated on trust, ethic and professional credibility. With no dedicated collaborative link between the university and the researched company to support this doctoral research, the fieldwork, which involved visits to the company headquarters, on-the-premises interviews and observation, was made possible by the relationships that I established personally.

The first interviewed senior executive has used his position of influence to select a group of additional relevant interviewees. Subsequent interviewees have been recruited partly using the snowball sampling strategy, when the interviewees recommended further candidates basing on their judgement of their relevance for the study and partly through purposefully contacting particular candidates whose expertise was identified as especially valuable for the research themes. Overall, the research ambition was to achieve a sample as representative as possible to include top decision makers, founders of the company, key engineers, managers at different levels and units and the firm's partners. However, regulated access to the premises of the company and busy schedule of the executive staff meant that sometimes potential interviewees deemed crucial for the study had been unavailable. Methodological limitations of data collection in a corporate setting are inevitable and sometimes considerable, forcing the researcher to look for alternative methods to access data and additional data sources. In such cases, primary data collection had been compensated to the extent possible by accessing on-line executive talks and strategic technology presentations by the company's key individuals. Employing additional methods of data collection was also aimed at completing the data collecting through interviews.

3.4.4.3 Observation

Meeting ARM's staff outside the corporate settings at events such as industrial shows and conferences, analyst and investor events, career talks at universities and presentations at professional societies' meetings provided an opportunity for observation. I was part of the interaction during these events in the researcher role, which makes the method participant observation (Creswell 2007). Participant observation is a qualitative, interactive and relatively unstructured experience that allows examination of instances of complex interactions between people (Yin 2009). The method allowed me to note how the company represented itself in a different context than interviews and conversations with me. I captured what I was observing in my impression sheets. I also took photographs where it was appropriate, for example, of striking illustrative information in ARM's presentation slides. I recorded voice memos of anything that I felt was worth following up, following interactions with ARM employees in interviews and public events.

Observing ARM at external events was important to get to know the company outside the headquarters environment and learn more about the public "persona" of ARM. External events with ARM's participation form a highly important and substantial part of its business activities. ARM has a significant presence at technical conferences and industrial fora such as ARM-run ARM TechCon, but also Consumer Electronics Show, Mobile World Congress, Embedded World, Open Compute Summit and other digital electronics and semiconductor industry events that take place around the globe. However, in this instance, the attendance and opportunities for observation have been limited to the events based in the UK due to the resource constraints for travel and the need to focus on some events among the vast number of the industry's events with ARM's participation.

Observation has been a valuable method that enriched data collection, helped to validate the interview data and document analysis and enabled a valuable opportunity to cross-check emerging themes, insights and findings (Yin 2009). A benefit of this method has also been the opportunity to meet groups of ARM's employees at once and have informal conversations with them, which consequently increased the understanding of their engagement with innovation and helped to make sense of the broader organisational interactions and culture of ARM. For example, ARM's reported engagement with a wide variety of stakeholders, including that of non-commercial nature, could be observed at a

Smart Homes and Clean Power conference, where ARM participated as the lead sponsor. ARM engineers explained and explored the potential of ARM low power cheap and tiny microprocessor technology in smart homes and energy systems to a broad range of attendees such as entrepreneurs, investors, industrialists, patent attorneys, expert consultants, academics, aspiring students, policy makers and other public sector representatives.

Broadening the data collection site beyond ARM's home environment and observing the company's engagement and interactions at external events was very important because this context was indicative of ARM's priority areas and strategies for ecosystem development and offered evidence of how ARM's values and culture manifested themselves in actual practice in comparison to the policies outlined in corporate documents (ARM Values 2013). It was also an opportunity to reflect on how ARM informs and is informed by audiences in its external environment. For example, a technical presentation by an ARM's senior engineer at a Royal Society conference has been an indicator of ARM's effort to engage with academia, disseminate information about ARM's technological advancement, keep abreast with academic research in relevant fields and actively scan for relevant scientific and engineering ideas in the academe. Also, the career talk at Nottingham University by an ARM business development manager is evidence of ARM's culture that proactively attracts young talent and encourages positive change.

Observation is a quality of a curious mind and observation was also part of the interviews with ARM employees. As a qualitative researcher, I have been using myself as a probe to perceive the organisational environment, paying attention to how accessible and responsive people were, noticing the style of communication and exploring the perceived consistencies or differences in interactions. Methodologically, these data have been recorded in an impression sheet as soon as possible upon the completion of the interview. The impression sheet aimed to capture the context of an interview. It included the professional profile of the interviewee: position within the company, nature of the role, qualifications, background, number of years of experience in the industry as well as a record of the surroundings, style and language of communication and interaction manner during the conversation. Context plays an important part in communication. On the one hand, it adds meaning to the conversation and the interview can be understood

better with reference to the context. On the other hand, additional meanings can be recovered from the context and can be used to validate the interview content (Crotty 2009). In sum, the observational data have been useful for contextualising the interviews, which resulted in richer data especially pertaining to the company's culture and relationship management. Observation has therefore served as an additional source of data complementary to interviews and document analysis.

3.4.4.4 Validation

Information is rarely neutral. Whereas *technical information* did not present challenges in terms of generating bias, *witness information* in the data sources representing views, ways of thinking, conclusions and values of individuals or organisations bears a problematic bias (Yin 2009). Bias, both on part of the researcher and the informant, is not possible to eliminate for there is no one truth in human affairs against which to measure. Researcher bias is inextricable from personal qualities of the researcher such as devotion and interest, which after all are essentially human. Moreover, in the social constructivist view that I share, the researcher does not only project the bias of their personal interest and experience. Their interpretations are affected by the assumptions, values, cultural beliefs and the language of the social context in which the researcher lives and carries out research. Bias, therefore, includes both the dispositions of the researcher and the social characteristics of the research context. The same is true for the informant's interpretations. However, personal dispositions and interests can be a resource and an advantage. For example, for the researcher in gaining access to the object of study or creating a constructive atmosphere during interviews. For the informant in talking freely about their subject and present their frame of reference. My ambition, therefore, has been to deploy my own and the informant's bias carefully and deliberately, rather than to pretentiously try to conceal it. "People's accounts count" (Orbuch 1997) and human experience and socially embedded explanations were welcome and were considered valid data.

Both objectivity and subjectivity were sought in the data sources. Objectivity was understood as determination to reduce error by allowing least influence of personal preferences and seeking the best information available. The subjective statements and intuitions in commentaries, descriptions and indeed stories relating to the organisational

behaviour and outcomes added to the depth of understanding of the research ambidexterity topics. Importantly, in my analysis of the data, I followed the methodological recommendation to look "not merely for [information] content but more at how it is produced, how it functions in episodes of daily interaction, and how, exactly, it circulates" (Prior 2004, p.358). Interviews, documentary sources and observations were considered in their organisational and cultural context.

Careful and mindful evaluation of strengths and weaknesses of the material thus allows producing analysis that is more reflexive and rigorous even if the information it is based on is biased and does not meet the quality criteria with complete stringency. It has been the ambition to accompany the data collection with such evaluation and reflection. The reflection contributed to the *validation* of my research. I choose the term "validation" among the synonymous terms such as "trustworthiness", "authenticity" and "credibility" of the data to emphasise *the process* of assessing the accuracy of findings (Creswell 2007). This term also suggest that the researcher is making an effort to increase the accuracy of findings and that data has no intrinsic quality of "trustworthiness" and "credibility" that can be explicated by following a certain techniques. Every piece of research is ultimately a representation by the author and validation is an attempt of the author to assess and increase accuracy of their accounts, meaning that their findings should accurately reflect the data. Validation, therefore, may imply several techniques to help the author make their findings reflect their data accurately. Continuous evaluation and reflecting on the content and context of the material was one technique that I employed. Using various types of data sources and informants to provide corroborating evidence (triangulation) was another technique. Additionally, peer review (Ely et al. 1991, Lincoln and Cuba 1985) provided an external check on my research process. I had multiple discussions of my data with my supervisors at meetings and I presented my research to the academic colleagues in seminars and conferences. Finally, I presented my intermediate findings to ARM staff and solicited their views on the credibility of my findings and interpretations after the presentation – a validation technique referred to "member checking" (Ely et al. 1991, Lincoln and Cuba 1985, Miles and Huberman 1994). These validation techniques enabled me to produce a more rigorous analysis from the qualitative data that inevitably varies with respect to stringency.

3.4.5 Data analysis

In this section, I present the data sources in a tabular form to give an indication of volume of the data analysed and how I used the different sources in my analysis. I then go on to explain in more detail the process of analysing the data that allowed me to move from the raw sources to themes. Table 1 summarised the information.

Table 1. Data sources

Documentary sources by authorship	Type of data	Use in the analysis
Sources by ARM **ARM Holdings web page** www.arm.com/ - Annual reports	ARM Holdings annual reports (18 reports for all years while public company: 1997 – 2015)	Fine-grained tracking of organisational actions, performance and historical events. Detailed understanding of ARM business model. Longitudinal analysis of ARM performance, market growth and growth strategies (including key performance indicators). Understanding of new products and future market opportunities. Understanding of ARM's Ecosystem structure. Explicit elaboration of ARM values and culture.
- Company Profile	Milestones over 1985 - 2015	Analysis of new partnerships to deliver new products, Analysis of customers' innovations powered by ARM, analysis of ARM business and Ecosystem organisation. Analysis of

		ARM leadership and success stories.
	Structure of Executive Team and Board of Directors	Analysis of leadership and corporate culture.
	ARM's Innovative and Pioneering Ecosystem	Analysis of Ecosystem: partner relationships, communication between partners, overlapping markets
- ARM Infocenter	ARM non-confidential technical publications: ARM Architecture Reference Manuals; Cortex-A, Cortex-R, Cortex-M, ARM11, ARM9, and ARM7 Technical Reference Manuals. Research Papers from ARM Research and Development – 6 papers University Program Knowledge Articles – 11 articles	Understanding of the basics of ARM's products: main microprocessor architectures, microprocessor families, main features and main semiconductor product offering from ARM. Understanding the basics of the evolution of ARM designs and expansion of ARM product line. Understanding how ARM partners and the broader community of users use them.
- Connected Community area	Overview of Ecosystem members' activities in subject specific forums. Technology and market development overview (10 web articles) ARM engineers' blogs about ARM hotory, processor technology and	Understanding of the complex multi-directional relationship between users of ARM's technology and ARM. Understanding the scope of support that ARM provides to the community of users. Understanding the different roles of Ecosystem players

	associated collaborations (5 blogs) Slides of ARM's technical and business presentations at specialist conferences (4).	that use ARM technology and the amount of support that ARM provides to enable all to use and create ARM-based products.
ARM Webcasts	4 webcasts about ARM technology and partner collaboration.	Understanding interactive partner relationships and creating of innovation at the intersection.
ARM Twitter https://twitter.com/Arm (formerly ARM Community Twitter) and **ARM Facebook page** https://www.facebook.com/Arm/	Continuous tracking of posts over the data collection period (2011 – 2015). Announcements of events, partnerships, business milestones, launch of collaborative initiatives, etc. Links to articles about technologies and products underpinned by ARM designs, about business performance of partners using ARM technologies. Links to business articles about ARM. Links to multimedia resources: product demonstrations, evolution of technology.	Broadening analysis of ARM technological, business and organisational development to include the voice of partners and users of ARM technology. Integration of information from ARM and the partners on future innovations and partnership. Understanding of core of ARM business: the breadth and the depth of mutual engagement in technology development between ARM and semiconductor companies. Understanding the scope of ARM partner relationships: the industries and the humans that use ARM-based products.
ARMflix Youtube channel https://www.youtube.com/user/ARMflix and **AMR on YouTube**	ARM-based technology and markets (17 videos). ARM senior executives' and engineers' talks at conferences (15 videos). ARM technical presentations at conferences (8 videos). Conference panel discussions including members of ARM and its Ecosystem (7 videos).	Integration of information about ARM business: scope of technologies and relationships. Understanding ARM culture, values, communication.

	ARM university programme and training videos (4 videos). Public formal and informal interviews of ARM staff at different levels (11 videos). Business interviews of ARM executives (7 videos, 7). Google hangouts with ARM staff (1 video).	
Mixed sources: external sources' analytics of ARM and external sources interviewing ARM Seeking alpha stock market insights www.seekingalpha.com	ARM Holdings Earnings calls transcripts – 20 transcripts (ca 100 pages)	Triangulation of data about ARM business performance, product innovation and nurturing Ecosystem.
Gartner The Telegraph Businessweek EETimes Forbes Business Weekly The Register	Business and marketing analytics of ARM (1 Gartner report, 14 articles). Semiconductor technology evolution involving ARM and the partners (18 articles).	Understanding collaborative co-development of semiconductor technologies. Triangulation of ARM's accounts of partner relationships.
Wired ExtremeTech MIT Technology Review Tech Design Forum Anand Technology ChipEstimate TV	Articles covering ARM-technology and ARM-powered products: trends, markets, societal reflections (34 articles)	Understanding the semiconductor industry: dynamics, competition and partners' profiles and competition for markets. Illustration of technological innovation and evolution in the business context of the firms and their industry. Understanding the place of ARM in the overlapping industries.

YouTube	Partner business interviews relating to ARM (11 videos). "Behind the scenes" informal interviews with ARM partners at events (6).	Soliciting external accounts about ARM Ecosystem management. Soliciting external accounts about ARM culture.
Other publications about ARM	Two books about ARM: ACORN RISC Machine (ARM) Family data manual. (VLSI Technology Incorporated, 1990) Shared Purpose: A Thousand Business Ecosystems, a Worldwide Connected Community, and the Future (James Moore 2013) One academic paper about ARM Ecosystem: ARM Holdings Plc: Ecosystem Advantage (Williamson and De Meyer 2009). 1 business case study of ARM "A Vision for a Smarter World".	Soliciting additional external accounts about ARM history, business model and technological innovation, and culture.
Interviews ARM current staff ARM former staff ARM Ecosystem partners	17 1 1 (total of 19 transcripts over ca 250 pages)	Enriching understanding of central innovation processes that power ARM business. Understanding the context of innovation. Gathering specific information about the scope and type of innovation processes and people's interaction accompanying business and technological development.
Informal conversations	Ca 20, including telephone follow-ups. Notes recorded in 20 written memos and 7 digital voice memos	As above.

Nonparticipant observation During interview visits to the company At external events 1. Computing for a Sustainable Future" Royal Society Meeting, Manchester Science Museum 2013 2. "Smart Homes" conference at Cambridge 2013; 3. Sir Robyn Saxby Leadership Lecture at the University of Liverpool 4. "Investor's Day" London 2014 5. "Careers talk" Nottingham University 2012	19 (recorded in 19 impression sheets) 5	Establishing trust with informants during the interviews, becoming familiar with the context, facilitate interpretation of informants' accounts

The collected data was prepared for qualitative analysis. In the course of the research, all interviews were fully transcribed, all articles were printed and all multimedia material was downloaded for off line use (viewing and listening). Observations were reflected in impression sheets (field notes) and memos (written and digitally recorded). Only some of the downloaded audio and video material was transcribed, as it was not feasible or necessary to transcribe all of the multimedia material due to the sheer volume of it, as well as its varying relevance. Only the most relevant multimedia material, understood as directly relating to the research sub-questions regarding exploitation and exploration - was transcribed. Data collection, transcription and data analysis did not occur as separate consecutive stages. Rather, the data was *coded* and analysed at it came in, with the emergent patterns prompting the direction of further enquiries and data collection. The coding technique that I employed involved reading through the transcripts and assigning a word or a short phrase – a code - to a portion of the transcribed text that captures its essence in a summative and salient way (Saldana 2008). The first read through the transcripts, or sometimes the very process of transcribing, was accompanied

by the first cycle coding where sometimes longer summative phrases were assigned to portions of the data, for example, "persuading customers to buy ARM chips", "analysis of key players in the markets", "ARM the catalyst to initiate change in the industry", "innovation at the business model level", "what distinguishes ARM", "innovation achieved through Ecosystem", "customers take up risk", "no physical product" and other.

The first cycle codes could turn into question in relation to a statement in the transcript, for example "how is traditional industry different from ARM?" A code could evoke a very broad category, for example, "semiconductor industry characteristics". In vivo codes (Saldana 2008) were extracted at times – the words or phrases that are the direct quotes of what the informants said revealing their fresh perspective. They were especially helpful for understanding the data as they were the participants' own interpretations. For example, "the magic ingredient" explanation of ARM's underlying microprocessor technology was an in vivo code that I used in the analysis of the inter-relation of exploitation and exploration.

In the analysis of the interviews, first cycle of coding was done *to summarise* the data in a variety of codes. For documentary sources, first cycle coding was aimed at *reducing* this vast body of data to allow to focus on the interpretation of the emergent categories pertaining to ambidexterity. In both cases, after the first cycle coding, I began to search for patterns in the codes and interpret the meaning of the data. Analytical categories started to emerge, such as "dominance of exploitation", "customers' customers supply ideas for products", "examples of exploration", "change initiated from the top", "evolution", "incremental development", "new ideas", "radical innovation", "relating innovation to current activity", "clarifying different types of innovation" and other. Thus, coding was a way for analytical categories, and subsequently themes, and to emerge from the data. Following Charmaz and Saldana, I view codes and analytical categories as two separate elements of data analysis (Charmaz 2006, Saldana 2008). Essence-capturing codes, when clustered together according to a pattern, give rise to analytical categories which in turn allow analysis of their connections.

Second cycle coding was performed after the initial analytical categories were discerned. Second cycle of coding involved re-interpretation of the pertinent parts of the texts in order to 1) group the first order codes and 2) detail these aspects deeper and 3) to capture the data's primary content and essence, not necessarily related to the

ambidexterity concepts. The second iteration of coding now involved more analysis of the data as I systematised the categories and searched for patterns in the data. I also stated to generate explanations for the patterns that I observed. The data inevitably presented irregularities which I also captured in the further categories. Coding also prompted to see areas which needed additional data, in which case I sought to fill the gaps by determining appropriate sources of the needed data and gathering the data. The concurrent data analysis and collection enabled me to research the empirical context deeper and develop more categories pertaining to different aspects of the organisation.

Consecutive iterations of coding were aimed at further filtering and highlighting the salient features of the data. Given the analytic lens of ambidexterity and the falsificationism design, I looked for categories that both resonated with ambidexterity concepts and were outside these ideas providing an alternative explanation of innovation processes. Grouping analytical categories in this way allowed me to compare and contrast the innovation practices in ARM to the postulates of innovation ambidexterity theory – the goal I set out in my research. Analytical categories were clustered under six major themes: exploitation, exploration, ambidexterity, IP business model, ecosystem organisation and innovation culture. Since the aim of the thesis was not to construct a new explanation that would interpret my data in the sense the grounded theory method proposes (Charmaz 2006, Glaser and Strauss 1967), the themes have not been developed further into a theoretical framework. Instead, they have been distilled to be juxtaposed with the claims of ambidexterity theory. Given the theory testing - not theory building - research design, the analytical path of codes in my empirical analysis ended at generating main themes from the collected data[1]. They were then juxtaposed with the main elements of innovation ambidexterity theory that have been distilled in the theoretical chapter. The juxtaposition is the main subject of the discussion in the empirical chapters below.

[1] I do not refer to my coding method as "grounded theory method" despite the fact that its principles and practices are similar to the coding that I do. This is because I do not aim to go the full way from "ground up" and build a new story, a new theory, from my findings. Because the analytic path of my codes ends at distilling themes traditional qualitative coding (Creswell 2007, Saldana 2008) suffices for my research aim, in my research design.

3.4.6 Structure of the empirical analysis

The empirical part that follows is comprised of four chapters. I introduce the company in chapter 4 "Setting the scene for the empirical investigation. Innovation that started ARM", where I talk about the origin of ARM's technology, business and the people behind it. The following chapters look systematically at what can be considered manifestations of *exploitation* (chapter 5), *exploration* (chapter 6) and *innovation ambidexterity* (chapter 6) in the studied firm. As problematised earlier, innovation ambidexterity theory often employs images that bear little resemblance to organisational actuality and do not reflect the internal fuzziness of processes and structures in a company that is tasked with sustaining stability for today and adapting to the changing environment of tomorrow. The aim of the empirical chapters is to test and analyse whether the ideas of organisational ambidexterity apply in the context of ARM. To recap, the exploitation-exploration framework rests on the three central elements: 1) *the definition assumption* that exploitation and exploration are distinct organisational modes, opposing in nature and in a trade-off relationship organisationally, 2) *the balance assumption* that ambidexterity is a simultaneous pursuit of an equally high degree of exploitation and exploration supported by dual structures, processes and thinking to support the conflicting exploitative and explorative activities and 3) the proposition that *implementation of ambidexterity is essential* to ensure technological continuity and ultimately organisational survival. I will use the empirical case of ARM to evaluate innovation ambidexterity theory and review the established assumptions. I test the concept of exploitation on the example of ARM technology domain, the concept of exploration – on the example of ARM's business model and the proposition of ambidexterity balance – on the example of ARM ecosystem organisation.

Domain separation is a legitimate tool in the organisational ambidexterity literature (Lavie and Rosenkopf 2006, Lavie et al. 2010, Stettner and Lavie 2014). It has been argued to produce more consistent conclusions about the content and balance of exploitation and exploration activities because it takes into account different organisational circumstances that influence innovation in different domains. Thus, domain separation is a helpful analytical tool and a structuring device to start to identify differences in types of innovation. I expect, however, that the analysis of the ambidexterity phenomena will at times go beyond a dedicated domain and the distinction

between the twin ambidexterity concepts will blur. ARM's technological innovation is closely intertwined with business innovation that delivers technological value to the customer and organisational innovation that enables the company to bear on technological opportunity. Engineering, business and organisational innovation are closely intertwined capabilities that are difficult to analyse in isolation. Yet in this thesis, I will tease them apart and analyse them separately, in sequence, to draw conclusions about different content of innovation activities and balance between them.

In accordance with the outlined methodology, the focus of the analysis is placed on the organisational and inter-organisational levels from the standpoint of an individual organisation - ARM. The qualitative case study of ARM will serve to demonstrate the day-to-day practice of ambidextrous organisation and compare it to the central propositions and assumptions of innovation ambidexterity. The empirical evidence will then allow to extract and interpret the critical differences to the established theorisations and evaluate the usefulness of ambidexterity as a theory.

In the empirical chapters that follow, I examine how the central elements of theory of ambidextrous organisation play out in the rich empirical context of a leading technology company. But before proceeding to the in-depth analysis, let us get to know the company first.

4 Setting the scene for the empirical investigation. Innovation that started ARM

4.1 Origin of ARM's technology

Like many successful companies in the semiconductor industry, ARM had a start as a spin-off project. A team of twelve founding engineers was housed in a converted eighteenth century barn in the village of Swaffham Bulbeck near Cambridge in 1990. The new company began as part of Acorn Computers, the company that pioneered computer awareness in the UK and was producing computers for the British home and the educational computer market at the dawn of the personal computer era in the early 1980s. Acorn had produced a number of successful models: the Atom and the BBC Micro were widely adopted by schools and households in the UK (Williamson et al. 2009). Because of the target markets of new personal computers (PCs), Acorn designed computers that ran on microprocessors that delivered good performance at low cost, small size and low power.

Acorn Computers produced a dominant brand in the UK, but IBM, Apple and Intel, among other, were launching PCs with improving processor characteristics and faster performance. To face the competition on increasing PC performance, a new research project was set up in Acorn's Advanced Research and Development (R&D) team that would address the increasing performance needs. The R&D team aimed to develop Reduced Instruction Set Computing (RISC) that was based on the insight that a small, highly optimised set of instructions enables a much faster execution of each instruction and thereby provides increased performance. The RISC processors were designed to be simple, which also made them relatively low-power, as opposed to Complex Instruction Set Computing (CISC) used in early computers which tried to pack as many actions into each command of code as possible. The outcome of this project was the Acorn RISC Machine, later changed to Advanced RISC Machine, which became the first ARM processor. Thus, ARM processor was born out of a revolutionary idea, which was to be developed into the global architecture standard for RISC chips, one of the two central

microprocessor architectures remaining today. The ARM chip was grounded in performance oriented architecture and inherited Acorn's capabilities of designing against the criteria of small size, low cost and low power. These qualities became ARM's processors hallmark characteristics.

To move RISC technology from the R&D laboratory to the commercial environment, Acorn partnered with VLSI Technology, a semiconductor company based in Silicon Valley in the United States, who provided the necessary manufacturing facilities and skills that Acorn could not afford (Williamson et al. 2009). In 1985, the first samples of ARM1 chips 3 micrometres (μm) in size were delivered in working silicon by VLSI Technology (Levy 2005). ARM2, the first production version of the ARM processor and the simplest RISC processor in the world at the time with "only" 30,000 transistors quickly followed (Levy 2005). The instruction set of ARM2 was improved to maximise the performance of Systems on the Chip based around the microprocessor and included sound generating capability - an important feature for home and educational computers (ibid.). Despite the added features, the ARM2 processor still had a small size and low number of transistors. It was also manufactured by VLSI who now obtained rights to use ARM designs for cost-effective complete solutions. Acorn continued to support the RISC team in creating further improved versions of the ARM processor.

Over the years, Acorn endured financial ups and downs to the point that the company's management decided that the ARM chip team was a luxury it could no longer afford. It attempted to sell the ARM project twice but the deals fell through (Williamson et al. 2009). In 1990, the project was saved when a new and determined customer arrived. Apple was focusing on the emerging personal digital assistant market and worked on an entirely new category of computing device, the Newton handheld computer. Engineers at the VLSI Technology design lab and the Newton design team at Apple agreed that the ARM low-power, low-cost chip designs would be a natural fit with the requirements of the Newton (ibid.). Apple was to become the third "parent" of ARM, after VLSI and Acorn Computers.

ARM610 was a notable design. It was specifically designed for Apple and contained many changes that Apple requested in order to be deployed in its planned products. While eager to use the technological advantages of ARM600 in the Newton, Apple was concerned about using a competitor's design in one of its strategic projects.

Apple would be more comfortable to work with a company separate from Acorn. Interested not to lose Apple's custom, Acorn agreed to spin off the ARM project as a separate company. ARM Limited was born, which was jointly-owned by Apple, VLSI Technology and Acorn (Williamson et al. 2009). VLSI Technology acquired a license from the newly established company to use the processor technology in its products, becoming ARM's first licensee. Apple's Newton turned out to be a commercial failure, but, even though the Newton project was short-lived, its lasting legacy was preserving the ARM know-how and helping to launch ARM Holdings (ibid.).

A new joint venture formed in 1990 between VLSI Technology, Apple and Acorn marks the foundation of ARM Holdings (Levy 2005). The spin-off's team of twelve members invited Robin Saxby, an engineer and entrepreneur with a vast experience in the semiconductor electronic industry, for an interview for the CEO position and subsequently offered him the job. In his new role, (now Sir) Robin Saxby launched ARM, or Advanced RISC Machines Ltd., on November 27th, 1990. Saxby's ambition was far from small: "to attack the growing market for low-cost, low-power, high-performance 32-bit RISC chips" (Levy 2005, p.15) and "to become the global standard for RISC chips with a target of embedding ARM designs into 100 million chips by the year 2000" (Williamson et al. 2009, p.4). ARM greatly exceeded the target shipping about 400 million chips in 2000 alone (ARM Holdings plc Report and Accounts 2000).

The serendipitous development of RISC architecture was one factor that enabled ARM's position in the industry. We know now that the opportunely developed RISC architecture was the technology that gave ARM an advantage later in the course of the evolution of digital technology. The parameters of low power and small size turned out to be relevant in the era of mobile computing. In the meantime, another innovation was pioneered by ARM in the way that the young business was to be organised, which shaped even more the industrial position and the success of ARM. The overview of the origin of ARM's business model, and the leadership that propelled it, will complete the description of the innovative foundations that were subsequently shaped to bring ARM to its position today.

Setting the scene for the empirical investigation. Innovation that started ARM

4.2 The unique characteristics of ARM

Business studies record that it is uncommon for a start-up company to have a clear idea of what it is going to do and how (Bhide 1996) However, documentary sources about ARM's origin show that, from the very beginning, ARM had a clear design philosophy and adhered to the idea of a licensable microprocessor with a strong determination (Edwards 2010). This circumstance makes ARM quite unusual. The way that ARM's innovative technology has come to shape the innovative partnership model also offers unique specificity. This historical specificity deserves a more detailed discussion. It will be useful in examining the current state of innovation in ARM in the main empirical analysis.

The emergence of Reduced Instruction Set Computing in the late 1980s was an important event in the computer industry. VLSI Technologies, who first implemented ARM's full system solution for small computers and fuelled the development of the RISC architecture, document the early development of the new architecture in the "Introduction to the Acorn RISC Machine (ARM) Family Data Manual" (VLSI Technology Inc. 1990). The technical detail of the overview that follows is borrowed from this documentary source.

Advanced RISC Machines and its successor ARM Holdings were not the only businesses working on the RISC architecture. Several different suppliers announced new computers based on the RISC architecture, tapping into the new performance-oriented design methodology. All claimed that RISC offered much higher performance than the more common Complex Instruction Set Computers (CISC). Along with familiarising themselves with the new characteristics of the emergent computer technology, the designers had to learn the new approach to the whole process of designing the central processing unit (CPU). Namely, they had to consider the whole chip as a single unit and optimise the functioning of all components of the system at the same time (VLSI Technology Inc. 1990).

Traditionally, the design of the most commercially produced CISC computers was centred on the CPU, which meant that the CPU was designed "in a vacuum", without concerns about other elements in the system such as memory controller, video controller or other (VLSI Technology Inc. 1990, p.1-4). This often led to the situation where the

CPU was designed to be high-performance, but the performance could not be exploited without resorting to expensive system elements which either were not optimised to the CPU or were unnecessarily more advanced than the given performance level of the CPU, which dramatically increased the cost of the overall design. *Partitioning* the CISC chip around functions such as memory management unit, scalar processor and floating point processor, had an advantage of being able to use each unit without the others and starting sales even if nor all components were available. However, the CISC partitioning around functions often sacrificed performance and was not cost-effective (VLSI Technology Inc. 1990, p.1-3).

RISC system designers understood these concerns and realised that RISC architecture may be the only solution when new applications appeared that could not be addressed cost-effectively by CISC architecture. The designers learned how this new technology could be partitioned. A new systems approach to the CPU design treated the CPU as a single unit where interfaces between the elements of the system were defined around the basic computer fundamentals such as performance, memory requirements and the size of circuits of the chip rather than functional blocks. The partitioning around the basic interface functions was also the design principle in multi-chip solutions, which have been increasingly required commercially, for example, the Acorn RISC Machine System was designed around these basic computer parameters (VLSI Technology Inc. 1990). The alternative form of partitioning and the top-down approach optimised around the microprocessor core resulted in a small computer system that could bring excellent performance to the user at a significantly lower cost than ever before (VLSI Technology Inc. 1990).

At the time, a number of competing architectures existed in the industry, alongside the emergent RISC and the CISC dominant in the PCs. At the time, the industry struggled with the performance of computers which were large, slow and complex. The idea for RISC architecture entered ARM from universities, which were increasingly interested in simpler ways to execute instruction sets and increase computer performance. The small team of ARM decided that the simpler RISC processor architecture could be built from ground up within the team. As a start-up, ARM needed to identify a differentiating strength which was found in the capability of the RISC architecture to improve the computer performance in a new way. ARM realised that the future of improving computer

performance lay not in increasing the amount of instruction sets performed per second ("raw MIPS"), by then already counted in millions, but in increasing millions of instructions sets per second that can be *performed per watt of energy* (MIPS per watt). ARM was the first to introduce the energy efficiency parameter into the design. Sir Robin Saxby says that "we were the first people to really worry about cost and power efficiency" of microprocessors in a SoC (Saxby quoted in Bulkley 2001). This set ARM on it hallmark path of designing energy efficient microprocessors and made low power designs its core technological differentiator from competitors.

Additionally, RISC was a prompt choice for ARM not only for being different, but even more so for being feasible to be built ground up by the small engineering team with limited resources. The simplicity of RISC architecture did not require a large number of transistors like the counterpart CISC, which meant that RISC processors were also cheaper to build. ARM's Vice President of R&D recounts:

> *"ARM did not put themselves above CISC, so we were better because you had to be if you are asking for money from an investor. But they [the founding team] drew a different curve and they traded off some of their betterness to actually be cheap. And I think this was one of these decisions that came out of necessity and it established and changed the industry over the twenty years" (Flautner 2013).*

This design philosophy was summarised in ARM's mission statement that the company announced to the investors in the original company brochure (Figure 7). The engineering philosophy has remained unchanged today. It reads: ARM's mission is to "design competitive low power consumption high performance low cost processors which become the accepted standard in the market they address. In support of this mission ARM Ltd will develop peripheral cell designs, software and software tools and provide a design service to third parties" (Flautner 2013).

Figure 7 ARM Mission statement - unchanged from its origins (From a presentation of Flautner, Vice President of Research & Development, ARM Ltd, 2013)



At that point, ARM also articulated its business ambition to become a globally established standard for RISC architecture and have 100 million ARM-powered chips shipped by customers by the year 2000 (Edwards 2010). Although developed to power a PC for home use in the early 90s, ARM architecture was to become a global standard in the non PC market. With the rapid advance of the mobility era and proliferation of a plethora of mobile electronic devices, ARM's RISC architecture became "the first choice processor architecture for anyone not building a PC" (ibid.). The company attained the envisioned presence with a 95% of the share in the mobile market (ARM Annual Report and Accounts 2011).

The ARM architecture had accidentally acquired another characteristic, which turned opportunely into a major advantage and defined ARM's architectural fate (Levy 2005). As mentioned earlier, in 1980s and 1990s there were a few companies who produced RISC processors. For example, Hewlett-Packard developed Precision Architecture (PA) RISC, Scalable Processor Architecture RISC (SPARC) was created by Sun Microsystems, DEC created a 64-bit RISC processor Alpha AXP, Intel's first attempt

at RISC architecture was the Intel i860 microprocessor design and MIPS designed nearly one third of RISC microprocessors available in 1990s. However, most of these vendors were designing RISC chips that were relatively big (SPARC, Intel i860), while ARM, constrained by its resources insufficient for creating a large and complex device, opted to develop a small-scale processor that was also cheap (Levy 2005). The features that are now the hallmark technical advantages of the ARM processor were born out of necessity faced by the ARM's young team of engineers who had only limited resources and unsophisticated design tools at their disposal.

The focus on small, low power, but flexible and efficient RISC technology gave ARM a winning proposition. The technology was met with interest from both the semiconductor giants and original equipment manufacturers (OEMs). The semiconductor companies could embed the RISC processor core as one part of the larger multi-core chips and still differentiate on the final proprietary System on a Chip (SoC) design. OEMs would be able to supply their improved consumer products in their respective markets. This allowed ARM to connect advantageously not only to the immediate semiconductor customers, but also align their offerings with the requirements of a broader network of OEMs. The small but motivated ARM team maintained the open approach, communicated widely and kept up the ambition of making their products more usable and adoptable potentially by a broad range of customers. The ideas about the ways of deploying ARM technologies in the semiconductor businesses of others took shape in the ARM team and gained traction with the customers, confirming that the chosen strategy was appropriately identified and advantageous. These ideas were the seeds of the ecosystem approach that would soon start intensive growth.

4.3 The purposeful development of ARM Ecosystem

By the time of its official formation, ARM had a solid technology platform, an engineering team with more than five years' development under Acorn's wing and two leading-edge shareholders and customers: Apple providing financial support and VLSI Technology providing a sophisticated design tools technology (Williamson et al. 2009).

Robin Saxby had high aspirations for the new company "to strike out for something" big rather than "just be in the hand-to-mouth chip design consulting business" (Saxby quoted in Williamson et al. 2009, p.3). So it was looking for a way to leverage

the technology more broadly within the value chain for electronic devices. At this crucial starting point, ARM's CEO was facing a variety of strategic options about how to best organise and grow the business. ARM's innovative thinking, which propelled the next generation performance oriented RISC architecture, was also applied to decisions regarding the business model and organisational form of the fledgling company. It resulted in adopting a collaborative ecosystem approach that promoted ARM's technologies, created value for the participants and consumers and eventually made the company a thriving business. The approach, however, was not obvious to choose. It also took time, understanding and focus to foster a large and diverse ecosystem capable of generating any significant value for all parties involved. Crucially, leading the Ecosystem and underpinning Partners' products with their designs also required that the Partners let ARM do that. ARM has been working on its customer-oriented culture from the very outset as well.

Initially, ARM management considered several options for taking the business forward. One was partnering with Apple who would help to drive future product development. Another was merging the business with a semiconductor company and using its financial capacity to support the microprocessor division. The third option was to create the fabrication-less, or fab-less, chip company that would design and market chips, but outsource the chip fabrication to specialist semiconductor manufacturers - an innovative approach pioneered in the 1980s by companies such as Xilinx, Chips and Technologies and Qualcomm (Williamson et al. 2009).

The fab-less model had proven successful for a number of small innovative digital electronics companies emerging in the 1990s who focused on specialised technology components and occupied specialised niches of the semiconductor value chain without the need to invest in costly fabrication plants. An increasing number of companies started operations in a wide range of areas to provide critical components for the SoC: from the materials underlying it, the electronic design automation processes necessary to fabricate them, to the evaluation tools and software necessary to test and run the chips. The tendency for specialisation among the smaller companies in the semiconductor industry was reciprocated by the disintegration trend among the large semiconductor companies like Fairchild, Motorola and Texas Instruments, who were breaking down their vertical organisational structures spanning the entire semiconductor value chain and selling off

their internal manufacturing facilities to subcontract manufacturers in, for example, Taiwan and Japan. In response to the fabless businesses seeking to outsource manufacturing, the pure-play foundry model was established in 1987 by Dr Morris Chang with the founding of the Taiwanese Semiconductor Manufacturing Company (TSMC) which was purely dedicated to providing fab-less companies with silicon wafer fabrication facilities for manufacturing, assembly and testing of the chips (Hurtarte et al. 2007).

The increasing capacity of external wafer manufacturers and a growing pool of complementary knowledge distributed across small specialised firms propelled the fab-less business model from the "opportunistic tactics" of avoiding prohibitive costs of building a vertically integrated semiconductor business to the "strategic imperative" (Hurtarte et al. 2007, p.3) of utilising the high-quality skills and competences available in the surrounding industrial environment to build complex product systems to serve the market. In other words, it was no longer necessary to rely on locating and owning all the necessary resources for full product development within the boundaries of the firm. The semiconductor industry started to shift from what was fundamentally a closed internal environment towards an open environment and an open innovation model: firms could now access resources and ideas from the outside knowledge landscape as well as create ideas for external use by others, alongside traditional in-house knowledge production and use (Chesbrough 2003). ARM identified its business as the business of "selling ideas", or intellectual property, to enable the products of others to come to life making them a partner in the semiconductor value chain.

Having no great stock of resources, ARM did rely on going outside its boundaries to resolve this problem, but it acquired its innovative character in the aspects of business as well as the technology foundation: It was not merely using the resources of others to gap-fill its own lack of resources but became an integral resource in itself in the innovations of its partners. And today ARM is not innovating on its own, but with different partners where innovations are conceived with the needs of individual partners in mind, but implemented by ARM in standardised solutions that have the ability to satisfy as many partners' requirements as possible. Identifying a best possible compromise between the diverse partners' needs is an exceptional managerial skill in its own right that also distinguishes ARM.

Setting the scene for the empirical investigation. Innovation that started ARM

Becoming a vertically-integrated semiconductor firm covering the entire chain of activities in-house was never a feasible option for ARM, given its limited resources. The cost-saving fab-less model in partnership with semiconductor companies was a much more feasible alternative (Williamson et al. 2009). However, ARM was concerned that if it were to become a fab-less company, it would be exposed to competition from the semiconductor giants like Fairchild, Intel, TI and Motorola, who certainly would not give up designing their proprietary microprocessor technology (ibid.). Producing and integrating all components of the large and sophisticated SoC that most of the fab-less companies were doing would be too risky, expensive and overall inexpedient for ARM, the company whose core competence was in design of only one element of the complex SoC - the microprocessor (Williamson et al. 2009). Therefore, to avoid getting into direct competition with the industry's giants ARM decided take the fab-less model one step further to become not only fab-less but "chip-less, fab-less chip company" (ibid.,p.4). It focused on offering the "know-how" of designing the microprocessor chip to external companies and helped to pioneer the intellectual property business model in the semiconductor industry.

While it may be tempting to view this outcome as path dependent, the technological and business innovations were by far not obvious as other strategic options were available to ARM. The conception of the IP business model was instead motivated by the technological opportunity, as well as factors of competition, industry pressures and organisational constraints simultaneously acting on ARM. However, ARM benefitted from those pressures with the vision of Sir Robin Saxby to push the concept of licensable microprocessor technologies, partner with the players in the industry and create a new global standard of RISC designs, which was unconventional in the industry of the time. ARM's vision was to evolve the direction for the industry as much as being evolved by it.

5 Exploitation

5.1 Introduction. Test site for exploitation. Structure of the chapter

We have learned about the origin of ARM business, its technology, licensing and royalty business model and the ecosystem organisation in the overview chapter above. In the empirical chapters that follow, I take a closer look at ARM's technology base and organisational context and examine the workings of ARM in terms of the exploitation-exploration framework. I will start with testing the concept of exploitation.

Exploitation has been classically described as "refinement, choice, production, efficiency, selection, implementation, execution" (March 1991, p.71). Cumulatively, it has been defined as maintaining and refining current activities (Taylor and Greve 2006), using existing knowledge in well-understood ways (Schumpeter 1943), learning by doing (Smith and Tushman 2005) and focus and experience (Lavie et al. 2010). Most generally, the concept of exploitation reflects the idea of organisational *stability*.

ARM is an established business with a distinct technological expertise that serves the technologically advanced semiconductor industry and the cutting-edge digital technology industry. It is a technology intensive and innovative company. Innovation in ARM is not purely technical in nature. The company innovates in the ways technological value is produced (organisation of the business) and delivered to customers and users (business model). ARM's technological, organisational and business innovations are closely intertwined and are also sensitive to broader social factors shaping technology: expectations and concerns of the society regarding the role of digital technologies in the various social spheres. The starting point of my analysis, however, is the domain of technological products, because it is the centre of application of innovation efforts in the company. In this chapter, I analyse the technology domain to test the idea of exploitation in the scope of the definitions given above.

To understand the nature of innovation in the technology domain, I will take three approaches to ARM's technologies. First, I present ARM's technological specialisation and demonstrate intensive engineering effort in the company (section 5.2). Second, I overview some of ARM's historic product designs to demonstrate the path of technological evolution that led to the current state-of-the-art technological offerings

(sections 5.3 and 5.4). And third, I examine ARM's current technological offerings to understand the scope and impact of ARM's technologies and ultimately, the nature of innovation that enabled them (section 5.5). These three perspectives will enable tackling ARM's complex technology base and facilitate a clearer analysis of the type of innovation that advances the company's technology base. The three perspectives will also ensure that all aspects of technology development - overall, past and present - are examined to make conclusions about the nature of innovation at play. In section 5.6, I analyse findings in relation to the theoretical concept of exploitation and make conclusions about the test of exploitation.

5.2 Engineering savvy

First and foremost, ARM is a company that centres on technology, the type of technology (semiconductor technology) that undergoes continuous and intensive innovation in a variety of specialist technical areas that enable the technology per se: hardware and software aspects of chip design, connectivity protocols, performance and power characteristics, security and other features, semiconductor materials, automated manufacturing and other. The semiconductor industry is disaggregated into specialist companies that each focuses on a certain stage of design and manufacture of the silicon chip.

ARM is a specialist supplier to the semiconductor industry. It specialises in developing microprocessor designs and associated semiconductor technologies that enhance and complete digital functionality of the System-on-the-Chip (SoC). As silicon chip designs become more complex, ARM has to develop the next generation of products and services expertly to ensure that a silicon chip designer can quickly build a low-power and high-performance chip and that a digital product manufacturer can create complex products using a combination of ARM technologies, third-party and in-house operating systems and applications (ARM Holdings plc Strategic Report 2015). ARM, therefore, has to work closely with all of the semiconductor industry's networks of specialised expertise and keep abreast with the developments in the broader digital electronics industry to ensure that it is developing the right technology for the partners in the industry. This is a vast innovation domain that also includes business and organisational innovation: any semiconductor product is a result of multiple parties working together in

a coordinated manner to contribute their expertise to bear on the opportunity (ARM Holdings plc Strategic Report 2015).

ARM's main focus is the microprocessor – the central component of a SoC and the brain of any digital device. Every ARM microprocessor is based on the ARM architecture, the low-power high performance RISC-based architecture that distinguishes the company and provides a competitive advantage. However, ARM's products are not the architecture per se, nor are the microprocessors. ARM's main products are microprocessor cores – chip layout designs that are the intellectual property (IP) of the company. Additionally, ARM produces the crucial IP components of a SoC such as the graphics processor and security features. The company also provides software, development tools to test and evaluate electronic designs and applications and physical IP for use by ARM's foundry partners that manufacture chips using advanced manufacturing processes.

A director of an ARM-acquired company comments:

> *"ARM is **extremely** (original emphasis) engineering savvy company, it's an engineering company in and out in my opinion, not in a negative way, but in a very positive way. So, they always hold technological savvy extremely high […]". (Interviewee 9, Director of an ARM acquired company)*

More than two-thirds of ARM's employees are engineers working in research and development (ARM Holdings plc Strategic Report 2015 p. 10). The majority of new joiners to the company are also engineers hired to increase R&D capabilities (ARM Holdings plc Strategic Report 2013). Engineering background is a quality which unites ARM's employees and to a large extent makes up the company's culture, providing a common ground to the teams.

> *"Almost all [of ARM's employees] have an engineering background and they understand silicon pretty deep. Even if you talk to Graham [note: Graham Budd, the COO], he understands silicon. If you talk to people on the marketing side, they understand silicon. They've probably even developed it once upon a time…. The sales people and the marketing people ... actually have a hands on understanding of what they are selling." (Former CEO of an ARM acquired company, interview 9, 2013)*

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The company's managers commonly have a technical background and most of ARM's executive team has several years' experience in technical roles within and outside the company (ARM Holdings 2016b). ARM's talent development manager tells:

> *"It's very technical culture. […] senior managers will have a very deep technical understanding". (ARM senior HR manager, interview 6, 2012)*

ARM's research and development budget constitutes between 20 and 30% of revenues. In the most recent financial year, ARM invested £215 million in R&D to broaden its product portfolio (ARM Holdings plc Strategic Report 2015). Another £74 million was invested in acquisitions of companies to accelerate product development and create new revenue streams for adjacent markets (ibid.). R&D investment into product roadmaps continues to grow year on year. ARM acquires external technology not vastly, but regularly (ARM Holdings 2014a).

While most of the engineering and R&D resources are targeted on developing the roadmaps for the current product-lines, about 17% of ARM's engineers are engaged in future technology development looking into 10 - 20 years' time. In the past year, the number of engineers working on new products has doubled: 488 engineers, led by Chief Technical Officer Mike Muller, are working on "blue sky programs" researching new types of products (ARM Holdings plc Strategic Report 2015, p.4).

Overall, ARM employs about four thousand people. The company is not very large by the semiconductor industry standards:

> *"Whereas our competitor is a 100 times our size, […] we are still a small company, relatively". (ARM's top executive, interview 3, 2012)*

Yet, its impact on the industry and markets is significant. Of 47 billion chips containing a microprocessor shipped in 2015, ARM processor designs were in around 15 billion chips, representing a 32% market share (ARM Holdings plc Strategic Report 2015). The strength of the impact is stemming from the combined asset of ARM's technological specialisation and the IP business model. ARM is a designer and supplier of *constituent* technologies that impart the essential computing capabilities to a plethora of digital devices. ARM top executive offers the following characterisation:

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"We provide a little bit of magic ingredient, and everyone else does something with the magic ingredient. The innovation is massive."(ARM senior manager, interview 1, 2011)

ARM's processor designs, complementary SoC technologies, design tools and software form a solid *platform* that underpins a vast ecosystem of semiconductor vendors and original equipment manufacturers (OEMs). The ecosystem of partners and ARM's technology base are closely inter-related and mutually reinforcing assets: ARM's products embody knowledge drawn from throughout the industry. The ecosystem of partners, in turn, benefits from the certainty and reliability of ARM's smoothly evolving technology platform.

"We are providing the building blocks to everybody", the interviewed senior manager continues.

Certainty, reliability and gradually evolving nature are the qualities of ARM's technologies that the customers seek and value, because they allow to build a reliable and lasting foundation for their products. The foundation-forming nature of ARM's technology base and the customer pull dominating technological innovation are the characteristics that propel ARM's designs to the level of ubiquity. I will mark them as the first emergent central qualities that drive ARM's success.

