COLLABORATION FOR RESEARCH AND DEVELOPMENT: UNDERSTANDING ABSORPTIVE CAPACITY AND LEARNING IN R&D CONSORTIA ACROSS PHASES, LEVELS, AND BOUNDARIES

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OMID OMIDVAR

Manchester Institute of Innovation Research

Manchester Business School

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ABSTRACT

Collaboration for Research and Development: Understanding Absorptive Capacity and Learning in R&D Consortia across Phases, Levels and Boundaries

A thesis submitted for the degree of Doctor of Philosophy (PhD)

Omid Omidvar-2013

The University of Manchester

Over the past two decades, the literature on Absorptive Capacity (AC) research has been burgeoning with enormous empirical and theoretical contributions to the field. Yet, there is not much advancement in understanding the internal dynamics of AC and the concept remains a black box in a large body of research. This study aims at contributing to this body of knowledge by examining the development of AC throughout the lifecycle of R&D consortia. In particular, it examines the pre-conditions of AC across its three dimensions corresponding with the phases of consortia: exploratory, transformative and exploitative learning, and investigates the role of disciplinary, organisational, and intra-organisational boundaries in the development of AC.

Utilising a case study research strategy, the thesis analyses AC in three R&D consortia in the alternative materials, pharmaceuticals, and aerospace industries and embraces qualitative methods with interviews and documents as its main sources of data. The collected data is analysed through template analysis technique assisted by the NVivo 8 software package.

The theoretical contributions of the thesis are fourfold. First, findings indicate that AC is not an exclusively organisational or dyadic capability, but a three-level concept unfolding at the consortium, interface (between consortia and organisations), and organisational levels, and in exploratory, transformative and exploitative phases throughout the consortium lifetime. On that basis, a model for AC in R&D consortia is developed and its underlying learning mechanisms and conditions across levels and phases are discussed in detail. Second, the thesis contends that the development of a *shared space* which provides the opportunities for participation and development of shared meaning across organisational and disciplinary boundaries in R&D consortia serves a critical role in the development of AC. The characteristics of the shared space and the conditions for its development are specified. Third, by integrating adaptation mechanisms to the formulation of AC, the thesis contributes to understanding of AC as a dynamic capability-a higher order capability to change operating routines and processes. This finding feeds into the argument that AC is both path-dependent, by storing knowledge in routines, processes and artefacts through exploitative learning, and path-breaking, by modifying and changing prevailing processes and structures through exploratory and transformative learning. Finally, the thesis argues that understanding learning in R&D consortia necessitates taking into consideration the effects of disciplinary and organisational boundaries simultaneously. It is argued that organisational boundaries can influence the transfer of knowledge even within disciplinary domains, which challenges the excessive focus of practice-based research on disciplinary boundaries in cross-disciplinary collaborations, calling for further exploration of the role of organisational boundaries within a given disciplinary domain. These theoretical contributions are accompanied by a set of managerial implications for the formation and governance of R&D consortia, as well as policy implications for evaluation of policy interventions in collaborative research schemes.

DECLERATION

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright statement

LIST OF ABBREVIATIONS

AC: Absorptive Capacity

CoP: Community of Practice

CRF: Case Report Forms

DTI: Department of Trade and Industry

DTP: Development Test Plans

EC: European Commission

EMC: European Medicine Collaboration

EFPIA: European Federation of Pharmaceutical Industries and Associations

FEA: Finite Element Analysis

FP7: Framework Programme 7

KM: Knowledge Management

PVD: Physical Vapour Deposition

RQ: Research Question

SOP: Standard Operating Procedure

SC: Social Capital

TiN: Titanium Nitride

TPT: Triode Plasma Treatments (TPT)

SVHC: Substance of Very High Concern

TiN: Titanium Nitride

TSB: Technology Strategy Board

To Maryam

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Chapter 1. INTRODUCTION

1.1 RESEARCH OBJECTIVES

Defined as a firm's ability to recognise the value of external knowledge, assimilate, and apply it (Cohen and Levinthal 1990), Absorptive Capacity (AC) is regarded as an important capability for managing external knowledge, and a determinant of inter-organisational learning (Lane and Lubatkin 1998, Lane et al. 2001, Lubatkin et al. 2001), competitive advantage (Zahra and George 2002, Todorova and Durisin 2007, Escribano et al. 2009, Lichtenthaler 2009), innovation and firm performance (Tsai 2001, Rothaermel and Alexandre 2009).

The AC literature has been burgeoning in recent years. Owing to more than two decades of research, authors have contributed to conceptual advancements of AC from a static capability embodied in R&D intensity (Cohen and Levinthal 1990, Tsai 2001) or the level of prior knowledge of the firms (Kim 1998, Mowery et al. 1998) to a dynamic capability (Zahra and George 2002, Lane et al. 2006, Todorova and Durisin 2007), or an evolutionary concept (Van den Bosch et al. 1999, Lewin et al. 2011). Valuable insights have been provided about the antecedents and determinants of AC (Lane and Lubatkin 1998, Jansen et al. 2005), its underlying processes and routines (Lichtenthaler 2009, Lewin et al. 2011), and the role of individuals, and agency (Jones 2006, Easterby-Smith et al. 2008a).

Despite the fast-growing literature on AC, a number of valuable research areas remain unattended to. First, we argue that the extant AC literature lacks a contextualised examination of the constituents or microfoundations of AC (Lewin et al. 2011). There is a general understanding that AC is an important factor for firms, regions, and nations, and high levels of AC lead into innovations and competitive advantages. However, merely looking into the outcomes of AC without understanding its internal dynamics can turn tautological given the fact that in many instances of empirical research, the operationalisation of AC has overlapped with the operationalisation of its consequences such as learning, innovation, etc. (Lane et al. 2006). Highlighting this issue, Volberda et al. (2010) stressed that researchers have mainly used AC as the independent variable and there is a need for opening the black box and looking into its components at the inter-organisational and intra-organisational levels. We still know little about what constitutes AC, and even in conditions where we know the components and underlying processes, they remain abstract and ungrounded in empirical findings.

This research aspires to contribute to this broad research domain by examining the development of AC in R&D consortia. Among many other reasons, we have chosen R&D consortia as the empirical context of the study because a) it provides a knowledge-intensive context for collaborations in innovative areas, and b) it involves multiple partners which is different from the conventional context of dyadic relations researched in AC literature. Analysing AC of individual organisations in isolation cannot provide the rich context of knowledge transfer and learning which we aspire to examine. On the other hand, dyadic relations have been studied by many researchers (Dyer and Singh 1998, Lane and Lubatkin 1998). Therefore, this study explores AC in the context of R&D consortia, and it presents the first objective of the research as:

> ***Research objective 1:*** *To contribute to a contextualised view of absorptive capacity in R&D consortia by 1) identifying the challenges for co-creation, transformation, and exploitation of knowledge and 2) identifying the mechanisms that address these specific challenges through 3) opening the black box of the AC.*

We are, moreover, of the opinion that there is room for improvement in understanding of the formation of R&D consortia, and its effects on learning performance. Extant literature has explored and explained the mechanisms of the formation of R&D alliances. The three major theoretical arguments for the choice of alliance formation include the transaction cost theory (Williamson, 1975, 1985), the resource-based view (Penrose 1959), and the social network/social capital perspective (Burt 1992, Gulati 1995, Ahuja 2000). However, while the factors that affect the choice of partners within collaborations have been discussed in the literature, there have been fewer attempts to unravel the dynamics of the formation process of R&D consortia. Moreover, it is of interest to see how the dynamics of the formation influence the AC dimensions, and conversely how AC relates to the formation of R&D consortia dynamics. Accordingly, the second research objective is:

> ***Research objective 2:*** *To contribute to a more contextualised understanding of the preconditions of formation mechanisms of R&D consortia and to see how these conditions affect the development of AC throughout the collaboration lifecycle.*

1.2 THEORETICAL FRAMEWORK

1.2.1 THE BROAD THEORETICAL UNDERPINNINGS

One of the main themes of the thesis is that it revolves around problematising the learning underpinnings of AC. The conventional approach to learning and knowledge transfer embodied in the simplified succession of knowledge acquisition, assimilation, and application does not reflect the complexity of inter-organisational settings in R&D consortia. As suggested by some authors, today's organisations are experiencing an increasingly complex *ecology of innovations* (Dougherty and Dunne 2011). In R&D consortia, organisational contexts and the domains of expertise that their members belong to are diverse. Such a diversity, in turn, translates into a number of boundaries demarcating interpretations, languages, and practices. Therefore, for AC, neither learning nor the knowledge transfer processes - in their simplistic trilogy of knowledge/sender/receive (e.g. (Szulanski 1996)) - are discernible without exploring the very context of learning, the (pre-existing) boundaries in situ, and the mechanisms to bridge those boundaries.

Trying to avoid these potential drawbacks, we enrich the approaches to learning in AC research with practice theorising. Our analysis of AC involves two theoretical moves. First, we do not take boundaries for granted; we identify them, explore their dynamics throughout the collaboration, and analyse the mechanisms that give rise to their crossing within the consortia. Second, we do not reduce learning to the three steps of acquisition, assimilation, and application of knowledge, as it is in AC literature, but, by adding practice-based and situated learning views, we seek to develop a rich and contextualised view of AC.

As far as the approach to the boundaries is concerned, we explore three types of boundaries. First, we explore the disciplinary boundaries which demarcate the domains of expertise. Given the diversity of partners and their speciality domain, R&D consortia inevitably deal with disciplinary boundaries (Roelofsen et al. 2011). This type of boundary is important to our analysis since it influences knowledge transfer in a multidisciplinary work context through generating variance in languages and meanings, and divergence in perspectives (Oborn and Dawson 2010). Second, given the diversity of the types of organisations that participate in R&D consortia which include public organisations, private companies, SMEs, etc., the organisational contexts vary to a certain extent. Accordingly, the organisational boundaries comprise the second type of the boundaries of interest in this research. Thirdly, in R&D consortia, there is a boundary which separates the participants in collaboration from the other members of individual organisations who do not participate in research (Scarbrough et al. 2004). This is what we refer to as intra-organisational boundary.

As far as the approach to learning is concerned, we complement the extant approach with the practice-based approach to knowledge and learning. We argue that, in a large body of AC research, the underlying *epistemology* has been that *of possession* (Brown and Duguid 2001). We argue that such an approach is inadequate in addressing learning in R&D consortia given the heterogeneity of boundaries and the diversity of partners. We posit that a practice-based view to knowledge with its emphasis on the context of knowledge and how it develops in situ can enrich our understanding of AC. Therefore, we complement the dominant approach to learning in AC research with the practice approach in order to analyse learning mechanisms that support AC.

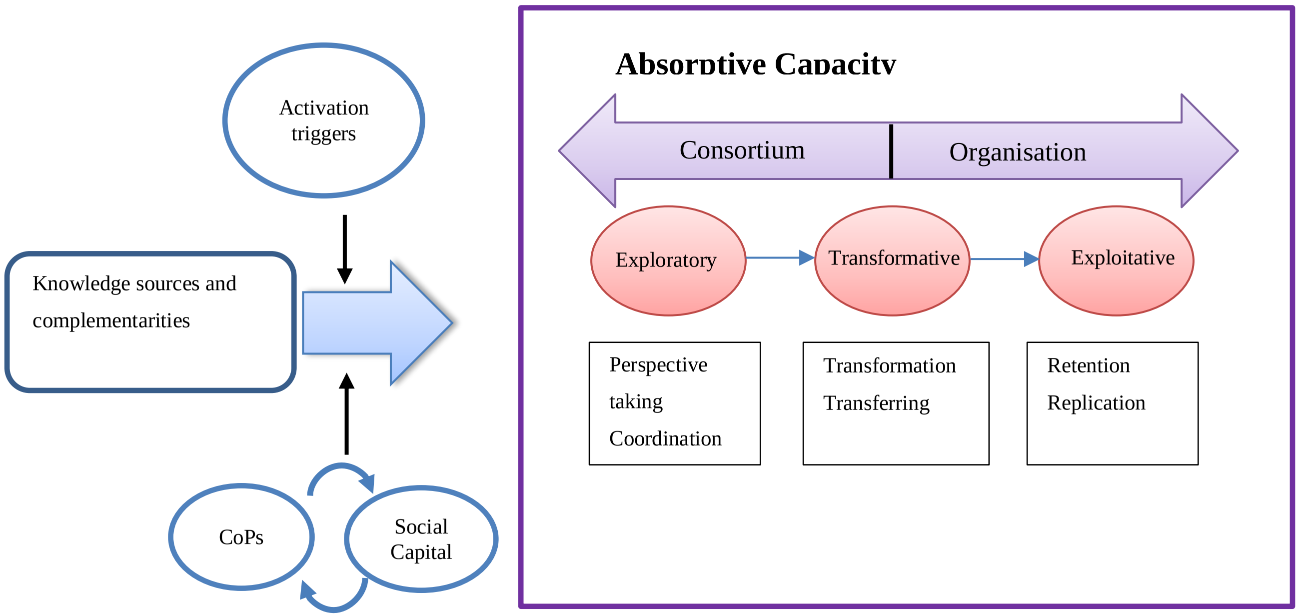
1.2.2 THE FRAMEWORK IN BRIEF

Figure 1 demonstrates the theoretical framework of this study. This framework is not purely deductive (i.e. through literature), but it is a mixture of deductive and inductive theorisations after thoroughly analysing the first case (we will return to the methodological handling of the framework in chapter 4). The full details of the theoretical framework will be presented in chapter 3.

The theoretical framework suggests that the existence of knowledge sources or complementarities is the departure point for the analysis of AC. In general, external knowledge sources can include merger and acquisitions, licensing, and inter-organisational relationships like R&D collaborations, alliances and joint ventures. Since R&D consortia constitute the empirical field for our inquiry, they broadly determine the knowledge sources and the type of complementarities (i.e. our sources do not include mergers, or licensing). However, in the thesis, we will seek to narrow down our research about the nature of complementarities that R&D consortia offer. Following Doz et al. (2000), we define an R&D consortium as “a legal entity established by [more than two] organizations that pool resources and share decision making for cooperative research and development activities”.

As suggested in Figure 1, we expect that activation triggers moderate the relationship between the complementarities and knowledge sources, and AC. They can be internal – like a firm facing a crisis, or a problem that they want to solve- or they can be external- like a technological shift in the industry in which an organisation is active (Zahra and George 2002, Todorova and Durisin 2007).