By 2015, ARM's partners have shipped over 60 billion ARM-based processors (ARM Holdings plc Strategic Report 2013, ARM Holdings plc Strategic Report 2015). In 2014, ARM celebrated passing the 50 billion shipped chips mark with the release of three videos (ARM Holdings 2014f). One of the videos illustrates the company's technological impact on the following examples:

"ARM designed intelligent chips, our ecosystem partners have built these chips into all kind of products – from sensors to servers: touch interface, wireless connectivity, 360 degree camera, smart watch, connected toy, smart phone, automotive, 4K curved digital TV, quadcopter, tablet, satellite navigation, 3D printer, motion tracker, gesture recognition, smart glasses, servers. If you joined all those chips together, they would stretch to the moon and back or would wrap around the world more than 12 times" (ARM Holdings 2014e).

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ARM's CEO Simon Segars details that "It took 18 years to ship the first 10bn ARM chips, but just five years to ship the next 40bn" (Armitstead 2014). The shipment "expanded in parallel with the phones" (ibid.), explains Segars. To note, mobile has historically been ARM's primary market. Now it is a market dominated by ARM designs. If one owns a mobile phone of any kind, there is a 95% chance[1] that the phone is powered by microprocessor technology developed by ARM (ARM Holdings plc Strategic Report 2014). ARM's market share in mobile devices including smartphones, tables and laptops is more than 85% (ARM Holdings plc Strategic Report 2015). Even though not many users are familiar with ARM's name, with mobile phones turning into a global digital infrastructure, ARM's technology has reached about 75% of the world's population (ARM Holdings plc Strategic Report 2013 p.19).

Over the years, ARM has expanded beyond its initial focus on the mobile application and has gone towards "chips with everything" (Saxby 2006), designing chips for a vast array of objects and machines. Of 15 billion chips shipped by ARM partners in 2015, less than half went into mobile devices, while the majority brought low power high efficiency computing to the Internet of Things, servers and networking equipment (ARM Holdings plc Strategic Report 2015). ARM's long-time motto *"The Architecture for the Digital World"* reflected this position. As ARM is now turning more objects not only digital, but also interconnected, mobile and ubiquitous, capitalising on its small, cheap, low-power and high performance microprocessors designs, it re-emphasised its ubiquitous influence in a new motto: *"We shape the Connected World"* (ARM Holdings plc Strategic Report 2015).

ARM is a technology intensive company focused on delivering crucial IP components of a SoC to a wide ecosystem of partners: semiconductor manufacturing foundries, fabless semiconductor designer companies, original equipment manufacturers and wider users. By focussing on the central element of a digital device, ARM places itself advantageously to benefit from and promote cutting-edge innovation that is

[1] ARM has achieved more than 95% share of mobile handsets. In other words, of all existing mobile phones 95% are based on ARM processor designs. In the year 2015, however, the market share of what is now defined as "the mobile computers" decreased to over 85% because it now included tablets and laptops.

nowadays overwhelmingly digital. ARM's technology designs find implementation in *digital products* such as mobile phones, tablets, laptops, specialised computers, networking equipment, industrial automation, home entertainment and infotainment systems that have been revolutionising virtually every sphere of human activity. Moreover, ARM is increasingly bringing *computing capabilities* (along with mobility, sensing and interconnectivity) to everyday and high-tech *objects* that formerly have been *non-digital* turning them into intelligent smart homes and cities, digital health and learning technologies, wearable devices, intelligent automotive and consumer goods, smart agriculture, fish farming and other food production, all of which are creating a paradigm of an even greater revolutionary promise, the Internet of Things.

The diversity of technological artefacts and their revolutionising impact are powered by technologies whose main characteristics, as we have seen, are *focus*, *specialisation* as well as *foundation-forming nature*. ARM's products and engineering expertise form a comprehensive technology platform that delivers *reliable* and *certain* products to the customers. It is a *gradually evolving platform* strongly oriented on the customer and guided by the needs of the customers or *customer pull*. *Gradual innovation*, stemming both from customer orientation and fundamental physical properties of the technologies, is its important characteristic. In fact, evolutionary, incremental innovation is an inherent characteristic of the stabilised semiconductor technologies paradigm of the last decades, best evidenced in the historical perspective. The section below gives a historical overview of ARM processor technologies to bring out this evidence and demonstrate these qualities in ARM's technological innovation.

5.3 ARM's historical designs. Smaller, faster, cheaper

Inasmuch as products are understood as technologies created for concrete application and commercial returns, product innovation in the commercial domain in the modern day semiconductor industry takes a fundamentally evolutionary path. This is true for ARM which is part of the industry and subject to its processes.

An interviewee comments:

"We always try to evolve our product, that's the evolution and evolution is actually the easiest way of changing the future product. We've done the

design of A or A plus some little bits. It's a very easy sell". (ARM Vice President, Interviewee 4, 2012)

The insight is indicative of two aspects. First, it acknowledges the dominance of the evolutionary path. Second, and a more important one, is that the evolutionary path is in fact non-problematic for innovation in the current environment. It's is an "easy" product innovation strategy. Not in terms of technological development, but in terms of future sales, i.e. profitability and business stability. In what follows, I examine this path and its qualities.

Over the years, ARM has produced several generations of microprocessor cores. The virtue and the very purpose of producing a new generation of products are to improve on the performance and functionality of previous designs. The journey of ARM's product innovation is essentially the journey of modern semiconductor innovation: improvements in transistor and integrated circuit technologies propel microprocessor technologies. The advancement of the microprocessor technology is usually evaluated on the basis on three characteristics: (1) its integration capacity, indicated by the smallest line width in the chip measured in micrometers (μm) and, subsequently, nanometres (nm), (2) its memory capacity measured in bits and (3) its speed measured in mega and, subsequently, in gigahertz. Whenever a new generation of a microprocessor is introduced, these main characteristics get enhanced, i.e. incrementally extended to a higher value. Typically, new features are also added to enhance functionality. Performance improvements are also accompanied by a systematic decrease in size and cost, as captured in Moore's law (Moore 1965). Microprocessors become smaller, faster, cheaper, with better memory capacity, higher energy efficiency and more diverse features. An ARM employee gives a description in a nut-shell:

"Over times as the markets and the technology evolve ... people are looking at something that is smaller, faster, more efficient, has additional special features in it." (ARM business development director, Interview 7, 2012)

The characteristic pace of technological advancement in integrated circuits has been captured in the 60s by Intel co-founder and Fairchild Semiconductor's R&D director Gordon E. Moore by in a famous observation that a number of transistors on a chip, and by extension the microprocessor efficiency, doubles approximately every two years (Intel

2013). Moore's law is perhaps the semiconductor industry's most analytic underpinning. Semiconductor roadmaps have been based on principles derived from Moore's observations.

These patterns have also been used for decades to guide engineering technologies, to organise industrial collaborations and to predict and map the industry's growth (ITRS Teams 2011). Importantly, Moore's law is not a kind of inevitable technological force in itself; it is a purposeful intensive engineering effort, accompanied by substantial R&D investments, to drive down the cost and size of the chip, while driving up performance and functionality (Mulligan 2011). It is the engineers' *choice* to follow the evolutionary, incremental pattern, that, since its exponentially growing benefits emerged, has become the inherent, fundamental law of the semiconductor technology as well as the industry (Mulligan 2011). The law, and the industry's adherence to it, still hold today, although the traditional evolutionary scaling is said to be approaching its limits, prompting new revolutionary change that will imply new ways of looking at the problem, revolutionary computational technology at the atomic level and innovative restructuring of the industry's value chain. In the meantime, the present day integrated electronics in its current applied form is evolutionary.

> *"The commercial reality is very different from new science". (Co-Founder of ARM, interview 13, 2014)*

Another interviewee adds:

> *"(Unless) they come up with some revolutionary biotechnology manufacturing". (ARM senior manager, interview 1, 2011)*

Simplistically, all principles of Moore's law have applied to ARM technological innovation. The overview of ARM historical designs below illustrates the general evolutionary path in ARM core technologies.

At the same time, we will see that the evolution of ARM microprocessors was not simply a sequence of engineering advancements. Improvements in the product offerings were accompanied by strategic decisions regarding the business model and organisational form of the company. Path-setting opportunities for innovation in the product offerings shaped, and were balanced by, the company's search for path-breaking opportunities

outside the technology domain. This has been an indispensable part of technological innovation.

5.3.1 ARM1

As explained above, ARM's microprocessor designs are based on the ARM architecture: the low power, high performance architecture based on the reduced instruction set computing (RISC). In its early years, ARM produced just a few microprocessor architectures and microprocessor cores. ARM's first design was a single processor design ARM1 based on the architecture ARMv1[1]. Not many ARM1 processors were produced and the design was never properly commercialised. In fact, the few ARM1s that were built went as a co-processor to an early personal computer, the BBC micro. The intention of Acorn Computers (the future ARM Holdings), however, was to design a microprocessor architecture specifically to power its own computers in the 1980s. The goal was fulfilled when the Acorn RISC Machine architecture, which eventually gave the company its name, was used to produce the first ARM-based Archimedes computer in 1987. The Acorn RISC architecture was inspired by the Berkeley RISC project (Sequin and Patterson 1982). The RISC processor was designed to perform a smaller number of types of computer instructions so that it can operate at a higher speed performing more millions of instructions per second (MIPS)[2]. By stripping out unneeded instructions and optimizing pathways, RISC processors provided outstanding performance at a fraction of the power demanded by more popular complex instruction set computing (CISC) devices. The architecture gave the advantage of addressing the new personal computer market with a new type of architecture that was powerful enough for an emerging graphic based user interface, yet at the same time did not require substantial resources and state-of-the-art research and development facilities to be built. ARM1 was a low-power 6MHz central processing unit (CPU) fabricated by VLSI with a die area of 50 mm^2 containing approximately 25,000 transistors and using 3,000 nanometers (3 micrometers) process. Today, an Apple designed CPU Hurricane,

[1] The suffix "v" distinguishes the name of the architecture from the name of the core.

[2] Million instructions per second, a measure of a computer's processor speed.

based on the ARM 64-bit 2.34 GHz ARMv8-A architecture, has a die area of 125 mm^2, 3.3 billion transistors and is manufactured by Taiwan Semiconductor Manufacturing Company (TSMC) using 16 nm FinFet process.

5.3.2 ARM2

The ARM2, based on the architecture ARMv2, was Acorn's first processor family comprising two processor cores. They included the same instruction set as ARM1, but also featured new "multiply" and "swap" instructions to speed up calculations and ease synchronization of multiprocessing and multitasking that will become an essential capability of computers. The two ARM2 cores had the performance of 4MIPS at 8 MHz and 7 MIPS at 12MHz. The ARM2 was developed for the Archimedes computers but they were still implemented in field-programmable gate arrays (FPGAs) in 2001. The core has an added benefit to today's manufacturers of ARM2-based FPGAs, because they do not need to pay royalty on it. The core was designed in the 1980s by Acorn before it turned into ARM with its IP business model.

Further incremental innovation holds. The successive architectures kept on introducing advantages to the corresponding processor families. The correspondence between the naming scheme of cores and architectures though is not always straightforward. After ARM2 came ARM3, but ARM4 and ARM5 never existed - the names were reserved for simpler designs which were never created as the company transitioned from Acorn to Advanced RISC Machines Limited. ARM2 and ARM3 are the architecture ARMv2, while the following ARM6 and ARM7 are the architecture ARMv3.

5.3.3 ARM3

The ARM3 family had the first integrated memory cache of 4KB that increased computing speed by reducing the overhead of memory access operations and resulted in an increase in processing speed to 12 MIPS at 25MHz. The processors in the family contained 300,000 transistors comparing to 30,000 of ARM2. The ARM3 chips was produced for Acorn Archimedes personal computers.

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5.3.4 ARM6

The development of the ARM6 family was an interesting historical point. As before, the cores brought with them technical improvements, but also triggered a landmark business innovation. Introduced in 1993, the new cores were first to support 32-bit memory address space, comparing to the previous architectures which implemented only 16-bit address space, which meant that they could have significantly more memory. Another technological innovation was the introduction of ARM-based hardware. The inherent memory limitations in the existing PCs were addressed by in-slot memory boards. Several versions were produced in the family: 20MHz, 30Mhz and the 33MHz speed containing about 36,000 transistors. All had ARM's flagship feature - very low power consumption. The 33MHz ARM600 version was used in the Acorn RISC PC and offered performance of around 28MIPS. It included a co-processor bus to plug in an external co-processor or expand memory. The ARM610 processor featured an on-board Memory Management Unit (MMU) to handle memory, a 4KB cache and it could switch itself from little-endian operation to big-endian operation that allowed a large value broken into small ones and to decide on an order to place it in a memory. This processor design went into Apple Newton personal digital assistant that needed a powerful, low-power processor for sophisticated graphics manipulation. This turned out to be a landmark historical point.

A dedicated design team at Acorn collaborated with Apple Inc. and VLSI Technology on the newer versions of the processor core, which was later spun into a separate company, Advanced RISC Machines Ltd. The Newton failed for technical problems and high price dooming the company's processor design. The introduction of the processor architecture into a product that failed made the CEO Robin Saxby realise that the company could not sustain success on single products (Walsh 2015). This led to the decision to introduce the IP business model: to license a processor design to many semiconductor companies for an upfront license fee and an on-going royalty on every ARM-based chip shipped. This was an innovative thought: path-dependent and stable microprocessor technology development had to find more innovative ways to be commercialised to be sustainable as a business. Starting from the ARM6 processors released in 1992, the cores were sold as IP and manufactured under license from Advanced RISC Machines, Ltd. ARM's first licensee was the co-founder VLSI

Technology, followed by GEC Plessey Semiconductor (GPS) and the Japanese Sharp. The fourth licensing deal with Texas Instruments (TI) in 1993 was a milestone event that validated ARM's innovative business model and expanded ARM's industry position. This time, ARM's license did not include stand-alone RISC chips, but microprocessor designs to work in tandem with other cores. TI licensed ARM cores to integrate with its own digital signal processing (DSP) cores into dual-core devices for cell phones and embedded control products in the growing automotive market (Niruthambath 2010). As IT became a major adopter of ARM's IP, it confirmed acceptance and scalability of ARM's innovative business model and linked ARM to a specialised market beyond the cell and feature phones. Design integration also allowed ARM to expand its market presence without stepping on the toes of strategically important partners (Electronics Weekly 1993). The partnership with TI also initiated ARM's "idea of partnership communities and turning enemies into friends" (Saxby 2014).

As ARM broadened its licensing strategy to include standard architectures for integration into microcontrollers and microprocessors, this significantly increased ARM's presence in the embedded systems market (Niruthambath 2010). TI remains ARM's major partner having shipped over five billion ARM-based products (ibid.).

5.3.5 ARM7

The ARM instruction set has undergone further enhancements. The ARM7 processor cores were released over 1994-2001. The early ARM7 cores were based on the ARM6 designs and ARMv3 architecture, but used half the power of the ARM6, were around half the die size and offered an increased performance by a factor of 2. ARM's main technological advantage of the balance between high performance and low power consumption was strengthened further. While the ARM6 was well suited for early personal computers with an improving graphics interface, the ARM7 made small portable mobile phones a reality and helped usher in embedded computing.

The ARM7TDMI processor core released in 1994 was ARM's first big success. It implemented the ARMv4(T) architecture. The ARM7+Thumb+Debug+Multiplier+ICE contained a row of innovative features. One was the introduction of 16-bit Thumb instruction set that provided improved code density allowing it to bring the power of ARM processing into cheaper and smaller devices. The feature was prompted by Texas

Instruments (TI) who was looking for an overall cost-effective system to supply to Nokia for their mobile GSM phones. The company's small size and adaptive culture gave it a response-time advantage in product development. In 1994, with the mobile revolution making small mobile devices a reality, ARM was in the right place in the right time. TI licensed the ARM7TDMI which was designed into the Nokia 6110. Nokia 6110 became the first ARM powered GSM phone which proved enormously successful.

The ARM7 processor family became ARM's flagship design for the mobile market. Licensed by over 165 licensees and shipped in about 10 billion chips, it has been one of the most widely used ARM cores due to the application in the mobile and numerous deeply embedded systems. The ARM7 designs enabled ARM to secure more deals, which helped to formalise and strengthen the licensing and royalty business model. The licensing deals, in turn, created new opportunities for the development of the RISC architecture. Innovative features of the product designs were shaped by and channelled into new business opportunities. This interaction was also supported by innovations in the organisational structure: ARM's ecosystem organisation takes its start from strengthening IP business model. With licensing deals becoming a priority, ARM concentrated on establishing relationships with design partners. New remote offices, such as the one in Japan and Silicon Valley, were opened to communicate and collaborate with new design partners.

5.3.6 AMR's other historical designs

Need of more performance drove introduction of subsequent processor cores. The ARM8, the ARM9 and the ARM11 are the last of the legacy designs (classical processors) (ARM 2016h). The ARM8 based on the ARMv4 architecture was designed in 1996 to fill a gap between the elegantly minimal, embeddable ARM7 cores and the very high performance StrongARM processor, a collaborative project between DEC and ARM to address the upper end of the low power embedded market. The ARM810 version was designed both as a stand-alone microprocessor to power the established market of PDAs and portable computers and as a core for embedded low power, portable applications where power consumption was relevant, but high integration capability was essential (Larri 1996). Measuring 53.5mm^2 in size, the ARM810 delivered 84 MIPS at 72 MHz and was manufactured at 0.5micrometer (µm) process technology.

Exploitation

With the ARM9 design family introduced in 1998 (ARMv5 architecture, except for the ARM9TDMI which is also ARMv4(T)), ARM switched from a von Neumann architecture (Princeton architecture) to a Harvard architecture which significantly increased the processors' speed. The ARM920T more than doubled the performance of the ARM810 with 200 MIPS at 180 MHz.

Announced in 2002, the ARM11 was based on the powerful ARMv6 instruction set architecture. The versions ARM1136J-S™ and ARM1136JF-S™ delivered up to up to 1GHz speed in under $2mm^2$ in size at 65nm process technology (ARM 2016d). TrustZone® security technology was introduced with the ARM11 family which now represents the third pillar of ARM powered computing alongside low-power and high performance. The version ARM1136J-S™ was the winner of the prestigious Microprocessor Report Analysts' Choice Award in the Embedded IP Processors category in 2002. The ARM11 designs diversified embedded applications to include: network infrastructure equipment, consumer products such as digital TV, set-top boxes, games console as well as automotive infotainment: in car entertainment, DVD player and navigation equipment.

The above reviewed processor cores are ARM's classic processors which are now obsolete and no longer licensed, except for latest ARM9 and ARM11. The designs displayed the same evolutionary pattern, driving up the power consumption-performance trade-off and targeting low-power and high performance applications, as a separate or combined technical edge and a competitive advantage. From then on, ARM's microprocessors are called Cortex – the company's modern, currently licensed processor cores.

5.4 Historical designs: evolution, incremental innovation, exploitation

Based on the empirical evidence so far, I will begin to systematise the emerging characteristics of ARM's technological innovation. We have seen that ARM's core competence lies within the stabilised paradigm of the semiconductor technologies. The company operates in the semiconductor industry that over the past decades took a predominantly evolutionary innovation path. Innovations in the established industry are typically incremental, as technological goals become clearer and companies move towards large-scale production. It is true for ARM: the company zeroed in on the RISC

architecture as its core expertise that differentiated the company. The necessary microprocessor core specifications have also been well understood. Driving up performance characteristics and enriching product families with complementary technologies were thus the clear design objective that advanced the RISC architecture from an opportune technological discontinuity to the level of a dominant design in the integrated electronics industry. Incremental technological innovation was also of great commercial importance because it enabled extending the characteristics to suit mass markets and trigger economies of scale.

The important features of ARM's technological innovation are thus:

Incremental and evolutionary. The increment of improvement in the processor performance characteristics has been illustrated above. The increments are easily quantifiable in the corresponding units of measurement and they adhere to the regularities formulated in Moore's law. Achieved performance and functionality improvements in microprocessor core families are extended in successive designs. However, technological evolution is always a co-evolution and the resulting change is systemic. Incremental quantitative improvements in ARM's technology accumulated to produce impact beyond the technological domain both within and outside ARM. As we have seen above on the example of historical turning points in ARM's business, certain events in the technology development triggered more radical innovation in the company's business model and organisational structure of the business as well as in the industry's value chain. ARM's improvements in microprocessor technologies and cost-effective supply of the IP via the licencing business model have allowed partners to do more experimentation and differentiation in their respective markets.

Focus and specialisation. The company was started around the specific expertise in the low power small size RISC processor designs and cultivated it as the core know-how, which required deepening the expertise and increasing focus and specialisation. Further technological innovations aimed at boosting the competitive edge and set technological innovation on the generally predictable trajectory of improvements. In the 25 years of its existence, ARM maintained the focus on the microprocessor designs and gradually added complementary technologies, but R&D was carried out along the generally predictable trajectory at a the pace expected in the industry. Deepening specialisation in the base-line microprocessor architecture design, however, required

increasing the scope of scanning activities for all major innovations in the industry in order to adequately meet customers' demands for the base-line technology. In this sense, deep focus in ARM goes hand in hand with broad horizon scanning.

Platform-forming quality. ARM has to consider the technologies and needs of different semiconductor manufacturers and OEMs and find a right balance between their different demands to then come up with a design that would suit the most important requirements common to them all. Each ARM design, therefore, always aims at achieving the best compromise between the diverging demands of specific partners in a way that would benefit a large cross-section of the Ecosystem partners and enhance ARM's technology platform. The advantage of the platform-forming quality of ARM's technology works both ways: it accesses a large pool of innovative ideas and allows ARM to develop better products than competitors who lack an equivalent Ecosystem, while the Ecosystem partners benefit from processor designs that are better aligned with their future needs. From a small specialist IP supplier of RISC processor technologies ARM has become the "glue" that binds a network of partners together and the "magnet" for expertise fragmented between different participants of the value chain.

The above listed characteristics resonate with the definitions of e*xploitative innovation* in ambidexterity theory. To reiterate, exploitation is associated with the focus on existing competence, its incremental refinement and improvement, path dependence and technological trajectories (He and Wong 2004). The overview of the historical designs brings out these features. Inasmuch as product innovation in ARM builds on existing competence, incrementally enhances qualities of microprocessor families and is contained within the same technological trajectory, it can be characterised as exploitative. This is a helpful evidence in the sense that ensures that the analysis is targeting the phenomenon of exploitation. The evidence, however, is not unequivocal to put the exploitation "stamp" on the nature of the technological innovation in ARM.

These qualities do not reflect the possibilities for diversification, experimentation and radical impact that ARM's product innovation creates for the Ecosystem of partners. To simply mark the exploitative qualities of ARM's technological innovation is to overlook vast possibilities for capabilities for recombination and development that ARM's technologies enable to its Partners in the diversity of their respective markets. One can easily put metrics on ARM's technological product innovation, but the

recombination possibilities that they provide are much more creative and potentially radical than metrics. ARM *enables* partners to do innovation. What ARM often does is "step back and let other people do the innovation" (Muller 2016). There is a strong realisation that metrics is not a goal in itself, but an enabler to solve a problem: "we should not get hung up on 'can I make this smaller, can I make this faster, you actually have to think about what's the real problem you are trying to solve" (ibid.). Evolutionary technology development includes contribution from the environment that bring about innovation: engineers often know what is possible to do with technology, but they do not know how the users may use it. ARM's technological innovation is inconceivable from the contribution of the Ecosystem.

Additionally, the historical overview can epistemologically skew the representation of technological development to create an image of a linearly unravelling process, as opposed to the lived experience where the future steps of product innovation are not as clear. Present events as they occur typically seem more game-changing ("we live in special times" assumption), while past events in retrospect seem sequential and logically unfolding. It is perhaps also true that with Moore's law approaching its limits, presumably more unconventional effort is necessary to push technologies to the new frontiers. With this in mind, I will turn my analysis to ARM's current products to glean nuances of technological innovation and complete the test of the notion of exploitation.

5.5 ARM's modern technologies

In the race "to put a high-performance, power-efficient supercomputer in the palm of the consumer's hand"[1], ARM kept on driving up its pillar processor characteristics of performance, power efficiency, implementation size and, recently, security in new processor designs. Interestingly, in the evolutionary development that continued, aspects

[1] John Kalkman, vice president, Samsung Semiconductor, Inc. on the announcement of the ARM® Cortex™-A7 MPCore™ processor and big.LITTLE processing technology. https://www.arm.com/about/newsroom/arm-unveils-its-most-energy-efficient-application-processor-ever-with-biglittle-processing.php Accessed 25.10.2016

of the incremental improvements have changed. Moore's law that still govern the development has now come to mean more than Moore's original observations about falling costs as the number of components per circuit went up (Moore 1965). Two more metrics: power consumption and size kicked in the design, where complexity has also become an exponentially increasing metric. ARM Fellow, and VP of Technology in the Media Processing Group, Jem Davies highlights these aspects in a public keynote to ARM developer partners an industrial conference and summarises the change in the technological evolution (AMD Fusion Development Summit 2011). While in the early day of mainframe supercomputers technological evolution concerned only functionality that was improved by building a bigger, more expensive computer, the move to the personal computer changed the metrics that the players in the industry were pushing. It has then become functionality per dollar (cost to the manufactures or price to the user). In the following move to portable and battery powered devices, that has changed again. Devices evolve in functionality per unit energy per unit cost. Functionality divided by energy divided by cost is the current metric in the industry today which the companies are building for. This is a very difficult thing to optimise for, because power affects all aspects of the design. The metric is central to ARM roadmaps. ARM know-how is in optimising it.

Over time, other types of IP products have been introduced, such as graphics processor and physical IP components. Cortex cores are ARM's modern processor families. Today, they have been described as "the world's most power and performance efficient processors" (ARM 2016e). Incremental improvements in the architecture and the chip layout eventually enabled *superior features and functionality* that became fully performance competitive with the existing processor technologies in the traditional computing markets. More importantly, the superior characteristics, though taken on an evolutionary path, have been produced *strategically*. They have been built upon the value proposition of the RISC architecture (simpler, cheaper, smaller and more power-efficient) which has been purposefully extended into markets new for the company (both previously existing and emerging).

We have seen earlier that ARM has expanded beyond its traditional mobile market and established a stronghold in the embedded automotive market since 1993. The company's extreme focus on the core competence did not lead to rigid structures and co-

evolutionary lock-ins with the company's traditional product markets. ARM's technological savvy continued, but strategically probed for new applications with an aim to change the existing order of things.

ARM's CEO describes in a public report:

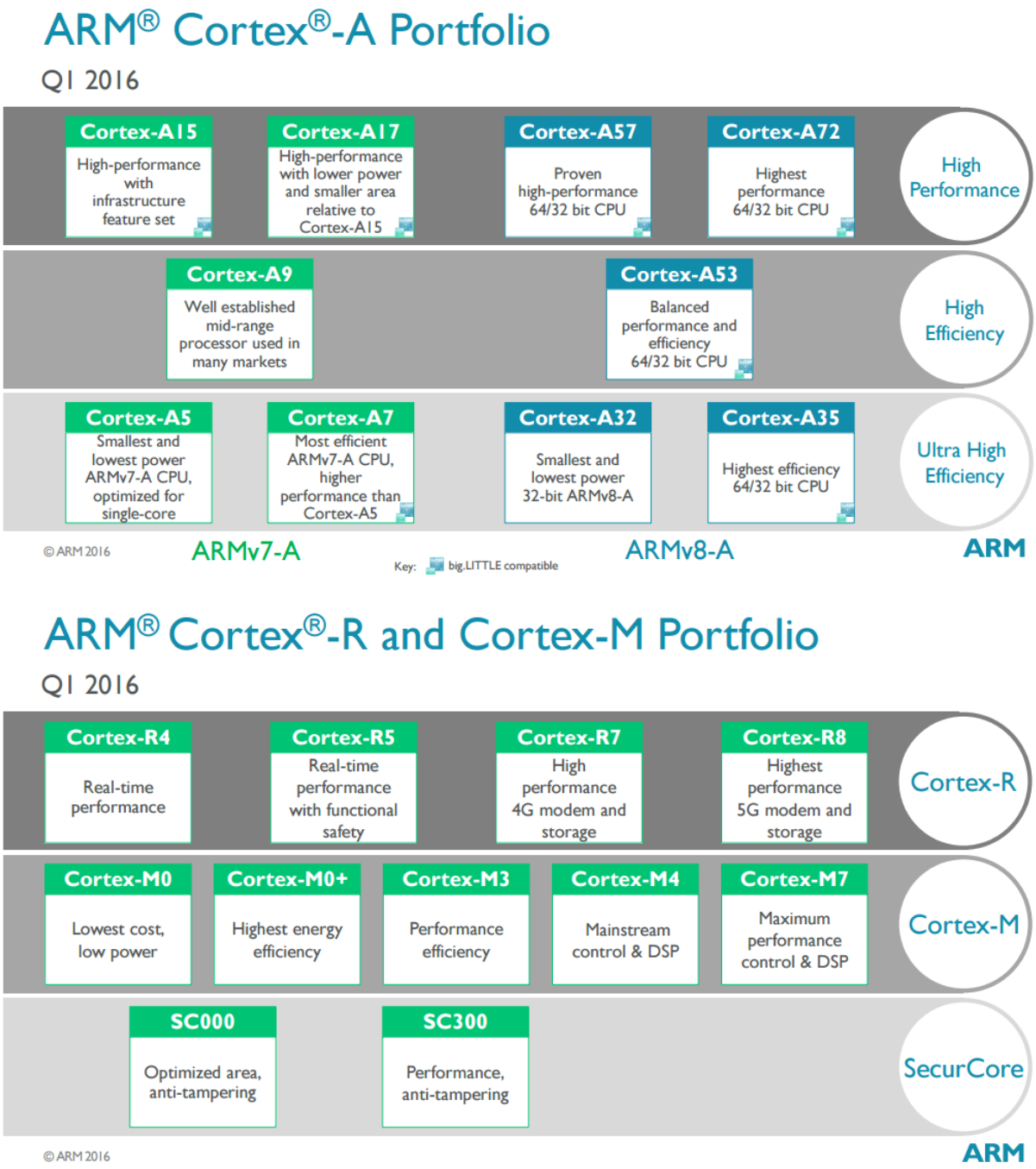
> *"We didn't know which markets would take off first, or how the technology was going to be used, though we always knew that ARM was going to change how and where computing happens, and that this was going to lead to a revolution in the digital products that we all use every day." (Simon Segars, Strategic report 2015, p.16)*

The certainty of the evolutionary path of semiconductor innovation and the uncertainty of potential technology uses combined in an R&D strategy to produce a product line that is both highly specialised yet flexible: "the ARM® Cortex® series of cores encompasses a very wide range of scalable performance options offering designers a great deal of choice and the opportunity to use the best-fit core for their application without being forced into a one-size-fits-all solution" (Silicon Labs).

5.5.1 Cortex A, R and M family

ARM's products web page provides the following description of the Cortex processors. Cortex-A series is a family of *applications* processors for complex operation systems and user applications such as "mobile devices, networking infrastructure, home and consumer devices, automotive in-vehicle infotainment and driver automation systems, and embedded designs" (ARM 2016j). Cortex-R series is a family of *real-time* embedded processors aimed at applications "where performance requirements and timing deadlines must always be met" "to avoid hazardous situations", for example, in medical applications or autonomous systems (ARM 2016l). Cortex-M series is a family of *microcontrollers* optimised for miniature, low-energy, cost-sensitive applications like sensors that can be found in fitness trackers and the Internet of Things objects (ARM 2016k). Interesting to note, the cores' suffixes form the word "ARM". Figure 8 on the next page presents the Cortex products portfolio as of Quarter 1 of the financial year 2016.

Figure 8 ARM Cortex-A Portfolio and ARM Cortex-R and ARM Cortex-M Portfolio (ARM 2016e)



Having achieved a wide range of performance options through incremental enhancements over the years, ARM's computing has come to cover diverse functionality. An ARM's top executive highlights:

> *"Our architecture goes into everything from micro sensors that don't even use any power from a power supply, they are scavengers [that] take energy*

from the environment, right the way through to server farm chips, supercomputers. We do the whole spectrum. There is no other company in the world that does the whole spectrum." (ARM senior manager, interview 1, 2011)

An important quality of ARM's technological innovation that has emerged in the previous sections comes to the fore here as the key quality of ARM's innovation as a business. Namely, that gradually accumulated, strategically channelled *quantitative* improvements in technology parameters bring about *superior technology* that at a certain point induces a *qualitative* change meaningful in the area of technology application, user innovation and other forms of technology's social existence. In ARM, the incremental enhancements have not resulted in a technological breakthrough per se, but initiated a significant organisational change in the industrial Ecosystem and pushed the wider socio-technological paradigm from the era of mobile computing to the era of ubiquitous computing. In other words, changing the technological basis of the company has modified the organisation itself, but also altered its industrial landscape and the society's interaction with the digital technologies.

The interviewee continues:

"We've ... been innovating out of our traditional mobile phone area down to sensors ... right the way up to high power chips. So we are now covering the entire computing spectrum, whereas 5 years ago we were really seen as a mobile phone company."(ARM senior manager, interview 1, 2011)

ARM's industrial strategy, market position and the company's very identity have been undergoing substantial re-thinking, while the very basis of the company's business - its technological savvy - has continued to evolve, preserving the focus and specialisation. The entire computing spectrum referred to above is in fact underpinned by about three dozen of processor designs. Yet, ARM's specialised IP, deployed by a vast ecosystem of adopters in their respective markets, has come to underpin what has been called the "Cambrian explosion" of computing devices. ARM Director of PR and Corporate Affairs mentions the phenomenon in a public interview:

"There is going to be this Cambrian explosion of devices and form factors and functionalities." *(ARM Director PR and Corporate Affairs talks about MediaTek 2014)*

Exploitation

The "Cambrian explosion" of form factors of digital technologies of course refers to the Internet of Things, a welcome growth opportunity for ARM. It is a *metaphoric parallel* to a sudden burst in the evolution of the natural world which created the astonishing diversity of new life forms (Fox 2016). The relevance to ARM technological innovation is in that small environmental changes can trigger major evolutionary developments. Although the expression "Cambrian explosion" is more and more frequently used in ARM's recent public communications to describe the growth of IoT (Fuller 2017, Son 2016), it should perhaps not go beyond this common point of logic. The Cambrian explosion in the natural world, after all, was preceded by an ecosystem of very simple organisms and the triggers of that revolution are not very well understood (Fox 2016).

The Internet of Things is a new revolutionary paradigm qualitatively different from the previous of era of mobility. It is a "a quiet revolution" though (Witchall et al. 2013), precisely because the changes that led up to it were incremental and the technology adoption was slow. But because computing capabilities became exponentially smaller and cheaper, demanded considerably less power and enjoyed complementary fields like mobile and cloud, the ubiquitously deployed computing on a mass scale resulted in a significant shift in how and where computing happens. We see that *billions* of ARM-based microprocessors and microcontrollers are enabling a *vast diversity* of *smart* computing devices that deliver *new value* to the user. ARM CEO Simon Segars elaborates in a public interview:

> *"In the mobile, we looked to put more and more performance, more graphic performance, more video performance into a smartphone platform, and then the software has evolved on top to deliver user experiences. And essentially the smartphones, whilst the uses do change, [are] a very similar form factor from one to the other. In IoT the breadth and diversity of applications can be as diverse as a tiny sensor in a field somewhere working out when the crop needs watering to something that is a high bandwidth data and maybe a security camera in the middle of a city where the implementation is completely different."* (ARM CEO Simon Segars for CNBC 2017)

Exploitation

The central argument that has emerged is that small incremental changes produce paradigm-shifting technologies. I will zoom in on the product line once again to support the argument.

5.5.2 Antecedents and consequences of focus and specialisation

The "Cambrian explosion" and the Internet of Things from ARM as well as the above mentioned entire spectrum of computing devices are in fact enabled by a product line that is relatively narrow. An important quality of ARM's product base is flexibility and diversity stemming from the possibility to re-design and integrate, not from a large number of discrete designs per se. As of the end of 2016, ARM licensed a total of 29 Cortex cores (ARM 2016g) in addition to the seven classic cores in the ARM9 and ARM11 families that continue to be licensed (ARM 2016b, 2016c). The growth of ARM's processor family is relatively modest with two to three processor designs introduced in an average year (ARM Holdings plc Strategic Report 2013 p. 17).

Interviewees comment that ARM's product innovation rationale is not to produce a wide range of *custom designs* to suit the diversity of the ecosystem partners, but to keep the product line as narrow as possible and meet the demands of as many customers as possible with designs that are *customisable*. In other words, ARM is a lean company that addresses the needs of a vast ecosystem of customers with a relatively few types of microprocessor cores. ARM top executive explains the economic basis for this rationale:

> *"…in this market, one of the interesting challenges [is that] it's strongly in our interest to keep a number of products that we produce as small as possible. … if one of these each costs 15 hundred million dollars to create and you have to go through the full complex validation, quality assurance on any new product that you create then you don't want to create one and then create a subtle variant of it later on. … And it's actually in the customer's interests that we have as few products as possible, too. Partly because if we have too many products they have to buy more. [Also …] products compete amongst each other and also it makes it more difficult for the ecosystem to support those products." (ARM top executive, interview 5, 2012)*

Exploitation

The economic rationale for keeping innovation focused is that "too much variety can be a bad thing" (Davies 2011). ARM Fellow and Vice-President Jem Davis explains in a public keynote at an industrial summit:

> *"Too much variety for the Ecosystem of the developers who are writing the code for these devices… Developers need to be able to support a range of platforms, for a range of market segments, for a range of the devices and you need to be able to reuse your code across the platforms. And too much variety, too many different tool chains, too many different instruction set architectures is actually a negative economic effect for the industry […]"* (Davies 2011)

Thus, the factors accounting for the narrow product line and influencing the scope of innovation are:

1. Cost of R&D and IP protection,
2. Substantial length of time to produce a new design (5-7 years),
3. Requirement of sufficient distinction among designs not to create competition within own equivalent products,
4. Not oversupplying the ecosystem.

Connected to these are two other crucial antecedents: (5) revenue generation and (6) customer orientation. The interviewee continues:

> *"[ARM] engineers who are developing products have got customer commitments, they've got projects time scales that they are working to and they have to deliver on those, that's the life blood of the company, get the revenue in the door. So, they can't go off and randomly do some other wacky piece, you know. I mean we try and we have tried to create a culture where people do have space to innovate within their job but they are not going to go off and do something completely different. And we don't really want those particular people to do that, what we want is we want everybody to feel that they should always be looking to improve the effectiveness of what they are doing to be able to innovate in methods to improve the effectiveness of what they are doing. … Not necessarily to go off and spend half of their time doing completely random things." (ARM top executive, interview 2, 2011)*

This evidence is also useful because it allows characterising ARM's product innovation a different way, by what it is not. In this context, it is *"can't … do wacky piece", "not going to … do something completely different"* and *"not … doing random things"*. It is the opposite, which confirms the "*looking to improve the effectiveness"* synonymous characteristics identified above.

At the same time, an important part of the context here is *"a culture … where people have space to innovate"*. Culture to innovate counteracts the focus on efficiency. Technological innovation is supported by culture. This can be illustrated by the motto "*think brave but think back to reality"* of ARM's co-founder Sir Robin Saxby (Public talk by ARM co-founder Sir Robin Saxby 2014), which communicates the very real commitments to customers, investors, product roadmaps and revenue generation combined with the importance of looking beyond that. The latter perhaps does not even stand in contradiction to specialisation with regards to cutting-edge microprocessor technology. We have seen at the beginning of the chapter on the example of ARM engineering savvy that in this knowledge intensive industry, insights come to those who have deep technical knowledge of what semiconductor technologies can do. Organisational culture plays a decisive role in an ambidextrous organisation and ARM's culture is discussed in depth further in this thesis.

Customer orientation has been emphasised by the interviewees at ARM as a central factor defining the extent of new product development:

> *"We don't do any product development unless we have a lead partner. By the time we even starting the development of a new product we will already have signed some customers." (ARM business development director, interviewee 7, 2012)*

In more general terms, Sir Robin has emphasised the same with reference to ARM: "business is more customer pull than technology push" (Saxby 2006). And also:

> *"Technology push is always minor. You have this great idea, but people only buy things that they need". (Public talk by ARM co-founder Sir Robin Saxby 2014)*

However, an important nuance about customer orientation must be added here that strengthens even more the argument of ARM's focused specialised innovation, as

reflected in the narrow product line and illustrates the intensive thinking process that goes behind the focused specialisation. Customer pull is a necessary, but not sufficient condition to initiate a technological innovation. Putting a new product in the R&D pipeline is a long, expensive and not always the most reasonable route to solve a customer's problem. ARM always starts with understanding what problem the customers is facing and tries to solve it with an existing solution. An interviewee explains:

> *"(Coming) up with a solution that solves the customers' problem is very expensive, you have to wait 7 to 10 years before you get X, Y and Z. So, the first approach will always be what we have today or tomorrow, what we have coming between now and when this supportive feature could arrive that could be more innovative and could change the problem. A slightly different solution than X, Y and Z but still kind of fixes the problem of customers." (ARM Vice President, interview 4, 2012)*

And:

> *"(We are) always trying to identify the problem first and solve it with available technology before putting a new product into the pipeline. When they (customers) are asking for X, Y and Z, it might be what the current supplier supplies, it's very often we're trying to get into the market where the current supply is a solution. Well, actually what do we have and how could we solve that (with the current technology)? ... Cause everybody knows it takes us a long time to get it through the pipeline. ... So, that will always be the first initiative. Adding things to our products will always be the last option if you will." (ARM Vice President, interview 4, 2012)*

Technological innovation in ARM is based on understanding the needs of the customers, identifying their "pain points" and trying to solve them efficiently with a solution from ARM: either existing or by initiating a new product development. Interaction with the partners to understand, anticipate and suit their needs is key. No single organisational mechanism or incentive can support the diversity and dynamic of the relationship with more than a thousand of partners in ARM ecosystem. That is why *culture* that supports the spirit of technological innovation and gives primacy to partners becomes an extremely important part of the organisation. These attitudes are hard to

pinpoint and replicate, that is why the inter-relation between the focused partner-oriented ARM and the diversity of players who utilise its technology is where the "magic" happens. Let me elaborate on that in the next section.

5.5.3 "Magic ingredient"

ARM is a *constituent* brand and a supplier of *technology components* of a SoC that are then built by ARM's licensee and integrated into original equipment by ARM's partners further down the value chain. To use the metaphoric explanation of one interviewed ARM's senior manager:

> *"We provide a little bit of magic ingredient, and everyone else does something with the magic ingredient. The innovation is massive." (ARM senior manager, interviewee 1, 2011)*

The focused, specialised, shaped by customers' needs SoC technologies enable vast and diverse innovation in technology use. It may seem paradoxical that what constitutes "magic" in ARM's product characteristics is specialisation, focus on improving effectiveness and close alignment with customers' commitments and product time lines. Adding the characteristics identified in earlier sections, the "magic" also comprises the incremental and the evolutionary, as well as design flexibility.

At a closer examination, this is not a paradoxical contradiction, but a legitimate quality, or *morphing* of qualities: specialised technologies are in fact conceived and built with radical applications in mind. As mentioned before, technological evolution is not a random process of variation and selection and Moore's law is not a blind technological force but a strategic direction. *In the commercial domain, technology content (engineering specifications) is closely tailored to technology use (market application). In this case, technology is not an entity oriented on itself. E*ngineering improvements are *selected* and *refined* not for the sake of experimental, explorative advancement per se, but to improve products' market applications and wider social adoption. In fact, many of the cutting-edge applications do not need the very latest technology and the existing technology components provide necessary and sufficient features and functionality.

Exploitation

At the same time, diverse unconventional applications, as well as new social implications of them, come about when the computing technologies that underpin them have advanced and diversified enough. The latter, still, is an evolutionary process:

> *"Ultimately, most product ideas are the evolution of the previous products. Even if they are revolutionary in terms of what they are used for, our magic dust evolves". (ARM senior manager, interview 1, 2011)*

The next two sections shed more light on the mechanisms of ARM modern product innovation.

5.5.4 Variance reduction

New distinct product offerings, capitalising on the rapid improvements in semiconductor technologies, make some of the company's previous product designs obsolete. A logical managerial decision is then to remove the obsolete product from the current offerings in order to keep the technology base up-to-date as well as focused and narrow – the quality that ARM respects, as we have seen. A new product family *displaces* an old obsolete one. The upgrade from the ARM7 processor family to Cortex family in embedded applications provides an example of that.

On its web page, ARM published a note recommending an upgrade from a highly successful ARM7 processor family, that since its introduction in 1994 helped to establish ARM as the architecture of choice for the digital world, to the more efficient Cortex processors, "the Architecture for tomorrow's Digital World" (ARM 2016a). While the ARM7 processor family has been very successful, with over 10 billion ARM7-based devices deployed in a vast variety of cost and power-sensitive applications (ibid.), ARM now recommends an upgrade from this classic processor family to more superior options, including the Cortex family.

For example, the users of ARM7TDMI-S in the embedded market are recommended to upgrade to "the Cortex-M0 and Cortex-M3 processors [because they] offer a much superior alternative enabling tomorrow's embedded applications by delivering more features at a lower cost, increased connectivity, better code reuse and improved energy efficiency" (ibid.). The upgrade does not only illustrate evolutionary improvements in the new product offering, but also the evolutionary "dying out" of the

old, previously highly successful product. Another important indicator of an evolution is the lack of a disruptive change associated with the migration, which "in most cases [is] fairly straightforward" (ibid.).

The migration options from the ARM7 to ARM's other classic processors and Cortex family processors are given in Figure 9. It shows the evolutionary move along the axes towards higher efficiency, higher performance and more features. The new generations of products are moving "North East", which is also the key characteristic of *sustained* (not *disruptive*) innovation (Christensen 1997).

Figure 9 Design migration from the ARM7 (ARM 2016a)

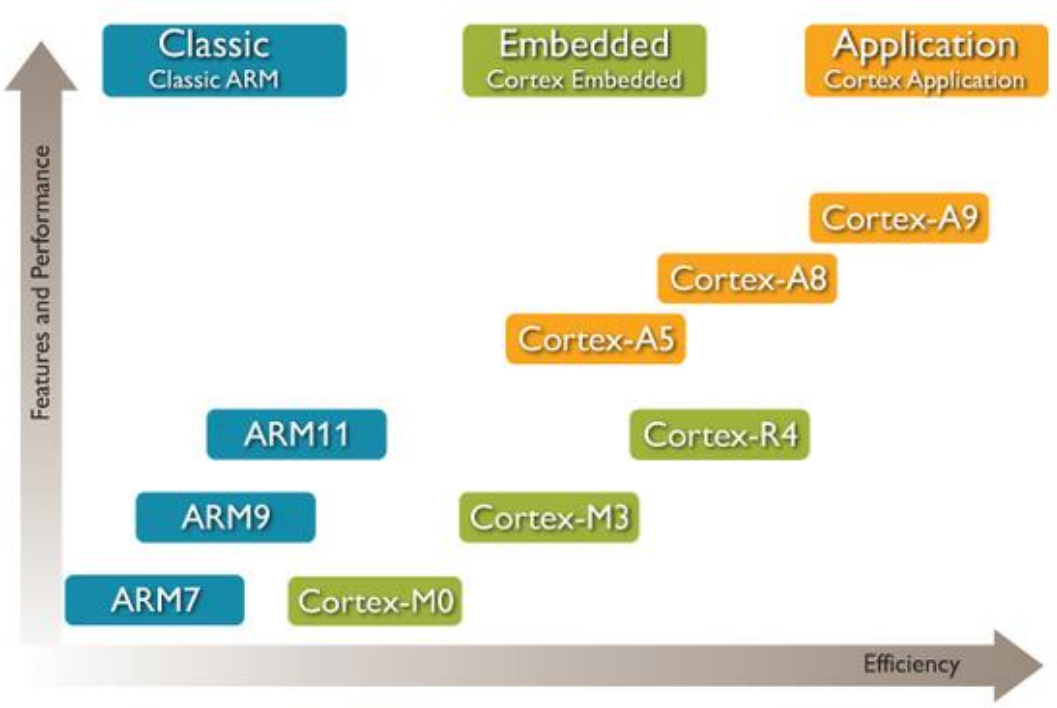


Table 2 below that accompanies Figure 9 on ARM's web page (ARM 2016a) gives suggestions about the most common migration paths from ARM7 based designs to the next processor generations. Here, I have highlighted in red the characteristics that once again illustrate the incremental nature of improvements in the successive processor cores.

Exploitation

Table 2. Upward migration paths from ARM7 to next generation

Current processor	Upgrade driver	Alternative ARM processors	Benefits of upgrading
ARM7TDMI-S	Application upgrade	ARM926EJ-S, ARM968E-S, Cortex-A Series	▪ Higher performance ▪ More features
		Cortex-R Series	▪ Better determinism for real-time processing ▪ Higher performance ▪ More features
	Socket upgrade	Cortex-M0	▪ 1/3rd the silicon area - smaller size ▪ 3x power savings - higher energy efficiency ▪ Flexible, powerful and fully deterministic interrupt handling - new features ▪ Higher code density ▪ Simplified software development
		Cortex-M3	▪ Higher performance ▪ Superior efficiency and flexibility ▪ Flexible, powerful and fully deterministic interrupt handling - new features ▪ Low power modes ▪ Higher code density ▪ Simplified software development
ARM7EJ-S	Application upgrade	ARM926EJ-S	▪ Higher performance ▪ More features

New designs offer qualities that are better, higher (or lower, but better), simplified and contain more features that solve customers' tasks better. Obsolete products are discontinued and removed from the IP portfolio giving space for new processor designs with more superior characteristics that better suit customer needs.

5.5.5 Variance increase

Over time, ARM's product portfolio expanded to include other products that complement ARM core and allow to create SoC seamlessly entirely from ARM. An illustration of this strategy is ARM's other central product - the ARM® Mali™ multimedia series of processors - that embody a complete multimedia solution that

customers can implement into their SoC design. Added to ARM's product portfolio through acquisition of a Norwegian company Falanx in 2006, "the Mali Graphics Processor Unit (GPU) is a combination of hardware and software that enables high quality 3D graphics and video deployable in a different types of electronic devices with a display from mobile phones to car infotainment systems" (ARM Holdings 2006).

Today, ARM's product portfolio, alongside the microprocessor cores and multimedia technologies, contains all technologies essential to designing and manufacturing the full ARM-based solution. All of ARM's main products are IP products aligned with ARM's licensing strategy. ARM online product portfolio (ARM 2016i) describes the following main products. ARM Artisan® Physical IP library is an IP product that contains specified routines that tell the manufacturer exactly how to build a particular chip. F19System IP is a collection of interconnections, controllers, debug and trace and IP tooling that are designed, validated and optimised to be used with Cortex processors and Mali multimedia IP to allow designers to build better embedded, mobile and infrastructure systems. Wireless IP is the ARM CORDIO© family of radio IP solutions that delivers low-power, low-voltage wireless radio connectivity to SoCs. ARM Internet of Things (IoT) solutions are the ARM mbed™ IoT Device Platform that enables a software ecosystem that serves a common platform for developing connected IoT devices. ARM also provides software tools to debug, analyse and optimise ARM-based applications throughout the development cycle and offers comprehensive support, maintenance and training services to assist developers with designing their ARM-based applications and producing a complete SoC.

The ARM architecture has also evolved to include security features such as TrustZone and SecurCore technologies that have become "the third pillar of ARM", alongside the key characteristics of low power and high performance (ARM 2016f). All in all, the microprocessor IP, together with the supporting software and services, allows ARM's customers and partners to capitalise on the technologies from the hands of one supplier.

The complete solution is essential to the manufacturing process of the semiconductor licensees. Offering complete solutions increases uptake of other core products making product such as Mali GPU, physical IP, an important revenue generating part of ARM's product portfolio. Complementary technologies such as software and

development tools for ARM's processors allow developers to get their designs started quickly and concentrate on the differentiating features of their applications. Time to market and continuity are important to the designers who can port ARM architecture on further generations of their products and applications and jump start their products. The developer resources from ARM are intended to cater for developers and not bring financial returns per se and thus are increasingly provided by ARM for free.

Over the past decade, ARM has expanded its product portfolio significantly. The variance increase in the product portfolio was through an evolutionary growth of the microprocessor product lines and the introduction of complementary technology tightly connected to the microprocessor technology. ARM does not increase variance by adding a technological component dramatically different or unrelated to its existing product roadmap. ARM does not aim to reinvent itself. ARM's product innovation strategy is to fill more and more technology gaps to produce a complete SoC from ARM. An interesting feature of this evolutionary trajectory is that the more elements ARM fills, the more opportunities it creates for the ecosystem to thrive by producing both complementing and competing technologies. The SoC remains a massively complicated technology and components from ARM are sometimes still not sufficient to make a full SoC. Other IP is necessary to design an SoC and certainly manufacturing capabilities are required to complete a manufactured device. ARM's growth notwithstanding, there is still enough space for a thriving ecosystem. Co-evolution of ARM's focused technology with the partners' diversification continues.

5.5.6 ARM's technological frontiers

ARM recognises the importance of looking at the technological frontiers and innovating beyond the comfort zone of its traditional technological competence. Thinking about where ARM's technology should be moving *in the long-term is part of the evolution of ARM's technology.* Namely, this implies assessing where its existing markets are moving, what new markets are emerging and what growth opportunities may be achieved with ARM's technological know-how in the markets that have not been traditionally theirs (ARM Holdings plc Strategic Report 2014 2014a). Long-term innovation is the point in the future to where ARM's technology is envisaged to evolve.

Exploitation

It is the extension of the evolutionary past into the new horizons, not arriving there with something completely new.

The domain of *technology application*, or market innovation in business terms and social use of technology in broader terms, is where the long-term, *more explorative* innovation takes place for ARM. Customer orientation still strongly shape the directions and boundaries for it. The search for new technology is closely aligned with the trends and the pace of innovation in the industry, as well as with the long-term needs of the customers themselves, considering the changing environment. For this reason, the term "blue-sky research", which means open-ended search with no anticipation of immediate application or commercial return, is applicable to the technological innovation in the sphere of technology use, not IP product development per se, and is done with great caution:

> *"You've got your corporate R&D which is where you potentially start branching out into areas that are less closely coupled. … And this is … I always wanna say blue sky, but it's not blue sky research. It's a balancing act between the bottom-up requirements that actually come out of the discussions with these people (ARM 2.0 Divisions) and the marketing teams that sit within the [Product] Division who are the main interface to talking to our partners and their customers who are understand some product trends in mobile phones over the next years and bringing that information back into here [Product Divisions]." (ARM top executive, interview 5, 2012)*

The "blue-sky" research in ARM remains tied to the demands of the customers, the customer customers' and is decided in the collaborative iterative discussions of the technology needs in the market. Blue-sky research is not experimentation and exploration out of the blue. The blue-sky research of this type is the furthest that technological innovation is taken by ARM. The company does not employ business futurists who explore general socio-technological trends and play with ideas, because "there is a point beyond which you are just not knowledgeable enough to have an informed view" (ibid). Innovation at the far end of the explorative pole, the blue sky innovation, is not practiced in ARM. It is also not necessary for the company to initiate this type of innovation if it is not relevant for its customers and ARM's future products. Otherwise, the customers provide all explorative intelligence about the future technology trends:

Exploitation

"We have good insight because our ecosystem is several years ahead of products." (ARM Senior Manager, interview 1, 2011)

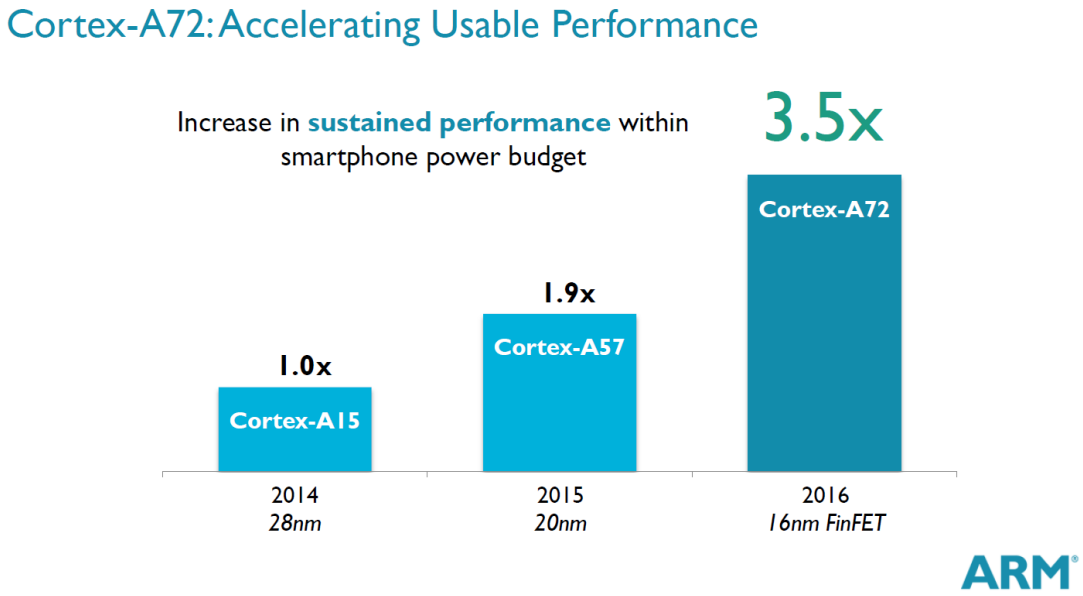
In view of this, and to do credit to the cautiousness of the previous interviewee in using the term, I will conclude about the degree of exploration in ARM with a quote another interviewee:

"We don't do blue sky research. We never have done. We are more applied." (Interviewee 1, ARM senior manager, 2011)

An example of an ARM "blue sky" innovation will clarify the meaning of the long-term innovation through evolution rather than by changing into a completely unrelated technological trajectory.

In 2011, ARM announced the new ARMv8 64-bit architecture that was completely different to ARM's previous 32 and 16-bit processor designs. Cortex-A57 and subsequently Cortex-A72 cores are the innovations that stand out. They extend the reach of ARM low power architecture into the high performance applications, such as premium 64-bit mobile, servers, supercomputers and other enterprise-class hardware (ARM Holdings 2011). The dramatically increased performance characteristics of the newest Cortex-A72 core in comparison to the highest performing 32-bit Cortex-A15 and the first 64-bit core Cortex-A52 can be seen in the Figure 10 below.

Figure 10. ARM 64-bit innovation. Highest performance and power efficiency for new markets (ARM Holdings 2015a)



The new product line was introduced by ARM in response to the industry' rising demands for higher performance due to the companies' growing data processing needs and energy consumption, driven by growing cloud storage, data processing trends in enterprise and richer user experiences in consumer markets (ARM Holdings 2011). Rising performance requirements have been a familiar trend, but applications such as servers that require to store and process big data in an energy efficient way has been a completely new market for ARM. It is a market, though, that closely aligns with ARM's core proposition of high performance within a cost and energy budget. ARM has decided to move into the new server application, because it promises long-term growth as more and more servers will be required, especially in data centres of cloud-based provider as more and more data needs to be stored.

In fact, the work on the 64-bit architecture was started as early as 2007 as an idea in the then ARM 2.0 part of the business ring-fenced around the ARM CTO. Importantly, the unit was tasked to think about innovations unrelated to current product lines. The result has been the extension of ARM's existing microprocessor know-how and the low-cost low-power value proposition into the new high performance applications market. The ARM 2.0 structure, together with its counterpart ARM 1.0 structure, are analysed later in the thesis in section 7.1.1.1 in chapter 7. But it suffices to say for now that the

outcome of innovation in ARM 2.0, which strongly resembles the buffered exploration structure, was the evolutionary extension of ARM's technological competences into a related digital industry's market and meeting the anticipated customers' need. We see again that the borders between exploitative and explorative innovation blur.

An example of ARM's other technology - the low power tiny microcontroller cores for embedded applications - provides another interesting illustration of the explorative qualities of the exploitative technological innovation, which blurs the distinction between exploitation and exploration. It also begins to shed light on the connection between these interconnected qualities. I will briefly introduce the example and will elaborate on the significance of this emergent quality.

ARM Cortex M0+ microcontroller is on the opposite side of the spectrum from the high power ARM-A72 core. It is an exceptionally low-power and small core designed for simple cost-sensitive devices that require computing capabilities. Essentially, in the words of an interviewee, "*it is an Internet of Things product cause it's such a low power consumption, it can probably run off a very small solar panel" (ARM Senior Manager, interview 3, 2012).*

Cortex M series microcontrollers have been an extremely successful embedded processors exactly because they were a miniature, low power, low cost design that gave computing capabilities to non-ICT *things* such as wearable health monitors, environmental monitors and motor control. Like 64-bit architecture, it was a result of work of the ring-fenced explorative ARM2.0 business unit. At the same time, other ARM products, the embedded microcontroller has been the result of ARM's way of evolving its technology: to extend ARM technological expertise into new markets that align with its expertise. In this instance, the *evolutionary* trajectory of miniaturisation, adding the pertinent features of wireless and secure connectivity and an extremely small cost enabled ARM to meet the emergent market needs of *the Internet of Things* (IoT) that was a new direction of the overall direction of socio-technological change that quietly led to a revolution in the ICT (Witchall et al. 2013).

The proliferation of traditional things with embedded computing to calculate and control parameter of now an *IoT device* has touched all major industries, as well as lives of people in the ways that made us once again rethink our relationship with the

technology. The advancement of the semiconductor expertise to a further level of complexity to engineer such devices, the collaborative work across the industry partners to join the hardware, the software, the connectivity capabilities, data storage and the privacy and security aspects thereof as well as the impact on the society adopting such technology make the claim about the paradigm changing quality of IoT justified. We see that the evolutionary microprocessor technologies have led to the "quiet revolution" of the Internet of Things (Witchall et al. 2013). For the company, it means that the increased technological specialisation and deepening semiconductor expertise have to be at all times aligned with the innovations of the partners who produce end market devices and have to serve the diversity of innovation in the application of technology. ARM's priority, is therefore, is not only cutting-edge technological innovation, but also careful management of the relationships with the industrial partners to ensure such alignment.

In his keynote at ARM TechCon 2016, ARM CEO Simon Segars tells:

"We [ARM] have all these different components that can be put together on a chip. They are tools, they are building blocks for others to go innovate with. They, i.e. all of you hopefully here today you, are gonna take those things that we do and create something spectacular with them. I believe that the Internet of Things is going to create an enormous impact. It's gonna create, I believe, more impact than everything else that's gone in computing before." (ARM 2016m)

By deploying ARM's evolutionary components in revolutionary devices like the IoT, ARM's IP business model and Ecosystem organisation have come to the fore as the interface between exploitative semiconductor technologies innovation and explorative applications of the technologies. ARM is saved from the necessity of blue sky exploration of their own by the Ecosystem of partners who take the risk and produce a diverse range of end products that had not existed before. ARM responds to the Ecosystem partners' requirements and designs its technology with the revolutionary applications in mind, but their own evolutionary technology development remains unchanged. The important aspect of this co-evolution is that the technological evolution is never about pure engineering. It is about the flow of knowledge that is multi-subject and involves, in most general terms, rethinking the ways the collaborative work between different parties in the society is organised to bring this type of technology to social use. More specifically for the company, it means nurturing the business relationships and the Ecosystem

organisational model that ensures that. In his address to the attendees of ARM TechCon 2016, ARM's CEO highlights:

> *"Knowledge is an interesting one. Three years ago the study highlighted a skills gap. People were concerned about access to the right people with the right skills to help them develop IoT. Here, the category of people where the knowledge was at question was actually senior management (Simon Segars pauses and makes a face to emphasise). Then we can help, and having come to this event, have them come to other events that many others in the industry are putting on to enable transfer of knowledge and learning about IoT, cause I think that's a technology that can positively impact every business. Together we are committed to continuing the great work that we've done over the last 25 years, continuing to work with you so that jointly we can deliver the technology of the future. Thank you very much." (ARM 2016m)*

5.6 What is exploitation in ARM's technology domain. Conclusions for innovation ambidexterity theory

The characteristics of ARM's technological innovation can be summarised as follows:

- It builds on ARM's pre-existing skills and competences in RISC architecture that are incrementally extended to the cutting-edge frontiers of engineering and technology application.
- It follows the customer pull and responds to the industry trends
- It is evolutionary in its essence following Moore's law. Vivid evidence is "when one compares the first version of the RISC architecture ARM1 designed in 1985 with 3000 gates with Cortex M0 designed 20 years later, one would see that Moore's law is almost respected. Cortex M0 designed in 28 nanometres is occupying 1/10,000 of ARM1 area designed in 2 micrometres (Esteve 2012).

We have seen that ARM's technological innovation is incremental, evolutionary technology development driven by Moore's law along the predefined trajectory in a highly specialised technology base. This type of innovation is both fostered and strategically channelled to enable diverse, quantitatively different innovation in the area

of technology application (Partners' market). Evolution, incremental enhancement, extending the existing competences within the predefined trajectory and tight commitments to customers and revenue generation are all classical characteristics of exploitation in the ambidexterity literature (Lavie et al. 2010).

As an approximation, we could perhaps *choose* to view ARM's innovation in the technology engineering as more exploitative, while innovation in technology application as more explorative. The devil, however, is in the detail. The quantitative technology improvement gains the substantial scale and has the potential to produce a qualitative change in the way the technology components are combined to produce a new value, in the way this new value is delivered to the customer, and ultimately, in the impact the technological and organisational innovation has on the business itself and the larger society. There is no easy way to segregate the effects of such innovations. Diversity, extending beyond the technological trajectories and existing markets, orientation on long-term, more uncertain horizons are, in turn, the classical characteristics of exploration (Lavie et al. 2010). However, the distinction between exploitative and explorative innovation blurs in ARM's technology domain. ARM's products are enabling previously non-existing applications, are transformed into diversified applications and help to co-create new paradigm changing forms of computing.

I have argued that in ARM's commercial domain, technology content is indistinguishable from technology use: Cortex-A family is for application, Cortex-R is for real time and Cortex-M is for microcontrollers. Products' characteristics and specifications are designed with a concrete market application in mind. *ARM's technologies become the "magic ingredient" (ARM Senior Manager, Interview 1, 2011), enabling "massive innovation"(ibid.), "the Cambrian explosion" (ARM atMediaTek 2014)* of computing form factors and a helping to launch the paradigm changing revolution of the Internet of things, albeit is a quiet one (Witchall et al. 2013). As microprocessor technology content equals the technology application (as the very purpose of its design), exploitation becomes functionally morphed with exploration. In ARM, *exploitative innovation transform into explorative innovation*. Deepening specialisation feeds diverse technology applications. Exploitation is a precursor of exploration on an evolutionary technological continuum.

Exploitation

The *scale* of ARM's *focus* is also highly relevant for the conclusion about the nature of exploitative innovation. To use the words of an interviewee:

> *"We do the whole spectrum. There is no other company in the world that does the whole spectrum. Our architecture goes into everything from micro sensors that don't even use any power from a power supply, they are scavengers, they take energy from the environment, from vibration, right the way through to server farm chips, super computers." (ARM Senior Manager, interview 1, 2011)*

The scope of ARM's platform microprocessor technology is vast. This is a characteristic is also a quality that messes up straightforward conclusions what exploitation is. This is the technology that has all been incrementally developed pushing the performance metrics which can easily be seen. Yet, the interviewee highlights, "y*ou couldn't say it's all microprocessors. It's different sizes, different flavours"* (ARM Senior Manager, interview 1, 2011).

ARM's engineering innovation cannot be of any other kind, dramatically reorienting itself with regards to the function in the value chain position and the customers it serves and switching the technological trajectory. ARM's engineering experience in designing the key elements of the SoC is the company's main asset that will not be abandoned, but will continue to be extended into future innovations. The interviewee continues:

> *"Is ARM going to move like Nokia did many years ago being a galosh company to being a mobile phone company? I don't think anyone believes that at the moment." (ARM senior manager, interview 1, 2011)*

The very characteristic of incremental, evolutionary change in the semiconductor technologies is worth elaborating. The notion of incremental innovation, understood as step-wise gradual improvements, is deceptive in that it is associated with low impact events (Christensen 1997). In the case of ARM, and the integrated electronics industry on the whole, incremental does means improvements are step-wise, but the steps have two decisive qualities: they are (1) very big, (2) very fast in a fairly predictable direction. Recombined creatively by the diverse players across the industrial value chain, these technical improvements have potential for dramatic impact over and above the

technology domain. Some of the qualitatively new characteristics of quantitative improvements in ARM's technological innovation are:

1. Change becomes systemic. Cumulatively, incremental improvements are more than the sum of the individual enhancements, but a new quality that may have much stronger *explorative* potential. Exploitative modifications in the area of *technology development* enable explorative innovation in the area of *technology application* which in turn relate to *wider social implications of the technology's existence.*
2. The pace of the semiconductor industry roadmaps is notoriously fast. Improvements in technology parameters, as captures by Moore's law, are exponential. The implication of exponential rate on *stability*, the defining quality of exploitation, is tremendous. Is stability in such a fast pace still stability? Does it make it easier to innovate if the direction of the exponential improvement is predictable from Moore's law?

Taken together, the vastness and pace of incremental improvements in the semiconductor technology also mean that the degree of engineering and organisational knowledge and skills needed to make the incremental advancements and continue to bring new values to the users of digital electronics is non-trivial. For ARM, it means path-dependent opportunities for innovation in the technology domain prompt path-breaking innovations in *organising* for technological innovation. In it, exploitation and exploration are blurred.

Moreover, the innovation activities across ARM's domains are closely interconnected so that they cannot be easily teased apart. Since the choice has been made regarding the differentiating RISC competence and ARM's ambition in the industry, particular organisational decisions and processes necessary to derive value from the technology base were put in place which in turn assembles in a certain organisational structure for ARM. Thus, there is a logical connection, or co-evolution, between the technology base and the organisational mode of the firm. From launching its first product, ARM has been putting in place support infrastructure to ensure that the customers have a variety of choices in design tools, operating systems, support services and all other aspects of support to build an ARM-based chip. This high level of support of customers, in fact, has become one of ARM's strengths directly related to the large number of licensees of ARM technology. The support structure, therefore, benefits and support the ecosystem by helping partners make the most out of the ARM products. The logic of the

central role of the CPU on a SoC dictated that a variety of partners with complementary technologies and resources had to be assembled to bring the microprocessor chip into the final implementation. These technical factors prompted the inception of the partnership model that enabled the assembly of a vast array of complementors and consequently gave rise to the ARM ecosystem.

6 Exploration

6.1 Test site for exploration. Structure of the chapter

We have seen, in the example of ARM's technology domain, that exploitation and exploration cannot be easily delineated and separated. Although a distinction can be made between incremental, evolutionary and exploitative innovation, which fundamentally characterises semiconductor technology development, and experimental, explorative innovation which is more typical in the area of technology application, such a distinction would not fully reflect ARM's work. Exploitation and exploration are morphed in ARM's technological innovation. Microprocessor technologies are indistinguishable from their uses. Their functionality is planned and implemented by engineers with new, cutting-edge, applications in mind and their incrementally improved characteristics enable significant changes in the way how and when computing happens. Evolutionary microprocessor technologies underpin potentially revolutionary uses of new types of digital devices.

ARM's business model comes to the fore as a vehicle for deploying incrementally developed technologies in a wide range of potentially radical applications and an interface between exploitation and exploration. It is itself an instance of a more radical innovation that changed the company's prospects in the industry as we have seen from the company's history. ARM's licensing and royalty business model, coupled with the partnership organisational form that was adopted to support it, has been lauded in the industry as original, unique, pioneering and game changing (Anand Technology 2013, Fisk 2016, Levy 2005).

In this chapter, I use ARM's business model innovation to test the concept of exploration. I will repeat the logic of the test of exploitation in the previous chapter and analyse to what extent the qualities of exploration are manifested in ARM's business domain. I once again set out from March's classic definitions and see how the understanding of exploration as "search, […] experimentation, […] flexibility, discovery […] and play" (March 1991, p.71) applies to ARM's business innovation. Exploration has also been associated with "organic structures, loosely coupled systems, path breaking, improvisation, autonomy and chaos" (He and Wong 2004, p. 481) and implies higher

uncertainty, risk and long-term pay-offs. Most generally, it is equated with the organisational capability to adapt to its environment which will inevitably change – *flexibility*. In this chapter, I examine what qualities innovation in ARM's business domain displays and how they relate to these theoretical conceptualisations of exploration.

I begin the chapter by collecting and analysing the evidence of prominence of innovation in ARM's licensing and royalty business model (sections 6.2 and 6.3). I then analyse the workings of ARM's current business model in relation to the theoretical conceptualisations of exploration (sections 6.4.1 - 6.4.5). To extract conclusions about exploration, I discuss the innovativeness of the business model at the point of its introduction in the company's early years and at the current point of its established functioning in the matured business. This will allow insights into how explorative innovation change over time. This is parallel to the examination in the previous chapter of the qualities of exploitative innovation over time on the example of evolution of semiconductor technologies. Section 6.5 presents ARM's additional models makes conclusions about their relevance for the business model innovation. Finally, in section 6.6 I make conclusions about the relation of the extracted features of ARM business model to the theorisation of exploration.

6.2 ARM's business model innovation

While ARM's low power small size high performance RISC-based microprocessor technologies are its crucial asset and distinct competitive advantage, the company is widely lauded in the industry for its innovative way of delivering the technological assets to the market - the licensing and royalty business model (Fisk 2016, Yarow 2010). The importance of ARM's business model for its success has been emphasised above its technological assets by the interviewed ARM's staff, partners and the industry representatives alike. A comment of an executive of an ARM acquired company illustrates the common theme:

> *"The key to ARM success is yes, brilliant engineers, fine, a lot of companies have brilliant engineers. The real innovation in ARM is the business model. That's the real innovation. … That's why ARM is where ARM is today." (Former CEO of an ARM acquired company, interview 9, 2013)*

Exploration

For the test of exploration, it is important to understand what qualities make ARM's business model "the real innovation", the kind that is more significant for the company's success and more distinct than the engineering ethos that so strongly characterises the company. As declared in the introduction above, I start the test of exploration from assembling the evidence that speaks for the prominence of innovation in the business domain.

6.3 Why business model is "real innovation". A historical perspective

Semiconductor intellectual property (IP) has existed for decades since the advent of the semiconductor industry (Fabless Semiconductor Association 2003b). However, as discussed above, it was confined in "the tall towers" (Chesbrough 2003) of centralised semiconductor incumbents who developed proprietary IP for internal use, strictly protected it through patents and trade secrets and warehoused any know-how they could not immediately use in their own business. The innovative decision of ARM was to break away from the closed in-house innovation and create a company supplying IP for external use. In doing so, it introduced a degree of vulnerability to others that the industry incumbents had shied away from. ARM was founded with the clear vision to focus exclusively on licensing microprocessor IP out as a discrete entity to third parties. Throughout almost three decades of the company's existence, the business rationale has stayed unchanged. In a nutshell, ARM's fab-less chip-less business model is as follows: in return for an upfront license fee ARM supplies its technology designs to semiconductor companies who then design and manufacture new SoCs around the ARM core and subsequently pay a royalty for every chip they sell that contains ARM technology (ARM Company overview ARM Company Overview 2014).

The IP business model is often credited as the key element of ARM's success over its engineering prowess:

> *"Technology is interchangeable, the business model is the primary competitive advantage" (ARM senior manager, interview 14, 2013).*

The idea to move away from fabrication of integrated circuits and, furthermore, to move away from design implementation of all components on a system-on-a-chip to the production of design architectures only was originated by CEO Robin Saxby,

purposefully hired to give vision and strategy to the fledgling spin-out. "He was the grit in the oyster that formed the pearl", described an analyst at Morgan Stanley financial services, the corporation that worked with ARM Holdings on the initial public offering and listing on the London Stock Exchange in 1998 (ARM Annual Report and Accounts 2010). In retrospect, the idea turned out to be part of the paradigm-shifting industry rearrangement towards open innovation. In the new industrial organisation, firms increasingly started to use external knowledge alongside their own know-how, apply external and internal paths to market, created business models that captured different parts of the value chain and constructed more complex organisational architectures to support these new possibilities. At the time of the decision, it was certainly a daring choice that was different for the industrial landscape: *"real men had fabs […] real men built chips"* recounts the prevailing view Mike Muller, ARM's founding and current CTO (Mike Muller in Edwards 2010), *"there was no IP business model, the whole fab-less world didn't really exist"*, he comments (Mike Muller ARM's CTO 2014). As discussed above, the industrial dynamics that produced decentralisation and specialisation were in place: the fab-less concept had been pioneered and the semiconductor product companies segmented into integrated device manufacturers, early fab-less companies and hybrid models reciprocated by pure-play foundries that were providing semiconductor manufacturing services for all product companies (Hurtarte et al. 2007). This evidence reveals a further layer to the evolution of ARM and to understanding where ARM is now and why. This layer represents the strategic leadership and entrepreneurial vision of its top manager Sir Robin Saxby, which has already been noted in the historical overview.

The decision to become an IP company was the next step away from the fab-less concept but ARM had a vision to identify it and ventured to undertake it. Robin Saxby has sought to dispel the "ground-breaker" image he is often credited with and has commented on the *imitation* character of the decision: *"the ARM business model was an evolution and I certainly don't claim to have invented it"* (Saxby in Edwards 2010). But it was Saxby's determination to preserve the business model unchanged that shaped ARM's unique position. Many of ARM's original team repeatedly recount Robin Saxby saying that *"we will build chips over my dead body"* (ARM top executive, interview 17, 2014). The consequences of this decision being the unique business model that the company adhered to even when resource constraints were not an issue and the novel

"Ecosystem of Partners" organisational form that ARM nurtured, both of which have been the credited with being *"the crown jewel of ARM's business"* (ARM top executive, interview 2, 2011). This implies that although the firm has grown and is capable of evolving beyond its IP ecosystem models, it is choosing not to. Instead of vertically integrating the value chain, ARM is innovating by expanding and nurturing its Ecosystem while its business remains around IP and the thematic areas relevant to its core business. Thus, it is expanding its potential to add new value to its existing partners and to attract in newer partners into its ecosystem.

In 2002 Robin Saxby was knighted for services to the information technology industry (The Gazette) and received the Global Semiconductor Alliance award for his achievements in the industry in 2012 (Global Semiconductor Alliance 2012).

Ultimately, the adoption of the distinctive IP model was due to a combination of several factors: industrial, individual and technical. The disintegration of the semiconductor incumbents, transition to the fab-less model and increasing complexity of integrated circuits stimulated technology development across businesses. In the disaggregated value chain, ARM saw the opportunity to allow companies that did not have microcontrollers or CPUs to become a CPU company and do technology integration by adding their value to the microprocessor IP, rather than doing organisational integration by joining their business with a CPU company. This was the original start of ARM's business (Anand Technology 2014).

The focus on the microprocessor design thus prompted the choice of the business model and necessitated a network approach to organising the company. There is a certain parallelism between the technology base of the company and its organisational structure. Just as the RISC processor is embedded in an architectured product system that makes it useful, i.e. the complete system on a chip or a higher level system of a digital electronics product, so did ARM, in order to create value, had to be embedded in the network of complementary firms who would produce the components at each level and integrate them at the next higher level of the architectured organisational system. An observation that the *nested physical architecture of the product system* of a specialised technical firm is mirrored by the *nested network of producers and markets* through which the product is made and sold is relevant in the case of ARM as well (Christensen 1997). This network of producers and markets which utilise ARM's IP in their products has become ARM's

Ecosystem of partners, supported by the online collaborative information platform called ARM Connected Community. ARM's focus on microprocessor technology and the specificity of its IP business model favour the ecosystem approach, because in the first instance, it enables the assembly and delivery of complex integrated solutions through the contributions of a vast variety of specialised partners while allowing ARM to stay focused on their own technologies. In the second instance, it generates revenue increasingly as more and more partners engage to create products powered by ARM technologies.

The architecture of the SoC ties together several components, but the microprocessor core, as the name suggests, is the central component of the system. Specialising in technologies that "lie at the heart of advanced digital products" (ARM Company Profile 2013) ARM management had taken an explicit decision to act as a unifying platform, as opposed to remaining a small external supplier of the core, and assemble a collaborative partnership of specialised firms who would each add complementary skills, knowledge and technologies necessary for the completion of the SoC and, subsequently, a higher level digital electronics product. ARM has come to play a pivotal leadership role in promoting the collaborative partnership and serving as a communication platform towards a common baseline and a "stabilising influence" in technical and business issues in the semiconductor industry (Williamson 2009, p.9).

It is historical accounts that take us back to the point of the introduction of the business model that offer a number of insights into why the business model innovation was considered particularly distinct. I will once again take a historical perspective to bring out features of innovation in ARM in the business domain.

The decision to exclude manufacturing completely and definitively and license technological designs instead was taken in 1990, essentially at the company's very start. To return to ARM's early days once again, Robin Saxby, invited as CEO to join the engineering team of twelve working on the original technology, launched Advanced RISC Machines Ltd. (ARM) with a clear yet bold strategic vision to design a base technology only, license it as intellectual property and propel it to the level of a global standard.

In an interview, Sir Robin tells:

"I wrote a lot of questions then I have had some meetings. I wrote some notes and I looked at where all the holes were and where the opportunities were and it was from day one: we are going to be the global RISC standard. We are never going to make chips. … So ..., I had a very clear vision and the other people joining after about a year, some of them got it very quickly, some of us didn't believe it, but it's really like fashion. We took the whole community with us, people start believing and maybe this can happen" (Interview with Sir Robin Saxby, co-founding CEO of ARM).

The idea to license base microprocessor technology was truly novel. More common paths for ARM would have been to partner with Apple to drive its R&D, to merge with a semiconductor company or to outsource manufacturing. In fact, the fabless business model had emerged that did exactly the last. The fabrication-less chip companies partnered with the semiconductor foundries that manufactured the chip then sold them to original equipment manufacturers (OEMs). ARM took the fabless chip business model one step further and became a supplier of microprocessor technology IP to semiconductor companies and avoided OEMs altogether.

No comprehensive empirical evidence has been collected to reveal the exact entrepreneurial insights of Sir Robin that motivated the decision, but one piece of tangible evidence was the failure of individual devices that contained ARM technologies. Indeed, this remained a continuing risk under the IP business model, which is why the model was also underpinned by the goal to make RISC architecture the global standard. The IP business model and the partnership strategy were ambitious and promising, yet their implementation boiled down to a step-wise process of carefully signing the deals and establishing the relationships. The ecosystem of partners had an uncertain and humble beginning. An ARM co-founder and former top executive tells:

"The way I would describe it is that every deal in a start-up is important. For example, in the summer of 1991 we were spending money, the cash flow was tight, there had been promised the salary rises but we could not afford it. I had a communication meeting with everybody and said clearly there will be no rises until we have some money. That was again unanimous within the company. And what actually happened is we closed the deal around December 1991. I told them to pay us cash upfront a few hundred thousand

pounds and the result of that was a pay check for all the employees which strike as sort of most Christmas thing. So that was the first selling point. And then there was the next one Samsung, Texas Instrument…. So in the early days it was really a case of … balancing the cash flow and every deal was pulled in" (Former top executive and a co-founder of ARM, interview 13, 2014)

The interviewee continues:

"And that almost continues forever because with the business which is basically licensing and royalty you get the big lump of license fee it's a very uncertain situation. Every few years we used to say, you know, royalties will never come because what happened is all the first products, end products, were failures. That included the Apple Newton, that included the 3DO multiplayer and then the first one to take off was (a) modem. It was a sigh of relief and I guess after about 1993 we probably knew we were not going to go bankrupt and then the question was "how do we grow?"(ibid.)

Continuing the partnerships approach was the precondition for both success and the very viability of the business. The partnership strategy was inseparable from the IP business model.

In a brief history of ARM, an ARM employee provides the following insights on the distinct innovative qualities of ARM's partnership business model:

"Due to these factors ARM realized they could not sustain success on single products, and Sir Robin introduced the IP business model which wasn't common at the time. The ARM processor was licensed to many semiconductor companies for an upfront license fee and then royalties on production silicon. This made ARM a partner to all these companies, effectively trying to speed up their time to market as it benefited both ARM and its partners. For me personally, this model was one that was never taught to us in school, and doesn't really show its head in the business world much, but it creates a fantastic model of using ARM architecture in a large ecosystem – which effectively helps everyone in the industry towards a common goal; creating and producing cutting edge technology."(Walsh 2015)

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The IP business model is highly praised not only because it overcame the hurdles of the beginning, but because it opened up bigger and better opportunities for long-term growth. It turned potential competitors into interested partners and triggered a change in the industry to divide labour and resources that allowed tackling the growing complexity and cost of making a SoC amongst the specialist contributors. The business decision and the partnership strategy were radically innovative because *an analogous problem in the industry had not been solved this way before*. The decision was also *non-obvious* and *uncommon*. Importantly, it offered *a new value proposition* to the industry participants. ARM's Chief Technical Officer and one of the founding team Mike Muller explains the historical decision in an online podcast:

> *"There was no IP business model, the whole fabless world didn't really exist. [The opportunity] was really driven by the fact that people could do integration. And there were people that had microprocessors and the people that didn't. The big chunk of our business was allowing people that didn't have the microcontrollers to get into being a microcontroller company." (Mike Muller for Anand Technology 2014)*

Thus, ARM's business model altered the way product development was happening in the industry. It re-arranged the contribution of the participants and itself matched the started change in the industrial structure towards disaggregation and a "fabless" model. Mike Muller continues:

> *"Then you have the whole fabless thing cut in and with the fabless model there were brand new companies coming along that certainly did not have microprocessors, microcontrollers and wanted to license out technology, so there were several different factors came together. That said, our IP model happened because of SoCs and it also happened because of fabless." (ibid.)*

The fact that the business model was uncommon and non-obvious implied a high level of uncertainty and risk. Even more so because the strategic vision was also very ambitious – to become a global standard and ship millions of ARM-based chips, an increase of thousands of orders of magnitude to the shipment, for instance, of ARM610 that powered Apple Newton.

Mike Muller comments further:

Exploration

> *"When we were still in the company before ARM working on the original technology, the vision [was] that we were going to sell millions and that's what our CEO said and we kind: "millions, you must be joking!" And then we got spun out and we became ARM and our CEO at the time kind of: "we're going to be the global standard, we kind of went "you're gotta be joking", but we'll try real hard. And we've pulled it off. Do I think we were gonna do it? No, I have to confess I thought the odds were stacked against us." (ibid.)*

At the same time, the IP business model eliminated risk and costs associated with semiconductor manufacturing. By excluding manufacturing, the IP business model allowed overcoming the problem of limited financial, human and R&D resources available to the young company. It turned an additional risk of setting up a semiconductor company in a geographical location with virtually no significant semiconductor industry into a growth opportunity. The IP business model made ARM start global from day one and opened up opportunities for scaling up the business through partnerships worldwide.

To summarise, the following factors prompted the adoption of the IP business model:

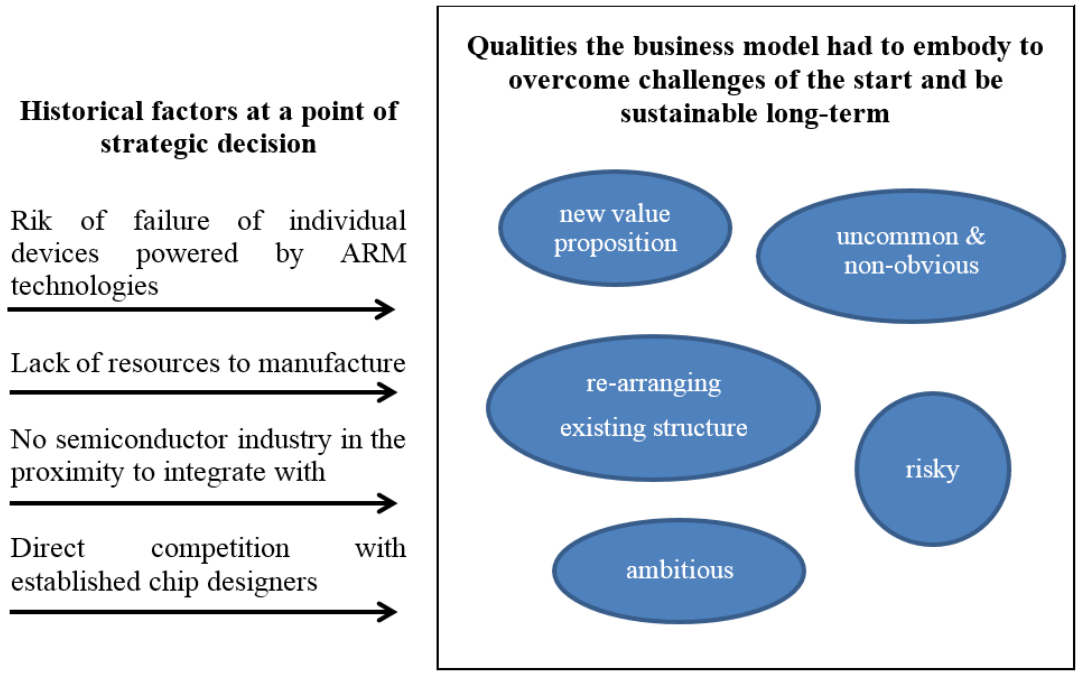
- risk of failure of individual products powered by ARM's technologies and the subsequent risk of failure for ARM
- lack of resources to manufacture the complete SoC of increasing complexity
- no proximity of the semiconductor industry to complete the semiconductor product value chain
- emerged trend of disaggregation of the semiconductor industry and identified opportunity to provide buildings blocks to the industry

Exceptional strategic thinking and a business model solution were required to address all of these factors in a sustainable way. A business model that would make the company's technological know-how its product and target it at a large ecosystem of customers would allow for counteracting these factors at the critical starting point. The business model could also be sustained in the long-term, provided the strategy is carefully executed. The adopted IP and partnership business model reflected this innovative thinking. The radically innovative qualities of the business model were:

- uncommon and non-obvious, granting access to technological designs as intellectual property to an ecosystem of many customers
- offering a new value proposition to the industry's participants. Now, the value was in the design idea and re-combination of functionalities rather than functionality implementation and manufacturing. Technological advantages of RISC architecture were the essential foundation of the new business proposition to offer designs only.
- re-arranging the existing industrial structure, disaggregating the established in-house product development and creating an ecosystem of partners who develop new concepts together
- risky, setting on a path not treaded before
- ambitious, aiming at thousands of orders of magnitude increase in shipping volumes and becoming one of the few (ultimately, one of the two) industry's standards.

How the historical factors at the company's foundation shaped the qualities of the strategic decision can be presented visually (see Figure 11). In short, the particular challenges at the start and the need to sustain the business long-term demanded a business strategy both insightful and effective to resolve them.

Figure 11 Factors shaping innovativeness of decision regarding business model



Exploration

Circled blue in the figure are the indicators of substantial novelty and the qualities that make ARM's business strategy "the real innovation", to use the words of an interviewee above. The strategic decision to adopt an IP business model was uncommon and non-obvious, risky, ambitious and re-arranging the existing order in the product value chain in the semiconductor industry and organisation of the industry's participants. These are the qualities that *accord with the definitions of exploration* in the innovation ambidexterity literature. ARM's business model is, in this sense, explorative. The historical perspective has produced a picture of business model innovation that is consistent with the received ideas of exploration. It has been illustrated that the qualities that distinguished ARM's business model at its launch substantially correspond to the theoretical conceptualisations of explorative innovation.

I will now switch my focus from the historical perspective to the current functioning of the IP business model and continue my test of the notion of exploration. I will examine what qualities the same business model holds today and if its distinct characteristics continue to fit the theoretical conceptualisations of explorative innovation.

6.4 ARM's business model today

Today, ARM's business model is established but no less praised in the industry and cherished by ARM. In a metaphoric description of an ARM executive, it is the "crown jewel" and the "sacred cow" of the company. ARM top executive comments on the importance of innovation in the business model:

> *"There is a kind of core, crown jewels if you like […]… you have to look after your sacred cows, […] but actually we are quite flexible on that to work on that with our partners to come up with something that works. […] Having that external look, outside kind of focus is incredibly important." (ARM top executive, interview 2, 2011)*

The prominence of the IP business model can be heard in the metaphoric description. It is certainly no less important today than it was at the starting point. Its value, however, is now not in the insightfulness and ability to resolve challenges that the initial strategy had. The value of the business model, now that it has established, is in its successful functioning and profitability. In the 2015 annual report, ARM reported that

cumulatively 1,348 licenses have been signed, with 173 new processor licenses signed in the year 2015 and $1,489 million generated in revenue and £415 million in profit (ARM Holdings plc Strategic Report 2015 p.25). Importantly and unsurprisingly, it is the value that the executives want to protect and preserve for the future of the company. At the same time, there is a realisation that flexibility must also be present in the business strategy and that the place for it should be found in *the Ecosystem of Partners,* in new processes, strategies and structures.

The Ecosystem of Partners is inherent in the logic of ARM's licensing and royalty business model. The ecosystem relations have been carefully created by the company in the understanding that it is the crucial prerequisite of the business model's actual scalability, sustainability and ultimately profitability. In fact, the ecosystem organisation is equated with the business model which is sometimes called the "Partnership model" (Levy 2005, p. 15). In this sense, they are closely intertwined organisational domains. I have described them both earlier in the course of my analysis. Below, I analyse ARM's business model in its relation to the ecosystem of Partners from which it gains its strength. This interaction is the foundation of the company's business and focusing on it will allow me to draw further conclusions about the nature of business innovation in ARM. I will develop this analysis first by reiterating the main rationale of the business model that brings out the connection to the ecosystem. I then review the business model in Partner relations and on the times scale. This will complete the analysis of ARM's IP business model. The section after will introduce additional business models that ARM employs before the final conclusions about the nature of innovativeness in the business domain are drawn.

6.4.1 The workings of ARM's licensing and royalties business model

The main rationale of ARM's business model is iterated in ARM's every annual report. It can be summarised as follows:

> *ARM licenses its technology to a network of multiple Partners, mainly leading semiconductor companies. Semiconductor licensees pay an upfront fee to gain access to ARM technology. They then incorporate ARM designs alongside their own technology to create smart, energy efficient chips. ARM receives a royalty on every chip sold that uses an ARM technology design.*

> *The royalty is typically based on the price of the chip (ARM Holdings plc Strategic Report 2015). The license revenues are aimed to cover ARM's costs of developing the technology, while the royalties are re-invested back into the business or returned to shareholders (ARM Holdings plc Strategic Report 2013).*

Online, ARM executive vice president for marketing and business development Ian Drew explains ARM's business model in an analogy: *"we are making knitting patterns for technologies suppliers"* (Fisk 2016). Another analogy is to *"think of ARM's employees as a group of talented chefs that only makes recipes. They then sell those recipes to restaurants around the world. Each time a meal is cooked based on an ARM recipe ARM is paid. When a chef uses an ARM recipe, he can add his own garnishes, appetizers and sides"* (Yarow 2010, p. 1).

ARM's business is fuelled by signing up licensees. Each license creates a revenue stream that may generate royalties for over 25 years. Growing the base of licensees and licenses is the first key performance indicator for ARM (ARM Holdings plc Strategic Report 2014 , ARM Holdings plc Strategic Report 2015). Investing over one third of revenue back into R&D (ARM Holdings plc Strategic Report 2015 2015), ARM pushes the boundaries of chip design forward, thus spreading the cost of expensive R&D among many participants in the industry. Access to ARM's technologies through the IP business model allows companies in the industry to concentrate on their core capability, without having to invest in costly processor R&D themselves, and bring their products to the market quicker. Elsewhere, ARM's business has been described as the R&D unit for the semiconductor industry (Yarow 2010). This characterisation resonates with ARM's self-description repeated through the annual reports highlighting that:

> *"We design complex technology that would be expensive for our Partners' R&D teams to develop. The design of a processor or a library of physical IP requires a large amount of R&D investment and expertise. In addition, the creation and development of an ecosystem of software and tools companies that support ARM's technology and its licensees would be difficult to reproduce. We estimate that a major semiconductor company would need to spend over $100 million each year to develop and maintain its own architecture. With ARM designing the architecture once and licensing many*

> *times, ARM is able to cover its own R&D costs and also reduce the cost for each semiconductor company. ARM's Partners are then able to invest in the complementary technologies that go into a System-on-Chip. This leads to more choice in digital electronics for OEMs and consumers. (ARM Holdings plc Strategic Report 2014 p. 21)*

Indeed, the licensing and royalties business model gains strength from scaling, i.e. *repetition and replication* in new markets or with new partners. *"Designing once and licensing many times"* is the business rationale of the IP model (ARM Annual Report and Accounts 2010 p.2, ARM Annual Report and Accounts 2011 p.16, ARM Annual Report and Accounts 2012 p.7, ARM Holdings plc Strategic Report 2013 p.17.) *Exploitation* of the business model is the commercial point of it. Royalties provide a steady cash flow to the business and it is a long-term business model that is implied to be used unchanged. Altering the IP business model is not the type of business innovation the company considers. Including manufacturing into the business model is the direction that ARM categorically excludes. *"We'll make chips over my dead body"* was the mantra of Sir Robin Saxby in the early days of ARM (Saxby quoted in Adams 2016) and it is still emphatically so:

> *"So, people are saying, why aren't you going to the chip industry cause you've got the crown jewel in the middle so you can do that. And if we did do that of course it would instantly destroy our existing business. And the chances are we would, unlike people like Intel for example, we don't have 40 years or whatever it is of experience. And as an executive team we certainly know that we are not going to do that. And that's like mantra that's been created:* ***we are not going to go to chips, we are not creating chips*** (original emphasis: the interviewee is banging the hand on the table as he is pronouncing each word). *Whenever a new idea comes along which involves creating our own chips, it either doesn't make into the room or goes away." (ARM top executive, interview 5, 2012)*

Now that the IP business model has been established and is being exploited to generate continued profit, let me examine where innovation for ARM comes from, given that the product development continues to evolve in an incremental exploitative fashion too.