FIGURE 1: THEORETICAL FRAMEWORK



We are also convinced that the formation of consortia depends on the pre-existing Social Capital (SC) and Communities of Practice (CoPs). First, pre-existing SC facilitates the identification of potential partners. We define SC with respect to its two major dimensions: structural capital and relational capital. *Structural capital* pertains to the linkages among actors; it relates to the opportunities actors have to build a relationship (Burt 1992). Prior ties and the frequency of interactions are the most important aspects of structural capital. *Relational capital* reflects the nature and quality of interactions; it relates to the motivational aspects of social capital including trust, and mutual expectations and obligations. SC contributes to the formation of collaborations through actors' linkages and through providing a favourable context of mutual expectations and trust (Adler and Kwon 2002).

Second, pre-existing CoPs (at the inter-organisational space) can affect the opportunity for forming the consortium too. A community of practice is a unique combination of three fundamental elements: a *domain* of knowledge, which defines a set of issues; a *community* of people who care about this domain; and the shared *practice* that they are developing to be effective in their domain (Wenger et al. 2002 p.28). CoPs are specifically valuable across the organisational boundaries in fast-moving industries as they help with adaptation to environmental changes (Powell 1998). While SC determines the linkages and the conditions for interactions among various actors and potential partners, the domain of expertise and the ability to exchange knowledge are determined by the pre-existing CoPs.

The rectangle in Figure 1 encompasses our formulation of AC. Using Lane et al.'s model of AC (2006), we define AC as "a firm's ability to utilize externally held knowledge through three sequential processes: (1) recognizing and understanding potentially valuable new knowledge outside the firm through exploratory learning, (2) assimilating valuable new knowledge through transformative learning, and (3) using the assimilated knowledge to create new knowledge and commercial outputs through exploitative learning" (Lane et al. 2006 p.856). However, we enrich their model by dismantling the previously unattended notion of boundaries in AC. At the consortium level, boundaries mark disciplinary differences or organisational differences. Within organisations, they demarcate functions or separate those participating in projects from the rest of the organisation.

The theoretical framework, moreover, indicates that learning mechanisms vary in different dimensions of AC and across various types of boundaries. It suggests that the three dimensions of AC are sequential and unfold in time. Exploratory learning builds on *perspective taking,* and *coordination*. Perspective taking refers to understanding and interpreting the others' viewpoints, interests, and thoughts through positioning them in relation to one's own knowledge. "This taking of the other into account, in light of a reflexive knowledge of one's own perspective, is the perspective-taking process" (Boland and Tenkasi 1995 p.362). On the other hand, coordination mechanisms include a set of procedures and means for collaborating in distributed work, even in the situations with little consensus (Akkerman and Bakker 2011).

Transformative learning relates to assimilating knowledge, and with integrating the newly identified knowledge with the existing knowledge. In transformative learning, assimilation deals with mechanisms that transcend mere understanding of the new knowledge. On the one hand, it relates to combining the new knowledge with the existing knowledge using the prevailing competencies (Zahra and George 2002) or changing the knowledge structures in order to integrate the newly acquired knowledge with the existing (Carlile and Rebentisch 2003, Todorova and Durisin 2007). On the other hand, we posit that transformative learning, as the bridge between exploratory and exploitative learning, consists of transferring mechanisms which enable moving knowledge across space and time.

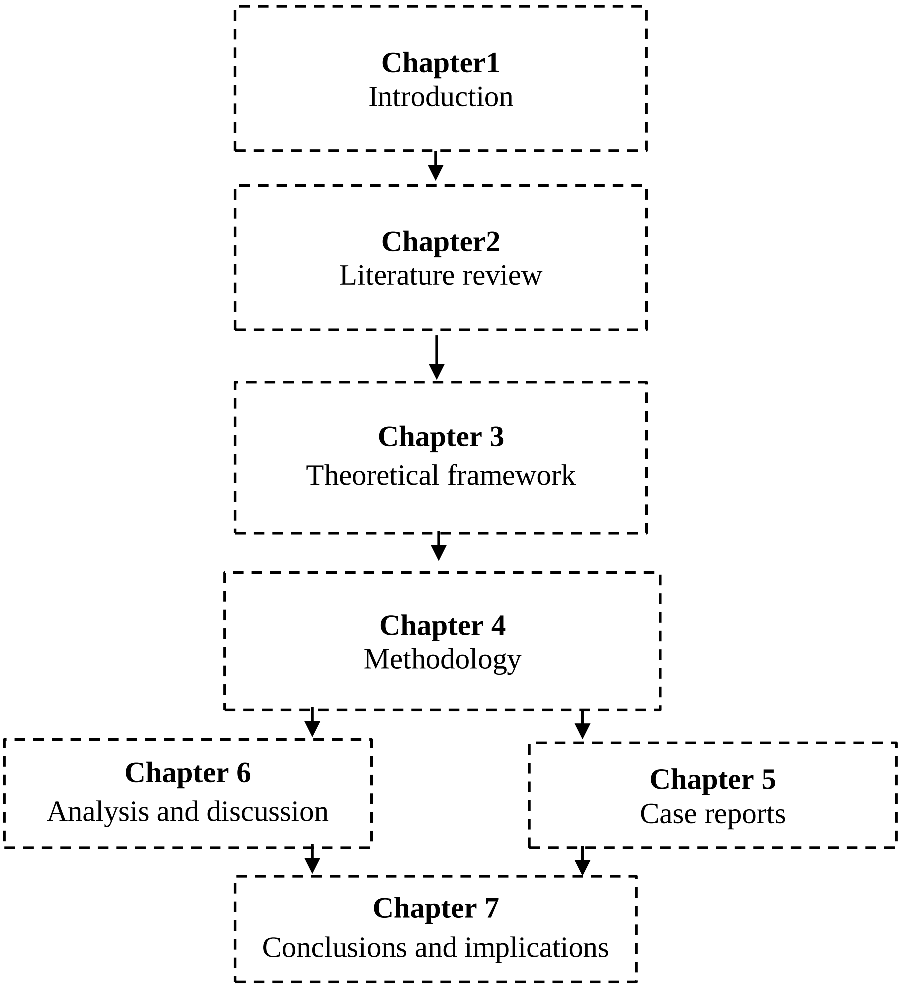
Finally, exploitative learning relates to applying the assimilated knowledge by utilising and recreating knowledge. It is mainly concerned with *retention* and *replication* mechanisms. Through retention knowledge becomes embedded within organisations by decreasing in its level of abstraction and through becoming routinisied within the organisation (Zollo and Winter 2002). On the other hand, exploitation entails a degree of replication. When knowledge becomes applied in organisations, it inevitably becomes replicated in different areas. Therefore, replication is an integrated aspect of application. Lewin et al. (2011) have also pointed to the importance of replication of superior routines in AC.

As evident in Figure 2, we posit that exploratory learning predominantly occurs at the consortium level, dealing with a number of inter-organisational boundaries, whereas we contend that exploitative learning pertains to the organisational level, predominantly dealing with intra-organisational factors. Transformative learning relates to the interface level as it deals with both dimensions equally. In reality, the separation that we make between the phases are not as straightforward as we present here and, for instance, exploitative learning can happen in collaboration with partners at the consortium level and exploratory learning can occur within organisations (Holmqvist 2003, Holmqvist 2004). However, we do make these presumptions because a) by adopting this separation, we remain aligned with the three-dimensional conceptualisations of AC, and b) a considerable aspect of learning at the inter-organisational level is exploratory and at the intra-organisational level is exploitative.