6.4.2 ARM's business model in relationships

ARM's licensees are its direct customers, but they are called "Partners", alongside other users of ARM technology, because of the close reciprocal relationship that ARM establishes with the users of its technology. The close relationship allows ARM to develop products that are aligned with the needs of those who license and use them:

> *"We have strong relationships with pretty much all of the world's semiconductor companies, certainly all the semi-conductor companies that matter. And there is a lot of value in those working relationships, both in terms of being able to do business effectively but also in terms of making sure that we create the right products. The trust that's in those product relationships is key to ensure that we get information that will help us to make products that will gonna be right (for them)." (ARM top executive, interview 2, 2011)*

ARM is a business-to-business company. Serving customers' business needs makes ARM product development focused and customer-led, not inspired by its own exploratory ideas. In its product innovation, ARM does not experiment and explore, because it has to deliver on the commitments to the customers to enable them to create their respective products. ARM's position in the industry, the business model and the technology domains are closely inter-related. This excludes the possibility of separating exploitation and exploration across domains because domains are inseparable. Aspects of business, technological, organisational and user innovation have to co-evolve. This happens in the process of close, reciprocal, iterative, long-term interaction with the Partner which also blurs the boundaries between ARM and a Partner company. I will give an insight into the character of such an interaction by means of one example. I will then demonstrate the scale of such interactions in ARM.

Consider an example of an interaction between ARM and an ARM's customer (a semiconductor licensee) in the process of new product development. I highlight the important features of the interaction. An ARM Vice President tells:

> *"They (licensee) will obviously **also talk to OEMs** and then **will talk back to the manufacturers**, so this is a long channel back, a long channel for us to get direct information, so **we will also gonna talk to an OEM** and say 'you*

*should use this product from us' and they will actually go: it's actually completely unsuitable, cause **you're missing X, Y and Z**. And that information **we will feed back** and say 'well, this market is 500 million units, it's a really important market, to get into this market **we should add these features** to our products'. And then obviously **the business team** take that as an impulse and **might add to our product**. And if they do, **then we'll go back** to the market **and say** well actually **in a year's time we'll have this feature**." (ARM Vice President, interview 4, 2012)*

Innovation between ARM and a partner is a process of co-creation and discovery in an iterative process of technology negotiation, which includes knowledge flow from other parties outside the immediate interaction. We see that several parties exchange knowledge before ARM may decide to introduce a customer-led innovation. However, this is not the end of the product development process. ARM negotiates the proposed technological solution and shapes the final solution over a number of iterations:

"Now the key thing here is that what is today important might not be important tomorrow. You might think that X, Y and Z are important, but actually X, Y and Z are today's problems, so how can you look at it as being a fundamental technology problem that will still be there tomorrow? So, you have to be careful, especially with the product pipe-lines, cause a full product pipe-line for us is about 5 to 10 years depending on how big the feature is. If you do full R&D on this feature and once R&D is developed it needs to go into the architecture, and architecture goes into micro architecture, the micro architecture goes to silicon, the silicon goes into the OEM. That might take about 7 years." (ARM Vice President, interview 4, 2012)

Reassessment of the nature of the innovative contribution and re-consideration of its usefulness in view of the long time-line and costly product development are the additional dynamics that are taken into account, disturbing the roles of who is "exploiting", who is "exploring". The interviewee continues:

*"So, generally it's very expensive, you have to wait 7 to 10 years before you get X, Y and Z. So, **the first approach** will always be: what we have coming between now then that could be more innovative and could change the*

*problem. A slightly **different solution** than X, Y and Z but still kind of **fixes the problem of customers**."(ibid.)*

The goal of innovation is to find a solution to the customer's problem. It is not resolved quickly by adding a missing capability, but it is a process of diagnosing a problem, assessing available means to solve it and applying creativity to choosing a certain technological solution among the possible alternatives:

*"The key thing when they are asking for **X, Y and Z is** it might be **what the current supplier supplies.** […]. Well, actually **what do we have** and how could we **solve that**. This is always by **far the first discussion**. Cause if you do **go back to […] the factory** and you ask for X, Y and Z and they will say 'well, why are you trying to do this? What is the problem?' cause we **always go back to the problem** and then again here where we **loop at the problem**, how can we solve the problem again **from the engineering product marketing point of view.** Their first thoughts will be about how can we solve it **with the current technology**? Cause everybody knows it **takes us a long time** to get it through the pipeline. So, that will always be **the first initiative**. **Adding things** to our products **will always be the last option** if you will." (ibid.)*

We see that product innovation between ARM and a Partner (customer) is an iterative, multi-channel process of negotiation and problem diagnosing that to a large degree involves choosing the exiting technology as a solution. Social interaction and feedback from others are a crucial part of it.

We have seen that a single act of interaction regarding product development with a licensee is complex. The added complexity is the dynamic of the relationship with the partner that ARM has to consider in its innovation choices with other partners. An interviewed ARM's partner describes the different facets of the relationship:

*"The relation with ARM works on many different levels. One that they are a **customer of ours**, they use our software to develop and verify their IP. On the other side, **they are a partner** in the sense of these technical collaborations: when ARM is planning to introduce something new in terms of their IP offering, they talk to us about it and we identify if we need to do something,*

> *we provide solutions which are compatible with ARM's tools and solutions to the mutual customers' base. And so* ***we have to work together*** *when they are developing new solutions, etc. In some small areas, it's a less issue for us,* ***we actually compete*** *with ARM: there are some products that we produce that compete with the product that ARM produce, like software embedded design and embedded software debug.* ***So, we are a competitor, partner and we have a customer relationship as well****." (ARM Partner Relationship Manager in an ARM Partner company, interview 19, 2014)*

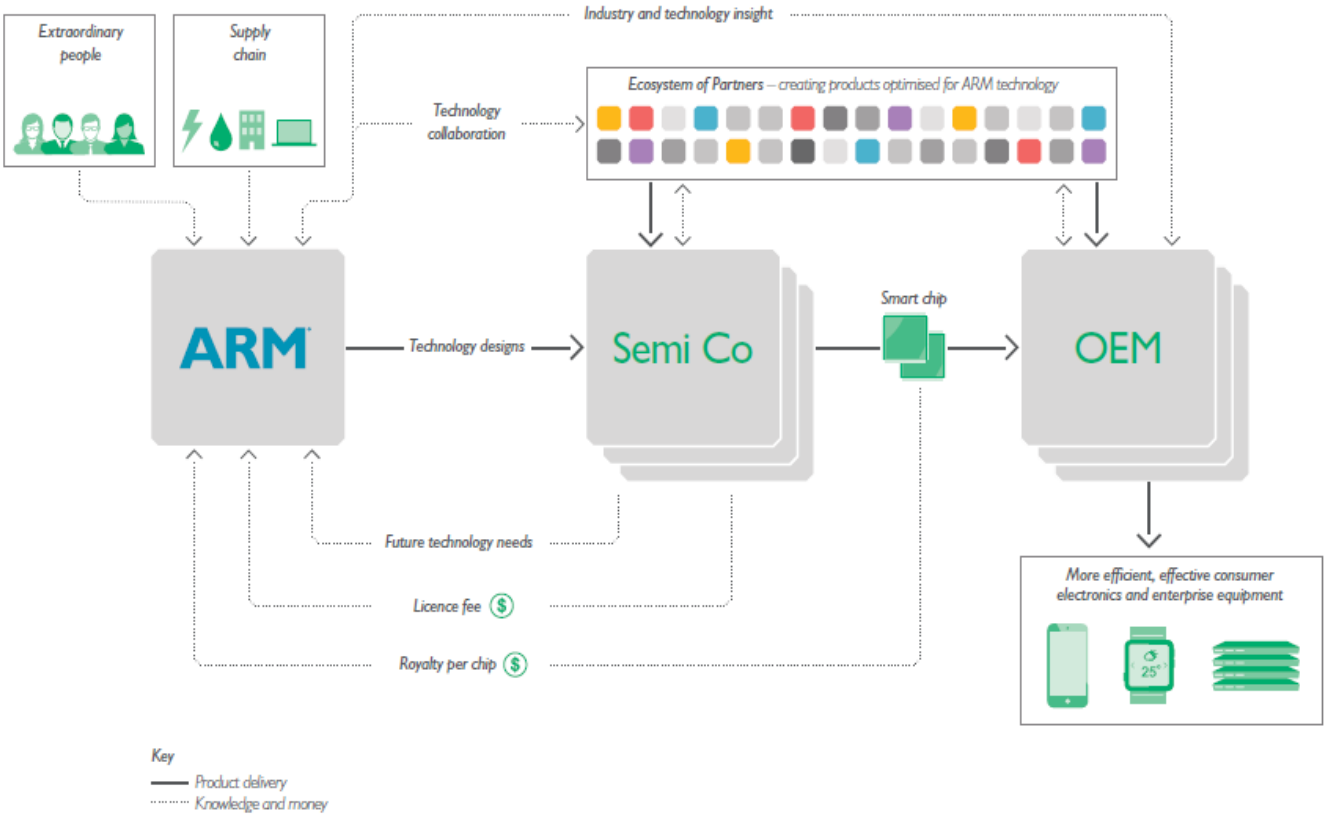
ARM and its partners work so close that the boundaries between the contributions in this collaborative work blur. The interviewee continues:

> *"I have to champion the ARM's cause inside [my company]. I think that people inside my company sometimes think I work for ARM, because I always champion the ARM cause rather than my company's cause: it's striking the right balance between those things (what ARM offers and what is conceived internally)" (ARM Partnership Manager at a Partner company, Interview 19, 2014).*

Not only are the interactions in a single product development instance a multi-party, iterative reconsideration of the possible technological alternative to solve the customer's problem, but there is an added dynamism of the changing roles of the partners in the interaction that need to be considered in the interaction. Moreover, the sheer scale of the interactions with one thousand Partners is enormous. Figure 12 below shows ARM's reciprocal relationships with its Partners in the Ecosystem: the semiconductor customers and original equipment manufacturers (OEMs) down the product value chain and the contributors from diverse professional communities and suppliers up the value chain.

Exploration

Figure 12 ARM business model relationships (ARM Holdings plc Strategic Report 2014, p.20)



ARM is the world's leading semiconductor intellectual property supplier. Its business is placed in the semiconductor industry, which involves the companies engaged in creation, design, support and manufacturing of the final product of the industry - the silicon chip. Because of the complexity of the final product, no one company can create the complete System-on-a-chip alone and the end product of the industry is created at the collaborative interface between diverse partners of the semiconductor ecosystem coming from different specialised niches from across the globe. Whereas ARM interacts with a number of diverse partners, the company works most closely with the semiconductor product companies: designers and manufacturers of silicon chips who complete Systems-on-a-chip, as well as with as supporting tools companies, operating system companies and the community of software developers. To iterate, ARM's direct customers are its licensees: the semiconductor manufacturing companies and fab-less companies (ARM Holdings 2014c).

In their day-to-day activities, industry practitioners do not uniformly delineate or strictly define their industry because of the breadth of the tasks, engineering complexity,

competence overlap with other industries and geographic span of the industry participants. This makes a distinction of discrete type of competences provided by a partner to a structured and dual interaction like ambidexterity problematic. Ambidexterity in alliances literature is based on the possibility to distinguish contributions of partners to create an argument of distribution, or balance, of the ambidexterity roles as well as a clear picture what contributor provides what capability.

ARM's broader industrial community also includes tools providers, assembly and test services companies, electronic design automation companies, SoC design consulting and sales businesses, affiliated university researchers, open source and DIY communities in IT and other specialised partners that fill the niches of the disintegrated industry and provide various support solutions to the semiconductor product companies. Knowledge from these areas of expertise also flows to ARM and percolates into their product development.

Moreover, the semiconductor industry is a key enabler to a large number of other technology intensive industries employing smart electronics such as digital electronics industry, automotive, medical, machinery, home and entertainment. The semiconductor industry has these industries at its periphery. ARM Ecosystem spreads beyond the semiconductor industry, reaches customers' customers and connects to the wider digital electronics industry.

Technological innovation in the smart connected products connected industries to the extent that industry managers are constantly asking themselves the question "what industry am I in"? This is a relevant question for ARM engineers and managers as well, who look at innovation and change happening beyond the narrowly defined circle of the product development and at a broader less familiar landscape. ARM is doing horizon scanning of all corners of the broad industry. It talks to customers' customers, such as OEMs, mobile providers and others to collect intelligence about requirements and problems of the users of end products ahead of their silicon customers. ARM monitors change and innovation in all of the adjacent industries to which the company contributes. The spread of the horizon scanning activity that fuels ARM's own decisions on where to move next with its technology adds another blur on the clear division of what constitutes exploration and exploitation in the company.

Exploration

6.4.3 Centrality of ARM in the Ecosystem

Evolution of the microprocessor technologies initiated the industry's evolution. Dramatic decrease in size and increase in complexity made the task of designing a microchip so large that no single company has sufficient human, technical or financial resources to produce the whole silicon chip on its own and address all of the associated challenges (Saxby 2006). Vertical integration within semiconductor companies gave way to horizontal specialisation, diversification and expansion of the semiconductor industry. The IP driven System-on-a-Chip design has become the dominant business model in the industry with more than half of all integrated circuit revenue coming from fabless or outsourced operations (Fabless Semiconductor Association 2003a). It is anticipated that as silicon chip design becomes even more complex, the chip design companies will continue to outsource semiconductor IP from the specialist suppliers. This industry trend is beneficial for ARM as a highly specialised supplier of designs who offers increasingly complex functionality (ARM Holdings plc Strategic Report 2013 2013b). At the same time, outsourcing IP has substantial advantages for the industry participants first and foremost because it helps to tackle the industry's two major challenges: complexity and cost.

Design complexity inevitably brings about the problem of design cost. With the decrease in feature size and improvement in design tools, the design moved from single microprocessors and application-specific integrated circuits (ASICs) to more complex and more functional SoC designs which now incorporate entire microprocessors, memory blocks, timing sources, peripherals, external interfaces, analogue interfaces, voltage regulators and power management circuits on a single chip. Industry engineers state that "design complexity is increasing superexponentially because of the compounding effects of increased density and number of transistors and increased heterogeneity of design types on a single chip and the increasing number of factors that design tools and methods must consider with smaller feature sizes and higher levels of integration. […] Verification and testing complexity is growing superexponentially for the same reasons" (Vandenbussche et al. 2003, p.2-3). Already in 2001, the International Technology Roadmap for Semiconductors (ITRS) has identified design cost as "the greatest threat to the continuation of the semiconductor roadmap" (International Technology Roadmap for Semiconductors ITRS Teams 2011).

Exploration

The semiconductor intellectual property model can reduce the SoC developmental costs for the industry, accelerate time-to-market, reduce time-to-volume and increase end-product value (Fabless Semiconductor Association 2003b). However, navigating through "the Wild West" style of business infrastructure of IP vendors (Fabless Semiconductor Association 2003b, p.3) and integrating external IP can be extremely challenging. The challenges of integrating the IP that the engineers in the community face are illustrated in the quotes: "IP contracts are like snowflakes – no two are identical" (Savage, president and CEO, IPextreme 2013, p.2) and "mixed IP reuse is almost like an organ transplant. It just does not work perfectly. The specs look good but I want something different" (Kochpatcharin, deputy directof of IP portfolio management, TSMC 2013, p.3).

Thus, semiconductor IP reuse has both challenging technical dimensions and business model dimensions. To address the cost and engineering challenges, more and more industry participants are forming alliances to tackle the challenges and develop common processes jointly in collaboration. As an IP supplier, ARM offers solutions to some of these challenges. In its annual reports, ARM continuously emphasises the cost benefits it provides for the industry and gives its estimates that *"every semiconductor company would need to spend $100 million every year to reproduce what ARM does",* which *"represents an additional $20 billion annual costs for the industry"* (ARM Holdings plc Strategic Report 2013 p.17). It also repeatedly emphasises its business logic that has become the company's running theme in annual reports: *"By designing once and licensing many times, ARM spreads R&D costs over the whole industry, making digital electronics cheaper"* (ARM Annual Report and Accounts 2010 p.2, ARM Annual Report and Accounts 2011 p.16, ARM Annual Report and Accounts 2012 p.7, ARM Holdings plc Strategic Report 2013 p.17).

ARM has taken a leadership role to adjust to the industry's crucial trends and engage with the influential players thereby positioning itself amidst the industry's most meaningful conversations. The growing industry trend towards closer collaboration has been reinforcing ARM's partnership strategy, organisational structure and collaborative culture. ARM's strategy is to keep this unique agglutinating position and "to create a partnership with our customers and broader community of third parties to enable the creation of end products more efficiently through ARM than from any other source"

(Smith, ARM Fellow, 2008). However, leading a vibrant ecosystem that delivers genuine value to the participants is a humongous task. Global collaboration has become a new paradigm in the technology intensive industries which is blurring the traditional industrial borders. As the industry expands and diversifies, ARM's strategic challenge has become to dynamically re-adjust its alliances with partners and co-dependences on the partners' changing business models, processes, technologies and demands.

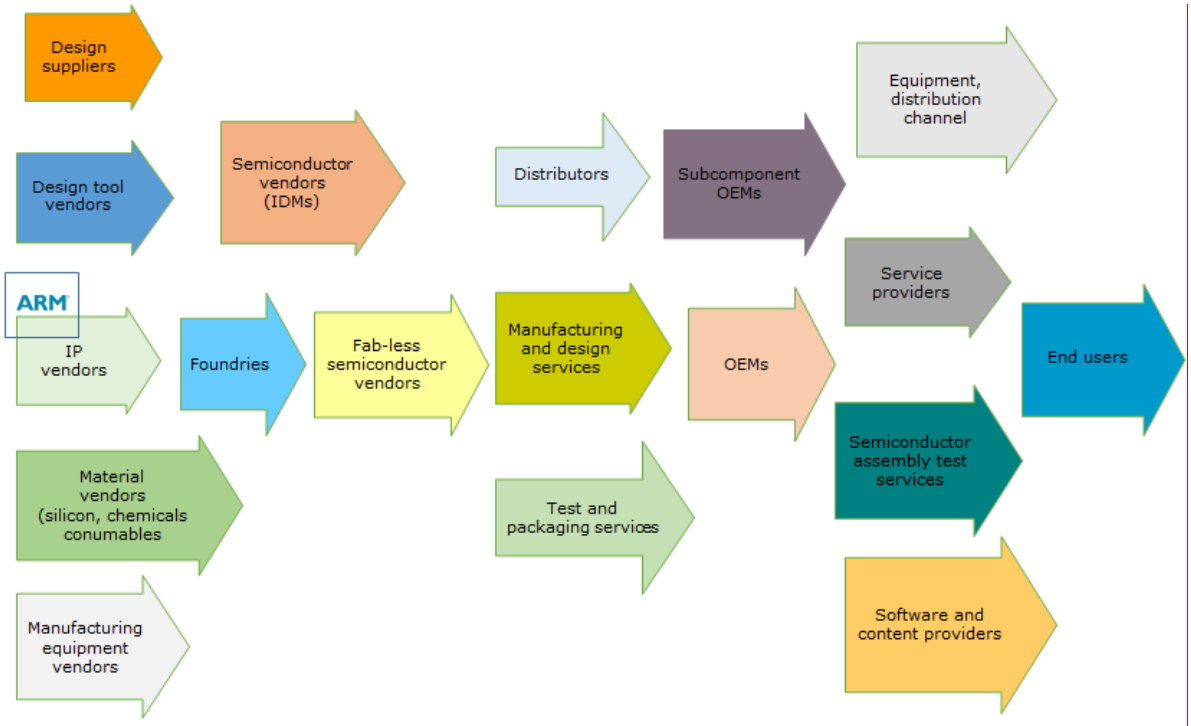
Understanding the place of ARM in the industry made it clear that partnerships and relationships are crucial for ARM's business. The questions that are relevant for ARM are: What is crucial for managing the Ecosystem? How will the Ecosystem Evolve? What new partnerships may be required? How the work with traditional customers may be impacted? How to seize new opportunities as the industry's composition changes? These are the questions of innovation and partner relationship management in ARM's Ecosystem. *Understanding the contribution* of ARM to the value chain will help to understand technological and business model innovation in ARM that are inextricably connected and draw implications for the binary concepts of exploitation and exploration.

6.4.4 Place of ARM in the semiconductor value chain

The semiconductor value chain is understood as a set of activities necessary to design and manufacture semiconductor devices (Wang 2007). Consumers of the semiconductor products: assemblers of sub-system or Original Equipment Manufacturers, are sometimes also included (ibid.). The notion of the semiconductor value chain is used to describe *the activities* in the highly inter-related network of specialist companies that work together towards the final product. The semiconductor value chain has evolved from a "linear chain", with manufacturing equipment and materials at one end and electronic product and services at the other, to a "networked model" (Millard et al. 2012, p.6). The industry's structure shifted from the in-house operations of an integrated device manufacturer that spanned the entire value chain to a network of specialised supplier companies that assemble at a global scale (Ehm et al. 2010). Such open, collaborative ecosystem became critical because "it enables to extract the best talent and the best value from every piece of the value chain to make [the process] really competitive" (GLOBALFOUNDRIES 2014). The diverse participants of the semiconductor value chain are presented in Figure 13.

Exploration

Figure 13 The participants of the semiconductor value chain and ARM's place in it (based on Rajendiran 2008, p.5)



Activities in the semiconductor value chain can be divided into design and manufacturing, since the emergence of fabless companies had split the industry into the two areas. *Fabless companies* are the designers that develop and market their own products. *Pure-play foundries* are manufacturers of chips for any semiconductor customer. The emergence of the SoC led to fragmentation in the design side of the value chain into intellectual property creation, electronic design automation, R&D, engineering and physical design as well as software and system design. The semiconductor value chain is highly disaggregated, but highly networked.

The segmentation and diversification of the semiconductor industry gave IP vendors like ARM an opportunity to integrate their IP into chips designed and manufactured by other parties. The early IP suppliers realised the benefits from focussing on certain types of IP. For instance, Rambus focused its efforts on the development of high-speed memory and logic interfaces. Imagination Technologies became famous for graphics and multi-media IP. ARM became the leader in the microprocessor IP.

In addition to developing the microprocessor IP, ARM is constantly "*exploring*" (ARM's own language) in what other stages of the value chain it can apply its IP business

model. *Replication* of the IP model in new products and new markets is an important business model innovation strategy for ARM. A number of additional business model allow ARM to acquire and integrate a strategically important technology quickly:

> *Such opportunities can take the form of acquisitions, licensing or acquiring third-party patents, or making investments in start-up companies. In addition to bolstering our IP portfolio, acquisitions large and small have brought many talented people into our organisation." (ARM Strategic report 2014, p.55)*

An example of the business model innovation is an acquisition of the American company Artisan Components in 2004 (ARM Holdings 2004). Artisan was the developer of physical IP libraries that provided manufacturing routines to link the processor design and its physical representation in silicon, which were also optimised to the manufacturing processes of the Taiwan Semiconductor Manufacturing Company (TSMC), one of ARM's most important licensee and largest manufacturers of ARM's chips. The acquisition of Artisan was prompted by the similarity of Artisan's IP business model to ARM's: for an upfront license fee, TSMC provided its customers with Artisan's libraries and paid a royalty to Artisan for each die that was fabricated using the libraries. The acquisition and integration of Artisan proved challenging, but the decision was unanimous among the company's executives because of the complementarity of the business technologies and the same business model logic (ARM co-founder and former top executive, interview 13, 2014). Licensing ARM's physical IP showed mixed results, with the licensing and royalty profits varying over the following years, but the high number of top foundries who adopted the IP indicates that the acquisition had potential.

Similarly, in 2006, ARM acquired the Norwegian company Falanx (ARM Holdings 2006) and added 3D graphics and HD video to its IP portfolio – a technology that complemented ARM's SoC capabilities and fitted the IP business model very well. ARM continues to look for more IP related opportunities in the industry.

To conclude, ARM is the provider of the critical component to the semiconductor value chain because the microprocessor design is a key factor in the success or failure of the whole semiconductor chip. The success of ARM's microprocessor design depends on the ability of the company to engage the semiconductor partners into the design process

and ensure a mutually beneficial collaboration. Partners, therefore, exert a critical influence on ARM's ability to create value from its technologies and on the future of these technologies. Collaborative partnership and partnership management are, therefore, ARM's strategic priorities. ARM puts strategies in place to position itself in the centre of the Ecosystem to tap into shared knowledge at as many nodes of the Ecosystem as possible and to create value at every interface between the company and its diverse Partners. The ARM Ecosystem becomes the vehicle for accessing and consolidating information from the Partners which is then embodied in the architecture for others to build and innovate around. Ecosystem approach is the precondition of success of ARM business and the businesses of its Partners in this very broad digital industry. Both ARM Partners and top executives who run ARM share the view.

> ARM Partnership Manager at a Partner company tells: *"We are only so successful on our own. When we are collaborative, that's when we are most successful. Because of the "global village" communications we are gradually becoming much better at breaking the barriers. It used to be a case where companies could become dominant in their national market place. And they could eliminate the competition, because they were protected effectively by a border. But they cannot do that so much anymore.* ***So they've got to collaborate in order to be successful*** *(emphasis added)." (ARM Partnership Manager at a Partner company, Interview 19, 2014, emphasis added).*
>
> ARM top executive tells ***"ARM's success has been amplified by taking an Ecosystem approach.*** *Next week we have our annual Partner meeting. In 1991, the first time we did that it was twelve people that sat in a room not much bigger than this one. We gonna be in Corn Exchange in Cambridge with a thousand people. And there are customers and our Ecosystem Partners and our customers' customers and we have operators, content providers, all sorts of people. And there are people that've been to this even 10+ years straight. Because the people who come, get a real value of it. It's not just talking of ARM, it's talking to their peers, their competitors and it's amazing to walk around thinking 'you two ought to hate each other, but I can see you are having a discussion about stuff'. We've evolved into this way where even* ***competitors coming together*** *can focus on things which aren't actually*

> *competitive. And **to solve a problem once** to allow them to spend more time to **differentiate their own products**. **The Ecosystem continues to evolve**. And I think **as these chips get more complex, it will be more and more important that we take this approach, not less**. If you become too dominant, innovation stops, because you get trapped in one person's view of how to drive the world." (ARM top executive, interview 17, 2014, emphasis added)*

The evidence once again confirms that building business in terms of collaboration and the Ecosystem approach, not in terms of the division of the value chain into discrete tasks or contributions, is seen as the precondition of the companies' continued success.

6.4.5 ARM's business model on a time-scale

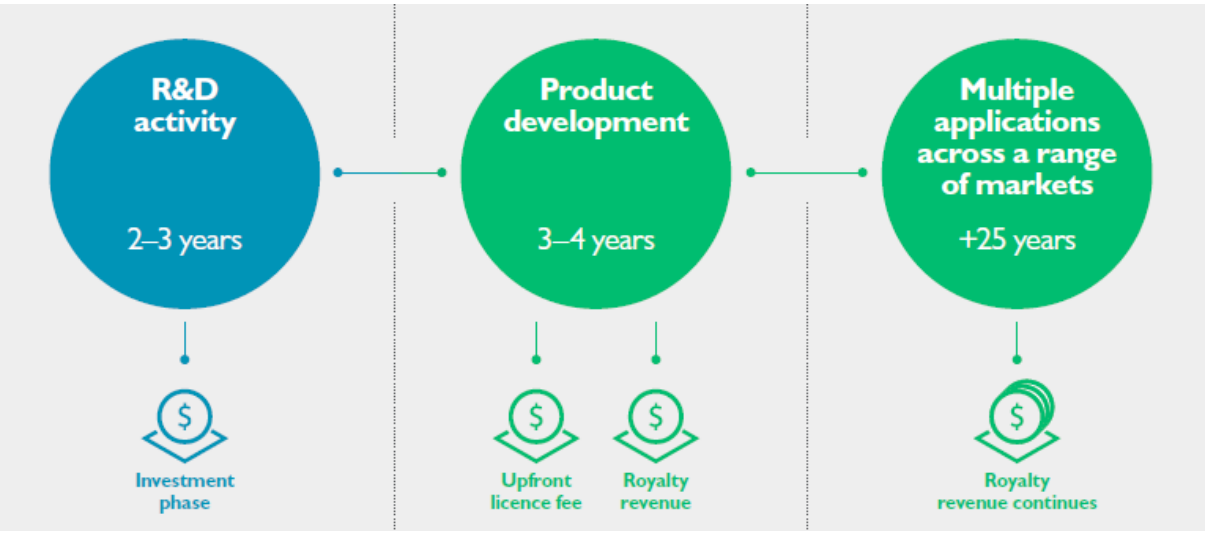
Another important aspect of ARM's business should be mentioned that disturbs the assumption of simultaneous exploitation and exploration. ARM is a very long-term business. ARM's IP business model is aimed at generating royalties long-term from designs that do not become obsolete for many years and can be re-used in many generations of products:

> *"ARM's technology can be re-used by our customers in many different products and end markets; these will generate royalty revenues for years to come. Technology that we started licensing more than 25 years ago is still being deployed in new chips and generating royalty revenues today." (ARM Holdings plc Strategic report 2015, p.25)*

For example, the ARM7 processors designed in the 1990s still account for a third of ARM processors shipped in 2014 (ARM Holdings plc Strategic Report 2014). From the point of view of technology engineering, the product design cycle is also fairly long taking up to 5 to 7 years' time *"from where we start our design, till it actually gets though to mass market, volume and product"* (ARM top executive, interview 2, 2011). See Figure 14 for the combination of the product development life cycle and the time line for revenue.

Exploration

Figure 14 ARM business model time-scale (adapted from ARM Strategic Report 2015, p.24)



ARM's own product innovation and the implementation of ARM's designs in their respective product by the customers is separated by a significant time. A top executive comments:

> *"Our business model means we typically don't realise the full financial benefit from innovations that we create for 5 years plus down the line with the licensing/royalty business model. The licensing component is obviously upfront. But we've got to develop a technology before the license and then the royalties will only flow maybe 2-3 plus years after that and in some cases up to 15, nearly 20 years after ARM products have been created originally. (ARM top executive, interview 5, 2012)*

The fact that ARM's technology, after it had been developed with a Partner, may seep into the Partner' innovations five to ten years later undermines the appropriateness of the assumption of simultaneous exploitation and exploration between ARM and Partners in the product development. Remember that ARM also talks to many partners before developing a product, it does not produce customised designs:

> *"Trying to anticipate where markets are gonna be in seven years' time so that the work done here on the products results in the right mix of technologies to hit the sweet spot of the markets. [Our people] are talking to customers' customer, in the case of the mobile it's to mobile operators, there is application developers, we'll talk to anyone (original emphasis) to try and*

> *get as many inputs as we possibly can to try and predict what we need to do in our products now so that in the seven years' time when they are going into the manufacturing customers want to buy them" (ARM top executive, interview 17, 2014).*

All of ARM products are licensable IP. The licensing business model has so far been ARM's only way to bring ARM's products to the market and generate revenue. However, while preserving the core IP business model, ARM is innovating around it. ARM's business model innovation includes a number of additional models to generate value.

6.5 Innovation in ARM's IP business model

In addition to the revenue generating IP business model, ARM offers access to its processors through two additional models: Processor Foundry Programs and ARM DesignSmart Program.

Processor Foundry Programs is an innovative variant of ARM's IP business model aimed at fabless semiconductor companies in emerging markets. It enables them to gain access to some of ARM processor technology without the large upfront licensee fee that the licensees would normally pay (ARM Holdings 2002). It is part of the two way licensing model: ARM sells a single-use *manufacturing* license for a processor core technology to one of its foundries. It then sells another single-use *design* license to the fabless design company to incorporate the ARM core in only one of its products, which would then be built at the licensed foundry. The traditional license that allows both design and manufacturing is split into two to allow the designer to design and the approved manufacturer to manufacture. As a result, the designers for emerging market can use one of ARM's popular microprocessor core designs in the design of a single product with a substantially smaller upfront fee, but a higher royalty on each product sold (Krazit 2003). A three-way Partnership is built between ARM, an approved silicon foundry and an OEM (ARM Holdings 2002).

ARM DesignStart Program. ARM also enables its physical and selected processor IP to be downloaded via the ARM DesignStart Program. It supports academic study by

providing an opportunity for universities to gain free access to ARM IP including the ARM University DesignStart Program (ARM 2017c)

Linaro is a not-for-profit engineering collaborative network that ARM created out of the need to provide a support for developing standardises open-source software for the ARM family of cores. The group of about 120 engineers works on the open-source software such as Linux kernel aiming to provide the best software foundations to everyone and to reduce costly low level fragmentation (Fisk 2016). The outcome of Linaro's work is open to everyone on Linaro web page (Linaro 2017).

ARM is continuously innovating around its IP business model. The IP rationale is extended into new markets or to new technologies to discover new opportunities to grow. Business model and technological innovation stay closely inter-related. The extension and modification of the business model allows ARM to extend its product portfolio with new technologies, to bring the existing technology to new market areas or get the opportunity to create a new technology in a brand new market (ARM Holdings plc Strategic report 2014).

6.6 What is exploration in ARM's business domain. Conclusions for innovation ambidexterity theory

I will now summarise the evidence that was revealed in the test of exploration in ARM's business domain. ARM's business was founded with the idea of the licensable RISC microprocessor design technology that has come to underpin billions of digital devices. It was an insightful and innovative decision both in terms of engineering, the business model and the very ambition of the business to become a global standard and sell millions of ARM-based chips. Amongst these innovative aspects of ARM, its IP business model and especially the Partnership that ARM has assembled around it, stand out as "the real" innovation, because over the years they have made ARM's business unique.

However, the licensing and royalties business model has been largely untouched over the 27 years of the business's existence, and intendedly so. The IP business model is *intended to be exploited* over long-term. "Design once and license many times" (ARM Holdings plc Strategic Report 2013, p.17) is the business rationale of the model that

provides a steady cash flow for the company that is not going to be disrupted. We see that innovative qualities of ARM's business model at its origin: new value proposition, uncommon and non-obvious, risky, ambitious and re-arranging the existing industrial structure, do not equal the path-dependent innovations of the business model later: the replication of the IP model in other markets or modifications to it. These are two very different types of innovativeness, but they are equally praised. One for being radical and not previously existed before, the other for having evolved and carefully expanded the Ecosystem of Partners through the path-depended modifications.

To preserve and enhance the unique core of its business, ARM modifies its business model to extend it to new areas and puts in place new models all aimed to support collaborative innovations in all corners of the Ecosystem. This is a spectrum of tasks driven by the goal to nurture the Ecosystem. We have seen it on the example of splitting the manufacturing and the design licenses for certain types of customers in the Processor Foundry programme. We will see it on the example of partnering with banks and credit card providers up the value chain of the technology, not the traditional silicon partners (ARM Holdings 2012). Importantly, ARM *replicates* the successful IP business model in other stages of the semiconductor value chain, extending to areas where there is also a clear technological complementarity. ARM provides some of its technology free of charge to universities to foster teaching, learning and research with ARM technology. ARM-supported Linaro community develops open source software for ARM-based devices.

Historically, ARM's innovative business model balanced out incremental opportunities in technological innovation and contributed to re-arranging the existing order of product development of the vertically integrated industry. Now, we see the impact of ARM's business model innovation on the industrial structure as well as technological innovation, which is now collaborative across a very broad Ecosystem. The business, organisational and technological domains are closely inter-related.

The qualities of technological innovation at any node of the Ecosystem are multi-channel, iterative, collaborative co-creation of a solution to a market problem drawing on a pool of knowledge collected from across the Ecosystem. The borders of such collaboration are not clearly defined and the type of contribution required from the participants is established in the process of negotiation in the technology co-development,

not sourced in advance. Another complication to the ambidexterity thesis of *simultaneous* exploitation and exploration, if it were to be expected to be divided in the activities of ARM and the Partner, is the evidence that ARM's focused technology development is separated from the combinative, innovative product development by a Partner by three to five to ten years' time.

In the ubiquitous technology of today that has penetrated the great variety of industrial and personal contexts, innovation involves too many technological and social uncertainties that an upfront clarity on what partner provides what capability, and sometimes what capability is needed at all, often cannot be foreseen. ARM, as a business, is only too aware of the importance of social aspects of adoption of electric cars, internet connected fridges, health monitors and home sensors that are powered by its technological know-how. Such technology is evolved collaboratively amongst the industry's participants from the start. ARM has to collaborate to be successful, not to exploit and explore.

7 Innovation ambidexterity

The study of exploitative and explorative innovation using the case of ARM has demonstrated that the processes associated with exploitative and explorative innovation are multi-faceted and ambiguous not to fit easily into the binary categorisation promoted in innovation ambidexterity theory. Exploitation and exploration can present themselves both as distinct instances and blurred variants, even within one and same organisational domain, depending on the concrete context and the perspective of the viewer/analyst. This is important because it reveals a new finding that the characteristics of exploitation and exploration are not pure or purely distinct. We have seen, however, that these activities and their transient variants are present in the workings of the company. This is also important because it crosses both schools of thought in the ambidexterity literature: that exploitation are exploration are at trade-off (March 1991, Tushman and O'Reilly 1996), yet they are seemingly reconcilable (Cao et al. 2009, Gibson and Birkinshaw 2004, Simsek 2009, Simsek et al. 2009).

In this final empirical chapter, I look at how exploitative and explorative types of innovation are implemented in ARM's organisational structure. According to ambidexterity theory's main proposition, successful companies are those who act ambidextrously. Here, I examine what ambidexterity implementation looks like in this successful technological company. I then compare the actual organisational design and mechanisms for ambidexterity, the "what is" of ambidexterity, with the received propositions of "what ought to be" (Keynes 1897, p.34 -35) according to the theory to complete the test of innovation ambidexterity.

7.1 Structures for ambidexterity

Just like with technological innovations, ARM does not stand still in innovating in its organisational form. The organisational form of the company is constantly being transformed to support development of core technologies and to stay attuned to the needs and innovations of the Partners. Building on the previous analysis of the emphasised innovativeness of ARM *Partnership business model*, it can be argued that the inseparable from it P*artnership organisational form*, in its broadest sense, is also a point of

application of some of the most creative and innovative efforts in the company. Organisational arrangements for combining efficiency and experimentation that the company's decision makers produce are the subject of the analysis of this chapter. More specifically, in this final empirical chapter, I focus on implementation of the diverse and ambiguous processes associated with exploitation and exploration in the actual ambidexterity design: the company's formal and informal structures, processes and strategies. In that, I consider the breadth of exploitation and exploration activities in all of the company's domains: technological, but also the inseparable from it domain of business ideas, internal organisational processes and partnership relations.

It is important at this moment to specify a point of difference between my analysis and existing works that have bridged ambidexterity and alliance relationships (Lavie et al. 2011, Lavie and Rosenkopf 2006, Lavie et al. 2010, Stettner and Lavie 2014). Unlike Lavie, Stettner, Rosenkopf, Nerkar and other researchers of exploitation and exploration in alliances, acquisitions and internal organisation, I do not produce a 2x2 matrix of 4 clear definitions of ambidexterity arrangements and then discern what is what in every domain or analyse benefits of each ambidexterity arrangement. My findings have already revealed that exploration and exploitation, and their associated variables, are blurred rendering any such attempt at demarcating or delineating neat ambidexterity arrangements inappropriate for what we see at play in ARM. Thus, in what follows, it is inevitable that neat explanations of what components an ambidextrous design includes cannot be made. These components will carry a degree of overlap. My analysis will concentrate on pinpointing and explaining these components, but also on emphasising the understanding that systematic grouping into neat exploitation-exploration ambidexterity arrangements will not be possible. This reality sheds new light on the idea of "domain ambidexterity" (Lavie et al. 2011) where firm might explore in one domain but exploit in another, achieving ambidexterity overall. The empirical analysis has already shown that exploitation and exploration are blurred across domains. Moreover, the domains are intertwined and also do not have distinct boundaries. Nevertheless, I will set out to test the ambidexterity implementation assumption in the context of ARM Ecosystem to complete my research goal.

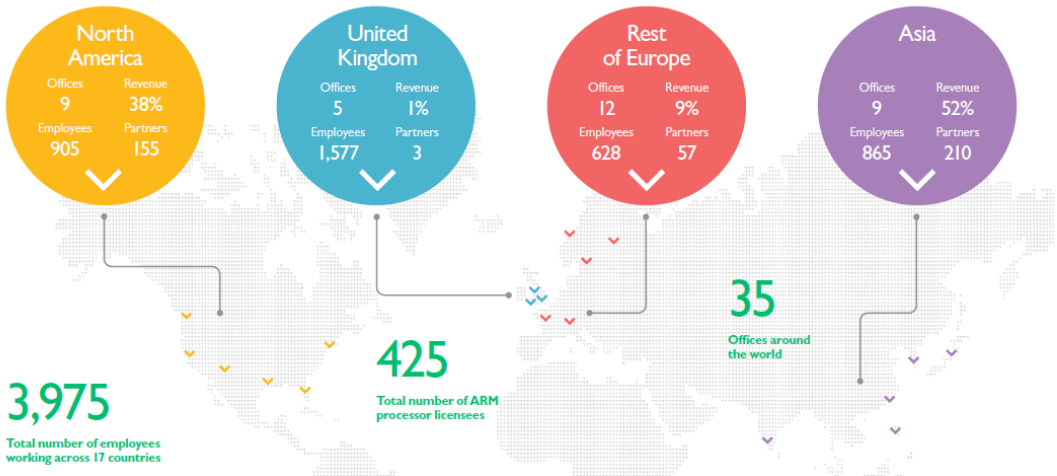
To produce a detailed and meaningful analysis and to make conclusions about mechanisms of balancing exploitation and exploration in this technologically and

organisationally dynamic firm, I combine two levels of analysis: an organisation level analysis of what I will define as ARM *internal structure* (within its formal boundaries) with a meso-level analysis that connects ARM Holdings plc with *ARM Connected Community of Partners*. The two levels will ensure that the *Ecosystem organisation* that is the essence of ARM's organisation is not ignored.

7.1.1 ARM Holdings plc. View from the inside

The 2015 annual report informs us that ARM employs 3,975 people in 35 offices across 17 countries world-wide (ARM Holdings plc Strategic Report 2015 p.2). Figure 15 from the report illustrates distribution of the staff in the offices world-wide, along with the indicator of the number of partners and share of revenue from a particular geographic location. The company is headquartered in Cambridge, the UK, which together with other UK locations[1] employs the largest staff, although the number of ARM partners based in the UK is the smallest and represents only 1% of revenue. An updated information from the company's webpage details that "by the end of 2015, that team had grown to more than 4,200 people in sites around the world" (ARM 2017a).

Figure 15 ARM business presence world-wide (ARM Holdings plc Strategic Report 2015 p.2)



[1] Blackburn, Loughborough, Maidenhead, Manchester, Sheffield and Warwick, the UK https://www.arm.com/company/offices/offices-europe

These boundaries – ARM employees and offices – will delineate the formal entity of ARM Holdings plc that I will consider the company's *"internal" structure*. From here, I begin to identify ambidexterity arrangements and mechanisms at play in ARM to complete my test of organisational ambidexterity theory. I begin my empirical enquiry at the heart of ARM in ARM headquarters in Cambridge.

7.1.1.1 ARM 1.0 and ARM 2.0

The collection of primary data for the thesis started with interviews with the members of the executive team and senior management of ARM. Ambidexterity themes emerged in the very first interviews. Perhaps the first immediate finding regarding ambidexterity was the reported non-formalised division of the company's activities into what was called ARM 1.0 and ARM 2.0. In the words of a top executive, ARM 1.0 was concerned with efficiency and extension of *"business as usual today"*, while ARM 2.0 was created to *"ensure that we are not missing the opportunities … a bit different from our core business, … not completely different, but different from what we are secure and comfortable with"* (ARM top executive, interview 2, 2011). Importantly, the division into two structures within the company was not formalised on the organisational chart. A re-organisation that brought the *conceptual* distinction between the structures has been reported by the company's senior executives and managers in interviews. It was not listed as a formal restructuring in the corresponding corporate report (ARM Annual Report and Accounts 2010). The structures were delineated internally by the executives and the names were created for internal use to help *to talk* about the differentiating priorities of ARM's growing business. For example, the two orientations have been described the following way:

> *"How much resource effort do we put into developing potential technology, but also new business ideas, potentially for areas that are outside the scope of business as usual today. If we decide we're gonna create a new type of IP for integrating into a System-on-Chip then that's effectively an extension of what we do today. But if we decide, for example, that there might be an innovative way to create long-term revenue streams from selling some kind of value added service that somehow lead back to hardware product which is our core competency, something like that is completely outside our current*

business model, but it's still something that we should be thinking about and making sure we don't miss an opportunity to grow and diversify the business. … We call this ARM 1.0 and ARM 2.0." (ARM top executive, interview 5, 2012)

The ARM 1.0 and ARM 2.0 innovations can also be distinguished by the implementation timeline, reflecting the technology readiness:

"We … have two tag lines within the company, we have the ARM 1.0 which is the base-line ARM business and then ARM 2.0 which is looking at things a kind of further ahead, 10, 20, 25 year time frame on where we are … going with business." (ARM business development director, interview 7, 2012)

Ambidexterity was initiated in ARM by the structural separation of exploration from exploitation. Whereas innovation has always been an important driver of ARM's business, it started to be differentiated in ambidexterity terms as the company's industry engagement grew larger and its technology became more complex. Ambidexterity has become an important part of the company's business thinking and strategy. The structural separation was the first ambidexterity design that was adopted to manage the increasing complexity of business and technological innovation. ARM top executive talks about the importance of challenging the established business and creating a dedicated space for exploring more bold business opportunities for the future:

The fact that we've got this hugely valuable core, the pearl if you like, centre of the business that we have today, we are very aware that that has happened to many companies, the whole environment can change and it can go away. But right now it continues to be a hugely valuable pearl and when you have a hugely valuable pearl you don't want to do something that might cause it to get damaged of some sorts. I think that's makes it a bit more risk averse that we would otherwise be, so we are continuously having to push against that to try and or to ensure that we are not missing opportunities. People like our CEO Warren[1], very much see part of his role as being able to challenge the

[1] Warren East, ARM CEO in 2001-2013. The interview took place in 2011

> *status quo and encourage us to think outside the box and look at other things and changing the organisation [to] have more chance of … at least have done the investigative work to be able to make decisions on whether you are going to go off in some different direction. And that's which is what this new bit of the organisation (ARM 2.0) is about. (ARM top executive, interview 5, 2012)*

We see that the ambidexterity challenges of preserving the profitability of the business today while exploring opportunities for tomorrow and preparing for change in the industry conditions are high on ARM's agenda. Ambidexterity is part of the new thinking at the highest level of strategy that the executive team is directly concerned with. As we will also see later, ARM 1.0 and ARM 2.0 have the attention of the dedicated executives, with the integration and coordination of exploitation and exploration taking place at the level of the senior management team as a whole.

The descriptions of exploration in the scope of ARM 2.0 given by the interviewees are cautious and modest, but it is a clear attempt to install structural ambidexterity within the company. ARM 2.0 is a conceptual departure from the "road-map" type of innovation that has always been present in the company, distanced from it not simply by a longer time frame, but by qualitatively different criteria and values that motivated it. As before, when the incremental evolution in ARM processor technologies led to a qualitative change in application of the technologies, the differentiation of the habitual "road-map" innovation from the explorative innovation of ARM 2.0 was a qualitative change that came with *evolution*. The need to decouple ARM 1.0 and ARM 2.0 structures and buffer explorative innovation from the processes and cultural norms of the established IP business was sensed around the year 2011 when the company gained significant industrial influence, paralleled by the company's growth in size to about 2000 employees. At this point, a clearer direction of what opportunities to pursue and how to mobilise resources for them became vital. This also has to do with the fact that at the same time, ARM processor functionality has evolved and become quite sophisticated to open up more radical opportunities in new markets, which also required new thinking and a new strategy. The organisational evolution is, therefore, co-evolution: ARM's engineering knowledge, technology, engagement in markets and business skills co-evolve with the organisational form.