1.3 THE STRUCTURE OF THE THESIS

The thesis consists of 7 chapters, including the introduction (Figure 2). Chapter 2 provides an overview of the extant AC literature, its evolution over the past two decades and its major critiques. Then, it moves to discuss the R&D collaboration formation literature. Based on this literature review, research gaps are identified which then, in combination with the two research objectives that we set in this chapter, inform the research questions (presented at 2.4). Literature review, moreover, informs the theoretical framework of the study presented in chapter 3 which represents a detailed account of the theoretical framework of the study. In chapter 4, the methodology and research design of the whole thesis are explained in detail. Chapter 5 portrays the narratives of the three case studies by exploring the history of the three examined R&D consortia and the important aspects of learning and knowledge transfer in the cases. This chapter is aimed at familiarising the reader with the contexts and stories of the three cases, preparing them for a more theoretical analysis which will follow in chapter 6. Chapter 6 applies the theoretical framework to analyse the research data and to refine and enrich the theoretical framework. Finally, chapter 7 presents the conclusions of the research by summarising the main findings in relation to the research questions and by discussing the theoretical and managerial implications of the study.

FIGURE 2: THE STRUCTURE OF THE THESIS

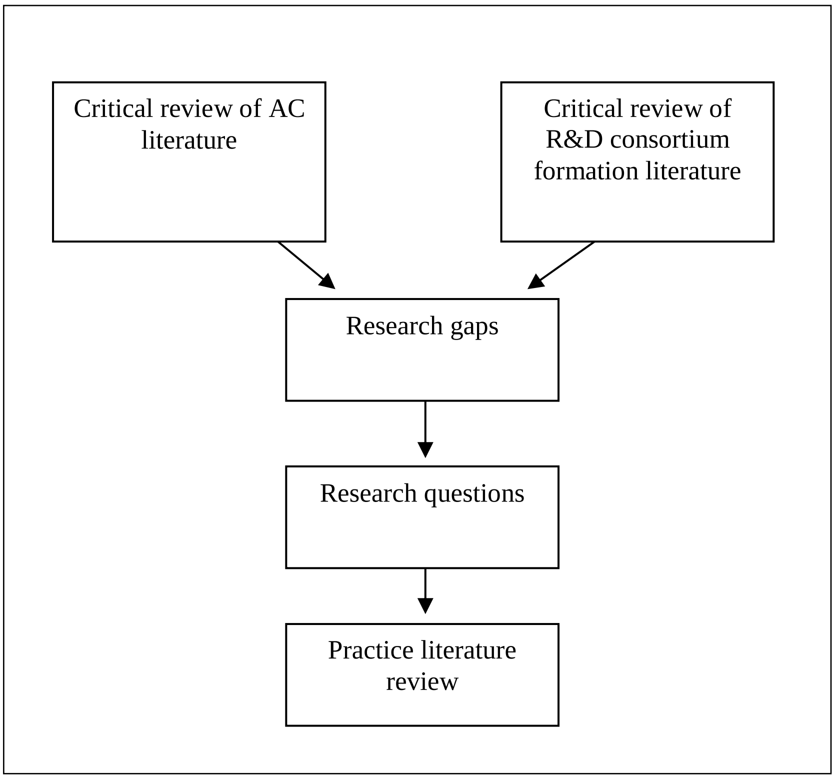


Chapter 2. LITERATURE REVIEW

2.1 INTRODUCTION

This chapter explores the bodies of literature which have informed the thesis. We start by reviewing the AC literature, looking into its origins and its main research streams. Then we proceed to discuss some potential inadequacies in AC research. Afterwards, we focus on the formation of R&D consortia based on which we introduce some gaps in the literature. Based on two sets of identified research gaps, and considering the research objectives that were established in the first chapter, we present the research questions. The final part of the chapter focuses on the practice approach as one of the pillars of the study. However, since in this study practice approach is mainly employed in order to inform the theoretical framework, we do not introduce gaps in this body of literature, though the critiques are presented at the end. Figure 3 demonstrates the outline of this chapter.

FIGURE 3: THE CHAPTER OUTLINE



2.2 ABSORPTIVE CAPACITY

2.2.1 THE ORIGINS OF THE CONCEPT

The two articles written by Cohen and Levinthal (1989, 1990) are known as the seminal work in which the notion of AC was introduced (although the latter work is more widely cited and recognised by researchers). Before the introduction of AC (Cohen and Levinthal 1989, Cohen and Levinthal 1990), the importance of utilising and managing external knowledge had been well recognised by management researchers (Allen et al. 1979, Tushman and Scanlan 1981, Allen et al. 1983). However, at the time of the authoring of the 1989 and 1990 articles by Cohen and Levinthal, a systemised understanding of how external knowledge can lead to firms' competitiveness was still lacking. The two papers, therefore, can be viewed as the initial moves to contribute to this domain of literature.

In their 1989 article (Innovation and Learning: The Two Faces of R&D. *The Economic Journal*, 99(397)**,** 569-596), Cohen and Levinthal's conceptualisation of AC was inspired by their interest in an economic understanding of firms' behaviour. The contemporary approach was that external knowledge is a public good and there is little cost involved in identifying and assimilating it. However, Cohen and Levinthal argued that a firm's ability to successfully intake external knowledge, i.e. to identify, assimilate and apply it, depends on the investment it makes in R&D. As such, their departure point was their interest in what gives firms competitive edge over their rivals from a purely economic point of view.

In their 1990 article (Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly,* 35(1)**,** 128-152), Cohen and Levinthal expanded their conceptualisation of AC from a purely economic perspective to one that included the cognitive characteristics of learning. More specifically, in this contribution, by linking the dynamics of individual learning into organisational learning, they developed a cognitive theory of AC. They started by discussing how individuals with accumulated knowledge in certain areas are more likely to absorb knowledge in those domains. Afterwards, by making an analogy to organisations, they discussed that the prior knowledge that organisations accumulate determines the effectiveness of their later efforts for acquisition of new external knowledge.

Having such emphasis on learning aspects of AC and discussing its individual psychological underpinnings enriched the theoretical power of AC, rendering it appealing to both organisational and innovation researchers interested in understanding the usage of external knowledge by organisations. It is, therefore, not surprising that among the two articles, the 1990 article has received considerably more citations, and is widely recognised as the seminal AC article.

2.2.2 COGNITIVE APPROACH

Cohen and Levinthal's work built upon two inter-related learning views. First, their work was largely influenced by organisational learning literature developed in the 1980s (Fiol and Lyles 1985, Levitt and March 1988). This literature distinguished between individual and organisational learning by contending that 1) organisational learning is more than the summation of individual learnings and 2) features of organisational cognition such as organisational memory, mental maps, norms and values are more enduring than those of their members (Hedberg 1981 p.6). Second, Cohen and Levinthal mobilised the work developed by cognitive psychologists who studied how individuals develop their memory and cognition (Bower and Hilgard 1981). Prior related knowledge or problem solving experience makes individuals receptive to new knowledge in the respective domain: "…prior knowledge enhances learning because memory – or the storage of knowledge – is developed by associative learning in which events are recorded into memory by establishing linkages with pre-existing concepts" (Cohen and Levinthal 1990 p.129). As such, problem solving and learning are of a cumulative nature. One's ability to learn increases along with their level of previously accumulated knowledge. Likewise, the more knowledge or problem solving experience an individual gains, the more likely that they can absorb new forms of knowledge.

Combining these views, Cohen and Levinthal developed a cognitive formulation of learning which links dynamics of individual cognition into organisational ones. After establishing their argument for individuals' AC, they argued that organisational AC follows the same logic i.e. the more knowledge accumulated in organisations, the more they are receptive to assimilate and use new knowledge. Like individuals, organisations have memories which can be used for stocking knowledge/ information. Similarly, the broader the knowledge base of an organisation, the more probable it is that it will detect new external knowledge and 'absorb' it.

In addition to the knowledge stock of the firms, Cohen and Levinthal posited that AC depends on the *mosaic* (Cohen and Levinthal 1990 p.133) of individual ACs. By mosaic they meant that absorptive capacity relies on the communications between individuals and interfaces between the departments within firms. In fact, this is an important difference which distinguishes AC of organisations from that of individuals. However, this debate stops in their theoretical part of the paper and receives no attention in their empirics as they operationalise absorptive capacity through R&D intensity or R&D investment. This is because they assumed that more R&D investment entails bigger knowledge stock, which is a proxy for AC.

The cognitive approach has been dominant in a large body of literature although there are two streams identifiable out of it. The first stream considers AC as an absolute concept, arguing that the ability to identify, assimilate and apply new external knowledge depends on the prior knowledge level of the firm (like Cohen and Levinthal’s 1990 article). The second group develop a more contextualised approach to AC, arguing that AC is a relative concept which depends on the characteristics of the sender-receiver dyad. While the approach of the former group is labelled as absolute AC, the approach of the latter is referred to as relative AC. Below, we discuss the two approaches in detail. Table 1 demonstrates the key contributions in both camps of the cognitive view, with descriptions.

TABLE 1: KEY CONTRIBUTIONS IN THE COGNITIVE CAMP

Key contributions to AC	**Type of AC**	**Theoretical determinants of AC**	**Research design**	**Description**
Cohen and Levinthal (1990)	Absolute	Organisational knowledge base	Quantitative	Prior related knowledge base of the firm determines its AC and the path it takes to develop. AC is motivated by the presence of knowledge and spillovers within the industry.
Szulanski (1996)	Absolute	Knowledge stock (managerial and technical)	Quantitative	AC of the recipient business unit determines the success of best practice transfer from other units when the knowledge is sticky.
Mowery et al. (1996)	Relative	Pre-alliance technological overlap	Quantitative	The level of patent base proximity between the firms forming an alliance in a dyadic relationship determines the success of knowledge acquisition from each other.
Kim (1998)	Absolute	Knowledge base Intensity of efforts	Qualitative	AC is a component of the organisational learning system. It depends on prior knowledge and intensity of efforts, but it dynamically develops through the process of proactive crisis building.
Lane and Lubatkin (1998)	Relative	Knowledge base similarity Structural similarity Dominant logics similarity Incentive structures	Quantitative	AC depends on the context of the relationship and the relative aspect of learning between teacher and student firm. These characteristics are relational so AC is a relative concept.
Meeus et al. (2001)	Absolute	R&D intensity Percentage of highly educated employees Budget deficit	Qualitative	AC builds on in-house R&D and total publication per research dollar recorded. In addition to AC, firm's connectedness to external community contributes to the performance.
Tsai (2001)	Absolute	R&D intensity	Quantitative	AC moderates the relationship between the network position and innovation of business units. The knowledge base (captured through R&D intensity) determines the level of AC.
Lane et al (2001)	Relative and absolute	Trust between partners Cultural similarity Flexibility and adaptability Business strategy	Quantitative	The three dimensions of identification, assimilation, and application of AC are dismantled. For each of them, different components are proposed. While the components for identification and assimilation of AC are relative and relate to the characteristics of the dyad, the application dimension of AC relates to the competencies developed internally.
Nooteboom et al. (2007)	Relative	Cognitive proximity between firms Patent profile overlaps	Quantitative	AC depends on the cognitive proximity between two firms. There is reverse-shaped relationship between cognitive proximity and learning. Too large or too little cognitive distance impedes learning and innovations.

2.2.2.1 ABSOLUTE AC

For researchers who have viewed AC as an absolute concept, AC shares two features. Firstly, it relies on the knowledge stock of the firms, business units, research departments, etc. Therefore, bigger knowledge stock implies higher levels of AC. Second, it develops purely at the firm level and is less concerned with the context of inter-organisational relations.

In this body of literature, the relationship between learning and AC is blurred (Lane et al. 2006, Sun and Anderson 2010). Although Cohen and Levinthal developed a recursive model of AC in which AC reinforces and is reinforced by learning, some authors have considered AC as the determinant of learning (or knowledge acquisition) and vice versa by examining the relationship either explicitly (Szulanski 1996, Meeus et al. 2001) or implicitly (Ahuja and Katila 2001, Tsai 2001, Rothaermel and Alexandre 2009). Szulanski (1996) examined that AC of the recipient business unit positively affects the transfer of best practices. Meeus et al. (2001) analysed the relationship between AC of the focal organisation and interactive learning with suppliers and customers. They used R&D intensity, the percentage of higher educated employees and the budget deficit during the projects (which was reversely coded) as the proxies for AC. However, their findings revealed that AC is a poor predictor of interactive learning. Tsai (2001) used R&D intensity as a proxy for AC and – by assuming a direct link between AC and learning – suggested that AC moderates the relationship between the network position of a business unit and its innovation. Rothaermel and Alexandre (2009) had similar findings indicating that AC, captured by R&D intensity of a firm, moderates the relationship between the firm's ambidexterity and its performance.

A second group have contended that learning efforts increase AC of the firms (Kim and Lee 2002, Schilling 2002). Authors in this strand have argued that firms that develop learning in certain areas demonstrate higher ability to absorb external knowledge in those areas. Through experimenting in a specific domain, firms develop an understanding of what they aspire to acquire from their external environment which results in higher AC. This stream of research has had fewer contributions.

A third group, following Cohen and Levinthal’s recursive model, have maintained that the relationship between AC and learning is recursive (Kim 1998, Autio et al. 2000). Kim (1998) developed a model of learning systems in organisations of which AC is a part. Although, for Kim, AC built upon knowledge base and intensity of efforts, his qualitative research design allowed analysing how the recursive learning mechanisms and path dependency proposed by Cohen and Levinthal (1990) unfold. Proposing a stage-based model for organisational learning, Kim (1998) contended that AC is an element of the wider organisational learning system and discussed that it develops through ‘proactive constructed crisis’.

2.2.2.2 RELATIVE AC

A more contextualised approach to inter-organisational learning and AC was proposed by the relational view. Dyer and Singh (1998) developed a relational view as an extension to resource-based theory of the firm. They argued that a firm’s resources are not bound to their boundaries but are embedded at the inter-organisational relationships a firm involves. Following this logic, Lane and Lubatkin (1998) introduced the concept of relative absorptive capacity which is represented by the similarities between the firms’ knowledge bases, and organisational structures and compensation policies. They suggested that by increasing the similarities in the aforementioned dimensions between the members of a dyad, AC increases. In their 2001 article, Lane et al. (2001) expanded the formulation of AC to include more contextual elements of cultural compatibility, and trust. They dismantled the three dimensions of AC (identification, assimilation, and application), and concluded that while the former two dimensions are relational, and they are affected by the inter-organisational context, the factors that constitute the application dimension of AC are mainly organisational.