Innovation ambidexterity

Reaching the size of 2000 employees has been said to mark the growth point where challenges of the evolved business had to be addressed with a new strategy in a new organisational reconfiguration. The executive details:

> *"What's interesting now is by creating this new, it's only small organisation at the moment, but this new … ARM 2.0 organisation is part of the idea that it should be doing some of this work that previously perhaps the whole exec team has come together to do it on a continuous basis. And I see this is being a reflection perhaps of our evolution as we hit this roughly 2000 people size and scale of the business and our increasingly influential position in the industry. Everybody else is so busy, we really need to separate that out, have it as an on-going process." (ARM top executive, interview 5, 2012)*

The increased organisational complexity, as reflected by the growth internally in size and in influence within the industry, made it necessary to concentrate the "probing" efforts that had previously existed but had been dispersed across the company in a single dedicated team.

> *"…It is just interesting that to date … we've done all kind of little one-off initiatives to help with that but it's only really now at that these 2000 persons stage that we've put up a central focussed group whose responsibility is to go and drive this (ARM 2.0)." (Interviewee 2, ARM top executive, 2011)*

Although ARM 2.0 was a new unit with a broadly defined remit, it had two clear and essential purposes. First, it served to ring-fence *"people [who] have much more freedom … to be working on technologies that maybe relevant to the future direction of the business"* from *"the engineers who are developing products, [who] got customer commitments, …projects time scales that they are working to and they have to deliver on those - the life blood of the company - [who] get the revenue in the door"* (ARM top executive, interview 2, 2011). At the time of its formation, ARM 2.0 consisted of a "handful of people" (ARM business development director, interview 7, 2012) led by ARM Chief Technical Officer Mike Muller.

Second, innovation coming out of ARM 2.0 has to expand ARM opportunities beyond the comfort zone, but be customer-led and still align with ARM's core competences. The interviewee continues:

> *"We haven't gone as far as Google, for example, where they: 'Just so, right, you know, go off and do whatever you like'. We have not gone as far as that. And I don't think this will be appropriate for this type of organisation actually." ... [ARM 2.0] people have much more freedom, although it's still mainly relating to ARM 1.0 base business today." (ARM top executive, interview 2, 2011)*

It is the orientation to customers and the obligation to deliver on commitments to them that is prohibitive of open-ended exploration of the Google kind commented in the quote above. Unlike Google, who sell products to end consumers, ARM sells to businesses and so it must align its innovations with the demands of the customers and focus on the execution of the product roadmaps. Innovation in ARM, whether in the main product groups or of the horizon scanning type in ARM 2.0, always satisfies customer pull, not exercises technology push.

An important observation about the nature of technological innovation in ARM can be made here: exploration does not take the company further and further *away* from the previously exploited technology base. It loops back to the existing competences upgrading them to a different level. Novelty in ARM's area of expertise does not negate previously accumulated experience. The business of designing Systems-on-Chips of spiralling complexity benefits from experience because it leads to a better understanding and physical mastery of silicon technologies. Producing a silicon product at the current level of complexity without experience puts a technology producer on a long learning curve and in front of a high competence threshold to enter the business of SoCs designs, prohibitive of inexperienced and quick entrants. The experience in designing silicon technologies and the deep understanding that comes from it – the know how – are, in general terms, what ARM is selling to customers, allowing the customers to jump start their products without costly and long development of their own competences in the area. This is why wandering off the competence path as an innovation mode that can be practiced in companies with a different type of technology base, is inappropriate for ARM.

The logic of structural separation in ambidexterity theory, as well as the rationale behind introducing the ARM 1.0 and ARM 2.0 separation in ARM, is to buffer exploration from exploitation. This way, in theory, competition for managerial attention

and engineering resources of the company can be mitigated. Competition for resources of a tightly coupled organisation is a classical ambidexterity tension; structural separation is a classical solution to it (Tushman and O'Reilly 1996). We see, however, in the example of ARM, that the structural separation does not resolve the competition for resources entirely. It does create working focusses and answers the question "who does what", but it does not remove the question "why ARM 2.0 does it" that feeds the tension. Resource dedication needs to be justified and continuously reassessed by the management team, with the feedback from the front-line sales managers and engineers. In a way, the separation creates a new type of tension, namely on the part of the revenue generating main part of business feeling disadvantaged by the resources being pulled away from them. The interviewee explains:

> *"And you can imagine there is some bits of the company who will look at it and say: 'Wow, you're spending three people on doing this, we need three more engineers to run this critical project, why ... doing all this airy fairy stuff over here?. ... This stuff you are doing isn't closely relevant enough to what we think you need'. And then they are saying: 'Well, that's the whole point of us having to ring-fence'." (ARM top executive, interview 2, 2011)*

Structural separation, with the integrating oversight of the top management team, attends to the ambidexterity tensions, not resolves them completely. Introducing a structural ambidexterity design in the form of the internal informal separation into ARM 1.0 and ARM 2.0 businesses was driven by the need to emphasise and support the explorative innovation in the company. It was also the organisation's first formalised attempt to reflect the equally important but diverging priorities that have emerged as the business expanded.

7.1.1.2 The language of ambidexterity in ARM

We have seen that *structures of ambidexterity* were created in ARM *to differentiate* short-term and long-term strategic priorities of the growing business. Interviews reveal that the very *language of ambidexterity* has also been adopted in the company, not just for the need to differentiate, but to comprehend how *to combine* the divergent priorities and their distinct supporting structures. The terms "ambidexterity" and "ambidextrous organisation" have become part of the managers' vocabulary to make sense of continuity

of innovation and a challenging ambidexterity point of transition from innovations of today to innovations of tomorrow.

A member of ARM top management team uses the following language to describe the organisation into ARM 1.0/ARM 2.0:

> *"Internally, we've restructured the company and are referred to as an ambidextrous organisation. And we actually use the term 'ambidextrous organisation' across our all employees. ... We describe ARM business as it is today as ARM 1.0 and we've set up a separate structure which we called ARM 2.0, which is literally using the ideas of an ambidextrous organisation to say that the current business has to focus on delivering financial results. The quarter has to continue to evolve, product roadmaps and that kind of things, etc. But we are very cash generative organisation and we have to innovate for the future. And some of those businesses that we want to innovate in may be completely different cultures, systems, processes, etc." (ARM senior manager, interview 1, 2011)*

The two distinct ambidexterity structures make business sense only when there is transition from the existing technological offering perfected by ARM 1.0 to the new ideas explored and matured in the ring-fenced explorative unit ARM 2.0. The much discussed relevance of ARM 2.0 explorative ideas for the existing ARM 1.0 business is meant to ensure the continuity of technology and revenue stream. The above quoted "completely different cultures, systems, processes, etc." are not contradictive to the continuity. This innovation spirit has the same purpose of moving the technology forward. Radical products, supported by the new thinking and new systems, are vital to keep product lines alive. An ARM Vice President in charge of developing market segments explains:

> *"We are trying to break our current conception of products if you will. ...It's not that we actually break the revenue stream by coming up with a completely new revenue stream, although we do look at that as well, but obviously that's a much more difficult thing to identify. But we are looking from a product perspective, we are trying to introduce quite radical products to make sure we keep moving the technology forwards." (ARM Vice-President, interviewee 4, 2012)*

Innovation ambidexterity

Connectedness to what is known and departing from it are the two facets of ambidexterity (and the very point of adopting an ambidextrous organisation): to uncouple and then re-integrate the opposites to ensure transition from old to new (technologies, processes, structures) and thereby maintaining the continuity of business.

One common characteristic that ties ARM 2.0 with ARM 1.0 type of innovation is orientation to customers. The Vice President continues:

> *"Although we are trying to have new ways of working, still you have to match the perception of customers closer." (ARM Vice-President, interviewee 4, 2012)*

> *In a public interview, ARM CEO Simon Segars emphasises the point that innovation in ARM, also of the most explorative kind in a ring-fenced lab, is always guided by customer needs:*

> *"…We don't have our engineers sitting in the lab creating products and then we go to our customers and say: 'Hey, here it is, do you want to it?'" (ARM CEO Simon Segars, quoted from Poeter 2014, p.4)*

Now that I have gleaned the definitions of ARM 1.0 and ARM 2.0 from the interviews, I will look at the content of each structure.

7.1.1.3 ARM 1.0 and ARM 2.0: An image of structural ambidexterity

Engineering know-how underpins ARM's System-on-a-Chip IP business and research and development (R&D) activities drive its growth. R&D enables advancement in different product specialisms, which allows the company to anticipate and meet demands of the customers with better products and, thereby, remain in business. The ARM 1.0 and ARM 2.0 divisions were created to structure the different streams of R&D activities that accompany ARM's product specialisms, to clarify their strategic purpose and to prioritise their implementation. In other words, the ambidexterity separation was a way to acknowledge the importance both short-term and long-term innovation and to manage the broad spectrum of R&D activities in the company. An ARM top executive explains the relation of the different R&D streams to the ARM 1.0 and ARM 2.0 ambidexterity structures:

Innovation ambidexterity

> *"The other angle on this … is R&D and to what extent R&D activities … range from … very focused product development right out to almost 'blue sky' research which might or might not lead to any kind of product activity at some point in the future. And also… we've ring-fenced an organisation which works for the Chief Technical Officer which is called R&D (ARM 2.0). It's not the only bit of the company that does R&D, but those people have much more freedom to be working on technologies that maybe relevant to the future direction of the business, although it's still mainly relating to ARM 1.0." (ARM top executive, interview 2, 2011)*

ARM 1.0 encompassed the R&D activities of the five Product Divisions into which the company was organised at the time of the field work for this thesis in 2011. The Processor (CPU) division (1), Graphics Processor (GPU) division (2), Tools division (3), Support and Services division (4) and Physical IP division (5) constituted ARM's established business focused on delivering growth. The nature of innovations in the Product Divisions has been described as "*looking [at] one to five [years], simplistically. … They are products that broadly exist and it's the next version. … Literally, developing the microprocessors that are going into the iPhone 6, or iPad 5 or 6" (ARM senior manager, interview 1, 2011).*

The well-defined short-term revenue-oriented innovations in the Product Divisions are balanced with the next level of R&D – Central Corporate R&D – which is concerned with the future of the established product groups over the time span of approximately five to ten years:

> *"So how much do we put into those Product Divisions to develop their technology road maps for the future? How much do we put into Central R&D? … So Central Corporate R&D is looking at the time horizons slightly beyond where Product Divisions are likely to be looking at." (ARM chief top, interview 2, 2011)*

Central Corporate R&D focuses on innovations in the existing product groups along the specified roadmaps over the medium term. The team that consisted of about 50 staff members was tasked with exploring future ingredient technologies that will later

feed into the products. For example, the difference between innovation in the CPU Product Division and the Central Corporate R&D can be illustrated as follows:

> *"In our world of CPU …, these people* (CPU Division) *would actually be working on designing an implementation of a microprocessor, whereas these people* (Central Corporate R&D) *might be working on exploring new ways of creating part of the instruction set of a microprocessor which is not a product in its own right but it's maybe the technology ingredient."* (ARM top executive, interview 2, 2011)

Charged with exploring beyond the product R&D, Central Corporate R&D is '*where you potentially start branching out into areas that are less closely coupled*" (ibid.).

Finally, Advanced Product Division (APD) was placed within each Product Division, and as the names suggests, was concerned with advanced development of the corresponding product group over a long-term time span of about ten to twenty-five years. In the words of an interviewed top executive: *"This is… I always wanna say 'blue sky', but it's not 'blue sky' research"* (ARM top executive, interview 2, 2011). The organisational rationale behind having an explorative APD within an exploitative Product Division is to think about development of a particular product both in short-term and long-term perspective. In other words, to do exploitation and exploration simultaneously tied thematically to a particular technological subject. For example, the Product Division which is tasked with delivering efficient media processing technologies contained ADP which is concerned with the long-term future of the video and graphics technologies.

In this organisational set-up, exploitation and exploration can cross-fertilise each other: perfecting the technology on a daily basis can inspire ideas to reinvent the product for the future coming from deeper understanding of the technology. Also, working on the front-line delivering current products to customers gives better insights into the technology's future trends. The ideas and trends related to a particular group of existing technologies are more tangible and more likely to get implemented than abstract explorative ideas unrelated to available technological implementations. Complementarity of exploitation and exploration within ARM 1.0 is, therefore, in that exploitative knowledge makes explorative innovation more realisable when both focus on the same

subject matter. Also, the interlinking by a common technological subject matter and the divisional proximity enable the much desired ambidexterity transition from exploration to exploitation and continuity of product development.

The gradation of innovation activities in ARM 1.0 relating to the main product lines by different level of abstraction and positioning them organisationally is an interesting aspect of ARM's organisation at the time[1]. An interviewee describes the relationship between the PDs and the APDs:

> *"And then you got the sum of the ideas and requirements that people actually do know about in the business [innovation in PDs], or that do have some level of sponsorship … from the product divisions. Another way of thinking of this, is that you've got within each product division … let's call it Product Engineering who are actually developing new products and then you've got what we call APD which is Advanced Product Development which is inside the division. And these people are still working on quite well defined technology problems, but they are not actually creating a product. Well, the intention is that they are not actually creating a product, the fact is that quite often the boundary here tends to get a bit fuzzy, cause what tends to happen in probably most of organisations is .. you get a little bit of crunch on your product development resources here, … cause some of these people (APD) get stolen to prop up some of these projects (PD)." (ARM top executive, interviewee 5, 2012)*

While Central Corporate R&D undertakes a broad explorative innovation centrally in a single unit, Advanced Product Development Divisions are placed locally (thematically) within each of the five Product Divisions. We see that each R&D group is exploring further away from the subject of innovation in the Product Divisions. Each is gradually allowing more ambiguity and a more extended time-line. However, the innovations here are still very closely aligned with the needs of the established businesses and [do] "*not come of a very much of a surprise"* to the customers *(ARM top executive, interview 2, 2011)*. Central Corporate R&D and APD are looking at the future of the

[1] 2010 - 2013

existing technologies along the established trajectories and are, therefore, part of ARM 1.0 innovation. Given the reported distribution of the R&D activities on the time scale and the degree or abstraction from the current product offerings, innovations in the Product Divisions, Central Corporate R&D and APD can be expressed on a spectrum of innovativeness. The short-term 'improving effectiveness' type of innovations in the Product Divisions can be seen as more exploitative, while the more remote in time and more detached from the actual product implementation innovation in Central Corporate R&D and APD can be seen as more explorative. It is an interesting finding, because it shows that even within a unit designed to be exploitative (ARM 1.0) explorative innovation still happens. The analysis of ARM 1.0 unpacks the circumstances why this is so.

ARM 2.0, in turn, is a new structure dedicated to do investigative work to inform decisions about future directions of the business. It is decoupled from the product R&D divisions and it is *"the only point where it [innovation] is starting to become a surprise"* and where *"a little bit of tension starts to creep in"* (ARM top executive, interview 2, 2011).

Exploration in ARM 2.0 consists not as much in new technology development as in exploration of new market segments outside ARM traditional markets and innovation by acquisition. In other words, the mode by which exploration is achieved can be internal ring-fenced R&D, but most of the time is sourced externally. An ARM business development manager tells:

> *"We would involve the existing ARM 1.0 technology but then effectively to do something completely different, right, which is ARM 2.0 is about. We are likely to do that through investing in companies or basically acquiring technology." (ARM business development manager, interview 7, 2012)*

This acquisition-based explorative innovation in ARM 2.0 resonates with strategies for exploration across alliances in ambidexterity theory (Lavie and Rosenkopf 2006, Stettner and Lavie 2014). Most of the time, exploration is bought in and nurtured in the dedicated ring-fenced ARM 2.0 part of the company. Criteria for ARM 2.0 exploration by acquisition is acquiring companies that are different to ARM microprocessor business, in acquiring technology that is not about microprocessor and exploring software not

associated with microprocessors. Exploring outside the traditional areas means that ARM 2.0 also provides room for business model innovation and opportunities to explore beyond the usual partner relationships.

ARM's business in Internet security and the Internet of Things markets has started as part of ARM 2.0. Also, the development of high performance low power ARMv8 64-bit architecture that marked the entry into servers and enterprise-class hardware market took place in an R&D group ring-fenced around the CTO Mike Muller. Work on the 64bit version started in 2007 before ARM 2.0 was organised, but ARM's move into high performance 64bit processing has been in the spirit, and subsequently within the shelter, of ARM 2.0 until the ARMv8 64bit architecture matured and the new product was officially released at the end of 2011. This shows connection between ARM's main microprocessor business and the explorative ARM 2.0 part of the organisation. The alignment with the main technology base, for which we will see more evidence further on, is an indispensable requirement of ARM 2.0 business.

For example, in 2012, to set foot in Internet security business, ARM formed a joint venture with two established security companies Gieseke & Devrient (G&D) and Gemalto (ARM Holdings 2012). The goal of the joint venture was to improve security for smart connected devices to which ARM brought its processor cores with the integrated ARM® TrustZone® security technology and understanding of the semi-conductor industry, while G&D and Gemalto brought their mobile security software and services to remotely manage sensitive data. From an ARM perspective, this has been both a business model innovation: forming a new type of relationships with partners up the value chain (joint venture with software security companies – not licensing to silicon manufacturers), and a market innovation in mobile security – a market new not only for ARM, but in general, where ARM, capitalising on its secure processor architecture and ecosystem relationships, helps to pave the way for adoption of a common security standard in an ecosystem of secure service providers. An ARM business development manager details:

> *"So, that was a good example of using the core ARM technology but then looking further afield in the business, selling into banks or credit card providers. So, to be honest, the big difference is more in the business model. [In] ARM 2.0, one of the premises is we do not make money from chip guys.*

We've broadly concluded that to get to the next big thing we need to be looking at a different model, which is more selling higher up on the value chain." (ARM business development manager, interview 7, 2012)

Another example of ARM 2.0 explorative innovation is the acquisition of Sensinode Oy in 2013, a provider of connectivity protocols and standards for low cost low power IoT devices (ARM Holdings 2013). With Sensinode connectivity software ARM could allow web access very efficiently and very securely to the 'Internet of Things' devices already underpinned by ARM processor cores. The ARM Cortex® family of processors and collaborative mbed project, together with Sensinode's NanoStack and NanoService offering, provided the ideal foundation for a vast number of IoT applications including wireless sensors, smart connected appliances, home health applications, wearable electronics and machine-to-machine applications (ARM Holdings 2013). Sensinode software was a technological complementarity, but incorporating the software it into ARM's business model was a business model innovation and exploration. A senior executive of the acquired Sensinode tells:

"The challenge for ARM is it's a different business. I mean we are a software company. Software licensing is a different model from licensing cores or IP like that." (Top executive at Sensinode, interview 12, 2013)

ARM traditionally has been a hardware company and software has been identified as a big element of ARM 2.0. Exploring complementarity of hardware and software being the next logical innovation step, ARM was looking at leveraging ubiquity of its base processor technology with software and exploring the connection between hardware and software. This logical complementarity of competences mitigated risks of *software exploration* by linking it with the *established existing hardware technologies*. Like explorative activities in ARM 1.0, this explorative avenue in ARM 2.0 was coupled with and sought to complement the existing competences, not obliterate them. Competence complementarity of exploration with existing technologies and alignment with base business remain an interesting feature that holds true with regards to exploration also in ARM 2.0 division.

"I think we will need to feel comfortable that we have got good arguments to deploy to explain why ultimately us providing a product or service in this

connected but different area is actually gonna add value to everybody. And we have to work through that to be able to show in general it's a logical extension of what we are doing." (ARM top executive, interview 2, 2011)

The last point about explorative ARM 2.0 innovation, both by ring-fenced in-house R&D and acquisition, is that it is scant. Explorative ideas in ARM do not get taken further without rigorous justification and strong alignment with the base ARM 1.0 business. Even though acquisitions are the major part of ARM 2.0 exploration strategy, ARM's acquisitions are not that many, on average one company per year[1]. The business development manager explains why:

"And just to be clear, we don't do that many of these. … The real crack of that process … has to be a good strategic rationale for doing the investment. It has to align with base business, ARM 1.0 or more kind of further afield business 2.0, but it has to be a very strong crisp reason why we would want to invest into that technology and why we have to invest versus partnership." (Interviewee 7, ARM Business Development Manager)

An additional filter to the scope of explorative innovation is a formal assessment of innovation propositions that includes a presentation to the Corporate Development team and to the Investment Committee to consider investment into the explorative innovation. For large investments over two million dollars, propositions are forwarded to the External Board for further approval. It is a stringent process to narrow down explorative ideas to those which would be most aligned with, and complementary to, ARM main microprocessor business. Part of this process was in fact a re-evaluation of the portfolio of acquisitions at the time:

"Actually, right now my focus is more on divesting in companies rather than investing in companies. We are doing a lot of clear up of the portfolio." (ARM Business Development Manager, interview 7, 2012)

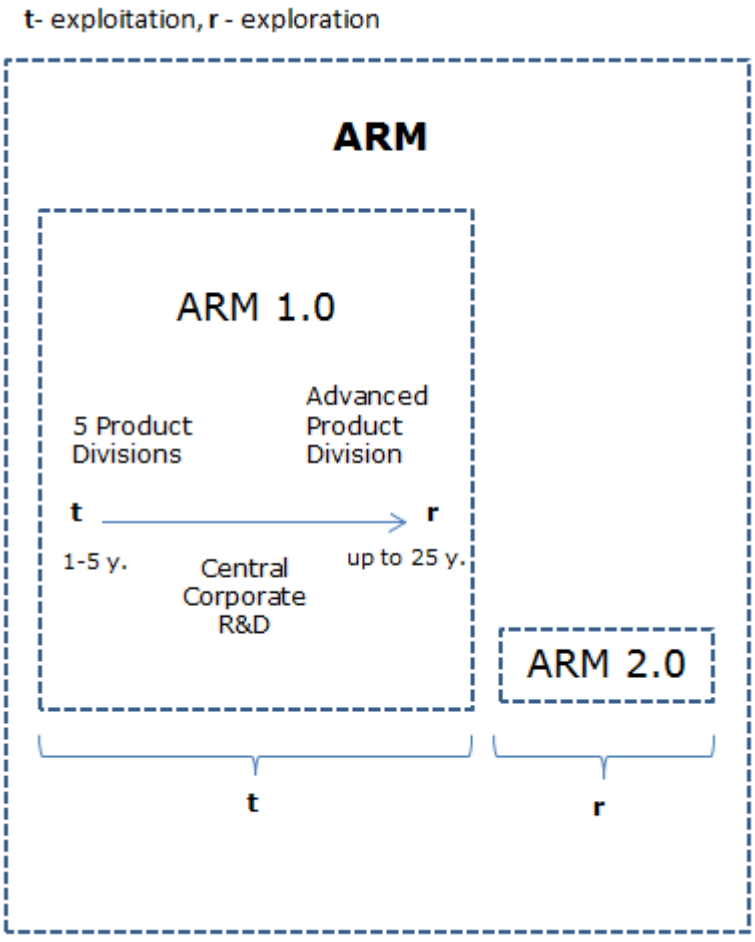
To summarise, the explorative ARM 2.0 structure encompasses technological innovation at the frontiers of the current offerings but in different markets (e.g. ARM v8

[1] Between 2002 and 2015 ARM acquired 17 companies (ARM Holdings 2015b)

64 bit architecture for the servers market), provides room for experimentation with different business models and complementary technologies (software) and serves to explore linkages with different types of partners higher in the semiconductor value chain than the usual silicon partners.

From the structure and function point of view, an image of structural ambidexterity within ARM can be manufactured (see Figure 16 below), where ARM 1.0 is the base-line exploitative business, source of revenue and *"the life blood of the company"* and ARM 2.0 is a space for different technology, business model, markets and customers, management methods and culture *"where it is starting to become a surprise"* (ARM top executive, interview 5, 2012).

Figure 16 Structural ambidexterity in ARM. View from the inside



However, the analysis of the contents of ARM 1.0 and ARM 2.0 breaks the image of structural ambidexterity. We have seen that there is a strong alignment and continuity of ARM 2.0 with ARM 1.0 and that exploration in the business model, links with partners,

markets, new technology and the very scope and outcome of explorative search eventually has to align with exploitation, seek complementarity with the existing products and provide continuity, not disruption, to the accumulated competences. In ARM, exploitative and explorative innovations, especially in the technological domain, are more compatible than polarised and certainly not as clear-cut as ambidexterity theory conceptualises. A close look at the balance of exploitation and exploration below sheds more light on the inter-relation between exploitation and exploration than the image of internal structural ambidexterity suggests.

7.1.1.4 Balance between exploitation and exploration. View from the outside

The theoretical notion of innovation ambidexterity projects the idea of equal amounts of exploitation and exploration, more so, an equally high amount of both activities (O'Reilly III and Tushman 2004, O'Reilly III and Tushman 2008). Ambidexterity research shows that not all organisations have the resource capacity to pursue both (Cao et al. 2009, Chang et all 2011), and when they do, it is rare that such organisations excel at both exploitation and exploration. The idea of balance, or recombination, of exploitation and exploration is the centrepiece of innovation ambidexterity theory. The preceding analysis of exploitation and exploration, and particularly the examination of the more obvious explorative and exploitative structures ARM 1.0 and ARM 2.0, bring us to testing the theoretical assumption of balance as an equal, and equally excellent, pursuit of exploitative and explorative innovation. Qualitative research is not aimed at quantifying and comparing the exact measures of exploitation and exploration. This proposition is targeted and tested by the qualitative examination, which in addition to comparing exploitation and exploration activities, unpacks their inter-relation which is crucial for understanding the assumption of ambidexterity balance and transitions between the two types of innovation.

It can be immediately seen that ARM 1.0 and ARM 2.0 are not equal structures. ARM 1.0 structure is much bigger in size and *"the main focus is to be honest on ARM 1.0"* (ARM Business Development Director, interview 7, 2012). The majority of the company's staff, and particularly engineers, are deployed on advancing the existing product groups. ARM 2.0 consists of just a *"handful of people"*:

"So, if I point out at how many day to day engineers are working on ARM 2.0 and ARM right now, handful of people - there is not a lot of people doing that." (Interviewee 7, ARM business development manager)

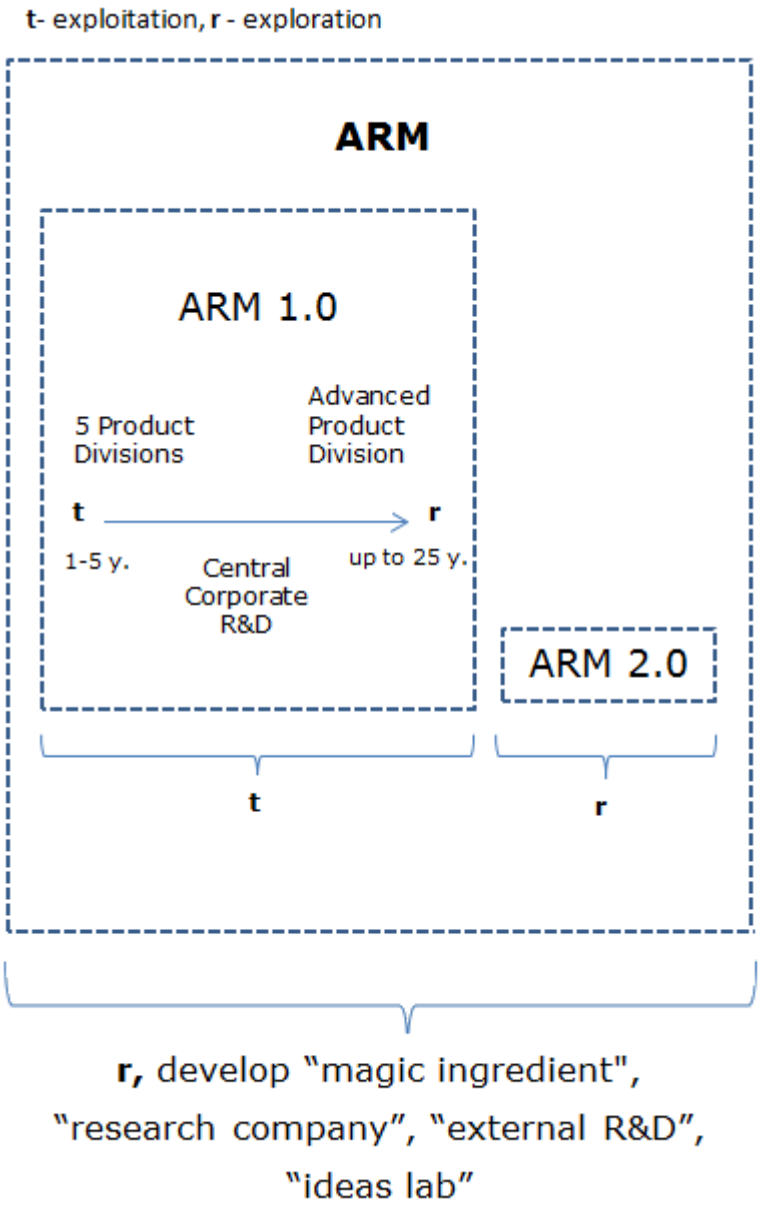
In this sense, it seems almost peculiar that in the knowledge intensive, "engineering savvy" company the explorative innovation of experimental, open-ended type is a fairly small "injection" into the main business. Moreover, customer orientation, like a reality check, is always present in ARM 2.0. As discussed above, innovations of both type ARM 1.0 and ARM 2.0 are anchored in customers' needs. ARM's IP business is inconceivable without the licensees and Ecosystem of Partners who set expectations and trends in the evolutionary of microprocessor technologies. We have seen that the crucial characteristic of both exploitative and explorative innovation in ARM is the ability to listen to and understand the needs of the semiconductor and OEM partners. Customer orientation serves as a coordination tool to interface the physically separate units of exploitation and exploration and contributes to ambidextrous initiatives. In ARM, pressures and expectations of partners in the semiconductor markets determine levels and content of exploitation and exploration that ARM will then pursue internally. These aspects matter more than the abstract ambidexterity ideal of having an equal amount of the activities.

In fact, the importance of the Ecosystem of Partners[1] to ARM and, conversely, the importance of ARM in the Ecosystem, mean that the internal view on ambidexterity is limiting. A switch of the perspective from the inside, that of ARM managers on the internal structure, to the outside, that from the standpoint of ARM's partners, reveals quite a different picture in terms of distribution of exploitation and exploration roles (see Figure 17). ARM is often seen as *"the R&D department of the entire semiconductor industry"* (Yarow 2010). ARM shares this perspective:

"To outsiders all of our engineering is R&D, because we almost like a research company. Cause we don't manufacture, we're intellectual property." (Interviewee 1, ARM senior manager)

[1] Meaningfully spelled with the capital "P" in corporate documents (ARM Holdings plc Strategic Report 2015)

Figure 17 Structural ambidexterity in ARM. View from the outside



Known in the industry for its technologically savvy know-how and for supplying intellectual property products, ARM is indeed often seen as "the ideas lab" (ARM Holdings plc Strategic Report 2010 p.26). The notable business rationale, iterated in ARM's annual reports, fuels the image of the external R&D lab for the Ecosystem: "ARM designs technology that would be difficult and expensive for our Partners' R&D teams to develop. It is more cost effective to license the technology from ARM than to develop it internally" (ARM Holdings plc Strategic Report 2013 p.17).

Innovation ambidexterity

The change of the perspective presents quite a different picture with important implications for theorising about ambidexterity. Now, what ambidexterity involves depends not only on the level of analysis, but also on the perspective from which the theorist/practitioner *chooses* to examine the level. This is good and bad news. On the one hand, it allows to describe an ambidextrous organisation from the perspective most useful for the purpose. On the other hand, it introduces one more dimension to ambidexterity conceptualisations, which does not necessarily help a systematic analysis. We see that the conclusions of what the organisation does in terms of exploitation and exploration (the organisational level analysis) depends on the perspective from which the organisation is viewed: internal (and then it is elements of the structural ambidexterity, but also the tremendous focus on exploitation) or external (and then it is the "R&D" unit, "ideas lab" and in these descriptions – the innovation hub for the industry). The important conclusion of the analysis of these structures and definitions is that no text-book definitions and structures to combine exploitation and exploration are found in this context. The notions of exploitation and exploration are blurred, and beyond the labels 1.0 and 2.0, the ambidexterity structures to support the two indistinct tasks do not resonate with the theoretical conceptualisations of clear-cut separation and equal share of exploitation and exploration. We see that already at the organisational level, the ambidexterity lay-out is not very straightforward.

In ARM's case, the boundaries between the company and its Partners are blurred. The Ecosystem underlies the business model, the organisational structure and the very purpose of the company's activities – its product development. Therefore, I view the company *as part* of the Ecosystem and as what it is *for* the Ecosystem, not as a unit of analysis in isolation. An ambidexterity analysis that excludes these relationships is reductionist and cannot be maintained. An interviewee, who offered elaborations about ARM 1.0 and ARM 2.0 structures, concludes that:

> *"The ambidextrous nature of the organisation is not ARM itself, it's the ecosystem." (Interviewee 1, ARM senior manager)*

7.1.2 Ambidexterity meets the Ecosystem

At the beginning of 2014, ARM was restructured to readjust the alignment with the Ecosystem. All product divisions were combined into a single product development team

with the aim to create a more compact organisation with a more joined-up portfolio of products that is better oriented to customers (ARM Holdings plc Strategic Report 2014 p.13). In his address in the Strategic report 2013, ARM CEO Simon Segars explains:

> *"As ARM technology is increasingly deployed by more companies into more applications, we need to ensure that ARM is organised to meet the challenges of higher expectations from more customers and more end markets. At the beginning of 2014, I restructured the Group to create an organisation that is more scalable and more accountable; one that will offer our customers a more joined-up product portfolio, ensuring better integration of our technologies in our customers' products. We therefore no longer have separate divisions, but instead a single product development team consisting of seven product groups […]." (ARM Holdings plc Strategic Report 2013 p.11)*

The Central Processing Unit Group, Media Processor Group, Physical Design group, Systems and Software Group, Architecture Group, Development Systems Group and Partner Enablement Group represent the critical parts of the integrated product development team. In the restructuring, the internal informal separation into ARM 1.0 and ARM 2.0 was *abandoned* and the language and thinking in these structural terms was *banned*. A top executive comments:

> *"We have actually **banned** use of the terminology 1.0 and 2.0 (original emphasis). And we've had a very interesting discussion as executives about the negative side effect of this […] harsh division. […] Most of the company is working on this (interviewee points at the new product groups). And ordinarily the whole WEB 2.0 is the great new thing and this thing (interviewee points again at the product divisions) is not actually good any more. This (the product groups) pays the bills. This is the most important thing." (ARM top executive, interview 19, 2014)*

This is an interesting development that for the first time shows that the ambidexterity thinking is *unhelpful* for the organisation. Firstly, because the "harsh division" does not adequately reflect *the spectrum* of innovation activities in the company and further evidence below supports this. Secondly, because the unit's title "2.0" implies

the superiority of exploration and devalues exploitation, which is misleading for the organisation. In the words of the interviewed executive, *exploitation is "the most important thing".* It is the biggest part of the business. It is the focus of the company and it is the technology that is attuned to the needs of a very diverse range of customers and is very much cutting-edge. In ARM, explorative innovation is meant to expand and enrich, not replace or overturn the innovation in the existing product groups.

Putting the Ecosystem first means that delivering on the commitment to customers with the current roadmaps is extremely important for the business. We see it once again, as we have already seen it in the analysis of ARM technological innovation, that orientation to customers is an *antecedent of exploitation*, which is key to delivering growth *today*. But the emphasis on exploitation does not blind-side ARM. ARM continues the horizon scanning activities post ambidexterity thinking. The interviewed top executive tells:

> *"I agree, if you spend your all time just worrying about today's problems and […] just doing the things that your customer is asking you to do then you are likely to get stuck in a local optimisation point (minima or maxima), but you are gonna get stuck locally. So you have to be thinking about the long-term." (ARM top executive, interview 19, 2014).*

ARM initiates explorative search, but the answers to explorative innovation lie with the Ecosystem partners. In other words, customer orientation is also an *antecedent of exploration* in the company. ARM's focus on Ecosystem should not be understood in the narrow terms of demand and supply. ARM speaks of "nurturing the Ecosystem" (Strategic report 2013, p.52, 54), that is actively engaging with a large number of diverse partners across the industry:

> *"We have 2000 people who have relationships. From new graduates up to the CEO into this one thousand ecosystem. And that 2000 is talking to every health care provider, every car company, every... The only people we don't talk to are consumers. (ARM senior manager, interview 1, 2011)*

The purpose of such engagement is to make sure that the company is developing the right technology for the partners. ARM continues to explore new market opportunities as well as develop the skills and capability of the employees so that they can engineer the

next generation of technology that will *enable ARM's customers to create innovative products* (ARM Holdings plc Strategic Report 2013 p.11).

Alignment with the needs of the Ecosystem is crucial for the success of the business *today.* Horizon scanning of the whole Ecosystem ensures that the alignment continues which crucial for *the long-term* success. The alignment with the Ecosystem, thus, serves the two-fold purpose of innovating for today while innovating for tomorrow. ARM does not need ambidexterity when it has Ecosystem relationships. Ecosystem organisational structure allows ARM to enable a wide variety of innovation (and source intelligence about future innovations) across the wide Ecosystem while its own activity remain focused.

Ecosystem relationships are ARM's strategic priority that is why the managers continue to reorganise the company to ensure the alignment. The organisation, which is itself fairly stable in its core components, audits the alignment and readjusts itself with modifications to the core elements: the technology base, business models and organisational form. In one such instance of readjustment, the rationale of ambidexterity was discarded as something that does not help the alignment, but on the contrary, misleads and does not adequately reflect the continuity of innovation processes in the organisation. What has been evidenced instead is evolution:

> *"It's about time-line. […] We had CPUs, we grew Tools as our business in its own right, the System Components have been part of this and separate on and off over the years, we started running Support as a business, we did an acquisition that led to the Physical IP. So, over time, there has been an activity of growing up. And this came up from "are we doing enough, are we thinking broadly enough?" But really this business grows new layers to it over time, but it only comes out of real work […] and we need to be constantly doing that. Pete Hutton[1] is now managing the seven general managers that ran that team. Very much focused on today, but also thinking about tomorrow." (ARM top executive, interview 19, 2014)*

[1] Executive Vice President (EVP) and President Product Groups, (ARM Strategic Report 2013, p.11)

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The evidence brings out the continuity of exploitative and explorative technological innovation, not the harsh separation and consequent hand over of explorative ideas for exploitative implementation. Exploration is the *"new layers"*, the extension of the existing business and it comes from *"real work"*, not from speculative experimentation. As before, the exploitative integrated product team is accompanied by the explorative New Businesses Development team who are looking at innovation in each of the businesses as they run.

In ARM, exploitation is connected with exploration in a very different manner than the theory suggests. Exploration stems from exploitation and is situated further on the implementation time-line. It is a different form of thinking about innovation, but it is not in opposition to the existing innovation mode. Exploration is not the opposite of exploitation, but *a way to reflect on it* and *leverage* the existing competence to a new level, at least for ARM. The interviewee continues:

> *"We have a team who are thinking in this time frame (long-term). We actually have a number of people who are thinking about this time frame. What we want to do is to develop new technologies, new businesses, new partnerships that are going to enable ARM to continue to grow. […]No business does this (interviewee showing curve up) indefinitely. So, you have to be thinking about what are you doing, what are you doing to broaden the applicability of the technology you've got, what are you doing* ***to leverage*** *the technology that you've got and* ***build new businesses?****" (ARM top executive, interview 19, 2014)*

Exploration in the classical ambidexterity conceptualisation as a single dedicated unit buffered from the rest of the on-going business has been discarded by ARM. Exploration is interconnected with exploitation and has not been confined to a single team. It is "actually a number of people" who are thinking in those terms, including senior managers whose work across functions remains important beyond the ambidexterity thinking. Ambidexterity theory does not have a monopoly on the importance of the integrating role of managers. As mentioned above, the job of the newly appointed President of Product Groups job is "very much focused on today, but also thinking about tomorrow" (ARM top executive, interview 19, 2014).

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Having abandoned the ambidexterity thinking, ARM has not dissolved the team who work at the furthest frontiers of ARM product roadmaps. However, the way of working in the exploratory team and the way of thinking about exploration has substantially changed to exclude the idea of opposition and buffered separation of the established and new businesses and to embrace more the idea of continuity.

The explorative R&D team that was started around ARM CTO Mike Muller in about the year 2000 expanded from a "handful of people" in 2012 to about 85 people in 2014. The annual report 2015 shows that the number of people working at the technological frontiers, both under the CTO and across the company, has increased substantially, with about 500 engineers dispersed across the company's units beyond the CTO's team. This exploratory work also resulted in revenue-generating businesses that were added to ARM product portfolio in a way that enhanced, not replaced ARM product lines:

> *"ARM is best known for the digital technology it provides to semiconductor companies, however, around 500 of our R&D engineers spend their time researching new markets and developing new technologies. In 2015 two of our research projects matured into revenue-generating businesses – Cordio and mbed Device Server." (ARM Holdings plc Strategic Report report 2015, p.31)*

> *"488 engineers [are] working on "blue sky" programs. ... Most of ARM's engineers are developing products extending our current product portfolio, with 488 working on new types of products." (ARM Holdings plc Strategic Report 2015 p.4)*

The re-instated focus on the Ecosystem has influenced the way the ambidexterity roles of exploitation and exploration are distributed *within the organisation*. That in turn affected the seemingly straightforward structural ambidexterity in ARM.

The Ecosystem rationale that fundamentally underpins the business model and the organisational form of ARM also influences how exploitation and exploration roles are perceived across ARM broader Ecosystem organisation. Ambidexterity roles, as well as the theoretical rationale as to what they should serve and how they should be implemented organisationally, *break down at the level of the Ecosystem*. The alignment of ARM

platform microprocessor technology to the diversity of needs of a thousand partners in the Ecosystem does not fit into the binary permutations of the kind: "we explore" in cases A with partners of type X and exploit in cases B with partners of type Y (Z, etc.). The amendments as to the domain separation in the ambidexterity in alliances literature (Lavie and Rosenkopf 2006) retain the simplified binary separation and do not hold much promise in explaining the process of *co-evolution* and *co-creation* in the Ecosystem either. Perhaps in alliances, contributions from partners to innovation are more clear-cut, but in the Ecosystem collaboration, innovation is co-creation and co-evolution. An activity to "explore" or "exploit" by either party will have a knock on effect on the innovation not only in the given domain, but across other domains of the company (business model, including sales and marketing and organisational form) as well as affect the process of co-creation of a *complex digital product* further in the value chain amongst the multiple partners.

> *"The inheritance of Partnership and innovation is absolutely a two-way street and it varies with Partners about when it drives more one way than another, but I would say more often than not it's a collaborative environment all from engineering, all throughout to marketing. It's a very collaborative approach. The only way it is possible is because of the culture of the executives from the top that empower this kind of culture." (ARM Connected Community manager, interview 16, 2014)*

This is important summarising evidence, which also highlights the mechanism alternative to ambidexterity structure, that is, the collaborative product development and Partner oriented culture exemplified by ARM executives. These mechanisms, unlike the ambidexterity, makes strong business sense for ARM:

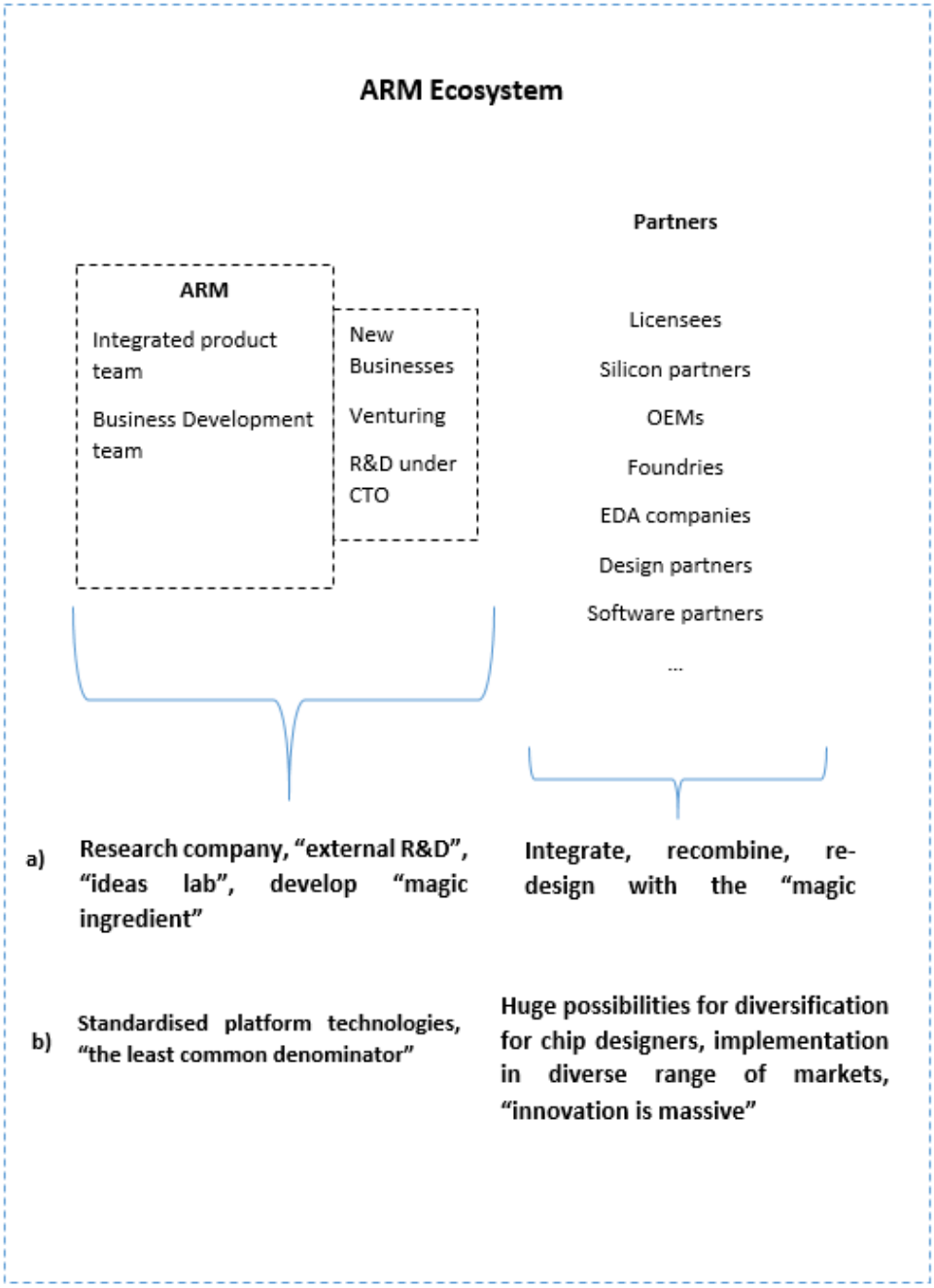
> *"I was asked by the Partners hundreds of times: "why are you so willing to offer me help? Why are all these benefits that are free?" And it's very simple: the more chips we sell the more royalty we get. Or to software companies: "If you make a better design, we will sell more products. Our royalties are built on the principle if our customers are successful, then we are successful. It's a different approach to a business model." (ARM Connected Community manager, interview 16, 2014)*

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In this emergent role, ARM culture receives an in-depth analysis in the section further below.

We are starting to see the breaking down of the ambidexterity categories. Figure 18 illustrates ARM's new organisational structure after the restructuring that abandoned ambidexterity. In this structure, as has been intended by the company, no clear ambidexterity roles and relationships can be found.

Figure 18 Breaking down of ambidexterity roles and relationships at the Ecosystem level. (Based on a drawing by an interviewed executive)



We see that internally, the integrated product team is the biggest part and the centre of the business – the group that previously in my analysis I attempted to characterise as "exploitative". I use the quotation marks for the theoretical category, because my findings now have come to differ significantly from the classical theorisations of ambidexterity. The integrated product team is closely interconnected with "exploration". Explorative teams are injected throughout the business. All "explorative" units are a fairly small

proportion of the company. Their role is not central, but strategically very important. They include the New Businesses Development team that *"is looking at each of the businesses as they run, is there more that you could do"*. It is the team that was formerly that *"harsh division of things"* which is *"developing stuff which is not products"*, which is *"not measured on revenue"* and whose outcomes have been created *"not under the pressure of product" and* which *"are fed into the roadmap"* (ARM top executive, interview 17, 2014). "Exploration" is also represented by some venturing *"the purpose of which is two-fold: it's about surveying the horizon and it's about looking for opportunities for building more layers on business"* (ARM top executive, interview 17, 2014). Importantly, venturing whose function, classically and simplistically, has been to bring a new capability (exploration) in-house quickly, can be represented on a spectrum of riskiness of innovation. ARM venturing can be more costly, because it has been *"de-risked" and is less uncertain"* (less innovative) or *"it can be a smaller investment, but the risk is higher"* (more innovative) (ibid.). An R&D group under the CTO is also looking at *"new business: long-term horizon, but what else can we do to build on [the roadmaps], how technology is gonna be used, what the company inflection points are in technology, what are <u>the opportunities to apply ARM's essence</u> (original emphasis)."* (ibid.)

In sum, the new internal organisational structure is a transformation of the previous organisational form whose elements can still be recognised, but the thinking behind the new organisation has departed substantially from the internal structural separation to reflect the closer internal inter-connection between different types of innovation activities and the orientation on the Ecosystem. In it, we see that ARM managers think about more dimensions of "exploitative" and "explorative" innovation types and their interplay than ambidexterity theory recognises.

A concrete example of technological innovation between ARM and an ARM Partner provided by an interviewed executive will illustrate the many points that *falsify* the theoretical claims of ambidexterity. I will present the somewhat extended example below. I will highlight the evidence relevant for my critique of ambidexterity and then comment on the significance of the points immediately after the quotes. The interviewee tells:

"We announced [that] we just bought the company called "Duolog"[1] *that fits here (interviewee points to the product groups). They have some technology that helps people putting chips together. The* ***company evolves as the technology evolves*** *- this is a* ***classic*** *case. You can look at a block diagram [of a chip] and you go: looks easy to me, six building blocks, you wire them up and that's it… The wiring of these chips is massively complex. And the technology that these guys have brought* ***with whom we've worked for quite a long time****, is going to help our customers to put these very complex chips together quicker. And the acquisition of that* ***came out of*** *this work (****integrated product team,*** *because Duolog helps to connect existing components), it wasn't over here (new businesses, venturing, team under the CTO – my comment), it was definitely in here (integrated product division). We see that the assembly of the chips is becoming a critical issue, our* ***customers do look to us*** *to solve a bigger and bigger problem as their chips effectively get bigger and bigger. And so it made sense to bring the technology in-house." (ARM top executive, interview 17, 2014).*

The interviewee continues:

"But this ***interface*** *(between the "exploitative" team and the "explorative" teams) is* ***very much blurred****. There is* ***a two way street of dialogue*** *between what they (the "explorative" teams) are doing and what the businesses (product groups) need. And they (the "explorative" teams) need to spend some of their time thinking about these things that maybe this team (main business) don't want them to think about, because* ***if they are not thinking about disruption, somebody else is.*** *But they also need to do things that are gonna to* ***help drive the product roadmaps*** *here. Anything what we do here (Integrated Product team) obviously have to be, similarly,* ***partly completely complementary and in some ways completely non-complementary****. Anything we do here (New Businesses, etc.) needs to be, again, complementary and*

[1] ARM to Acquire Duolog Technologies. 29 May 2014: https://www.arm.com/about/newsroom/arm-to-acquire-duolog-technologies.php [Accessed: 15.08.2017]

building on top of what we've got. So, ***this interface is very blurred****. We* ***don't have a hard line****: you only focus on that, I don't want you to look over there. Because a lot of the work goes on day-to-day.* ***There is a hell of a lot of learning that happens and the influence needs to go both ways****.* ***Where it comes together is the executive team****." (ARM top executive, interview 17, 2014).*

In the empirical reality of the company, the border between the new business and the existing product development teams is blurred and a two-way dialogue between them is absolutely essential. And this is not surprising, because this organisational picture shows that development of the existing roadmaps and new directions of the business are the aspects of the same task, not separate opposing tasks. They have to be "partly completely complementary, partly completely non-complementary" in their nature - the key dimension that ARM managers look for in their business development, but which does not sit within the conceptualisations of ambidexterity. ARM had attempted ambidexterity in its organisational thinking, but realised it did not work for them, because of all the above listed aspects that are relevant for ARM are excluded from the ambidexterity thinking. Moreover, an archetypical solution of structural ambidexterity, namely, the buffering of the opposing tasks from each other, or *"you only focus on that, I don't want you to look over there"* was exactly what ARM did not want. What the managers emphasise, and ambidexterity theory is silent on, is how to enable the cross-fertilisation of the different types of knowledge that is flowing across the different teams on a daily basis?

In this thinking of ARM that departs from what ambidexterity can offer, the example of Duolog acquisition is also seen as a *classic* instance of the company's *evolution*. What matters for the manager is the evolutionary growth of the company by adding a known complementary technology that is a great fit to the existing products and a product that customers have been demanding.

We see that on the one hand, ARM is perceived externally by the Partners in the Ecosystem as the knowledge-intensive "R&D department for the entire semiconductor industry" (Yarow 2010) from whom they source the development of costly and complex microprocessor IP. In the same vein, ARM described itself as the "ideas lab" for the broader industry (ARM Annual Report and Accounts 2010 p.26). On the other hand, it is

a developer of a standardised platform technology that consists of a relatively small number of microprocessor cores and associated technology. ARM clearly exploits its business model that is the more profitable the longer it is in place and it replicates the IP business model in other product lines. Its technology base is evolutionary and over the company's history it has not undergone radical shifts. ARM enables partners to exploit its technology in its existing form and implement it in their products to get quickly to the market. It also enables vast opportunities for recombination with partners' own technology and differentiation of designs that result in a huge diversity of end products. All these possibilities have been built by ARM into their baseline technology at the stage of R&D. This qualities of ARM technology and the interaction with the Partners mess up the conceptualisations of discrete exploitation and exploration as well as the straightforward ambidexterity solutions for the business.

We find that ambidexterity is inappropriate, or indeed, unnecessary in the broad context of Ecosystem:

> *"We're already involved in all the new businesses. We are a very sensitive organisation, we have tentacles into everybody. So one argument would be, we don't need an ambidextrous organisation, because we are the catalyst of a lot of what's going on to create new business opportunities." (ARM senior manager, interview 1, 2011)*

The ARM interviewee pinpoints another reason why the classical ambidexterity proposition does not apply in ARM Ecosystem context:

> *"The normal reasons for an ambidextrous organisation is resource limited corporations having to invest for the future whilst maintaining the present. We do have that problem. But we're lucky. By simply* ***focusing on our main business*** *(emphasis added), the risks of different technologies are taken by our customers. We get royalties from the winners and the losers. That's pretty interesting." (ARM senior manager, interview 1, 2011)*

The ambidexterity arrangements that the company tried within its organisational structure became unnecessary because its own Ecosystem business model has showed to adequately support continuous technological innovation and long-term business success – the role that ambidexterity logic claimed it does best. The interviewee continues:

> *"You could argue that the things that you are trying to achieve with an ambidextrous organisation are achieved through our business model. Because in the Ecosystem there are winners and losers, it's a Darwinian. We are providing the building blocks to everybody." (ARM senior manager, interview 1, 2011)*

The important finding that has emerged is that the ecosystem organisation, which is inextricably connected to its technology base and the business model, in ARM's case is a more adequate system to "balance" stability and change than ambidexterity. ARM's specialisation in the indispensable component of the digital electronic device – the microprocessor - makes it unnecessary for ARM to reinvent itself completely (through shifting between exploitation and to its opposite – exploration), like many of its industrial counterparts had to do when their *consumer* products became obsolete:

> *"If Ordnance Survey fails but Google maps wins, they are both ARM powered. The ambidextrous bit is, whereas most organisations have to balance risk within the company, to a certain extent our risk is spread not only across the whole industry, but all industries. So, if mobile phones become a commodity, that's OK, because iPads and tablet computers become common. […] The normal reasons for an ambidextrous organisation is resource limited corporations having to invest for the future whilst maintaining the present. We do have that problem. But we're lucky, you could argue that by simply focusing on our main business, … the risks of different technologies, different bets are taken by our customers. But we get royalties from the winners and the losers." (ARM senior manager, interview 1, 2011)*

ARM is buffed from risks by the Ecosystem which it serves. That is why it can and it does orient on evolving its technologies. No ambidexterity design is necessary.

ARM's industrial context and of course the position that the company has carved out for itself in the industry (see section 4.2) also plays a crucial role. The disaggregated semiconductor and the broader digital electronics industry are used to collaborative technology development where "exploitation" and "exploration" merge. I would argue again that in the disaggregated semiconductor value chain, this process of technology co-development and co-evolution is more than domain spanning exploitation and

exploration and partnering with companies who provide a missing capability as per ambidexterity interpretation (Gupta et al. 2006). It is perhaps the case in vertically integrated industries, where firms' boundaries are clearer and more closed, such that the companies do "buy in" a missing capability to create ambidexterity for their organisations. Industry practitioners with a broad industrial experience are only too aware of the difference between "bought in" ambidexterity and technological co-evolution in the ecosystem of thousands of technology developers. Interestingly, this central finding that I formulate in the final test of the ambidexterity proposition surfaced in the very first interview of the research project. The first interviewed ARM senior manager shared his observations:

> *"Health care system in under pressure, innovation in pharmaceuticals is generally running out of steam. I've just been with Sanofi. They've just bought Genzyme corporation, one of the world's leading genetics molecular biology. So, they are buying ambidexterity" (ARM senior manager, interview 1, 2011).*

The interview then continues:

> *"This [semiconductor] industry has completely blown apart. It's a disaggregated value chain. We license our technology to companies that design computers on a chip. But they don't make them, they are then subcontract the manufacture to massive companies in places like Taiwan where each factory is four billion dollars. And those companies then make silicon wafers. But there's then a whole different industry who do […] packaging. Then they sell those chips to Bosch, car automotive companies, who then take those chips and put them in airbags or brakes on car who then sell them to Ford. And then the software is just a whole level of complexity. So you might have a 100 companies doing what in the past one company did. And we are one of those companies. We provide a little bit of magic ingredient and everyone else does something with the magic ingredient. The innovation is massive." (ARM senior manager, interview 1, 2011)*

ARM's specialisation in the evolutionary microprocessor technology, the innovative business model powered by knowledge and the unique position in the Ecosystem organisation that the company has created renders dual-structured

ambidexterity arrangements inadequate to support the multi-channel adaptive interaction with a thousand of Partners in the Ecosystem. It would be an illegitimate attempt to try and manufacture an ambidexterity perspective onto ARM context to make the theoretical propositions fit. We see that ARM is not a text-book ambidexterity organisation:

> *"So we are not having a classic ambidextrous organisation. We have no capital investment, we only have people. Relatively speaking, people are more adaptive than machines. And arguably,* ***ARM is not ARM, ARM is its Ecosystem****. So, you can almost think in biological analogies.* ***You can think of it as ecology*** *(emphasis added)." (ARM senior manager, interview 1, 2011)*

Ecosystem should perhaps be a no-go territory for ambidexterity principles. Where firms have no clear organisational boundaries because knowledge exchange between the partners is on-going and multi-directional, and communication during technology *co-creation* is so close, it is unreasonable to fit such interactions into a binary system of ambidexterity. Ambidexterity is also quite prescriptive as to what novelty and experience are worth and what amount of these is needed for a business to be a success. Moreover, ambidexterity theory is obsessed with formal structures for organisational processes. The role of ambidextrous individuals and culture has been highly emphasises, but for something to which so much importance was assigned, it received a disproportional amount of attention relative its structures. Ecological thinking and more flexible systems to support co-evolution of technology, i.e. the individuals and culture of the relationships between them, are deemed by practitioners as more effective and important: "people are more adaptive than the machines" an interviewee notes. I dedicate to these questions the attention that they deserve in the following section.

7.2 Culture and values in ARM

In ARM Ecosystem model, the large number of customers is extremely important. In fact, ARM speaks of Partners rather than customers, because it *values* the *equality* and *mutual benefit of the business relationships*. In the Ecosystem model, ARM works closely with semiconductor companies, Original Equipment Manufacturers, Electronic Design Automation partners, designer and software partners and many other Partners to help them develop their roadmaps and at the same time aligns its own technology roadmap with what is happening in the Partners' markets. Because ARM Ecosystem includes more

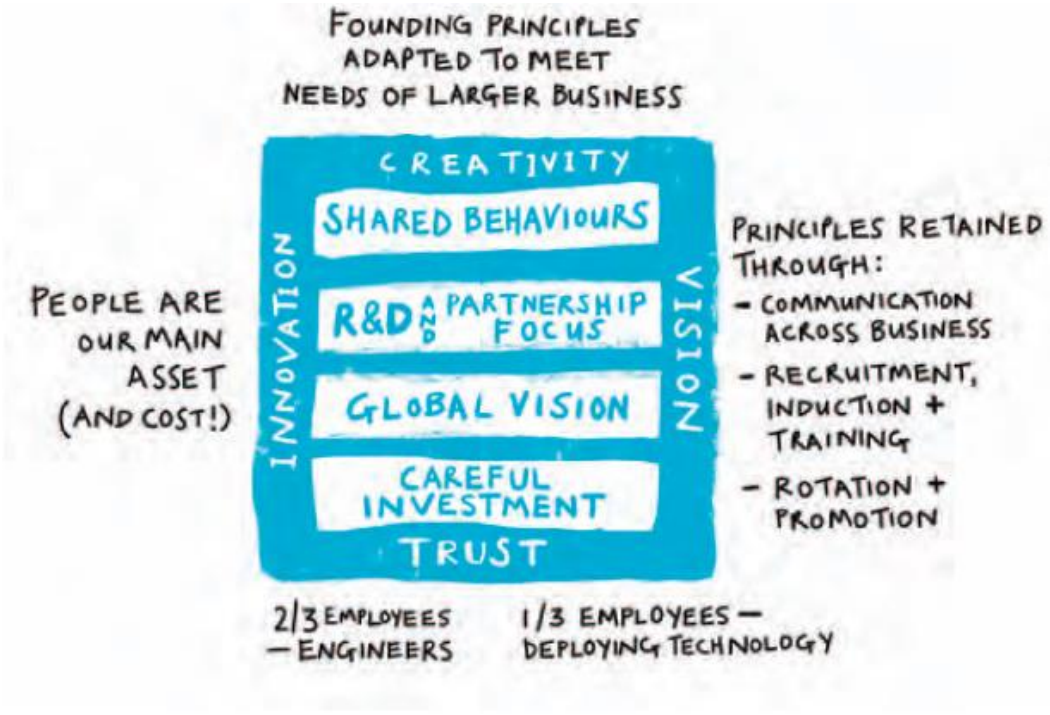
than one thousand partners, no set of formal rules can regulate interactions in this vast, diverse and constantly adapting Ecosystem. The culture of ARM becomes the underpinning system that guides interaction with the Partners and informs behaviour in the situations of uncertainty that innovation constantly creates. It is the vital element of the Ecosystem organisation whose purpose is to facilitate healthy partner relationships and more.

Organisational culture can be a powerful tool in creating exemplar behaviours. But cultures as ways of doing things and as part of organisational identities are sometimes difficult to pinpoint and their relation to the organisational outcomes is difficult to interpret. *Strong shared culture* is certainly found in ARM. It can be seen in the engineering savvy discussed earlier, in valuing its people and in the primacy given to the Ecosystem Partners. The company also has a distinct identity in the industrial landscape. The company's legacy of propelling RISC architecture to become one of the two industry-wide standards, the hidden but ubiquitous technology that it designs, its flagship Ecosystem model, and even its Britishness across the fields of the Silicon Valley, as well as Europe and Asia's semiconductor industry, create ARM's distinct organisational identity. While these are fascinating topics in their own right, here I will speak of culture in a narrower sense and focus on one of its main functions – to navigate the company in its business interactions and decisions.

Organisational culture is understood as a set of values that underlies the behaviour of individuals in the organisation, as opposed to the organisation's explicit strategy, structure and processes that are aimed at achieving desirable performance outcomes (Denison 1990, Gibson and Birkinshaw 2004, Ouchi and Wilkins 1985). In the words of ARM, "the ARM team is bound together by a set of principles and behaviours by which we operate" (ARM Annual Report and Accounts 2010 p.27). In ARM, values like orientation to Partners, trust, creativity, innovation and value for its people who drive the creativity and innovation have been understood early on. These values have been motivated by the intellectual property model for which the expert intellectual capabilities of its staff are as crucial as and the ability to recruit licensees and sustain long-terms business relationships. Managing the Ecosystem well has become vital as ARM's business has expanded and the shared understanding of how to keep the Ecosystem healthy – cultural values – has become even more important for the company. The

founding principles were formulated into clearer values and acquired a more central space in the organisation of ARM. Figure 19 below, borrowed from ARM Annual Report 2010, illustrates the fours key facets of ARM's culture and values (ARM Annual Report and Accounts 2010 p.27). Culture and values systematically feature in ARM's annual reports, which shows the strategic importance of culture for the organisation.

Figure 19 ARM values in 2010 (ARM Annual Report and Accounts 2010 p.27)



As stated above, the role of culture is to provide *guidance* in contexts *in a constant state of flux* where management by rule is impossible or inappropriate. Partly for this reason, culture can be quite broad and predicated on some central understanding about what areas in the organisation it has to support and what it should communicate. In ARM, one of such contexts is the interactions in the Ecosystem. An ARM interviewee tells:

> *"The innovation model that we have is highly predicated on the huge amounts of knowledge and market intelligence flow in both directions that comes from the relationships that are built up across a large number of companies". (ARM top executive, interview 5, 2012)*

In ARM, culture becomes the "tentacles", to use the expression of one interviewee, reaching out and sensing the needs of the diverse Partners in the Ecosystem. Another ARM interviewee puts it clear:

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> *"In order to make exactly the right decisions for the business, theoretically we need to be aware of absolutely everything that's happening in every digital market, which clearly is impossible. But we need to have a culture that makes us as aware as possible." (ARM top executive, interview 2, 2011)*

In ARM, culture complements formal organisational mechanisms for *knowledge exchange and exploration*. Or rather, culture becomes such an organisational mechanism as well. In this, cultural values are not passive baggage of the individual. They are *behaviours* that deliver agency as organisational mechanisms and incentives would. In 2011, ARM culture and values were *modified to align* better with ARM's renewed business goals. The culture and values were distilled to seven core behaviours. An ARM Vice President tells:

> *"We have seven ARM values, five actually, but we've added two recently […]: the delivery of results (1) is very important, then you've got things like team work (2), customer focus (3), proactivity (4), innovation (5), self-development (6) and responsiveness (7), so you've got seven. They are more like behaviours than actual values, they embody some more pragmatic actionable values if you will, the behaviour we'd like to see based on the values we have." (ARM Vice President, interview 4, 2012)*

For the organisational culture to serve its purpose, it needs to be genuinely shared amongst the individuals in the organisation and be in touch with their personal views, principles and ideas. Trying to impose culture from the outside will not have the effect for which it is intended – to give a platform for shared understanding and "glue" the relationships. The top-down and bottom-up consensual process of defining values safeguarded against this:

> *"So, what happened was they put a first pass to the exec, and then […] there was the subset of the exec that took their first start of ten, worked on it, circulated it around in really a usual ARM way. We've got the consensus around [that] this looks right and those became the values that we've added*

to the end of year Talent Assessment Processes[1]*, where people were switched to think about top ten key drivers […] that most highly correlate with engagement within ARM. Then changes where introduced. So, we've added it in when we believed that people would have a chance to understand and be able to employ them and demonstrate them." (ARM senior HR specialist, interview 6, 2012)*

The values can be seen on the left side of Figure 20 below. The interviewees speak about the seven internal values, because they were aimed at employees and guide the internal processes in ARM. The external values project ARM's strategy externally to the broad stakeholders from shareholders to the local communities. In any case, internal and external values significantly overlap.

Figure 20 ARM shared principles and behaviours (ARM Holdings plc Strategic Report 2013 p.10)



The process of identification of values was two-way. A list of values was proposed top-down by the company's leaders. Employees then "were switched to think about top ten key drivers" that "most highly correlate with engagement within ARM" as part of the end of year performance review, explains an ARM Human Resources specialist (ARM

[1] Talen Assessment Process, ARM's employee performance review process.

senior HR specialist, interviewee 6, 2012). The HR specialist shines more light on the process of the formulation of the values:

> *"We have the five original core values and […] they've moved over time. […] We've combined team work and selflessness together because we've added in responsiveness. So, there have been some changes there, but really they've been predominantly untouched until a couple of years ago and the recommendations for those were from Warren[1] and other members of the exec. We need a personal development value and we need an innovation value. I thought an innovation value would get a lot more push back. The general discussion was the innovation is actually inherent or implicit in a lot of the description of the other values. So, constructive proactivity was very much a big part of the innovation piece and also the delivery of results because obviously delivering innovative products." (ARM senior HR specialist, interview 6, 2012)*

The episode around adding innovation as a separate value is telling for our purpose of delineating innovation. As the ARM HR specialist reports, it was felt that innovation did not need to be emphasised as a separate value and, indeed, the proposition had been pushed back. Innovation was already perceived as an inherent element of everything that ARM did. "Innovation is grounded in today, in what we do, […] within the projects and at the point of partner/customer issues", continues the HR manager (ibid.). It is a common understanding across the company. "We are working with new technologies, so we are getting a glimpse of the future every day. […] The exciting bit with innovation is that you can't always tell. I like a bit of surprise and unexpectedness in my life, so who knows what's going to happen", pinpoints the idea the Director of Video at ARM Sweden in a YouTube video (ARM Holdings 2017). Innovation is part of day-to-day engineering work, of surveying dynamically changing markets, interacting with the diverse range of Partners, or even recruiting new talent.

The HR specialist adds a perspective on innovation in their area:

[1] Warren East, ARM CEO 2001-2013

Innovation ambidexterity

> *"I think we do focus on how we are being innovative in what we do, delivering on what business needs. […] When you're looking at recruiting somebody … we were talking about 'ARM shape' and the challenges to make sure that doesn't become the standard type. […] Inherent in that is cognitive diversity, different ways of thinking. When you interview somebody […], from an HR perspective we looking at who they are and where they worked, whether this is somebody who can work within a team and communicate their ideas effectively within that team. That they understand this weird sense for the greater good, which is the selflessness piece. Quite hard to detect but you definitely see it stronger in some than in the others when they are in the organisation." (ARM senior HR specialist, interview 6, 2012)*

Cultural fit of employees, and also companies that ARM acquire, to ARM's value system is extremely important because it creates *stability* in the system that is in place to support significant *change* in other spaces such as technology, Partner interactions and markets. Culture becomes a substrate that is stable yet malleable to support the constantly changing environment.

The presence of innovation in everyday activities across the company made it almost unnecessary to explicate innovation. This resonates with the point that types of innovation do not need to be distinguished either, as evidenced by the interviewee who said that "we don't need an ambidextrous organisation, because we are the catalyst of a lot of what's going on to create new business opportunities" (ARM senior manager, interview 1, 2011).

Innovation value was introduced as a separate item. As part of the innovation value, "innovation time" was built in the organisational design. A time-sheet code was introduced for "innovation time off" which was intended for a time off, but "people are encouraged to spend time together, to talk and interact because innovation does not work so well in isolation", the HR specialist adds. The interviewee continues:

> *"Creation, submission and then bringing [innovations] through to fruition - the classic Funnel approach - aren't particularly effective. It is about being opportunist and allow space and time for these things to happen and ideas to collide. We do believe that good ideas and innovations come from engineers*

having major insights, but also the discussion as well. […]Cause a lot of our innovation is a mix of product, technology and also business model and legal innovation in terms of licensing deals and business models. […] That was innovative in its day and we continue to push that as well." (ARM senior HR specialist, interview 6, 2012)

The values have been put in place because they are enabling the spontaneous and collegial behaviour, resulting in innovative outcomes, that a regimented activity would not be able to initiate. Importantly for our previous discussion of the distinction between exploration and exploitation is the evidence that innovation is a mix of technological, product, business model innovation as well as legal innovation in terms licensing deals and business relationships.

Part of the innovation time is the Innovation Day that a division in the company can hold to "do whatever they want: some people have got external speakers in, others might get customers in, partners in" (ibid.)

Not all values that are upheld in the company are formally articulated. For example, value of employees is one of ARM's old-time values, because people are the main asset in ARM's IP business (ARM Holdings 1999, p.3) Hence again, the importance of good hiring.

Another example of an unarticulated value is the "open door" policy. It is part of supporting communication and flow of knowledge in the company and removing hierarchy in the exchange of ideas.

"It really is an organisation where people talk about the 'open door' policy for the exec. […] Warren's door is open. He's our CEO and his door is open. And he's actively promoting open door policy. So, anybody can go up and knock on the door and say: "Have you got a minute? I want to talk to you".

You see grads from day one are introduced to the exec members, senior members of teams straight away. So, they are asking questions, they evolve, they are assertive, they are inquisitive. […] There is no barrier. […] And it's not actually described anywhere, in any of our values." (ARM senior HR specialist, interview 6, 2012)

Innovation ambidexterity

And

> *"I think ARM is very open culture, so not that many secrets in ARM. People are fairly open about what goes on. Our guys are very good at having a meeting to talk with anybody who wants to talk to them, they are not hugely precious with their time." (ARM executive assistant, interview 8, 2014)*

As a side note, the "open door" policy is a good example of how some values work best when people are not reminded that this is something expected of them.

At this point, it is worth mentioning that ARM was named the second Best Place to Work in the UK by the reputation and job site *Glassdoor* on the basis of anonymous on-line reviews by ARM employees (Glassdoor 2017b). Similarly, ARM CEO Simon Segars was ranked in 7th position on the list of the Highest Rated CEOs in the UK with a 96 per cent approval rating amongst ARM people (ARM Holdings 2016a, Glassdoor 2016). The employee reviews that generated the ranking covered pros, cons and advice to management about working in ARM. The high rate of approval amongst ARM employees suggests that the company is indeed internally aligned in terms of what employees value (Glassdoor 2017a).

Responsiveness, diversity and participation are the values that *serve organisational flexibility* and *accommodate innovation.* Inclusiveness and consensus extend from open-ended exchange of ideas to action-bound decision making. Diversity of viewpoints is purposefully introduced in decision making to safeguard from the two common dangers:

> *"If you've got any one person just having to make decisions on their own the chances are extremely high that a) you'll get it wrong, which of course you get it wrong sometimes and that's fine, but you get it wrong consistently in different ways and (b) you won't spot it. You will fail to spot the trends that […] are little small issues now but are going to develop into a bigger issues that will cause the demise of your business in 5 years' time." (ARM top executive, interview 2, 2011)*

The fear "not to spot it" is particularly interesting because it has become common in the modern high tech industry, although it is not exclusively a high tech phenomenon. Companies are constantly *paranoid* that something has changed in their environment and they are not going to spot it (Grove 1996). The leader is often the last one to know,

because most CEOs are "in the centre of a fortified palace, and news from the outside has to percolate through layers of people from the periphery where the action is" (Grove 1996, p.22). That is why ARM invites people from across the company into the decision making process. The CEO and ARM team are always on the ground in industrial conferences and exhibitions, some of which are run regularly by ARM for the industrial community, such as annual ARM Partner Meeting and ARM's technical conference TechCon, which have been regarded as extremely important by the interviewed ARM managers and Partners alike. This way, ARM make sure that they expose themselves to the changes in the environment and to evaluation and critique both from their "friends" and "enemies". The Ecosystem model itself both enables and demands this. ARM's culture of putting the Ecosystem first is the antidote to complacency that success can breed and key to the health of the business. Keeping close touch with the Ecosystem also allows ARM not to feel threatened by change. In the words of an interviewee:

> *"What I would say is that we've been that sort of classic British company of not being aggressive towards our competition. We've had good products that people have wanted to buy and had merit, [there] wasn't really a trick. But we've never been paranoid in any way." (ARM business development director, interview 7, 2012)*

In ARM's culture, being open to diversity and participation is combined with focus on execution:

> *"There is definitely a culture of being able to challenge anybody, but obviously at some point the decision will be taken, and then it's completely top down decision even though some of the people don't agree. But again, ARM tends to look at what is the majority opinion in this case. Well, this is consensual, if the majority of the engineers or if the majority of the function thinks this is the right decision, then it's probably where this decision will end up, even that some people might not quite agree with that." (ARM Vice President, interview 4, 2012)*

Execution does in fact remain the main priority. Innovation is important, but ARM iss business with a commitment to a large number of customers, that is why the delivery

of results to the customers is the priority. Delivery of results is the value number one. An interviewee points out:

> *"We have 'innovation' as well, as the seventh. But as I say 'delivery of results' is seen as the most important one, that one has been called out especially first out of seven. And the reason for that is that in the end we are business, we try to achieve things, so innovation is very important, but if you don't deliver your results you have agreed to, especially when it comes to customers, then that's seen as very bad for our reputation. That's why 'delivery of results' has been from day one one of the important attributes of our business." (ARM Vice President, interview 4, 2012)*

The values of the delivery of results and partner focus *serve organisational stability*. ARM is also *"very down to earth and hit your mile stones, please"*, points out an executive of an ARM acquired European company who continues:

> *"We had product plans that we agreed upon that we should deliver to hit certain milestones, pow pow pow. Those were of course tracked and we had financial milestones, sales milestones. And ARM is pretty good at tracking. There is no rocket science in that, […] and I think ARM in general is pretty good at executing" (former CEO of an ARM acquired company, interview 9, 2013).*

In parallel to ARM technological innovation that focuses on the current product roadmaps, ARM culture emphasises, or in fact is there to support, the delivery of results. But just like in the domain of technological innovation, in the relationship and culture domain, "it's a very very simple little thing that makes a big difference" emphasises the HR manager. For example, the responsiveness value ensures innovation: that one remains alert and perceptive to changes in the environment, so that innovation is not overlooked. "In the relationship capital, it makes a huge difference if you are responding quickly. And people often take it to extremes, they respond in all times of the day and night", the HR specialist concludes.

We see in the analysis that ARM organisational culture is mirroring all aspects of the organisational structure and strategy, in one way or another. ARM *vision*, for example, reflects the company's growth strategy:

"The vision originally was about being 'the Architecture for the Digital world' and […] that's really been achieved. So, the vision now is about having ARM technology being used everywhere to enhance people's lives. We've got 95% market share in phones, so there is not much more to do there. But […] we've actually got about 30% total market share of all digital electronic equipment. So, to use the ARM 1.0 and 2.0 analogy I think that the core vision is to take what we have built up and nurtured over 20 years, those ARM 1.0 businesses, and take that to its logical continuation as far as we can […] Into new markets like servers and all these thousands of the computers that are going to be sprinkled around everywhere in Internet of things and bridges and medical technology and all this kind of thing. There is a huge amount of potential there for life enhancing products to be created that we can get this technology into." (ARM top executive, interview 5, 2012)

Culture becomes the more perceptive and flexible "skin" to the formal organisational structure. It is a malleable "cover" that encompasses the formal organisational structures and is the first to respond to the changes in the environment while preserving the self-identity, before more formal organisational arrangements to support change are introduced.

Culture becomes *the glue* that holds the elements of *stability* and *change together*. In ARM, the organisational culture also encompasses a strong technical culture – the engineering savvy discussed earlier. The inextricable inter-connection between ARM technological products, its business model and the Ecosystem organisation gives ARM a unique profile that differentiates it from other players in the industry. Because ARM's culture is unique to its organisational circumstances, it is difficult to replicate or imitate by others. ARM's continuing success depends on maintaining the healthy relationships with the Ecosystem Partners. What is critical is that when it comes to "nurturing the Ecosystem" (ARM Holdings plc Strategic Report 2015 p.52, 54), values are more effective than formal organisational arrangements. ARM's values embrace the crucial aspects of partner relationships:

"Technology leadership and a kind of excellence and being humble, I think these are two kind of words that come around in our brand. We are leaders in industry, we do try to become very normal, one way humbling our

leadership if you will. It comes back from somewhat focus on our customers. It's not about us, it's about our Ecosystem. It's about the larger industry." (ARM Vice President, interview 4, 2012)

It must be noted that ARM's humble culture has been said by the interviews to stem from its Britishness (CEO of an ARM acquired company, interview 9, 2013; ARM Community Manager, interview 16, 2014). A European and an American interviewees have described ARM to be "very British", notwithstanding the company's global presence with offices spanning the USA, China, India, Japan, South Korea, Taiwan, eleven European countries and South Africa. The British Chief Executives and the Engineering headquarters in Cambridge set the example of *"not shouting from the rooftops about our success"* (ARM top executive, interview 17, 2014). When it comes to the British business culture, it is about doing it, not talking about it, as opposed to the American business culture, for example. An ARM Partnership manager shares their opinion:

"I would say ARM would have not been successful had it been an American company, […] part because of being humble is part of the British or English culture. It is not that they are not as prideful, it is not that they are not as competitive. They just don't have to say it out loud, which is, overgeneralised, is typical American. […] I would say that some of the challenges, but also success of ARM has been its focus on its key priorities and its key priority is ***not its fame***. ***It's focus on the technology and things are shifting*** *[…] (emphasis added)." (ARM Connected Community manager, interview 16, 2014)*

Thus, humbleness serves ARM the same purpose paranoia served Andrew Grove, quoted above, in leading Intel – to watch out for the shift in technology. Humbleness is also the quality that helps span international locations and deal with the cultural issues that inevitably occur. It is arguably another reason that makes ARM a British company, but also "not quite typical" (ibid.) British company, because what ARM has created with the culture in terms of the global multi partner Ecosystem organisation is quite unique. The Partner Manager continues:

"I worked with different American companies in the ARM Ecosystem and some of them are very outgoing, some of them are very brash, some of them are very forthright, and that's their approach [that] makes them interesting. But then there are companies in our Ecosystem that are humble – sure. And have I seen culture conversations […] within our team that take a while cause there are culture issues going on – sure. ARM has a very wide set of employees. When I meet partners based in other countries, there is almost always a local representative […] who are very supportive of how to delicately work with that partner. I throw out an idea and it won't work for them because it's against their culture, it's against typically of what they do. One of the great things about ARM is it's a very diverse population, […] a very different mix of people. Offices are different, they have very different culture, but it's still ARM."(ARM Connected Community manager, interview 16, 2014)

Since culture matters so much for the health and long-term success of ARM's business, ARM continuously fosters it. In 2015, ARM's organisational values were transformed once again to put even more emphasis on the Ecosystem. Values are an underlying system and every now and again the message behind them needs to be brought to fore, refreshed and realigned with the changing circumstances of the business. The new values put even more focus on the Connected Community and speak of the collaborative partner-oriented culture in a more embracing way (ARM 2017b):

"There's nothing ordinary about ARM. Our collaborative culture, unique partner ecosystem and our innovations that shape the connected world are all as extraordinary as our people". Our core beliefs, which lie at the heart of the business, are encapsulated in three simple phrases. They are the principles that guide how we work together to deliver results with global impact:

We, not I. We believe in collaboration first, egos last.

Passion for progress. We create innovation to make lives better.

Be your brilliant self. We stand for individuality, performance and fun." (ARM 2017b)

Figure 21 New values and culture of ARM (ARM 2017b)



In the fast changing environment, culture becomes more superior to management by the rule in instilling *organisational behaviour* that lead to desirable organisational outcomes. In the words of an employee of an ARM acquired foreign company:

> *"Culture builds strategy every day. A successful company is successful because of its culture, not because of its strategy. The strategy you can change, but culture is in the walls ... you have to convey the culture to your different sites and that's challenging to do. I think ARM did fairly good job in that." (Former CEO of an ARM acquired company, interview 9, 2013).*

Culture in ARM is aimed at shaping organisational as well as individual behaviour. It is communicating ARM's ethos to the outside, but is also strongly connecting to the individual in the company. The significance of the culture is that it percolates through all levels of the organisation. As a contrast, an organisational mechanism to initiate a certain activity in the organisation would only concern certain groups of individuals. A genuinely shared culture brings all levels of the organisation into alignment and aligns the organisation with its environment.

This is a major task which itself needs to be carefully managed. While the ambition of ARM is to instil this perception for a multifaceted, fast changing, uncertain environment in every individual, the agency of initiating and fostering such culture lies with the company's leaders. It becomes critical to develop this kind of human capital:

> *"And then from more of an individual perspective, the ability of managers and leaders to operate in those two styles of work well and identifying people who can handle that ambiguity. It's quality and management of leaders. (In ARM) we talk about techno-commercial leader. So, one of the other challenges is how you develop those people. How we can we improve the*

quality of what they do and how can they (get) the right culture and enable people who can work in that ambiguity". (Interviewee 6, ARM HR senior manager)

Finally, two themes have emerged from the empirical analysis of the culture that encompass the various discrete values of working in ARM. Interestingly, they resonate with the familiar theoretical conceptualisations:

"We've always talked about culture being a combination of hard work and fun. And when we've looked at it, another key driver […] in our top five is challenging and interesting work, and that maps most strongly to fun. So, within ARM, the concept of fun is about challenge of the work. So, this is where the innovation piece, the creativity, the opportunity and freedom to be creative comes. Very important in ARM as well. And that presents a lot of people with a challenge, cause some people can't reconcile fun and work." (ARM HR senior manager, interviewee 6, 2012)

This has been voiced in 2012, but the modern ARM values have preserved these values and combined them with the inclusive collaborative environment – within and beyond ARM:

"We're talented individuals who challenge, encourage and learn from each other in an environment that combines high performance with fun."(ARM 2017b)

Hard work, high performance and fun clearly echo March's "efficiency, implementation, execution" and "experimentation and play" (March 1991) – the backbone of ambidexterity theory. The ambidexterity proposition that fun and hard work are difficult to reconcile is also noted here. We find ambidexterity themes present in ARM's culture, just as we saw elements of the structural ambidexterity in ARM's organisational form at some point. But here again, they are used as archetypes, "umbrella" terms, or one word characterisations of the different styles and aspects of work that is going on across ARM's broad organisational context. "Hard work" and "fun" are the two broad spectrums of activities that the culture highlights, that are otherwise too broad, diverse and interconnected (just like "exploitation" and "exploration" in the organisational units) to be broken down into discrete actions and processes across the

company's blurred boundaries. Culture, like the ambidexterity themes in it, does not make sense when it is prescriptive and fixed hard and fast on paper. It is lived in real-life organisational contexts and experiences of the individuals, which are complex and fluid. An interviewee tells:

> *"There is a shared understanding of innovation as outlined in the values. That's written down in paper. But also the reality of that and real life experience, part of why ARM is a success it has been. We are continuously improving. It's not just big light-bulb moments, the 'we are changing the world' innovation, but incremental innovation and recombination of ideas to make things better." (ARM Learning and Development Consultant, interview 11, 2013)*

Culture is the glue that holds the elements of stability and change together. These elements include "continuous improvement", the "'light-bulb' moments" and "'changing the world' innovation", "incremental innovation" and "recombination of ideas to make things better". It is reliance on the accumulated experience that led to current success and being perceptive to shifts in the industry. It is a diversity of employees across countries and continents who are all still ARM. Culture is a mix of all these things. It is also a combination of written down values and shared understandings. It seems logical that only a mechanism that is itself flexible, encompassing, non-prescriptive, responsive and dynamic, like such culture, can adequately deal with the complex, dynamic environment with a large number of diverse participants and with the technological unknown: technology that is being conceived, its unpredictable uses and markets that do not yet exist.

I started this section by saying that cultures are notoriously difficult to define. The organisational culture of ARM stems from the unique inter-relation of its engineering expertise, the IP business model and the Ecosystem of semiconductor companies, original equipment manufacturers, developers, telecommunication companies, technology "DIY" community users and many others that ARM assembled over the years. It is key to the success of this business to put the collaborative relationships first, alongside delivering technological excellence to the Partners. ARM becomes a humble leader who emphasises the commitment to deliver on partners' needs and whose humbleness helps it to stay receptive to the shifts in the industrial landscape. ARM is *responding* to and *enabling*

innovation in the Ecosystem, while its own activity remains focused. For ARM technology base, there is a lot of value in *exploitation*. ARM culture does not inflate the value of innovation and does *not* exercise in *exploration for its own sake*. There is no job of a futurologist at ARM, because *"there is a point beyond which you are […] not knowledgeable enough to have an informed view"* (ARM top executive, interview 3, 2011).

In ARM's broad industrial landscape, uncertainty is navigated with the help of culture; certainty is managed by straightforward processes of execution. ARM managers deal with more dimensions of stability and change than the ambidexterity framework with its dual categories of exploitation and exploration is able to capture. In ARM's partnership organisation, management becomes an informed improvisation rather than applying the rules. It is "flying manually", not on an "autopilot", with culture guiding individual as well as organisational behaviour within the company and across its broad boundaries. Intangible values underpin tangible actions and processes that are executed to lead to the desirable business outcomes. The partnership culture becomes an extremely important organisational mechanism for ARM because it enables the partnership organisational form that is arguably the best way to evolve and manage the modern complex networked digital technology where no single product can be created by the efforts or any one company alone.

7.3 Other metaphors to understand innovation in the company

Metaphors are a way for an organisation to make sense of themselves, their activities and their relation to others in an intuitive and succinct way. Organisational ambidexterity is a theory and a managerial tool, but it is also clearly a term with a metaphorical meaning. The word "ambidexterity" is translated from Greek as two right hands and signifies the ability of a human to use both hands equally well. This meaning is transferred to the ability of an organisation to be equally good at exploitation and exploration (Duncan 1976, Tushman and O'Reilly 1996). The term creates an intuitive understanding of what the ability is and carries with it the assumptions of what is equal and what it is to be good at, as well as the proposition that it is a desirable skill to have. The latter, strictly speaking, is also a tautology, because doing two things well is of course better than doing them mediocre, or one well and the other one poorly, or doing only one

thing. The term may create a clear mental picture, but, as we have seen, it is far from creating a clear theory and does not pan out clearly in organisational reality.

The expression "ambidextrous organisation" was reported by the interviewees to have been used by ARM to describe the ARM 1.0 and ARM 2.0 organisational separation at one point in time. The use of the term by some top managers is in fact something that some ambidexterity scholars said would not happen (Birkinshaw and Gupta 2013, p.290). The empirical research gathered no evidence to allow me to establish whether theoretical ambidexterity principles were used to inform the ARM 1.0 and ARM 2.0 separation, but the ambidexterity terms were definitely used to describe it. We have seen that the phrase was often used to give the language to the company to understand the different strategic priorities of the business in more vivid terms. For this reasons, ambidexterity was more a tool of description than a basis for interventions. In other words, ambidexterity had a metaphoric use. Importantly, the idea of ambidexterity circulated in the managerial parlance in ARM for a finite period of time. The ARM 1.0/ARM 2.0 separation was reorganised and the language was forgotten, or to use the words of a top executive, it was *"banned"* (ARM top executive, interview 19, 2014). The metaphor, and the underlying rationale to whatever extent it informed the organisational design, had served its purpose while it lasted.

Ambidexterity was not the only metaphor that has been used by the company to understand its processes, strategies and relations. ARM uses many others, and indeed again, to different degree relies on the logical rationale behind the expressions. However, what is true of all these metaphoric tools is that they always serve well the purpose of providing an immediate and vivid picture of the phenomenon that they refer to. Here are the few examples of the metaphors in use by ARM that I have come across in my empirical research.

The cake/pie metaphor conveys the logic of growing ARM IP business. ARM managers say that ARM's growth strategy is not to make their slice of the cake bigger (ARM market share), but to grow a bigger cake (Ecosystem) and have a bigger slice of the bigger cake that is the markets of ARM Ecosystem partners:

> *"The more people participating in the value chain, the market grows more quickly. [We are] trying to make the best possible technology, our*

> *engagement […] is about growing the size of the pie, not increasing our share of the pie."* (ARM senior manager, interview 14, 2014)

"Growing the pie" strategy featured in the keynote of ARM Fellow and Vice President of Technology in the Media Processing Group Jem Davies at the Fusion Development Summit of AMD (see Figure 22 below) (Davies 2011). Growth strategies were a much discussed topic in the Summit, so ARM illustrated theirs with the metaphor: *"The best way to make more money – more pie – is not to try and bake pie all for you (locked into proprietary technology), but get a slice of a much much bigger pie. Grow the pie, get more in your slice – everybody wins"* (ibid.).

Figure 22 A presentation slide from keynote of ARM's Jem Davies on Fusion System Architecture, aka Heterogeneous/ambidextrous architecture (combining Intel x86 and ARMv8 cores)



Coincidentally, this is where the *metaphor* "ambidextrous" was used again, this time to refer to the fusion system architecture that uses both ARM v8 and Intelx86 cores, which was the subject of Jem Davies' keynote speech (Davis 2011). This is another instance of application of the ambidexterity metaphor by the company.

The skyscrapers metaphor is also used in ARM by the managers to describe and distinguish the different types of businesses that ARM is building:

> *"We describe the current ARM business for which we're known as skyscraper. And what we need to do is to develop new skyscrapers. […] But the metaphor that we've used is that we've built a really nice skyscraper and we got to keep it nice, make sure that the lifts works and it gets even taller. But in the same post code or zip code we need to start developing new*

businesses which could be bigger than the current skyscraper in 10-20 years' time."(ARM senior manager, interview 1, 2011)

But most interestingly, the interviewee neatly lays out "the skyscraper" metaphor on the ambidexterity principle:

"But in order to do that we need to give them the freedom to develop in a different framework than the skyscraper. Because if keep using that metaphor, the next skyscraper may need to be a completely different building: it may need a different architect, different food contractors, different builders. It's exactly ambidextrous organisation concept, but it's saying that one bit of the company is basically the discipline execution, very innovative but current road maps. And this one is unknown, it's ambiguous, it's unpredictable."(Interviewee 1, ARM senior manager)

The "skyscraper metaphor" appears to be simply another way of describing the different goals and needs of the business. Ambidexterity is the other possible way, which leaves the question whether it is on par with the analytic rigor of "the skyscraper" metaphor. It is also evidence that the notions can be easily tweaked.

The central rationale behind the ambidexterity separation of *exploration* from exploitation been long been captured by the manager on the ground in the expression "Skunk Work project" (Gwynne 1997), which has also has been mentioned by ARM's employees. The expression refers to a place specifically isolated from the rest of the organisation to encourage employees to research and develop a radical innovation. The actual historical event being that a closely guarded incubator was set up next to a plastic factory that produced strong smells, triggering the description with all its metaphoric power that such projects are an unpleasant thing to do, both literally and figuratively. In ARM, the description was applied to small explorative projects within ARM 2.0. It is framed not in derogatory terms, but as something that was encouraged as part of the main business and part of ARM's culture:

"I mean one of our product lines now is actually something you know, R&D, skunkwork kind of project which a kind of took off and then became a commercially viable thing to go down. We are a small organisation, (but) that is a massive demonstration of how there is the kind of permission within the

> *organisation that it is the right thing to do. We need individual kind of ownership of it rather than saying "right, ARM says it's ok to do". (ARM Learning and Development consultant, interview 11, 2013)*

An ARM Partner also mentions that their organisation uses the same managerial principle of buffering original ideas from the normal working environment, which may be a claim of organisational ambidexterity working, but the organisations uses the language of the "skunkwork" project:

> *"Some of the products which are focused in automotive originally came out of that group (in our company) that's actually … it's not really a research. It's kind of like skunkworks. This group exists to come up with radical ideas. They are constrained by resources and budget, but they don't have a definite revenue return in a short period of time, whereas obviously the product divisions do have to have that. Their revenue has to balance their budge more closely" (ARM Partner, interview 19, 2014)*

This is another organisational metaphor to describe what is essentially the structural ambidexterity's buffered exploration.

The *allusion* to the biblical story of *David vs Goliath* has also been made by the managers in the company, as well as by ARM partners, to describe competition between ARM and Intel, or in more general terms, the competition between the two organisational models that they represent. ARM usually has been seen as the small and less powerful David, whose perceived disadvantages in fact help it to triumph the giant Goliath Intel. Intel's predicament also exemplifies the central idea of Christensen's "Innovator's Dilemma: When New Technologies Cause Great Firms to Fall" (Christensen 1997). Namely, that large, seemingly unassailable, incumbents find it almost impossible to compete with new entrants when the technology or business model that they offer represent a radical shift away from the established practice. At a certain point, the new entrants' products become good enough to address a particular need in the market and over time, offer a significant benefit to a growing number of customers and eventually steal a substantial market share from the incumbent. For a long time, Intel ignored ARM because ARM did not appear to be a threat to Intel. ARM was seen as the small guy with the niche technology and the business not remotely as profitable as Intel's. But in the end,

like in the biblical battle, the advantages of the small David have become powerful to contest the much bigger and stronger adversary.