Other contributions have been less concerned with the context of the relationship as they have mainly focused on the knowledge base similarities. They have explored the relativity of AC within sender-receiver dyads through measuring the similarity between the knowledge bases as the facilitator of knowledge transfer between partners (Mowery et al. 1996, Reagans and McEvily 2003, Hoang and Rothaermel 2005, Kim and Inkpen 2005). These researchers have predominantly used patent data in order to measure the cognitive proximity in dyads. Inspired by theories of organisations as *interpretation systems* (Smircich 1983, Daft and Weick 1984, Weick and Roberts 1993), Nooteboom (2000) developed a more sophisticated cognitive approach compared with Cohen and Levinthal’s seminal work. He defined *cognitive distance* as the difference in cognitive function (p.73) as the determinant of AC. This approach built upon mental models and cognitive maps, assuming that a collective cognition (which is then the basis for AC) relates to the commonality between the mental models of individuals. For example, too large or too little cognitive distances will be futile in collaborations as firms will either dismiss the new knowledge because of the lack of AC or they will not learn anything from it as it is too close to their existing cognitive map (Bogenrieder and Nooteboom 2004, Nooteboom et al. 2007).

In brief, although in this line of research, some authors have explored the contextual dimensions of AC, the main assumption is that the similarity of knowledge bases between the sender and receiver organisations is the main determinant of AC. This, in turn, means that the underlying approach to learning remain cognitive (i.e. the transfer of knowledge depends on the overlap between the cognitive similarities).

2.2.3 EVOLUTIONARY APPROACH AND DYNAMIC CAPABILITIES

Another line of thinking in AC research revolves around evolutionary approaches to knowledge accumulation and learning. Researchers who followed the evolutionary model have argued that AC directs the evolutionary path that firms take and determines the responses they give to environmental velocity and change (Koza and Lewin 1998, Van den Bosch et al. 1999, Lewin et al. 2011). For instance, Koza and Lewin (1998) argued that strategic alliances co-evolve with the firm’s strategy, and predicted that AC affects this co-evolutionary process if an alliance is exploratory (i.e. alliances that involve innovation, developing new capabilities, or new lines of business) because the more challenging the knowledge creation and learning between alliance partners, the more significant the role of AC will be.

One of the key contributions to AC literature which extends the definition and conceptualisation of AC was Van den Bosch et al.’s (1999) article (Lane et al. 2006). In their work, Van den Bosch et al. proposed a co-evolutionary approach to AC at macro level (i.e. with its knowledge environment) and at micro level (i.e. within the firm). Within firms, AC co-evolves through the interactions between the level of prior related knowledge, expectation formations and combinative capabilities. At the macro level, and within the knowledge environment, AC evolves through a) being affected by the opportunities of knowledge acquisition and b) shaping and directing the ways through which the knowledge environment develops. Paying attention to the characteristics of knowledge environment is an important shift from Cohen and Levinthal's (1990) original conceptualisation in which the knowledge environment is benign. Unlike their model, which consisted only of AC and learning with recursive loops, Van den Bosch et al.'s loop consisted of AC, learning, and knowledge environment.

By exploring the environmental aspects, Van den Bosch et al. (1999), moreover, paved the way for future contributions which integrated the *dynamic capabilities* (Teece et al. 1997) view into AC literature mainly because dynamic capabilities assist firms with responding to environmental changes. Reviewing AC literature developed since its outset, Zahra and George (2002) offered a reconceptualisation of AC. They reasoned that two factors have contributed to this move. First, they discussed that various empirical applications of the concept had not converged to capture the same concept in past research. Second, they argued that having been used in multiple levels of analysis including the country level (Keller 1996, Griffith et al. 2003), inter-organisational level (Lane and Lubatkin 1998, Oxley and Sampson 2004), and organisational level (Szulanski 1996, Kim 1998, Van den Bosch et al. 1999), AC had become inconsistent in its manifestations and operationalisations. Therefore, using a dynamic capability framework, Zahra and George (2002) reconceptualised AC as a dynamic capability consisting of a set of routines and processes for acquiring, assimilating, transforming, and exploiting external knowledge.

This reconceptualisation enabled the development of a deeper understanding of AC. Although Cohen and Levinthal had discussed the three dimensions of AC, no clarity or consensus was achieved on how these three aspects are configured in firms, and more importantly, AC was mainly a black box (usually captured in the form of knowledge stock) with a set of antecedents and consequents. Zahra and George (2002) defined AC "as a dynamic capability embedded in a firm's routines and processes, making it possible to analyse the stocks and flows of a firm's knowledge" (p.186) and argued that AC contributes to the creation of and sustaining of competitive advantages. They disentangled AC into four capabilities of *acquisition*, referring to "a firm's capability to identify and acquire externally generated knowledge that is critical to its operations (p.189); *assimilation,* referring to the firm's routines and processes that allow it to analyse, process, interpret, and understand the information obtained from external sources (p.189); *transformation,* referring to a firm's capability to develop and refine the routines that facilitate combining existing knowledge and the newly acquired and assimilated knowledge (p.190); and *exploitation,* referring to the routines that allow firms to refine, extend, and leverage existing competencies or to create new ones by incorporating acquired and transformed knowledge into its operations" (p.190). They labelled the two former capabilities Potential Absorptive Capacity (PACAP) and the two latter ones Realised Absorptive Capacity (RACAP). While PACAP deals with the capabilities to identify and acquire external knowledge, RACAP relates to the firms' ability to internalise and exploit it. Finally, they argued that balancing PACAP and RACAP is the key to achieving efficiency in AC as too much emphasis on PACAP may result in learning but not performing and, the other way around, too much emphasis on RACAP may lead to a competence trap as firms become involved in excessively exploiting their existing competencies without moving to new areas.

This new model inspired the next wave of research in AC literature, though fewer studies empirically examined their conceptualisation comprehensively. For example, Jansen et al. (2005) identified three forms of combinative capabilities (systems capabilities, coordination capabilities, and socialisation capabilities) as the antecedents of AC that support the dimensions of AC in the Zahra and George (2002) model. Lichtentahler (2009) empirically tested Lane et al.'s model and concluded that the three dimensions of AC are complementary by demonstrating synergic effect between the three. He argued, moreover, that in turbulent technological and market environments, AC is more likely to lead into innovations. Viewing AC as a dynamic capability, Lane et al. (2006) proposed a stage-based model for AC which encompassed the three dimensions of exploratory learning, transformative learning, and exploitative learning. They discussed that characteristics of internal and external knowledge, environmental conditions, learning relationships, the firm's strategy, firm members' mental models, and the firm's structures and processes affect the development of AC.

One of the recent key contributions in this strand of AC theorising is Lewin et al.'s (2011) article. This article integrated evolutionary economics (Nelson and Winter

1982) with the dynamic capabilities view (Teece et al. 1997) to enrich the AC conceptualisation. Dividing AC into two sets of internal and external *metaroutines*, this paper posited that AC is an evolutionary concept. Internal AC metaroutines include variation, selection, and retention and replication while external AC metaroutines include identifying and recognising the value of external knowledge, learning from and with partners, and transferring knowledge back to the organisation. Lewin et al, then, argued that the complementarity between the two dimensions make AC a dynamic capability.

Table 2 presents the key contributions in the camp of evolutionary and dynamic capabilities.

TABLE 2: THE KEY CONTRIBUTIONS IN EVOLUTIONARY AND DYNAMIC CAPABILITIES

Key contribution	Focus of theory	Description
Koza and Lewin (1998)	Co-evolution	AC contributes to the firm's alliance portfolio co-evolution with its strategy. AC is more relevant in exploratory alliances compared with exploitative ones.
Van den Bosch et al (1999)	Co-evolution	AC develops in macro and micro circles of co-evolutionary effects. Path dependency of AC is not just internal but AC of a firm also determines how the knowledge environment shapes.
Zahra and George (2002)	Dynamic capability	AC is a dynamic capability which builds upon the configuration of potential and realised AC. The effectiveness of AC depends on the capability of firms to strike a balance between the two.
Jansen et al (2005)	Dynamic capability	Combinative capabilities constitute the antecedents for AC. Coordination capabilities mainly enhance PACAP while socialisation capabilities influence RACAP.
Lane et al. (2006)	Dynamic capability	AC consists of three sequential learning mechanisms of exploratory, transformative, and exploitative learning.
Lichtentahler (2009)	Dynamic capability	The complementarity between the three learning dimensions makes AC a dynamic capability. Environmental velocity, moreover, moderates the effect of AC on innovation.
Lewin et al. (2011)	Evolution	AC consists of external and internal metaroutines. The balance between the two sets of metaroutines leads into their complementarity and results in innovation.

2.2.4 RESEARCH GAPS IN AC LITERATURE

2.2.4.1 THE DOMINANCE OF THE EPISTEMOLOGY OF POSSESSION

What Cook and Brown (1999) referred to as the *epistemology of possession* is the dominant logic in AC literature. An epistemology of possession considers knowledge as a *thing* (Orlikowski 2002) to be acquired, stored, processed, and retrieved. It is partly inherent in the definition of AC as the ability to identify, assimilate, and apply external knowledge. As discussed, in their conceptualisation of AC, Cohen and Levinthal argued that organisational AC follows the same logic as individual AC, i.e. the more knowledge accumulated in organisations, the more they are receptive to assimilating and applying new knowledge. However, they made two assumptions in their conceptualisation of the concept. First, they assumed that organisations, like individuals, can associate and connect ideas and thoughts in order to comprehend new forms of knowledge, while they did not explain why these assumptions can be made and why organisations follow the same mechanisms of absorbing new knowledge as individuals do. Second, and more importantly, they made an implicit assumption that knowledge is a decontextualised entity to be identified, assimilated, and applied through AC. Such an approach to knowledge transfer, however, views ‘meaning’ as universal. In this view, the only problem in transferring knowledge is to decode it through syntaxes. Once the ‘syntaxes’ are set and sufficient capability for encoding and decoding knowledge is developed, there is little obstacle in transferring knowledge even when it is tacit (Nonaka 1994) or sticky (Szulanski 1996). At its roots, this approach takes the similarity of contexts between sender and receiver of knowledge for granted and treats meaning across various contexts as universal (Bechky 2003).

The cognitive stream of AC research explicitly or implicitly follows the assumptions made by Cohen and Levinthal. The main attribute of the cognitive approach to learning is that it decontextualises learning and views AC as the ability for connecting three sides of a triangle: the knowledge, its sender, and its receiver. As such, it is not surprising that the magnitude of the knowledge base (Cohen and Levinthal 1990, Kim 1998, Tsai 2001), and similarities and differences between the knowledge bases (Lane and Lubatkin 1998, Hoang and Rothaermel 2005), determine AC.

Conceptualising AC in the form of dynamic capabilities resolves the problems associated with extrapolating from individual cognition to organisational level through introducing the organisational processes and routines to absorb knowledge. However, this body of literature maintains the decontextualised approach to knowledge as an object to be absorbed and processed by a set of capabilities. By assuming an evident distinction between knowledge and its immediate context, in the dynamic capabilities view, AC consists of a bundle of routines and processes *aimed* at absorption of knowledge. For example, routines to search or routines to analyse market information (Jansen et al. 2005) are among the most cited constituents of AC to identify external knowledge, whereas routines to store and disseminate knowledge for combining existing knowledge with new knowledge are the ones employed for dealing with knowledge within organisations (Jansen et al. 2005, Lichtenthaler 2009).

2.2.4.2 THE DOMINANCE OF VARIANCE MODELS

A second issue in AC research relates to the variance approach that researchers have adopted to examine the concept. A large part of the AC literature has explored its antecedents (managerial cognition, structure of the firm, mental models, combinative capabilities, etc.) and consequences (performance, innovation, learning, competitive advantage). This has led to the formation and development of variance models of AC. According to Van de ven (2007 p.145), variance models seek to explain causalities by virtue of the relationships between input and output variables. As such, they model the (social) world through a linear relation between a set of variables.

However, variance models fall short in capturing many aspects of AC. The first problem of having variance models pertains to the path dependency of AC. There is a consensus among all the contributors to AC research that AC is path dependent (cf. Cohen and Levinthal, 1990, Van den Bosch et al., 1999, Zahra and George, 2002, Lewin et al. 2011), i.e. future ACs are determined by past ACs because the more knowledge an organisation collects, the more they become recipient to new knowledge. However, despite this emphasis on path dependency, there is neither adequate theoretical explanation about how this path dependency develops nor is there substantial empirical research that explores it (except from the studies that examine the recursive relationship between AC and learning). Highlighting this issue, Todorova and Durisin (2007) argued that a variance model based on linear causality between AC's antecedents and consequents cannot capture its path dependency.

The second problem relates to the limitedness of variance models in providing a rich account which opens the *black box* of AC. Since variance models reduce the context of AC to a set of input-output relations, they fall short in unravelling the internal mechanisms of AC. Variance models are mainly used in quantitative studies. Easterby-Smith et al. (2008a) state that the lack of development in AC literature originates from the dominance of quantitative methods which do not explore the *inner* processes of AC and how they unfolds within and between organisations. According to them, there is no point continuing debates on measuring and defining AC unless we identify its features, and it is only through qualitative studies that our understanding of AC can improve.

2.2.4.3 THE TAKEN-FOR–GRANTED NATURE OF BOUNDARIES

The last gap in AC literature results from the limited attention paid to the nature of boundaries in analysing AC. Although the notion of external knowledge is central to AC, and acquiring and exploiting external knowledge is key to gaining competitive advantage (Zahra and George 2002, Todorova and Durisin 2007), the notion of *external* is a problematic one. In the ever-changing context of business *ecologies* (Dougherty and Dunne 2011), organisational boundaries emerge, form, reshape and disappear in accordance with the changes in the environment. Literature suggests that identifying and defining boundaries is not easy as they are flexible and plastic (Akkerman and Bakker 2011). Organisations, as well as their members, belong to multiple communities, networks, alliances, groups, etc. which make boundaries dynamic and constantly negotiated (Hernes 2004, Dougherty and Dunne 2011, Mørk et al. 2012). This, in turn, makes it difficult to specify boundaries as pre-established and easy-to-observe entities.