An interesting interpretation on the comparison to David and Goliath is the insight of an interviewed Partner that *"in the David and Goliath problem, what Intel doesn't realise is that Intel is actually the David. It thinks it's the Goliath, but it's the David. Because it's not Intel versus ARM, it's Intel versus all of ARM licensees. And I think that this is the problem that Intel don't realise that they are the David, not the Goliath. They still think of themselves as big." (ARM Partner, interview 19, 2014).*

ARM's senior manager sees the competition with Intel the same way. ARM's Ecosystem advantage gathered momentum to give ARM crucial strength.

> "*When Intel go after ARM, it's not just ARM. […] That's the key thing. It's Intel versus pretty much the entire semiconductor industry. So, if ARM was to die tomorrow, that wouldn't just be making Intel all of a sudden a greater good. That would be impacting a very large, several hundred of our customers and that what's makes me confident that the industry will sort of rally round to sort this problem"*. (ARM Business Development manager, interview 7, 2012)

The Cambrian explosion was also used rather metaphorically to describe the diversity of new forms of ubiquitous computing that ARM designed miniature microcontrollers and connectivity and security technologies enabled. It vividly refers to the stage of the technology evolutionary development that brought about the Internet of Things. The parallel to the Cambrian explosion has been analysed above in the thesis (Section 5.5.2) Here, I will argue once again that seeing a deeper logical connection between the IoT and the Cambrian explosion seems ungrounded, because of the differences in their respective environments and the factors that triggered the events.

Finally, *the Switzerland of the Silicon world* is one more metaphor used by the ARM interviewees to describe ARM's position in the industry:

> *"ARM is a very open system. It's very small, it's two thousand people influencing an industry which is trillions of dollars. It's quite an odd company. I would describe it as the Switzerland of the Silicone World. Switzerland is a small country.. with United Nations. It always had a lot of influence, whereas as a country it's nobody, it's tiny. So we're the same, […].*

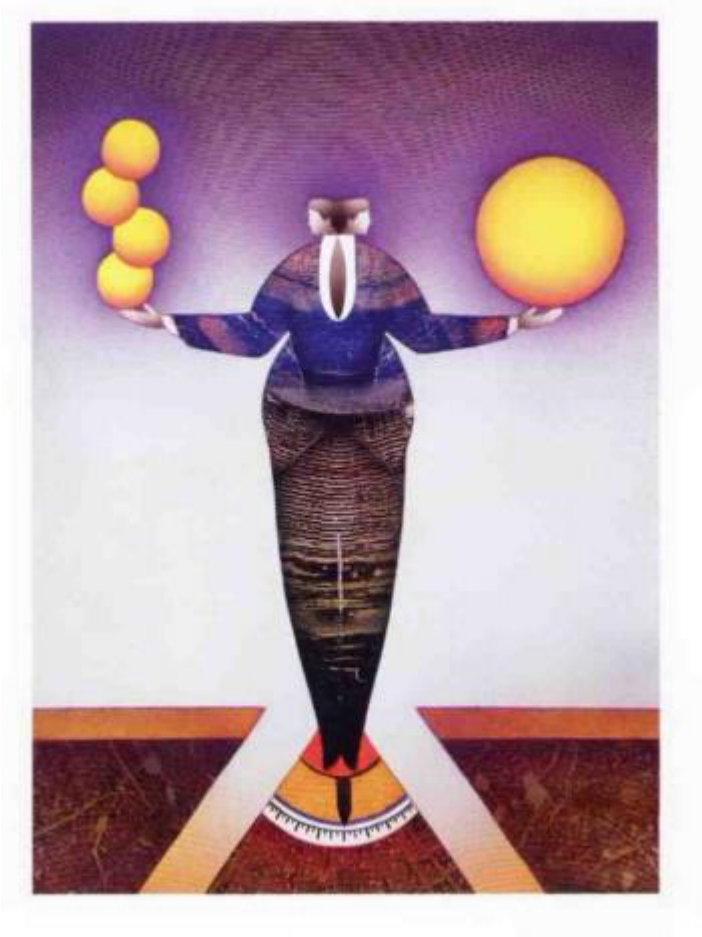
We are very influential in diplomacy. But we are not big in terms of revenue. So, the point related to your subject, is that in some ways, we are an adaptive organisation in many ways. Because as an IP organisation we are not locked in to current resource like factories. We are locked into relationships with everybody." (ARM senior manager, interviewee 1, 2011)

The metaphor vividly describes *some* aspects of ARM's position in the industry, but clearly does not fully and adequately reflect ARM's position in the Ecosystem of partners. Here, the metaphor "Switzerland of the Silicon World" *has a limited extent* to which it applies to the real-world context. It is true to all the metaphors named above. It is the nature of a metaphor to highlight *one, often the most vivid or the strongest, similarity* of the objects compared.

The similarities between the above mentioned organisational aspects and the phenomena from other spheres of human activity are figurative, that is, metaphorical. However, the problem pertinent for this research is the constant attempt to look for a deeper logical connection between the phenomenon whose attributes are borrowed and the organisational context to which they area applied. Academic research seems to be an attempt to look for further similarities, based on the mental image that the metaphor has created, and to attempt to extend further the metaphor that has captured some key feature of the empirical phenomenon well.

In case of ambidexterity research, there are also risks in being guided by the semantics of the term, creating ungrounded assumptions and biases of what is to be found in an empirical context. The assumptions arising purely from the semantics, such as the assumption of equal and simultaneous proficiency, as well as the superiority of being ambidextrous versus not having the skill, are clearly the key drivers in the ambidexterity research. The danger though is that the theoretical propositions stem from the semantics and the metaphoric imagery, such as of the "ambidextrous juggler" in the Figure 23 below (Birkinshaw and Gibson 2004) – not from the contexts of organisations.

Figure 23 Birkinshaw and Gibson's ambidextrous juggler (Birkinshaw and Gibson 2004)



Another major problem of using the term "ambidexterity" is that the research is expanding rapidly, but the limited frame of "ambidexterity" term cannot hold the findings that add more and more facets that are not in line with the initial assumptions tied to the semantic attributes. Ambidexterity of various fluid types of learning across various organisational boundaries is nonsensical.

Given that a number of vivid metaphors is used in ARM and that they are indeed helpful to clarify and communicate some of the organisational aspects to some extent, perhaps ambidexterity terminology in ARM is helpful when it were applied in the same metaphoric capacity as the "pie" growth strategy or the "Switzerland of the Silicon World" organisational form.

7.4 Innovation ambidexterity under scrutiny

In this chapter, I have reviewed the structures and processes in the organisation of ARM that can be considered representations of *exploitation* and *exploration* in an *ambidexterity design*. I examined the internal organisation of ARM and also ARM's broader Ecosystem because they are closely interconnected and the boundaries between them are blurred. "ARM is not ARM, it's the Ecosystem" and "Partnerships is in ARM's DNA" are the evidence from the interviews. The organisational level analysis and the test of ambidexterity in ARM's internal structure inevitably expanded to the level of ARM Ecosystem.

I have also examined the culture and values of the company to see to what extent they resonate with ambidexterity theorisations. Here, I draw conclusions about what the findings mean for the balance assumption of ambidexterity and the theory's central claim about the value of ambidexterity for the organisation: that the best, or even perhaps the only way to sustain organisation performance and growth is to pursue high levels of exploitation and exploration simultaneously.

First, I found that an informal internal separation into ARM 1.0 and ARM 2.0 types of business existed in ARM with the rationale to buffer the long-term innovation from the day-to-day revenue-driven product development. The structures and the rationale do strongly resemble structural ambidexterity. ARM 2.0 was a dedicated unit grouped around the CTO, it was not product driven and not assessed on revenue generation. However, contrary to the ambidexterity theoretical conceptualisations, ARM 2.0 was a significantly smaller unit and the ARM 2.0 type of innovation was a fairly small proportion of the business. Moreover, all exploratory activities of ARM were rooted in the main SoC competence, and had to have a strong relevance to the existing product maps. There was a temptation to call ARM 2.0 the "blue sky" research, and it has been subsequently done so to convey the spirit of the innovation, but the actual work was always rooted in ARM core competences, had a clear complementarity to ARM existing businesses and, most importantly, was engineered to meet the customers' needs, not out of open-ended experimentation and play. In this arrangement, ARM 1.0 was the explicit focus and the priority of the business.

Innovation ambidexterity

Further, I found that the ARM 1.0 and ARM 2.0 separation was abandoned and the ambidexterity terminology was banned. This type of thinking turned out to be unhelpful for the company, because it highlighted differences and disconnection between the innovation types, not complementarities and gradual enhancement that was important for ARM. Worse than this, ARM's own ambidexterity terms ARM 2.0 vs ARM 1.0 implied superiority of "the next great thing" and devalued the existing technological competences and relationships built into that ARM has so carefully created. ARM was not experiencing problems that the structural ambidexterity solution would aim to resolve. It was not facing the kind of problems that resource limited organisations designing conventional consumer products do. Its priority was not to re-invent itself and not to replace or overturn the old established products with new discoveries, but to continue to serve the needs of the customers and advance innovation in the Ecosystem, where the risks of product success or failure were taken by the Partners. The implication for the test of the ambidexterity balance is that no such thing exists in ARM. The units are not equal, not equally relevant, and must not be separated to suggest that they need to be balanced. The innovation for today had to be connected with innovation for tomorrow in the first place.

The existence of additional explorative units (Advanced Product Division and Corporate R&D) within the structures designed to be exploitative (ARM 1.0) is another evidence to falsify the structural separation and the balance idea. The proximity of explorative and exploitative innovation was due to the fact that the learning in the process of innovation is always two-way: not only explorative ideas feed into the next generation product development, but so does day-to-day exploitative work opens insights (into engineering the technology or market trends, for example) that would not be discovered without the deep understanding of the current businesses. In this sense, exploitation and exploration are not competing frames, but two aspects of the same task – to advance the business successfully into the future. APD and Corporate R&D were placed in proximity to ARM 1.0 precisely with the intention to think of the future of the existing technologies and collect spill-over ideas as the main businesses developed.

The longitudinal analysis of ARM's organisational structure shows that ARM's organisational form was reshaped to re-align the company with what was the real priority of the business: not the self-initiated exploration and exploitation, but attuning to the needs of the vast Ecosystem of Partners in order to deliver the type of products that they

want. At the level of the Ecosystem, ambidexterity tools were not only unhelpful, they stopped being necessary. Again, ambidexterity was not the solution to the challenges that were relevant for ARM. This is where ambidexterity was buried for ARM. The scope of engagement, the relationships and co-creation and co-evolution of innovation with a thousand of Ecosystem Partners mean that the ambidexterity generalisations, despite their attempt to reflect the dynamism and diversity, inevitably juxtapose the contributions of the internal organisation and the external alliance partners and pigeonhole the interactions into the dual categories of exploitation and exploration. In ARM, there is no such thing as an external Ecosystem. ARM is the humble instigator of the Ecosystem and the provider of the technology platform. It is the Ecosystem. We see that the attempt to ascribe the exploitation- or exploration-like roles to ARM and the Partners fail. Learning is happening both ways. This suggests that the Ecosystem organisation should be the boundary for applying ambidexterity thinking. An interviewee shared the though development by saying "the ambidextrous nature of ARM is not ARM, it's the Ecosystem". In it, the interviewee implied that the tasks of focus and flexibility are distributed across ARM's broader social system, not internally. However, it is not ambidexterity across the Ecosystem, because none of ambidexterity formal assumptions are found in the Ecosystem's collaborative, iterative, multi-channel communication in the process of innovation.

For ARM, the process of co-evolution, co-creation and co-innovation in close collaboration with the Partners, and the ecological evolutionary thinking that supports that, is certainly of more value than ambidexterity. The two-way interactions of ARM with its Partners: existing and new, on different tasks, with different input of novelty that often cannot even be labelled in advance are the usual Ecosystem relationships that help to give an answer to the question: How far does it have to go till it stops being ambidexterity? I claim that ambidexterity rationale breaks down at the level of the Ecosystem.

Finally, the examination of the ambidexterity implementations attempted by ARM made it clear that in ARM no specific managerial tools, fixed structures or mechanisms, ambidextrous or otherwise, were the foundation for management. With the Ecosystem being the priority, *evolutionary thinking* of ARM as an *ecology* has been consistently highlighted by the interviewees as the best way to navigate the business through its

changing environment. ARM's technology base is responsible for this priority. Modern digital technologies have reached a significant level of engineering complexity and involve complex issues of their social adoption. Today's networked digital technology requires a partnership business model, but partnerships are easier to say than to do. Culture becomes the cornerstone organisational mechanism to have control over the processes of alignment and adaptation in ecosystem. Culture that is itself flexible, contextual, malleable but lasting, is a much more helpful mechanism to shape the organisational and individual behaviour that would support the organisation's adaptation to its changing environment. The conclusions about the Ecosystem organisational structure and partnership culture have significant consequences for ambidexterity theorisations underpinned by the exploitation-exploration framework. I will now discuss in depth what the evidence means for the value of the ambidexterity claims.

8 Evaluating innovation ambidexterity theory: conclusions and discussion

The central principles of ambidextrous organisation and their enactment in the unique business and technological context of a leading technology firm have been the subject of this research. In the empirical chapters above, I analysed whether the established central assumptions and proposition of organisational ambidexterity theory apply in the settings of the semiconductor intellectual property designer ARM. Each of the empirical chapters progressively contributed to testing each of the fundamental elements of the theory to see if they hold in the empirical context. The theory claims that its principles are universal and that ambidexterity is useful for any firm. My research aimed to test these claims drawing on Popper's logic of falsification: if theoretical claims do not stand the attempt to falsify them by looking for contradictory empirical evidence, they need to be revisited (Popper 1959).

To remind the reader, the rich and diverse scholarship about ambidextrous organisation converges *on the proposition that any organisation has to simultaneously pursue high amounts of exploitation and exploration activities to enable continuous renewal and growth*. Ambidexterity, therefore, is considered to be *the desired ideal state* for any organisation. Inherent in it is the assumption that exploitation and exploration are *two distinct fundamental types* of organisational behaviour *opposing in nature* and *in a trade-off* relationship to each other organisationally, but which somehow *must be balanced* to achieve the desired performance. Implementation-wise, ambidexterity means the organisation's ability to reconcile tensions between exploitation and exploration in a certain organisational design.

Before proceeding to the critique and evaluation of ambidexterity theory, an important clarification must be made about what constitutes theory. In social sciences, theory may be seen as an empirical generalisation: a second order account of the first order observation, or as a normative ideal: good that needs to be practiced (Keynes 1897). "What is" and "what ought to be" are two different types of thought (Hume 2000, Searle

1964). A social theory is empirical and descriptive statements that form a body of generalisations about "being". It can then inform normative theory of what is "good". In most managerial and organisational research, normative inferences are not the immediate subject of conversations. Most of the time, the researchers are trying to understand what is going on in their empirical contexts, not infer the ideal value of the phenomena. It seems, however, that ambidexterity literature confuses these different types of thought. In the discussion that follows, I distinguish these two aspects. This is not habitually done in the literature, but this is critical for the conclusions about the value of ambidexterity thinking.

The aim of this research has been *to test innovation ambidexterity theory* in the form of its main assumptions and propositions *to make conclusions about the usefulness* of the theory's central concepts. Theoretical work of distilling the core elements from the rich but inconsistent literature on organisational ambidexterity has been the first stage of achieving this aim. The second stage has been the empirical test of the extracted theoretical elements in the context of ARM. The following assumptions and propositions have been extracted and tested:

1. The binary distinction of innovations into two archetypes: exploitation and exploration and their definition as being opposed to each other. Ambidexterity starts with the assumption about the distinct and inherently conflicting nature of exploitation and exploration and continues with the proposition that these conflicting opposites need to be reconciled. I refer to this group of conceptualisations as *the exploitation and exploration definition assumption.*
2. By definition and further theoretical elaborations, ambidexterity is the simultaneous presence of exploitation and exploration of an equal, and equally high, level. This is *the ambidexterity balance assumption*.
3. Implementation of ambidexterity in specific organisational structures, processes, strategies and embedding it in the behaviour of ambidextrous individuals lead to enhanced organisational performance. This is *the ambidexterity implementation proposition*.

The final stage of the research that completes the examination of ambidexterity theory is the evaluation of the theory's central elements against the collected empirical evidence. In this final discussion chapter, I revisit the core assumptions and propositions

of organisational ambidexterity in view of the empirical evidence collected from the case study of ARM. Drawing on the empirical evidence, I highlight the discrepancies between the theory's central elements and the presented evidence to make conclusions about the usefulness of the theory as the set of empirical generalisations. In this, I achieve my research aim.

In this chapter, I discuss the discrepancies between each of the extracted theoretical assumptions and the empirical evidence presented (sections 8.1.1 - 8.1.3). Basing on that, I critique the central assumptions and propositions of organisation ambidexterity theory (section 8.2). In section 8.3, I rethink ambidexterity generalisations and propose alternative theories that seem more promising in explaining the multi-directional multi-level processes of the organisation's adaptation to its fluid and fast-changing environment that is the 21st century digital innovation.

8.1 Manifestation of innovation ambidexterity in ARM

I entered ARM to discover how ambidexterity theory works in the actual empirical setting of a leading high-tech innovative company. ARM has created a foundation microprocessor technology that today underpins a hundred billion digital electronic devices (ARM 2017d). The company is renowned not only for its energy efficient System-on-a-Chip designs, but perhaps even more for its extremely effective licensing and royalty business model and the Ecosystem of Partners. More than one thousand partners have licensed and deployed ARM's designs in a diversity of digital products which have become truly ubiquitous.

Innovation ambidexterity, ubiquitously deployed in the literature to interpret innovation technological innovation, product development, strategic alliances and marketing and notably claiming to be *the* driver of sustained performance, *should be present* in the organisational design of this successful innovative high-tech company. I have chosen a case of a cutting-edge technology company with a successful global business that was thought to exemplify the ambidexterity processes in spades. However, the empirical investigation has shown that there are some serious problems with ambidexterity theory.

I will begin the discussion by stating once again here, as part of the formal conclusions, that interpreting ARM's technological R&D, business model innovation and organisational innovation by means of the classical ambidexterity categories has been a significant challenge. In other words, it has been difficult to pigeonhole the spectrum of innovations in ARM's multi-level multi-directional Ecosystem environment into the two concepts of exploitation and exploration. It was also challenging to identify an ambidexterity solution of a known type, given the dynamic distribution of innovation roles across the ARM Ecosystem. The terms needed substantial contextual adaptation before they could capture the empirical relationships in the studied company[1]. This casts doubt on their initial capability to explain and their subsequent sameness if they had to be modified for ARM context.

The granular analysis in the empirical chapters above has supplied a number of significant discrepancies between the categorical assumptions of ambidexterity theory and the "messy" empirical reality the organisation. The discussion here shines light on the biggest and most significant discrepancies that have revealed themselves in the examination. I will start by reassessing the first fundamental assumption - the definition assumption that exploitation and exploration are two distinct organisational frames.

8.1.1 The exploitation and exploration definition assumption

I tested the concept of exploitation on the example of ARM's technological innovation and the concept of exploration on the example of its business model. Testing these types of innovation in two different domains revealed more than the qualities of what could be considered manifestations of exploitation and exploration. Joining the insights about the innovation types from the two different domains offers interesting conclusions about how we may think about different types and degrees of novelty. These conclusions have important implications for the binary distinction into exploitation and exploration in theory.

[1] That is why I also put the terms in the quotation marks in several instances at the end of my empirical test because what was observed no longer corresponded to the classical definitions of exploitation and exploration

In the case of ARM, I have discovered that the textbook categories (March 1991, O'Reilly III and Tushman 2013, O'Reilly III and Tushman 2011, Tushman and O'Reilly 1996) do not apply to reflect the different types of novelty creation across the company's different domains. We have seen that ARM's technology has come to shape the IP business model and the Ecosystem organisation. The close inter-relation of the technological and business domains is the first reason responsible for blurring the distinction between what could be considered exploitation and exploration in ARM. Applying the clear-cut ambidexterity categories impoverishes a reflective account of adaptation processes employed at different points across the company's blurred borders with the Ecosystem.

It is for a reason that exploration is the point of departure of this part of the discussion. Exploration illustrates the problems of the definition assumption very well. ARM was founded on explorative innovation, both in the technological products and in the business model. Two and a half decades on, ARM still has a strong reputation of being uniquely innovative, while also being extremely focused and specialised. Interestingly, the company's innovator reputation has been largely credited for the licensing and royalty business model that the company essentially pioneered and nurtured into the Ecosystem of Partners, not quite equally so for the RISC processor technology with which ARM also distinguished itself as it propelled the architecture to the level of an industrial standard. The paradox, however, is that what is still considered the very innovative business model, has remained unchanged for over twenty five years of ARM existence. And quite intentionally so. The licencing and royalty business model is intended for long periods of time. "Design once and license many times" is the rationale that ensures profitability both for the short- and long-term. Short-term, the upfront license fee of several million dollars is intended to cover the R&D costs to ARM for developing the technology. It is additional revenue each time a new licensee is signed to the previously existing product. Long-term, royalties are an on-going revenue stream that in some cases has already been generating profit for over for two decades. Although ARM certainly adds new ways to generate revenue and looks for new opportunities to expand its business, there is no intention to radically change or replace the business model that functions so well as long ARM designs technologies that are in demand. ARM's main

focus is on getting the technology right and deliver on the commitments to the customers, while continuing *to exploit* the existing business model.

In ARM, innovation in technology and the business and organisational model are closely inter-related. The inter-connectedness of the domains is the central factor responsible for blurring the definitions of exploitation and exploration. Exploration in the technological/organisational domain, which is in theory associated with the change to a new technological trajectory, search scope, variance increase and open-endedness is associated in ARM with insights within the existing competence, alignment with the existing platform technologies, extending the IP business model into new markets, as well as orientation on concrete customer needs and a well-defined business end. Remember that no new chip design is started without at least one major licensee signed up. Remember also that technologically experimental and commercially uncertain markets, like the Internet of Things, are enabled by the technology that has been advanced incrementally by ARM over the decades. ARM retains commitment to its technical expertise, the successful licensing and royalty business model, but it also enacts its ambitious vision and innovative culture. ARM certainly acknowledges the value of thinking long-term and outside the existing product roadmaps, but the search for new opportunities is carried out along the existing technological trajectory.

The nature of exploration in the business model and technology at the start of the company is *not* the same as exploration in either of the domains later when the company established. The radicalness in ARM's todays established business is not the same as the radicalness of innovative ideas at the start that gave the business the distinct value proposition. The very different antecedents at play at different points of the company's existence account for the variation in the degree of novelty. Similar for different domains: "experimentation and play" with ARM technology is not of the same kind as "experimentation and play" with the company's business forms. Yet, this is all exploration, for the lack of a more nuanced term. The ambidexterity vocabulary does not allow us to capture the distinctions unless the terms are bent ad hoc.

The same goes to the concept of exploitation. After the company settled on the core technology, business model and organisational form, it was focus, incremental advancement and orientation on commercial returns – *by all classical definitions exploitation* - that guided ARM's innovation along the path of *specialisation*. To call

ARM specialist, however, is to disregard its broad engagement and close touch with the massive innovation across the semiconductor industry and the broader digital electronics industry. The company is focused, but its focus is constantly being shifted. The process of ARM's technological specialisation neither sits neatly within the notion of exploitation. The nature of ARM's technology base accounts for this in the first instance. We have seen that industrial R&D in the modern semiconductor technology is concerned with pushing the frontiers of Moore's law and expanding features. The corresponding competence is cumulative: the state-of-the-art does not obliterate the previously accumulated know-how. Furthermore, the incrementally improved performance parameters combined with added features often result in products that make a significant impact in the sphere of application. The Internet of Things, ARM's perhaps most important and uncertain emerging market, serves an example of how a new socio-technological paradigm is being enabled by incremental trends. Miniaturisation and low power computing in combination with new security and connectivity features that have accumulated incrementally combined to deliver a paradigm-changing impact on the way we equip ourselves with digital technologies. Cutting-edge innovation by recombination of incremental improvements is a much more viable strategy to achieve impactful and profitable commercial innovation than carrying out ground-breaking research into new materials or new computing methods aimed at revolutionising computing per se. The latter is found in research laboratories, not in commercial R&D departments.

The complexity and cost of producing a complete System-on-a-Chip solution are also the reasons why disaggregation of large businesses and specialisation by small firms prevailed in the semiconductor industry over the past decade or so[1]. Each party focuses on a specific part of the value chain to bring what it does best to bear on the common technological opportunity. The complexity and knowledge intensity of chip-making also mean a high expertise threshold, further favouring specialisation, experience and accumulation of knowledge.

[1] This is, however, is starting to change and companies in the industry are integrating and brining parts of the value chain in-house again. This industrial dynamic is outside the scope of this thesis.

Finally, the important factor that blurs the distinction between exploitation and exploration in ARM technological innovation is the paradigm changing quality of the very type of products that ARM is engaged with. In a sense, it is a paradoxical consequence of ARM's technological specialisation. I will elaborate. The microprocessor, or the System-on-Chip (SoC) based around it, is an *enabling, component* technology. It is a building block, albeit the central one, of intelligent digital electronic devices going forward. SoC technologies are *the means to* enabling *exploitation* and *exploration* at the user level, *not the ends*. While we may find exploration in the creative recombination of microprocessor component technologies that allow to achieve qualitatively different functionality, or in the experimental, previously non-existing application at the very point of the SoC engineering, SoC are no good on their own. The same design can go either the exploitation or exploration way, depending on the application that the user contrives. Remember, some of ARM-based cutting edge products run on microprocessor architectures designed decades ago. Others are made possible by the recent tremendous advancements in the key performance characteristics.

As I have discussed in depth in the respective empirical chapter, SoC designs are always application oriented. The features packed on a SoC (graphics, amount of memory, etc.) are tied to their intended application. In the semiconductor industry's value chain, specialisation downstream fosters diversification upstream. ARM's goal is to create *platform* technologies where the more standardised they are, the more opportunities for customisation and diversification they would allow to the users of ARM's designs. ARM's specialised design did not lead to co-evolutionary lock-ins with the mobile market where it was most successful. Neither ARM's focused execution of product roadmaps increased organisational command and control. Innovation around platform technology cannot be adequately interpreted with the binary tools of exploitation and exploration. Much more nuanced concept of *co-evolution* is needed to describe the spectrum of innovation in ARM's baseline technology that serves the diversity of Partners' needs in the *Ecosystem*.

In the empirical context, not only the boundaries of the exploitation and exploration are blurred and their sameness is compromised by their inability to refer to phenomena consistently, the assumption of their incompatible nature is not absolute. The empirical analysis shows that exploitation and exploration cross-fertilise each other. Exploitation

and exploration are *complementary*. We see that the better ARM is at evolving and extending its technology base, the better it is at exploring new markets and new technological possibilities. More precisely, the deeper the understanding of the silicon, the better are the insights into what can be physically engineered, what capabilities can be creatively combined and what truly revolutionary uses can be uncovered with the substantially improved technology. In this extremely complex technological expertise, the best and the most creative insights come to those who are the most competent and experienced, although the opposite is not necessarily true. Exploitative and explorative innovations are thus not opposing but complementing each other. The very distinction between them is blurred. For an engineer at their desk, they are certainly difficult to tell apart. The words of an ARM engineer and Senior Director of Video remind a very common fact known by practitioners: "With innovation, you never know". This nature of innovation does not change when it travels to the manager's desk.

The idea of complementarity of exploitation and exploration has been mentioned before in the innovation ambidexterity debate (DRUID Society Conference Debates 2012). However, it remained on the periphery of ambidexterity discussion because it is at odds with the dominant central assumption that organisations are either good at exploiting or exploring, with the tendency to do more of the former and less of the latter (Benner and Tushman 2002, March 1991, Sull 1999). The empirical case of ARM provides evidence that supports the idea of ***complementarity of exploitation and exploration***. Exploitation and exploration are two aspects of the task, not two disjointed tasks. They are innovation strands that are much more fluid and interconnected than the theory has recognised. The complementarity, not dramatic distinction between these aspects of the task, is also supported by the evidence of ARM's internal organisation. We have seen that exploratory units were placed into the division that was designed to be exploitative to capitalise on the spill-over exploratory ideas that are generated in the course of day-to-day engineering activities.

Continuity of exploitation and exploration, not disjointedness, conceptual or organisational, is evidenced by the case of ARM. Innovations in the main Product Divisions, Advanced Product Division and Central Corporate R&D were planned sequentially on a timeline, aimed at advancing the existing product lines over the reasonably foreseeable time frames. After the ARM 1.0/ARM 2.0 restructuring, the

integrated Product Development team was based on the same idea of continuity: to advance the frontiers of technology application into new, previously non-existing areas by relying on the existing engineering competences, established position in the industry and knowledge of the markets.

I shall detail the idea of continuity by adding two points of clarification. First, the image of the continuity must be detached from the idea of linearity. Innovating along the existing technological trajectory should not be understood as a unidirectional process fuelled by a steady input of new ideas that results in a technologically superior product. The continuity of exploitation-exploration activities is underpinned by multiple communication channels and feedback loops that exist between ARM customers and ARM engineers, business development managers, sales staff and executives. It is the process of *iterative negotiation* and *development* not of the most novel piece of technology, but of the best *technological solution* to a particular problem in the market. The latter point is worth elaborating, because it is commonly thought that the result of such problem-solving activity is innovation. The examination of ARM product innovation and culture shows that innovation, or exploration, is not a value in itself. We have seen that customers' problems can be solved with a technological solution that was created several decades ago. The ambidexterity assumes that the ability to change and re-invent itself comes exclusively from exploration. It does not. On the example of technological innovation in ARM, we see that a lot of the actual change is coming from exploitation. Exploitation must not be associated with something outdated while exploration is something novel and progressive. Exploitation and recombination of existing solutions resolves customers' technological needs, and is organisationally more expedient than the search for innovation per se. Additionally, activities such as *replication* of the previous knowledge or a business model in new contexts do not sit neatly within the binary distinction of exploitation and exploration.

In this, exploitation and exploration are cross-fertilising. We have seen that ARM's existing technological competences shape the direction of explorative search and that explorative efforts, even of the most "blue-sky" kind, are rooted in tangible commercial application and customer demands. Innovations do advance ARM's technology base further, but the new technological ideas build on the accumulated store of knowledge and enhance engineering competence of ARM, not obliterate it. In a sense, exploitation is an

integral part of exploration, because *experience* in the *evolutionary* semiconductor technology matters a great deal. Products do become obsolete, but the competence behind them does not becomes useless. In fact, some of ARM's products continue to be shipped for over two decades. It is in this sense that the spectrum of innovations in ARM main product groups is a continuity[1].

The second point of clarification, related to the first, is the point that different types of innovations do not exist in isolation (the point already illustrated by the lack of clear boundaries between exploitation and exploration). While a conceptual differentiation into different types of innovation (either into ARM 1.0 and ARM 2.0 or Product Divisions and Advanced Product Division) is useful for strategic and structuring purposes, and indeed was exercised by ARM, the practical value of ambidexterity is in the post-ring-fence, actual transitions from exploitation to exploration to exploitation again that enable continuity of technological innovation that sustains the organisation. By the point of ambidexterity transition I mean not switching attention between the buffered exploitation and the buffered exploration, or juggling the different tasks in the daily operation, but the next, managerially more challenging step: to decide when, how and to what extent to redistribute the focus and resources in order to implement innovations and growth in the newly identified strategically important directions. Innovation ambidexterity theory seems to pay a disproportional amount of attention to the trade-off and the mechanisms for co-existence of the opposing frames of exploitation and exploration and grossly under-investigate the crucial process of transition of exploration *into* exploitation, if they are at all to be thought of as discrete entities.

Sometimes, the idea of the transition of the exploratory innovation into exploitation is somehow implied in the theoretical proposition of *the ambidexterity balance.* The organisation "balances" or manages the needs of exploitation or exploration, thereby enabling organisational renewal and change. But just what the balance means remains ambiguous in the theory. Conceptual distinctions have been proposed to clarify the ambiguity - most prominently the proposition to distinguish the combined dimension of ambidexterity (the sum of exploitation and exploration) and balance dimension (the

[1] Or evolution of technological innovation, as discussed in sections 5.3 and 5.4.

difference between exploitation and exploration) (Cao et al. 2009). However, the conceptual efforts to clarify the meaning of the ambidexterity balance have not closed the debate on this point, because the fundamental assumption of some form of equal degree and a combination of them, implicit in the very term "ambidexterity", is problematic.

It is the central proposition of the theory that the transformation of new ideas into revenue-generating products and services renews and reinvigorates the organisation leading to improved performance. Ambidexterity research provides evidence that such points of transitions are associated with dramatic increases in firm performance (Mudambi and Swift 2011) but the evidence is based on an understanding of the transition as a switch from a period of exploitation to a period of exploration. This is one of the central confusions in the ambidexterity scholarship, because switching is strictly not ambidexterity, but the punctuated equilibrium. The approaches within the body of knowledge on ambidexterity cannot consistently explain how organisational structures for what can be considered "exploitation" and "exploration" change over time to ensure what ambidexterity calls "the transitions" or balance.

To conclude, we see a much more blurred picture of manifestation of novelty than the two categories of exploitation and exploration can offer. *Replication* of a previously successful explorative innovation, which has characteristics with of which there are more distinct types than the two archetypes, and which are more morphing on the and more transient in time. As a result, the concepts of exploitation and exploration have been *difficult to tease apart, delineate and sustain throughout the research project*, given the dynamism and morphing of innovation activities within and across the example domains. The problem is two-fold and regressive. Empirically, one cannot always tell if an activity is an exploration of exploitation. In theory, the terms are rather descriptive and their content is not fixed. The theory does acknowledge that the definitions are contextual, but it does not help the very real problem for the researcher where the empirical ambiguity is aggravated by the theoretical imprecision. It is up to the researcher to do the tweaking or simplification, which risk being voluntarist and quite substantial.

8.1.2 The ambidexterity balance assumption. Challenging the implementations of ambidexterity

The longitudinal analysis of ARM's organisational structure, with the episode of the ARM 1.0/ARM 2.0 structural separation and their subsequent reorganisation into the single Product Group oriented to the Ecosystem of Partners, sheds more light onto the inter-relation of exploitation and exploration activities. The literature proposes that exploitation and exploration should be pursued to an equal degree and at a non-trivial level simultaneously, which is reflected in the theory's assumption of ambidexterity balance. Connected to the previous assumption of the irreconcilable differences between exploitation and exploration, is the element of the balance assumption that the activities have to be reconciled. Internally, that creates a trade-off problem for an organisation whose resources are limited to afford both to an equally high extent and dedicate equal managerial attention to both of them at the same time. It has also been proposed that to overcome this internal tension, organisations balance exploitation and exploration across the organisational domains or even broader networks and alliance, where the focus on one type of innovation activity is maintained in one domain (internally) and the focus of another type of innovation is carried out in a different organisational domain or outsourced to a partner. The literature nuances as to what type of domain and alliance ambidexterity an organisation can create and what type of a missing capabilities a partner may provide (Lavie et al. 2011, Lavie and Rosenkopf 2006, Lavie et al. 2010, Stettner and Lavie 2014). It also suggests when the decision to spread across the broader organisational domains work best (Cao et al. 2009). Although the managers did seem to alleviate the organisational tensions by implementing these solutions, and the ambidexterity in alliances literature has produced some clarification on the distribution of ambidexterity roles between the different partners of alliances, these generalisations become insufficient and inadequate to explain a truly networked company with a networked technology base. It is indeed, a question, if that is true for many of the modern cutting-edge information technology companies. However, the tools that the alliance ambidexterity literature offers continue to pigeonhole the messy, multidirectional knowledge flow of the different types of learning which sometimes even cannot be categorised in advance, that takes place among hundreds of participants of a technology ecosystem.

Evaluating innovation ambidexterity theory: conclusions and discussion

We have seen that ARM attempted to install the ambidexterity rationale to separate the short-term focus on the execution of roadmaps from the long-term innovation for the future. However, the structural separation into ARM 1.0 and ARM 2.0 has been dropped and ambidexterity thinking has been found unhelpful and unnecessary. Where the conflict between the focuses is not a problem, structural separation and thinking in the dual terms of ambidexterity are not a needed solution. In other words, ARM innovation opportunities do not have an ambidexterity pattern that can be addressed by ambidextrous design. As demonstrated above, ARM is more interested in extending its technological know-how into the existing and new markets, not looking to create a new technological trajectory with which to reinvent itself. It capitalises on the continuity of innovation, deepening the technological focus and extending it to areas where "ARM's essence", technological as well as business, can be once again capitalised on.

The ARM 1.0 and ARM 2.0 separation that on the surface of it could fit the definition of structural ambidexterity, was not as clear-cut as the theory suggests: exploration was present in the unit designed to be exploitative and the activities of the exploratory unit were deeply rooted in the established technological expertise as well as strongly oriented towards customer needs. This has been done purposefully because day-to-day focused work on the main product lines generates insights that may be important to follow up and developed into future businesses. Such mutual learning happened not only among these internal units, but across the whole company in the interactions of the engineers, sales staff and heads of marketing divisions at the intersection with the Ecosystem. Because the relationship with the Ecosystem Partners is so close, with the Partners providing information about their needs and trends across the broader industrial landscape, ARM's organisational structure has been reorganised to realign its roadmaps with the needs of ARM's licensees (the direct customers), the developers of SoC designs, OEMs and others. The boundary between ARM and its Ecosystem is blurred. ARM's business was founded on the partnership rationale. The healthy interactions with the Ecosystem to co-create new generation microprocessor technology that the customer will need is ARM's priority.

The idea of ambidextrous organisation has been entertained in ARM because at some point the language was useful to understand different types of R&D. But in fact, the language of ambidexterity has been used alongside other organisational metaphors

that the company used to understand its strategy, business model and organisational mechanism.

Ambidexterity theory, with its epistemic *habit to polarise* the differences between exploitation and exploration and conceptualise mechanisms and structure to overcome a trade-off which *does not necessarily need to be overcome*, is lacking tools to illuminate the different stages of innovation and the processes of integration of different types of learning across different parts of the organisation in the course of collaborative product innovation and technological co-evolution. Many partners in the Ecosystem have a significant competence overlap and the distinction of who provides what types of insight is virtually impossible. Moreover, the very attempt to put a finger on what type of innovation is needed may be premature, because very often the outcome of what the collaborative parties co-create, recombine or imitate is not known in advance. We have seen that incremental, evolutionary trajectory of semiconductor technology innovation can result in the revolutionary paradigm changing qualities of the digital devices that come about unrecognised. As mentioned before, IoT has been a quiet revolution (Witchall et al. 2013).

The ambidexterity roles are also difficult to pinpoint because the definition of what constitutes exploitation and exploration varies depending on the standpoint from which the organisational unit is viewed. From the point of view of the Ecosystem, ARM is seen as the explorative "ideas lab" and the "R&D department" for the semiconductor and digital electronics industry that creates "the magic ingredient" technology components for the rest of the Ecosystem. Internally, it is an exploitative innovator – the focused provider of the incrementally improved, standardised platform technology that is shaped by the needs of the customers in a predictable way.

Several ambidexterity scholars have pointed out that ambidexterity does not have a finite static resolution through structures or strategies, but instead is attending to, never completely resolving, organisational tensions (O'Reilly III and Tushman 2011). It has also been suggested that managers have to embrace both activities rather than choose between the contradictory agendas (Christensen 1997). In this view, we can accept that ambidexterity is a *continuous act* of responding to stimuli to engage into exploration of different degrees of novelty while maintaining operational efficiency based on well understood processes and technologies of today. On the example of organisational

transformations in ARM, we have seen that ambidexterity cannot be reduced either to structural separation or to the "balancing act" of separating and re-joining existing and new product development. The empirical analysis shows that exploitation and exploration roles are blurred and distributed across the Ecosystem, because ARM's System-on-Chip IP business *equals* the Ecosystem.

8.1.3 The proposition of universal value of ambidexterity for an organisation

The interviewed ARM employees reported that the term ambidexterity was used across the company and that ARM referred to itself as an ambidextrous organisation at some point in its history. The informal separation into ARM 1.0 and ARM 2.0 and the reported rationale behind it closely resonate with the ambidexterity's structural separation, with one crucial difference that ARM 2.0 was a significantly smaller sub-division. Additionally, explorative structures Advanced Product Division and Corporate R&D were found in units designed to be exploitative. The separation existed for about three years from 2010 till the end of 2013. The striking evidence to its usefulness is that the terminology was banned. The ambidexterity thinking in terms of the opposites was abandoned and the company was restructured to create an internally more joined up organisation that is more focused on the Ecosystem. What seemed to be an ambidextrous organisation has been reconfigured because innovation opportunities in ARM's diverse Ecosystem environment did not pan out in ambidexterity's pattern. ARM does not have classical problems of a resource limited company with clear boundaries that needs to drive businesses for today while thinking about investing into businesses of tomorrow (Chang et al. 2011). In this sense, ARM does not face the ambidexterity's classical trade-offs, or only to minor extent. The licensing and royalty model provides a stable cash-flow and the company is well-hedged from risks of failure of consumer products by the Ecosystem. Its aim is to develop the right technology for all players in the Ecosystem. And so the company rearranged the structural ambidexterity and reorganised to align better with its Ecosystem.

It was not the general idea of ambidexterity per se, interpreted in the company as a relentless focus on the delivery of the current roadmaps combined with scanning the horizon and thinking about disruption, that caused the demise of ambidexterity in ARM. It was ambidexterity's terminology and assumptions that buried it for ARM. Thinking

about the activities as polarised opposites, the harsh organisational division between them, an unarticulated connection between them, the undermined value of the accumulated knowledge and experience and the lip service to the value of innovation for its own sake were the reasons why ambidexterity was unhelpful for ARM. What was important for ARM is learning across teams and across the Ecosystem as well as efficiency and agility and seeing them as aspects of the same task, with a relation of complementarity and continuity between them. ARM's Ecosystem, and the company's centrality in it, required quite different adaptation mechanisms than an organisational form with dual focuses and structures.

8.2 Evaluating ambidexterity theory

At each point of the empirical investigation: the test of exploitation, exploration, the nature of ambidexterity balance and the value of doing it, we find that the uncovered evidence does not sit neatly within the established theoretical conceptualisations. Ambidexterity's most essential conceptualisations do not hold in the context of ARM. Organisational reality is messier than a set of assumptions of what should be found in the organisation. We have seen instances where an oversimplified ambidexterity interpretations could perhaps apply, such as the case of the ARM 1.0/ARM 2.0 structural ambidexterity separation, or partnering of ARM with the others in the Ecosystem to be able to do what it does best and work with a Partner to provide a missing (manufacturing, design, software, etc.) capability. The latter, in fact, was the exact example given in an ambidexterity literature review (Gupta et al 2006) to illustrate a possibility of ambidexterity at the level of a broader social system. There, the authors offered the simplistic reasoning that "the complementarity between the semiconductor R&D and semiconductor production is obvious" (Gupta et al 2006, p.699). However, the ambidexterity images cannot be sustained in ARM's industrial Ecosystem context in view of the rest of the empirical evidence, so we have to stop manufacturing unjustified ambidexterity perspectives. The rationale for ambidexterity rationale falls apart at the Ecosystem level when faced with explaining the multi-channel, multi-directional, collaborative co-creation of innovation that takes place between ARM and its Ecosystem Partners. If ambidexterity roles cannot be clearly assigned, ambidexterity itself cannot be identified and reasoned. It is the case in ARM: the organisational boundaries have blurred

and so did the categories of exploitation and exploration. Therefore, further ambidexterity assumptions are impossible to sustain. This is how it has happened.

The sheer number of Partners and the richness of learning interactions between ARM and each Partner defy interpretations with the binary tools and adaptation mechanisms that ambidexterity thinking offers. ARM's partnerships are characterised by high dynamism: at any time the Partner can be a customers, a partner or a competitor of ARM or any combination of these roles. The roles of the parties in the interaction are constantly changing. Contributions from all partners are of value to ARM because the more intelligence it collects from the market, the better informed it is in the development of its product. ARM calls all those with whom it interacts Partners *because* of the changing roles and because the input of every Ecosystem company is valued, although some relationships *can* be defined more clearly (ARM's customers, are, for example, its licensees) and some *are* indeed more important (the lead licensees).

Furthermore, knowledge that the parties bring to bear on the technological opportunities may significantly overlap. The technological innovation is the result of recombination of existing, *inferential*, knowledge in ways that solves a critical problem. In the process of negotiating with customers the requirements of a new product, it is sometimes not clear who the author of the idea behind the new product was. The formal organisational boundaries of such interactions are also blurred: ARM techno-commercial leaders, engineers, as well as partnership managers – the overwhelming fraction of the organisation – spend a significant amount of time talking to the Partners, for example at regular industrial events or through close day-to-day communication. Close interaction is fundamental to the disaggregated semiconductor and digital electronics business, where the question "which industry am I working for?" no longer has a clear answer.

The management literature has long talked about the ability of the firm to synthesise the input of others and reconfigure its knowledge base based on this. Specifically, Kogut and Zander talk about "combinative capability" as the ability "to synthesise and apply current and acquired knowledge" (Kogut and Zander 1993), Henderson and Cockburn speak about "architectural competence" of the firm "to access new knowledge from outside the boundaries of the organization and […] integrate knowledge flexibly across disciplinary and therapeutic class boundaries within the organization" (Henderson and Cockburn 1994, p.66). The importance of strong firm inter-relations in such

"encompassing" technological change has also been noted (Nagarajan and Mitchell 1998). However, these synthesising abilities of the firm imply clear boundaries between the knowledge owned by the firm and the acquired knowledge that must be imported from beyond the firm's boundaries, as well as clear boundaries between the subunits of the firm - "the therapeutic class boundaries" (Henderson and Cockburn 1994). Organisational boundaries matter in these models, both between the domains and between the organisation and its external environment.

I find that no clear internal or external boundaries can be identified in ARM. ARM's technological and business domains bleed into each other. The microprocessor know-how and the IP business model are also inseparable from the Ecosystem organisation. The Ecosystem organisation, in turn, has no clear boundaries between its central firm – ARM, providing the central building block, the microprocessor IP – and the Partners for whom ARM's designs are the key factor behind success of failure of their products. The boundaries between ARM and the Partners are being erased through communication in the Partner events and community support, in day-to-day interactions, and in the very cultural identity of ARM equating itself with the Ecosystem. Not only is this the phenomenon found in ARM, but the semiconductor industrial environment in general has transformed from the more linear value-chain of the mid-1990s to a fragmented but highly inter-related network of specialist player, as noted in the empirical analysis. This is due to the exponentially increased complexity of the SoC design over the past three decades that now require a much higher sub-division of specialisms on the one hand and a much closer collaboration in the process of co-development of this extremely sophisticated and complex technology[1] on the other.

Ambidexterity thinking is sustained by the image of innovation taking place in confined organisational units and uniformly distributed between domains. Consider a typical description of an R&D unit, where members of the R&D team solely and actively make straightforward decisions about the types of competences (both clear-cut and

[1] The semiconductor industry has been said to enter a period of consolidation, as exemplified by a series of mergers and acquisitions (Rheines 2016). The industry's dynamics is outside the scope of this investigation.

known in advance) to source: *"The technological subunit faces the choice of whether or not to integrate knowledge from distant techno-logical domains or to focus on similar knowledge. It also faces the choice of whether to access knowledge from within the firm (either its own knowledge or that of other technological subunits in the firm) or from external sources"* (Rosenkopf and Nerkar 2001, p.289). This allows ambidexterity scholars to produce neat categories and structures that are divorced from the messy reality of negotiation of the unknowns among different parties in the process of innovation in many companies. As a result, ambidexterity theory has produced various structures and typologies, such as the above four types of exploration based on whether the technological sub-unit decided to source a similar or distant technology or span the internal or external organisational boundary (Rosenkopf and Nerkar 2001). Problems that such clear-cut theorisations produce are explained away. Innovation that has sourced a similar technology locally is not one of four types of exploration, but exploitation. This is a criticism made, in fact, by an anonymous reviewer to Rosenkopf and Nerkar (2001) which earned a footnote in the paper (Rosenkopf and Nerkar 2001, p.289). In the footnote, the authors recognise that the boundaries between distant and similar technologies are *fuzzy* and that the distinctions are *socially constructed*, yet such generalisations are made all the same and fed into the theory with the strong underlying assumption of actual existence of such boundaries. What the authors do not go on to recognise is that the boundaries that separate the decision making team from its environment are also fuzzy and constructed. *Innovation does not exist in isolation.* In ARM, sales staff brings extremely valuable knowledge from the periphery that is directly relevant to the decision of the executives, product teams and exploratory units. Already in 1996, Intel's CEO Andrew Grove spoke about the crucial importance of input from the front-line of the business provided by the IT managers and people in sales who bring intelligence to the executive team and R&D teams that are often enclosed in the corporate ivory towers (Grove 1996).

Much of the ambidexterity literature is structural. Ambidexterity theory is obsessed with pinpointing formal mechanisms for managing the interplay of exploitation and exploration, forgetting that innovation is about breaking the rules and allowing ideas to collide. Ironically, ambidexterity scholarship shines more light on processes which are already relatively clear (exploitation and exploration) and remains very vague on the

puzzling gradual transition in between. A few scholars in the field have been pointing to a key gap: how the organisational units for exploitation and exploration "can be kept simultaneously separated to 'prevent cross-contamination' and integrated to 'allow cross-fertilisation'" (Durisin and Todorova 2012, p. 70). Literature reviews, summarising the impressively growing scholarship on ambidexterity, continue to note that the question of how integration of structures charged with exploitation and exploration happens over time, remains unanswered (Raisch et al. 2008, p.693, Durisin and Todorova 2012, p.70).

The idea that organisations often respond to multiple uncertainties in their environment by increasing command and control whereas they should relax rules and structures to cope with the uncertainty, has been long expressed in management research (Mintzberg 1979). ARM has done exactly right: it responded to the different industrial dynamics in its vast, multi-faceted industrial landscape by formulating values and instilling a shared culture, not rules. Given the dynamic nature of the ARM Ecosystem, many of the agreements governing Partner interactions are flexible and avoid excessive detail and regulation. Ambidexterity theory, on the contrary, seems to keep looking for mechanical solutions by proposing newer and more nuanced structural arrangements for exploitation and exploration. The role of top managers in instilling culture and all employees embodying the culture is acknowledged (Birkinshaw and Gibson 2004, Lubatkin et al. 2006, McCarthy and Gordon 2011), but for such a powerful organisational solution whose key contribution to supporting organisational adaptation has been recognised, culture has received very little attention in the ambidexterity scholarship.

Ambidexterity theory extended the conceptualisations into alliance and partnership literature, proposing that a firm forms explorative R&D alliances with partners up the value chain and exploitative commercialising and marketing alliances with partners down the value chain (Lavie and Rosenkopf 2006, Lavie et al. 2010, Koza and Lewin 2000, Lavie and Rosenkopf 2006, Lavie et al. 2010, Stettner and Lavie 2014). The literature also applies the same rationale to the company's mergers and acquisitions. However, this is not how ARM works. ARM does not form traditional bilateral alliances, ARM has been building collaborative relationships since they were nine people in a barn. Over the years, ARM has built an Ecosystem of Partners around its microprocessor technology. We have seen that ARM operates in an industry whose business is to deliver complex solutions to customers by bringing together capabilities that are scattered in the diverse

specialist companies around the globe. Through collaborating with the Partners, ARM brings specialised knowledge from all the corners of the Ecosystem to inform ARM's own product development. The company both leverages and contributes to the extensive and varied Ecosystem. Creating and leading the Ecosystem that allows knowledge to be pooled from the vast and diverse number of Partners is a key factor behind ARM's success. In other words, what makes ARM successful is not ambidexterity, but the Ecosystem. In it, ARM is the leader only as much as the customers allow it to be. The management of the relationships in the Ecosystem becomes a crucial priority for ARM. By contrast, partner relationship dynamics seem to be completely absent from the alliance ambidexterity literature which remains silent on important questions such as how the dependence on partners providing a missing capability is managed and how power imbalance is avoided?

The matrices of ambidexterity via alliances of the type "we form alliance with an R&D partner/new partner/dissimilar partner to explore and with a marketing partner/old partner/similar partner to exploit" (Lavie and Rosenkopf 2006) do not apply in ARM not only because of the blurred distinction between the type of the contribution the Partner provides and the fuzzy boundaries between Partners' positions in the value chain, but because the Ecosystem simply does not work that way. ARM talks to everyone. It is *having conversations* with all its 425 licensees and beyond (ARM Holdings plc ARM Strategic report 2015). ARM interacts with partners in the multi-channel iterative way described in the empirical chapters above, with the aim *not to source* a missing perspective but to exchange the knowledge and *discover* what the solution to a customer's problem may be.

As a separate instance of falsification, I will attempt to apply the above mentioned matrix of Lavie and Rosenkopf (2006) to ARM's acquisition of Duolog discussed in an empirical section above. Lavie and Rosenkopf's (2006) concepts in the matrix may be summarised as follows:

Form of alliance	Exploitation	Exploration
Function	Down the value chain (e.g. to commercialise and market)	Up the value chain (to develop R&D)

Structure	Old partner	New partner
Attribute	Similar company	Dissimilar company

Duolog is a developer of electronic design automation tools that assist with the integration of complex SoC designs. It is certainly a technology complementary to ARM, because it helps ARM's customers to put SoC components from ARM together. By the function type, the acquisition of Duolog is an unclear choice (perhaps co-development, i.e. exploration?) because it is meant to facilitate use of ARM's technology. On the product development side, it is unclear whether to judge this acquisition as partnering with a partner up the value chain or partnering with a partner down the chain, because *the semiconductor value chain is not linear* and complementary technology means exactly both: a degree of similarity and a degree of difference. By the structure parameter, the acquisition of Duolog would be exploitation, because Duolog was an old Partner of ARM. Finally, it is again not clear how to interpret the attribute parameter (similar or dissimilar company), because as mentioned before, the players in the industry have overlapping competences as well as distinct specialisations. It is not clear how to judge whether Duolog is similar or dissimilar partner and therefore determine whether it was an exploitative or explorative acquisition on this parameter. If it were to be used by ARM's managers, the matrix is would be useless.

The explanation of ARM's top executive about acquiring Duolog in the evolutionary terms has none of the problems of the exploitation-exploration matrix and is much more logical:

> *"The **company evolves as the technology evolves** - this is a **classic case**. […] We see that the assembly of the chips is becoming a critical issue, our customers do look to us to solve a bigger and bigger problem as their chips effectively get bigger and bigger. And so it made sense to bring the technology in-house." (ARM top executive, interview 17, 2014).*

Additionally, acquisitions and new business ventures represent only a small fraction of ARM product innovation. Over the 27 years of its existence, ARM acquired about 30 companies and formed very few joint ventures (for example, with the

manufacturers of money Gemalto and Giesecke&Devrient to deliver new generation security services to them (ARM Holdings 2012). It would be misleading to judge innovation strategies in ARM through mergers and acquisitions only. They are as well part of ARM evolving its Ecosystem.

Domain and alliance ambidexterity explanations seem to hold in organisations with fairly clear internal and external boundaries, as well as clear juxtaposition and not overlapping between them. ARM Ecosystem, with the "global village" communication style and competence overlap that characterise the specialised, globally dispersed participants cannot be explained with binary types of adjustments. The mistake ambidexterity makes is that it fixes one parameter in the hope of achieving a desirable state of *equilibrium*. But evolution is always co-evolution and fixing a single species has a knock on effect on the rest of the ecosystem. Ambidexterity also has a flawed assumption that everything that is competing or conflicting needs to be reconciled. But it does not need to be and it cannot be. The relationship between stability and flexibility is not equilibrium, but homeostasis (Parsons 1951). The system is constantly trying to achieve stability, but it is always failing. The search for stability and the active effort to bring order to chaos are an important dynamic, but the system is always fragile and is always transient.

Ambidexterity loses the dynamics of evolutionary thinking. While the ambidexterity scholarship have made attempts to account for the organisational dynamics in more complex forms of organising (Turner and Lee-Kelley 2013), it mainly did so by introducing more dimensions to the central constructs (Giovanni 2005, O'Reilly III and Tushman 2008), recognising intermediate hybrid activities featuring exploitation and exploration (Koza and Lewin 2000, Lavie and Rosenkopf 2006), or explaining away the anomalies (Rosenkopf and Nerkar 2001, see esp. p.289). Some of the literature adds evolutionary thinking to the exploitation and exploration terms to strengthen the explanatory power of the terms (O'Reilly III et al. 2009, Tushman and O'Reilly 1996). The question arises: why are the exploitation-exploration terms, and more so, the legacy of their assumptions, necessary in the context where they clearly fail? Is it not better to study co-evolution in the Ecosystem with evolutionary tools? In this context, the theory seems to have made a full circle. In 1992 Tushman, the forefather of the ambidexterity concept, and Rosenkopf, the driver of ambidexterity to domains and alliances, started by

saying that technological progress is "the interaction of the technical option with organization and interorganization dynamics that shapes the actual path of technological progress" (Tushman and Rosenkopf 1992, p.311). They also highlighted already then that some products that are "open systems" in which "political, social and community dynamics operate to resolve trade-off between alternative technical choices" (ibid, p.325).

Attempt to rethink the fitness of the ambidexterity terms for the different firms' environment are rare (Eisenhardt et al. 2010). The studies that test ambidexterity theorising are virtually non-existent. In the body of the literature on ambidexterity there is only one visible study that analyses whether theorising on ambidextrous organisations are implemented by managers in their actual practice in the way that the theory proposes (Durisin and Todorova 2012). Durisin and Todorova conclude that "some core principles of theorizing on 'ambidextrous organizations' did not exhibit verisimilitude" (Durisin and Todorova 2012, p.72). In other words, what the theory proposes is not what companies do. Ambidexterity scholars, however, continue to cross breed ambidexterity with evolutionary thinking, nuance inter-relations between the core variables and develop new rationale to fix the anomalies when they surface.

I argue that this cannot be done endlessly and that there are contexts where exploitation-exploration concepts fail. Scholars recognise that interpreting exploitation and exploration for some contexts is challenging (Lavie et al. 2010) and to distinguish exploitation and exploration in such contexts, they propose to apply the criterion: if "the organisation persists with the technological trajectory and leverages its existing skills and capabilities, its operations are geared towards exploitation. […] In turn, exploration entails a shift away from an organization's current knowledge base and skills " (Lavie et al. 2010, p.114). According to this, ARM should be defined as an exploitative business, because it does not plan to switch from developing the microprocessor cores IP. To quote an interviewee, ARM is not going to "become a galosh company"[1] (ARM senior manager, interview 1, 2011). To call ARM exploitative is to neglect the innovation with

[1] Nokia, before becoming the producer of one of the most popular mobile handsets, was a manufacturer of rubber galosh, gas masks, paper and telegraph and telephone cables (Garber 2013).

truly paradigm changing qualities that the company enables. Applying the dual categories to ARM impoverishes the unique innovativeness of the company. The definitions do not work for ARM not because they are difficult to interpret, but because they are being applied to a wrong context. ARM is not a case of ambidexterity.

Finally, the crucial point of my critique is that the exploitation-exploration concepts do not seem to be helpful to explain innovation in the new paradigm of ubiquitous computing. After all, they were born to explain quite different technological contexts (Tushman and O'Reilly 1996, Tushman and O'Reilly III 1997). However, seminal papers in the field have based their theorisations on the examination of technology of the past or in the established industries and technological paradigms. Rosenkopf and Nerkar draw their conclusions about alliance ambidexterity from examining CD-ROMs of the 1990s (Rosenkopf and Nerkar 2001), Cao and colleagues nuance the measures of ambidexterity from studying high-tech parks in China in 2006 (Cao et al. 2009), He and Wong draw their evidence about positive effects of ambidexterity on performance from studying performance of manufacturing firms in Singapore and the State of Penang in Malaysia during 1999-2000 (He and Wong 2004).

Technology has once again transformed. The twenty first century technology has become smart and inter-connected. It generates volumes of data that require new approaches to security and privacy, with vast implications to the wider society. New digital technology has pervaded every aspect of the social life, changing industries and our social and private spaces. Such technology requires negotiation of complex integrated solutions, not delivery of standardised products and services in homogeneous volumes. Development of such products is a collaborative sharing of knowledge that is complex, messy and often uncodified. The exploitation-exploration framework, and particularly assumptions about how they should be reconfigured, does not seem to grasp it any longer.

However, in a recent review of the advancement of the theory titled “Organisational Ambidexterity: Past, Present and Future”, the forefathers of ambidexterity O’Reilly and Tushman (O'Reilly III and Tushman 2013), list qualitative studies of the typewriter manufacturer Smith Corona (Danneels 2011), Olivetti’s transition from mechanical to electronic technology (Danneels et al. 2013), history of Hewlett-Packard company (House and Price 2009) and organisational adaptations in Polaroid, IBM, Oticon all of whom were manufacturers of a standardised consumer products - as reliable evidence at

the forefront of the ambidexterity research (O'Reilly III and Tushman 2013). The recent large quantitative studies sampled in the same review perhaps started to embrace the modern networked technology, but they had to operationalise exploitation and exploration and, therefore, simplified the different organic forms of interaction in the modern technological innovation to produce their accounts (ibid.).

A real concern about the health of the research field, to the extent exemplified by the O'Reilly and Tushman's review paper (2013), is the exhilarated outpour of 44 citations of evidence of ambidexterity's value (O'Reilly and Tushman 2013, p.325) and only a cursory mention about the started work to identify the boundary conditions for the theory with no mention of such work at all (ibid., p.330). Organisational theories must explicitly state restrictions regarding space and time of their application (Bacharach 1998). If ambidexterity scholars do not explicitly specify the boundary conditions for the theory, as well as logical connections between concepts, ambidexterity will be impossible to disprove. I side with the epistemologists of social sciences who state that this responsibility must be taken seriously if we are ever to move beyond endless reinterpretations, criticism and counter-criticism (Bacharach 1998).

Furthermore, ambidexterity terms may have been useful in explaining innovation in manufacturing CD-ROMs, but doubtfully so in application to the innovation that goes into driverless vehicles. *"This is the most boring product on the planet"*, says an interviewed ARM' top executive pointing to my laptop, *"because there is not enough innovation that's happened there"*. ARM is a central force behind the mobile computing that superseded the era of personal computers, but there is more. ARM is behind the bigger change in where and when computing happens. The Internet of Things (IoT) changes the relationships between people and objects and introduces dimensions to technological innovations that are not pure engineering, but which engineering must consider.

As a conclusion, let me consider three examples of innovations. The first two are a pair of consumer products, two watches: one classically studied by the ambidexterity literature, the other one is an innovation powered by ARM and increasingly found in our day to day life. The third example will illustrate innovation in IoT.

Seiko watch became a global product after the managers of Japans' dominant, but globally still small watch producing company, decided to use the novel quartz oscillation technology with which it was experimenting internally, in its new products. Seiko became both a quartz and a mechanical watch company. This transformation has propelled Seiko's move into low-cost high-quality watch making industry. At some point, quartz watches replaced mechanical watches in the global watch industry. This innovation of the 1960s has been neatly described in ambidexterity terms by Tushman and O'Reilly (Tushman and O'Reilly 1996). Today, Seiko innovates by driving product characteristics and price towards North-East of the performance graph. Seiko's innovation is shaped by the demands of luxury watch wearers who wear them to complement their outfits.

Pebble watch started its life in 2012 when Eric Migicovsky posted a call to crowd-fund his idea on the crowd-funding platform Kickstarter. Pebble watch is a smart watch powered by ARM Cortex M3 that wirelessly connects to your smartphone to alert you of incoming calls and messages (Chang Gear 2012a). The project aimed to crowd source $100.000 all in all, but raised $3.3 million, more than any other Kickstarter project, only five days after posting the pledge (Chang Gear 2012b). It raised the total of $10.3 million through the one year long Kickstarter campaign, which was the most money ever raised for a product on the site at that time. But this is not the most important aspect of this innovation. Kickstarter's innovation is not only in providing access to money, but also to free market research. People only fund products that they would want to buy and believe are successful. Kickstarter also provides access to technology very cheaply and helps to get products to market very quickly with a very small team. This is, in fact, a favourite example of innovation, ARM-powered innovation, of an ARM's top executive who tells:

> *"Pebble, which is one of my favourite examples. It was ten people that got that to market. Twenty years ago, you couldn't dream of doing that. You would need so much capital to get the first product built it stopped most people doing it. Whereas now you need next to no capital to get this product built. You can trial it, you can get it to market, you can ship it through Amazon. It's going to drive more and more people to innovate."(ARM top executive, interview 17, 2014).*

Pebble watch costs about $100, looks techy and appeals to a very different market than the £5.500 Seiko Grand watch. Technological, market, business model and organisational innovation for these two products are dramatically different.

"Soap on a rope" is the innovation that has been awarded second place in the "Wearables for Good" competition. The competition was organised by ARM, the design company Frog and UNICEF to help create devices that will address maternal and child health issues. Previously, mobile phones powered by ARM technology have been used, for example, to help prevent the spread of malaria by collecting data about whether a person has been travelling through an infected area and build travel routes to avoid such areas. This time, the problem of cholera has been addressed with a wearable technology. Cholera causes diarrhoea. Diarrhoea is a major killer of children under the age of five. Every year, about 1.5 million children die from what is in some sense a very easily prevented disease. ARM's CTO Mike Muller explains their decision of the award in his keynote speech at ARM TechCon:

> *"It's one of those moments where as a judge you step back and you look at something and you go: 'I get it. It meets the brief. That's a winner'". (Muller 2016)*

The technology that addressed the spread of diarrhoea among underage children was a wearable, it was Change for Good and it offered a winning solution. It was a piece of soap on a rope. A coloured soap was attached to a rope so that it could be worn by a teacher and not get stolen. The teacher applies it to the children's hands at the end of the class, they then go off and wash them and come back to show that the hands are clean.

ARM deals with innovation and understands that:

> *"Innovation is not always about technology. It can be a business model. It can be as simple as changing people's behaviours and it's not always that we should get hung up upon 'can I make this smaller, can I make this faster?' You actually have to think about what's the real problem you are trying to solve."(Muller 2016)*

An important detail and a reminder for all those who manage innovation is that, the CTO Mile Muller continues:

"The team that came up with that they assumed that there is going to be some electronics wearable device, just like everybody else. And they went through the design process and they ended up with 'soap on a rope'."(ibid.)

I argue that the core assumptions of ambidexterity are incompatible with the kind of innovation given in these three examples. Innovation is often a deviant, not planned or controlled behaviour. Importantly, innovation is about exposing an idea to a wide environment, not nurturing it from within. It must not be trapped in one person's or company's view of how to drive innovation.

8.3 Rethinking ambidexterity generalisations

The aim of the thesis has been to test whether ambidexterity theory applies in the rich empirical case of a successful technology company. This research drew on the Popperian logic that theories should be subjected to risky tests to make them sufficiently rigorous (Popper 1952). The investigation has showed that the ambidexterity theorising failed in multiple ways when applied to the context of ARM Ecosystem. So, what are the consequences for theory of ambidextrous organising? I will reflect on this in the concluding section.

When empirical evidence does not match the theory's central propositions, quality of the theory is affected. In social science, a theory is a set of empirical and descriptive statements within a set of boundary assumptions and constraints (Bacharach 1989). Metaphors may become precursors to theory if propositions derived from their imagery are evaluated. Theory is always a model and an approximation of the empirical context, but it should reflect essential features of the context. This would equip a researcher with some generalisations to help understand other contexts, how they are similar or different and to help establish a pattern. Importantly, theoretical generalisations are bounded by the theory's assumptions. Theories must also include explicit restrictions regarding space and time to apply its theorisations (Bacharach 1989). Theories also must provide clear definitions to its terminology. The benefit of using precise definitions is for researchers to be able to study a phenomenon more clearly, understand its benefits and its limits and knowing where it is helpful and where it will not work. Theory is considered useful if it can explain and predict. In social sciences, it means to be able to tell how and why things happen and form a basis for interventions for practitioners. It is easy to see that when

these criteria are violated, all manner of confusion appears. Yet, this is exactly what has happened to research on ambidexterity.

When a new popular research field arises, there is a danger of the terms being thrown around carelessly so that they lose their specific meaning and, consequently, the power of the original construct. The exploitation-exploration terms have stopped having any defined meaning and become applied to any context without a defined boundary. Ambidexterity risks becoming an empty rhetoric rather than a helpful model. The central problem of ambidexterity is that the terms, which have been created for a quite specific context, have been enthusiastically extended by the ambidexterity scholar to a great variety of contexts without an equally robust re-consideration of fitness of the construct for new contexts. The theory has developed into a diffused body of knowledge in which a general model is difficult to see. Theories must be parsimonious and provide explanations with as few concepts are possible. Research on ambidexterity is doing exactly the opposite. Filigree conclusions idiosyncratic for particular research designs do not add up to a coherent generic model. Further research of the kind and application of the concepts to ever newer areas is simply called out for by the scholars in the field (O'Reilly and Tushman 2013), with seemingly total unawareness that the boundaries of the theory must exist somewhere. For example, the forefathers of ambidexterity O'Reilly and Tushman invite scholars to apply ambidexterity, ironically and not surprisingly, to ecosystems:

*"Another **promising** domain for ambidexterity research is to move from the firm (or corporation) as **unit of analysis** to the firm's **larger ecosystem**. As products and services become more modularizable and as communication costs decrease, the locus of innovation will increasingly shift to the community […]. If so, future work on exploration and exploitation **will have to move** from its current intra-firm and inter-firm focus **to** more awareness of **the larger community**." (O'Reilly and Tushman, 2013, p. 333)*

Many scholars will take it as a ticket to interpret ambidexterity concepts in the context of an ecosystem. However, I would caution against the rush to extend ambidexterity easily and endlessly. I would ask scholars to consider if the theory, as a system of generalisations created for particular contexts and bound by specific assumptions, is appropriate for new contexts. I would ask them to explore new empirical

grounds with a sceptical mind. Otherwise, the same mistake would be repeated aggravating already existing confusion in the scholarship.

Amidst all these issues, the value of ambidexterity is perhaps in the generalisation that any human organisation has to have a degree of stability to persist through time, but also the capacity to change. Understood that way, exploitation-exploration is a sensible thing for the organisation to be doing. Alignment and adaptability, or efficiency and agility are other ways to describe this, without the burden of the underlying ambidexterity assumptions. In this sense, it is not surprising that ARM is seeking efficiency in its business, while constantly trying to adapt to the change in its environment. However, the company is doing it not in the way suggested by ambidexterity theorising. My qualitative research uncovered important differences between the way the company innovates and what ambidexterity says successful technological companies should do. One of the key differences is to the theory's assumption that innovation always involves novelty per se and that the ability to change comes from exploration. It does not. This is what we saw on the example of ARM's technological innovations and on ARM's business as a whole. A lot of actual change is coming from exploitation. Day-to-day activities are very valuable because they create a lot of potential for exploration. It is not that exploitation and exploration are radically opposed tasks. They are aspects of the same task, aimed to achieve the precarious stability of the organisation.

Theory is a set of generalisations. A practical question is, therefore, how can managers use ambidexterity generalisations? The value of ambidexterity theory to a practitioner may be precisely in the general model that I have just described. We have seen that ARM's managers use different models embodied in metaphors to inform their strategies. On the basis of the empirical analysis, I have argued that management is an informed improvisation, rather than applying the rule. Managers are informed by some model and base their actions on some general understanding, but are always assembling decisions and mechanisms based on what is happening on the ground. The manager is, perhaps, a *bricoleur* (Levi Strauss 1962) analysing the relevant cues for their environment and assembling the tools to address them in real time. In this sense, keeping management models (including ambidexterity) clear and clearly identifiable in the literature would be of help to the practitioners. We have found that the practitioners are already familiar with the ambidexterity construct.

The ideas of adaptability and alignment are clearly part of the evolutionary thinking. I argue that it would be more appropriate to study *co-evolution* in the business *ecosystems* with the tools of the evolutionary theory rather than with the exploitation-exploration system of theorisations. The concept of a business ecosystem exists in management research (Moore 1993, 2013, Trevor and Williamson 2014, Williamson et al. 2009, Williamson and Meyer 2012) and some of its central rationale resonates clearly with my renewed conclusions about ambidexterity. It uses the same central generalisation as ambidexterity, but without the burden of the ambidexterity's core assumptions: *"[companies] face three opposing pressures simultaneously: to re-organise to become more agile while at the same time maintaining relentless focus on efficiency and remain true to a consistent purpose that engages and motivates their people"* (Trevor and Williamson 2014, p.1).

The role of culture, leadership and vision is a new important addition to the task of managing stability and change. In my research, culture emerged as critically examine a crucial support mechanism to navigate change. Culture also provides continuity and identity to self despite changes. When I entered ARM, I had an immediate realisation that there is a strong shared and lived culture there: they know what they are, what their business is about and what their goals are.

8.4 Limitations of ambidexterity thinking. Implications for practitioners

It is not surprising that in medicine, practice of doctors is influenced greatly by the advancement of knowledge in medicine and biology. Engineers adopt knowledge and technologies uncovered in research in engineering and physics. Agriculturalists, farmers and food scientists inform themselves about recent research in bioscience and adopt new discoveries made in bioscience. Managers seldom seem to run their companies based on theories from organisation and management studies. While the main outcome of science is to create and disseminate new knowledge, it is not always clear how the fields of organisation theory and strategic management contribute to managerial practice. What is obvious is that those practical contributions are limited. An article in the Economist once noted with an unabashed honesty that "consultants and business school professors are forever discovering great ideas … that turn to dust" (The Economist 2009 November 21, p.84). Great ideas and theories should allow practitioners and other researchers to apply

this great thinking to solve their problems. However, this does not happen often enough. It is not to say that academic research in management is irrelevant for practice and that the managers are from Mars and academicians are from Venus, on the contrary (Baldrige et al. 2004). However, dense and extensive analytic elaborations often go by the board in the daily practice for the reasons that I demonstrated on the example of ambidexterity theory. The theoretical body of ambidexterity is muddled and disjoined making it difficult for the manager to understand and locate useful knowledge. Ambidexterity theoretical generalisations fundamental for theory building impoverish the understanding of actual managerial practice: practitioners are operate with more dimensions of innovation than ambidexterity principles capture, and they are also more fluid and contextual. Producing fine-grained conclusions idiosyncratic for specific managerial contexts makes it difficult to judge the value of the findings in a different managerial context and potentially problematic to transfer the idiosyncratic findings to new context at hand.

It is no doubt a challenge to build theory that has both a scientific rigour and relevance for practitioners. Some scholars work on extending ambidexterity theory: fill gaps in the literature, elaborate mechanisms and reveal blurry connections between concepts of the theory. In my study, I makes a rare contribution, I delineate the boundaries of theory application. I have demonstrated that exploitation-exploration construct breaks down in the context of Ecosystem. Not only were the language and assumptions of ambidexterity unhelpful, they became counter-productive because they imposed a wrong pattern of going about Ecosystem innovation and relationships. The more nuanced terminology of *evolutionary adaptation* seems better suited to understand and manage the company's co-evolution in the broader *Ecosystem* where traditional company boundaries are blurred and innovation co-creation takes shape that does not fit into the dual exploitation-exploration framework. These are the concepts that ARM is employing to understand and nurture its Ecosystem organisation, with continuing success. The main practical implication of my test of ambidexterity is that if theories exhaust their ability to explain new contexts which are inevitably arriving, and if the efforts to update the body of knowledge accordingly create more problems than answers, then we should have no fear to shake our habitual assumptions and consider alternative explanations. Originality, after all, is what makes managerial research refreshingly interesting as well appealing to managers who are faced with non-trivial tasks on the daily basis.

9 Limitations of the investigation and avenues for future research

The research is a single case study of a technology company. It has been designed as a single case study with the Popperian logic in mind to take one case and look for negative evidence to the core theorisations of ambidextrous organisation to put the theory to test. Evidence of serious deficits of ambidexterity derived from the case is a basis for theory's revision. In this sense, my research has been driven by theory. I started my analysis from examination of the theory which has produced rich generalisations about exploitation and exploration. The central theoretical claim being that *any firm* engaged with the fast changing technology *should exploit the accumulated technological know-how to generate profit today while at the same time explore new opportunities that will replace the existing technology and processes and ensure profitability for tomorrow*.

However, ARM is quite a unique firm in its industrial landscape, for the reasons discussed in depth in this thesis. ARM Ecosystem buffers it from the risks and the turbulent environmental change and makes it different from a classic ambidexterity case of a resource-limited company having to undertake all the risks and to choose to invest either for today or for tomorrow. ARM's very technology base – the networked, constituent IP products, which are created collaboratively across the participants of the Ecosystem and which require the Partnership model to leverage it – is an unusual site to study ambidexterity. Unique cases are sometimes critiqued as unrepresentative of a general phenomenon and Eisenhardt and Graebner (2007) have pointed it out. Innovation ambidexterity theory has studied companies with fairly defined borders and homogeneous products. ARM is also not a classical company in the organisational terms. ARM's networked technology paralleled by its networked Partner Ecosystem organisation perhaps makes it an inappropriate test site for ambidexterity thinking. I argue, however, that the test remains justified. The theory claims to be universally applied to any firm or organisation (O'Reilly III and Tushman 2013). Given this, the study of ARM's technological expertise remains a reasonable choice of empirical context for the test of the theory. If anything, the evidence of ambidexterity categories failing in the examined case is the indication that the theory should not be applied to such contexts.

Limitations of the investigation and avenues for future research

This research has been an explorative work to enter the company and see how ambidexterity plays out in an actual business context. Given the limited time resources for the doctoral research and the researcher's background and choice of research design, the light has been shone on the certain aspects of organising in the company. A closer engineering angle on ARM's innovation would perhaps reveal other interesting sides to the interplay between exploitative and explorative innovation than the more ethnographic approach taken in this research.

More importantly, the investigation has revealed that ARM's innovation is closely interconnected with that of the Partners in the Ecosystem. This is a very important locus of innovation and customers' perspective on innovating with ARM may be illuminating. A closer examination of the innovation processes at the intersection between ARM and Partners would shed additional light on our understanding of the persistence of organisational forms and types of interactions through change. Given the limited time resources to complete this work, as well as challenges of accessing any significant number of ARM's customers, most of whom are not based in the UK, this avenue has not been taken. Encompassing the perspective of ARM's Partners into the analysis would add interesting and valuable insights into how stability and change is managed in the Ecosystem. This is an interesting and promising avenue for further research.

A socio-legal study of the use of the licensing and intellectual property would illuminate innovation in this aspect of the business model. Innovation in the IP, in connection with the growing and diverse Ecosystem is another interesting research direction.

It has emerged from the empirical analysis that culture is an important element of the organisation to accommodate the processes for stability and change. Shared organisational culture and identity is a powerful tool to create and support exemplar organisational behaviours that lead to desirable performance outcomes. Culture definitely deserves a closer qualitative examination in its own right. Ambidexterity scholars have identified the importance of culture for the organisation to be able to embrace the contradictory tasks of exploitation and exploration and the scholars have called for a closer examination of "new cultures and identities that accommodate exploitation and exploration" (O'Reilly III and Tushman 2013, p.19). I would, however, join sides with the Ecosystem scholars in viewing culture as one of the three pillars for the next

generation Ecosystem organisation: agility, efficiency and purpose, departing from the confusing legacy of the assumptions of the terms of exploitation and exploration. Organisations "reorganise to become more agile while at the same time maintaining relentless focus on efficiency and remain true to a consistent purpose that engages and motivates their people" (Trevor and Williamson 2014, p.1).

Evolutionary and ecological thinking seem promising in explaining the co-evolution of innovation and partners' businesses in the ecosystem organisation. The renewed generalisations about exploitation and exploration that I proposed can be developed further with the help of evolutionary thinking and concepts.

Post Script. Some further thoughts

9.1 Imagination Technologies and Apple. An ARM's "alternative universe"

The British semiconductor intellectual property company Imagination Technologies design and licence microprocessor cores and related intellectual property. A global leader with about 1,500 employees and £120 million annual revenue (Imagination Technologies 2016), Imagination Technologies are renowned for their multimedia processor designs that are used in smart phones and other electronic devices. Apple, Imagination's largest licensee, has licensed Imagination's multimedia IP to form the basis of the design of its graphics processor unit (GPU) that enables one of Apple's flagship features – the retina display – in iPhones, iPads, iPods, Apple TVs and watches. In April 2017, Apple publically announced that it will be bringing graphics design in-house and discontinue licensing Imagination's technology for its new products within the period of fifteen months to two years (Kollewe 2017). Imaginations share prices collapsed by 70 per cent overnight (Bradshaw 2017).

Imagination Technologies are a company very similar to Apple, but it has found itself utterly dependent on one licensee - a situation that ARM has so carefully avoided. Over the years, Apple has become Imagination's largest licensee and a cash cow for Imagination. Willingly or not, Imagination has come to rely on Apple for half of its revenue. The dependency has been worsened by the ownership structure of Imagination. Apple is also one of Imagination's biggest shareholders, with enough stake to make the company even more compliant and influence whether or not Imagination expands its client base much beyond Apple.

Following Apple's announcement to design graphics in-house, Imagination argued that it would be impossible for Apple to develop its own independent graphics technology without infringing Imagination's intellectual property rights. It is preparing for a legal battle with Apple over its IP rights. While the dispute with Apple is on, Imagination has been approached by several parties for a potential acquisition and initiated a formal sale process with the interested bidders (Kollewe 2017). Analysists speculate about the underlying aim of the Apple's move and its public warning of license cessation. Some suspect it to be Apple's bargaining tactic to acquire Imagination for its PowerVR GPU

weakened and depreciated (Kharpal 2017). Another plausible explanation is that, a "bargaining bully" (ibid.), Apple has been applying pressure on others in a similar relationship with Apple and sending a message out that if they do not act as Apple expects, Apple really will "pull the plug" on their businesses (ibid.).

While an in-depth account of the episode is outside the scope of this thesis, the story is a valuable lesson for an IP company about the importance of keeping the licensee relationships healthy. Had anyone in Imagination properly managed the case when more than half of the business depended on one customer, the dire situation could have been avoided. In this connection, it would be interesting to investigate how this "alternative universe" came about. How has Imagination Technologies become so utterly dependent on one customer, while ARM have managed to maintain a healthy ecology of licensees (which does include Apple, who bullies)? In fact, ARM also licensed Imagination's graphics IP, integrating and selling it alongside their own processors. But in 2006, ARM acquired Falanx, a Norwegian mobile graphics chip developer, whose Mali GPU became the new Graphics IP unit within ARM (ARM Holdings 2006).

To answer the question above, it is necessary to look into how the multi-faceted business relationships among the diverse players in the ecosystem are managed. Culture and values of the relationships are also central to answering the question. This can be an exciting avenue for further research.

9.2 Softbank acquisition of ARM Holdings Plc

A milestone event, important for the central themes in this thesis, took place in ARM's business after the empirical work for the thesis had been completed. In July 2016, ARM was acquired by the Japanese telecommunication company Softbank for £24.3bn following a two week negotiation process (Massoudi et al. 2016). Softbank's aims behind the acquisition was to secure a leadership position in the emergent Internet of Things market, which by Softbank's estimations, will exceed the mobile market in 2018 and grow to one trillion devices in twenty years (Son 2016). ARM low power miniature microprocessors, and particular the microcontrollers, together with wireless connectivity and the technology that will secure data inside the tiny low-cost chips, are perfectly suited for the IoT market. ARM designs are already being widely adopted as the architecture

for the chips deployed in the IoT devices. The IoT has been identified as the main future growth opportunity for ARM.

Speeding up the move into the IoT for ARM with the financial muscle of Softbank was one of the central arguments for the acquisition. ARM and Softbank seem to share a vision about the future technology and, according to ARM CEO Simon Segars, "with Softbank's backing, with the level of investment that they can make into this business, we'll be able to achieve more than we could standing on our own" (Acceleratingtech.com 2016). ARM's official responses centre around the importance of the joint effort and substantial investment needed to implement the new technological paradigm. One of the central messages of the executives is the assurance that "the business day to day will remain unchanged in its management and strategy" (ibid.).

However, this optimistic view, although in the traditionally humble and cautious ARM way, has its less optimistic respondents. An ARM co-founder Hermann Hauser expressed his disappointment about seeing the last British global technology company selling to the overseas buyer with the words: "This is a sad day for me and a sad day for technology in Britain" because the future of the great British technology company will be no longer decided in the UK (BBC News 2016). Other analysis expressed harsher views about the change of hands for ARM and stronger concerns about the fates of ARM's legacy under Softbank ownership. Recent news on the ownership structure has been Softbank' intention to sell 25% of ARM shares to a Saudi investment fund (Massoudi and Parker 2017).

It is an interesting context for analysis, in which the details of the grander political and economic landscape following the Britain's exit from the EU also matter. The situation is also part of the discourse about the prospects of technology companies in Britain that seems to lack the ambition to continue the risky economic and technological advancement and take the cash instead (Warner 2016). In all its many-sidedness, the new development has an important resonance with the main themes of the thesis: will ARM manage to retain the inner cultural alignment so crucial for the business now that the corporate landscape has changed? How will it manage the leap into the technological uncertainty of the IoT paradigm with the potential challenges of the new leadership, new ownership and new culture? These are interesting questions to investigate.

An important perspective to consider is that what the Japanese venture capitalists were buying was a de-facto monopoly. In the dissertation, we have accepted ARM's humility and benevolence at face value, but there was another way of looking at it. The whole Ecosystem has become so dependent on ARM that what ARM has created is a de-facto monopoly. The cost of switching for Partners from ARM is high. ARM has "stickiness", to use the words of an interviewee's making it difficult for Partners to leave the relationship and the dynamic of the product co-development. There is no effective competitor to ARM, because Intel is not a substitute for what ARM provides. The Ecosystem is considerably locked in. It is also locking out innovation in new microprocessor architecture. The questions to consider are: why would venture capitalist want to buy this lot? Are they seeing things rather differently? ARM's Partners see a weakness in ARM is spreading too thin. Its future is, perhaps, to split the businesses. Softbank's acquisition does not quite look like an investment in a classical case, where a VC is bringing in a particular capability to help grow a business and follow up with an initial public offering. VCs are not there for long term management. We see that the Japanese investors bought ARM and intend to sell a quarter of the company to the Saudi Arabian investors. This is not a usual scenario for an established company like ARM. It would be very interesting to investigate what the intentions of the VCs are and what it means for the future of the company.

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Appendix 1. List of interviewees

Interviewee's role (geographic location in the role)	Interview number	Year of interview
ARM senior manager X (UK)	Interview 1	2011
ARM top executive Y (UK)	Interview 2	2011
ARM senior manager X	Interview 3	2012
ARM Vice President (UK)	Interview 4	2012
ARM top executive Y (UK)	Interview 5	2012
ARM senior Human Resources manager (UK)	Interview 6	2012
ARM Business Development manager (UK)	Interview 7	2013
ARM Executive assistant (UK)	Interview 8	2012
Former CEO of an ARM acquired company (Europe)	Interview 9	2013
ARM Director of strategy (Europe)	Interview 10	2013
ARM Learning and Development Consultant (UK)	Interview 11	2013
CEO of an ARM acquired company (US)	Interview 12	2013
Former top executive and co-founder of ARM (UK)	Interview 13	2014
ARM Director UK	Interview 14	2014
ARM Former Manager of Connected Community (USA)	Interview 15	2014
ARM top executive Z (Global)	Interview 17	2014
ARM's Partner, a US company (UK)	Interview 18	2014
ARM Partnership Manager at a US Partner company (UK)	Interview 19	2014

Appendix 2. Example questions for an interview guide

Ambidexterity. Exploitation/exploration

What is your role in the company? How long have you worked in the company?

What parts of the company in your opinion can be called more conservative and which ones are seen as experimenting with new ideas?

Could you give an example of a product/process (in your department) that was recently dropped? How did that happen?

Who initiates the development of new products? Where do novel technology ideas come from (in-house, externally sourced)? (How do external partnerships feed into innovation activities? Examples?) How do new ideas/knowledge taken on board (how innovations emerge and what they go through to be taken to market?)

What are the biggest challenges around pushing innovative ideas further?

Do results achieved by a team at any point evaluated and rewarded? If yes, how in your opinion does it influence risky decisions/bold ideas by employees?

How are decisions about allocating resources to either novel or existing technologies made? What is the style of negotiating such resource allocation? Who decides that a particular novel idea would be supported/given a priority, for example, by allocating money for pursuing it further?

How different are the technologies you are working on now from what you currently have in the market place? How easily are new products launched?

At the level on an individual employee, how is the time between day-to-day duties and producing new ideas divided? What about “Innovation Time Off”?

How does orientation on the customer/competitors influence innovation (incremental? radical?) decisions and processes? How does the knowledge of the market help the company to improve its capabilities? (Example of market-pull products)?

Can you give an example of how customers/competitors' actions influence the company? What raises the sensitivity of the company to these external changes?

How does the company identify its weaknesses? Analyse mistakes? Incorporate feedback?

Do you see differences in the style of work of different units? How would you characterise them? To what extent do they communicate/collaborate?

How is communication of the main strategic direction ensured through all levels of the company?

What is the role of innovation in the company? Who is the catalyst behind it? What message is disseminated? Is it shared by all level employees?

What does the job of top-managers involve to ensuring new business directions are explored?

What managerial and cognitive skills do you think are important in this job?

What is the way for a non-managerial staff to contribute to innovativeness of the company?

How do the personal image and the message of the company's leaders help in promoting innovation?

What are the main issues that top managers face when they introduce change across the business?

How would you describe attitudes to change and novelty in the company? What are the core values of the company?

Organisational Change

What are the current marketplace trends in your industry? What qualities helped to get there and what is holding back from being further ahead?

What keeps you awake at night? What things are happening in your industry you wish you had control of and why?

What were the most substantial tech. breakthroughs during your time in the company? Can you comment on the impact of the new tech. on the company and beyond? Was this new product aimed at existing/new customers?

In the company's recent history (in your experience) how compatible are the new technologies/product with the previous one? How often/easily new products are launched to the market (tech. life-cycle)?

Who are the company's competitors? Is the competition obvious or sneaky? What are the aspects of organisation (corporate culture, relationship with customers, managerial and technical capabilities, property rights, business structure, etc.) that distinguish you from competitors?

Can you think of examples in the company's history when it redefined itself to differentiate itself from the competitors? (E.g. redefining the company as providing the environment rather than product, etc.)

Who are the company's (main) customers? What criteria are important for them when buying the product (buying behaviour)? What are their expectations of the product? How demanding are they to the product? How sensitive are they to its weaknesses?

To what extent is technology development oriented on the customer? (market pull/tech. push) How does the knowledge of the market help develop new products?

Who are the suppliers to the company? To what extent do the suppliers affect the way the business is done? Does the company contact/collaborate with the competitor suppliers of the same product?

What are products the company depends on? (software, hardware; mobile/digital devices)?

In the company's history have there been examples of external regulations impacting the business in a substantial way?

Changing Industry Structure

Practical tools to trace change in industry? Do you sometimes develop a map/diagram of the industry? Do such implicit things get translated into written descriptive analysis?

Do others in the company share your industry map and its dynamics, its future?

Does the vague outline of the new direction exist?

If I ask you to describe your company in a single phrase (that projects the meaning of the business), what would it be like? If at the time of change it is not easy to describe what the company is going to be, can you tell what the company is NOT going to be?

Identifying Change

"Silver bullet test" (Andrew Grove): if you had one bullet in your imaginary pistol, whom among your many competitors would you save it for?. Do you know who your most important complementor is?

How do you tell if next innovation is going to be a big thing or not? How is the significance of the new in-house technology assessed?

What practices/ what data are used as a guide in assessing the potential impact of new technology (experience, heuristics, intuition)?

How does a typical discussion to analyse the significance of new technology look like (how broad or intense is the debate? who are the participants: are they many, are they heterogeneous, which parts of the company are they from? anyone from outside of the company: customers, partners? fow long does it normally go on, **what emotions are involved?**)

Redeploying Resources

Over recent time, what significant changes in resource allocation (materials, people's time) took place and in what manner (all resources, partially, gradually)? Was the change in resource allocation more or less intuitive or consistent with the some articulated end results?

The Clarity of Direction

How do leaders envisage and communicate the future image of the company within the company and publicly? How articulate/ambiguous is it? How quickly are strategic decisions acted upon?

What is the state of mind of top management at the time of transition given the formulated strategic direction (inspired, demoralised? are messages given by the

company's leaders conflicting? being changed? are they detailed enough? do they generate trust among the employees and management?)

How is the company's team mobilised to work in an uncertain environment? Please give example of how do different teams within the company would communicate with one another (email, formal regular/informal spontaneous meetings, feedback options)?

How is the new strategy promoted?

To what extent do the prior actions have a pull, e.g. through prior commitments?

Looking at the leader's calendar: how is time allocated to the new and old tasks?

Culture, Values

How does a typical problem solving meeting look like (is arguing ferocious? friendly? diplomatic? perhaps humble? confrontational?) How do you overcome deference by juniors with expertise to seniors with authority?

What would be the desirable outcome of such a meeting? (result/process/strategy as a solution? How important is achieving preliminary consensus or tangible results?)

Are there specific ways of approaching problems that can be called corporate values? Any local mottos, catch phrases that capture the values or culture? Are some beliefs/values stronger than other (perhaps those having to do with the self-image and the dominant technology/business)? How do mottos/values help direct the business?

Are values/culture an important part of the company's identity? How have they been changing during you time here (examples)?

Are outside specialists (consultants, analysts, etc. with no stake in the business) sometimes engaged into decision making? Have they been appointed to the managerial positions?

What emotions are associated for you with change? Can you describe your personal feelings when transitioning through the change (do you feel helpless, confused, frustrated when something fundamental is changing and the things that worked for you in the past are no longer do any good?)

How do the values differ across different units of the company? Can you give example in what way do they complement each other and in what way do they discord?

Can you give examples of actions where mistakes could be later corrected and thus were allowed, and actions which had to be performed with no mistakes?

What do you feel your strategic points of change have been? Did you feel vulnerable? (in which case, what prompted your anxiety) or in a position of power (in which case: what gave you confidence: internal strength, control of external events)

How quickly does the external change in the rules of game get picked up? How does the information about change gets onto the radar and is taken it (explicitly admitting the change, struggling to evaluate/admit it? struggling to determine the magnitude of change and make decision to do something about it?)

The Role of Middle Managers

What information do middle managers or people on the front lines of the company (e.g. in sales) bring from the periphery? What warning signs do they notice? What are the typical things they bring to the attention? Can you give an example of how changing outside circumstances were picked up by the middle managers/employees working directly with the outside world (e.g. sales)?

How are "the signals" distinguished from "the noise"? How does the change get recognised? (through which channels? on which basis?)

How does the news of change percolate through the organisational layers and reach the leader? What is their typical reaction?

How is information about change evaluated?

Are there practices/tools within the company to detect change prospectively as opposed to the retrospective explanation and analysis? (Practices learned from the experience)

When the top management is rethinking the strategy change, what do middle-level employees occupy themselves with?

Is it possible for middle level employees to question the leaders' strategic messages (are they comfortable doing this, what is the means for that)?

Adjusting to the New

Please recount a period of adjustment and elaborate on what worked, what was traumatic, and has the firm benefited from it (if so in what ways?)?

How has the management been changed in response to the new strategic direction? (resignations, replacements, relocations to new assignments, demotions, adaptations, ‘going back to school’, etc.)

Can you give examples of the last time such transformations have been done and to what extent? How often does such reshuffling happen? How hard is it to do (emotionally, organisationally)?

Appendix 3. Abbreviations and glossary[1]

CPU	Central processing unit. The electronic circuitry within a computer that carries out the instructions of a computer program by performing the basic arithmetic, logical, control and input/output operations specified by the instructions.
Microprocessor	An integrated circuit that contains all of the functions of the Central Processing Unit of a computer
Microprocessor architecture	A description of the overall physical lay-out of the various elements of the processor. A microprocessor can either have a CISC (complex instruction set computing) or RISC (reduced instruction set computing) architecture. The RISC architecture is simpler, smaller and faster.
RISC	Reduced Instruction Set Computing is a type of microprocessor architecture that utilizes a small, simple and highly-optimized set of general instructions.
CISC	Complex Instruction Set Computing is a type of microprocessor architecture that utilises a large set of computer instructions that range from very simple to very complex and specialized. An umbrella term coined after RISC (Reduced Instruction Set Computing) was introduced to delineate everything that is not RISC.

[1] Definitions of terms related to ARM's technology are based on definitions provided by ARM in glossaries in annual reports (ARM Annual Report and Accounts 2011 , ARM Annual Report and Accounts 2012 , ARM Holdings plc Strategic Report 2015)

ICTs	Information and communication technologies
IP	Intellectual property. The general term for the products that are designs only or are creations of the mind.
µm	micro meter, one thousandth of a meter
nm	nanometer, one billionth of a meter
OEM	Original Equipment Manufacturer
EDA	Electronic Design Automation is a diverse set of software tools for designing integrated circuits and printed circuit boards
R&D	Research and Development
SoC	System-on-the-chip, or system-on-chip, is a computer chip where multiple functions are integrated on a single chip.

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