Second, AC does not deal with merely one type of boundary. Identification, assimilation and application of knowledge are not limited to organisational boundaries. Santos and Eisenhardt (2005) argued that only focusing on legal boundaries of the firm does not reflect the way organisations interact with their environment, partners, customers, suppliers, etc. Others have stated that knowing is situated in communities of practice who perform at the intra-organisational and inter-organisational spaces

(Lave and Wenger 1991, Boland and Tenkasi 1995, Wenger 1998). Communities of practice (CoPs) have boundaries too. The very fact that the practice of a community is not shared at its exterior and cannot be accessed by non-members is the main element of the boundary. Conversely, people who belong to the same CoP may find organisational boundaries less of a hurdle for knowledge exchange. For example, Duguid (2005) explained how CoPs can mobilise knowledge across organisational boundaries due to a priori-shared context of knowing which is embodied in their *network of practice* (the term he uses to talk about CoPs at a global level). Finally, projects have boundaries. While many organisations use projects to achieve innovations or technological change, the transfer of acquired knowledge into the wider context of organisations can be challenging (Scarbrough et al. 2004, Swan et al. 2010).

Accordingly, any process of knowledge transfer, absorption, and application inevitably deals with a mixture of boundaries. AC does not deal with one specified type of boundary (i.e. organisational boundary) but it also deals with a mixture of boundaries scattered spatially and temporally. This approach to boundaries as diversified and scattered entities is considerably different from the internal-external dichotomy addressed in AC research. Yet often, in the literature, the geography of AC is taken for granted, the distinction between *external* and *internal* is handled rather intuitively, and organisational boundaries are considered as the only source of discontinuity by crossing which, *external* knowledge can be transferred, assimilated, and applied (as an exception, see Easterby-Smith et al. (2008a)).

2.3 FORMATION OF R&D CONSORTIA AND AC

2.3.1 R&D CONSORTIA FORMATION

Thus far, we have reviewed the AC literature and have introduced its potential gaps. Since the second research objective of the thesis relates to the preconditions of consortia formation, and its influence on the entire collaboration, this section presents a literature review on collaboration formation and discusses the gaps afterwards.

The decision on whether to form R&D consortia has been an issue in collaboration formation literature for some time (Doz et al. 2000, Doz and Williamson 2002, Sakakibara 2002a). A number of factors have been identified as the determinants of the formation of R&D consortia. Three of the key factors include resource alignment, activation triggers, and social network.

Resource alignment: The principal assumption of the resource-based view is that firms form R&D consortia in order to pool their skills and capabilities (Das and Teng 2000). Das and Teng (2000) argued that when alliance resources are similar, the alliances are more likely to provide supplementary effects and when they are dissimilar, they are more likely to have complementary effects. Supplementary effects relate to the conditions when collaborations form in order to share risk, and achieve economies of scale. Complementary effects deal with the conditions when partners contribute dissimilar resources to collaborations.

Resource alignment has been substantiated in a number of studies of inter-organisational collaborations. Examining the chemical industry, Ahuja (2000) found that the technical and commercial capabilities that firms aspire to gain incentivise them to engage in collaborative R&D. Similarly, analysing 398 Japanese R&D consortia, Sakakibara (2002b) suggested that when resources are homogenous, achieving economies of scale is the main motivation for formation of R&D consortia whereas skill sharing contributes to the formation of R&D consortia when resources are heterogeneous.

Activation triggers: In addition to the resources which contribute to the formation of R&D consortia, some authors have discussed the importance of internal and external stimuli (Doz et al. 2000). Inter-firm collaborations have been known to be formed in response to environmental stimuli through a co-evolutionary process (Koza and Lewin 1998), or to radical technological shifts within industries (Rosenkopf and Nerkar 2001). When significant changes in markets or technological environments take place, firms look for new sources of knowledge which can potentially trigger the formation of R&D collaborations, especially if they do not hold the appropriate resources internally. In addition to technological advancements, market dynamics can contribute to the formation of R&D consortia. For example, Link and Bauer (1987) argued that the market threat imposed on firms by the entrance of foreign companies pushes them to form collaborative R&D.

Social networks: In addition to environmental pressures, some authors have discussed the role of individuals as innovation champions in the formation of R&D collaborations (Häusler et al. 1994). For example, the role of William Norris in the formation of MCC (the Microelectronics and Computer Technology Corporation) (Smilor et al. 1989) or that of Charlie Sporck and Bob Noyce in the early stages of the SEMATECH development (Browning et al. 1995) have been cited frequently. In the former case, there is ample evidence indicating how William Norris contributed to the formation of MCC through identifying the need, discussing it with the potential collaborators and involving the collaborators in the formation of MCC. In the latter case, the role of Charlie Sporck and Bob Noyce in leading and directing SEMATECH is evident. Bob Noyce was a charismatic leader during the initial phases of the consortium, and Charlie Sporck intensively invested in bringing employees from member companies together and generating consensus among them (Browning et al. 1995).

Moreover, the formation of R&D consortia is found to be influenced by pre-existing relationships and social capital. Some authors have found that past relationships induce trust among partners which contributes to the formation of new R&D collaborations (Powell 1996). Gulati (1995) argued that the existence of prior relationships cultivates trust in partners which, in turn, eliminates the need for equity-based R&D collaboration. In a longitudinal study focused on R&D collaborations, Ahuja (2000) found that social capital contributes to the formation of new collaborations. Together, these contributions illustrate the significance of social networks and social factors in the formation of R&D consortia.

2.3.2 ABSORPTIVE CAPACITY AND R&D CONSORTIA FORMATION

In general, R&D collaborations offer the opportunity to learn from partners. Literature suggests that collaborations enable knowledge sharing and exchanging through transfer of capabilities, skills, etc. The ability to learn from formal collaborations between organisations depends on the ability that individual partner organisations develop in absorbing knowledge. In this context, the literature discusses that firms which possess "partner-specific" AC (Dyer and Singh 1998) can reap the benefits of collaborations better than those that lack it. However, the question is how this partner-specificity develops in collaborations, and how it relates to the preconditions of alliance formation.

Value creation in collaborations stems from the learning opportunities that collaborations can offer. Yet, as learning involves interactions between actors who are bound to their immediate socio-cultural context within their organisations, inter-organisational learning does come with hurdles. For this reason, partner-specific experience can contribute to value generation in collaborations through nurturing trust, improving the management of collaboration, and establishing knowledge sharing practices. Some authors have suggested that the pre-existing partnerships can contribute to the development of partner-specific AC (Dyer and Singh 1998, Kim and Inkpen 2005) or to value creation in organisations (Anand and Khanna 2000, Kale and Singh 2007). They have used different notions to refer to a similar concept, such as partner-specific alliance experience (Hoang and Rothaermel 2005, Gulati et al. 2009), inter-organisational routines (Kale et al. 2000, Zollo et al. 2002), or target-specific experience (Porrini 2004). The main argument in this body of literature is that pre-existing relationships can help organisations to identify, assimilate and internalise knowledge when collaborations form. The previously developed knowledge about the partners assists organisations in identifying the relevant resources and skills, distinguishing the desirable from the unwanted knowledge, and applying and further improving that knowledge. Gulati et al. (2009) proposed two reasons for the effectiveness of partner-specific collaboration experience. They discussed that a) partner-specific collaboration experience generates efficiency as it reduces the transaction costs in knowledge transfer and b) it provides tailored experience from the collaboration which is rich and widely applicable to a certain partnership. With respect to the latter aspect, one can find dimensions like trust which is exclusive to the very partnership in which it has developed, that is, trust developed in a specific collaboration cannot be applied to other collaborations.

There are, however, two problems with regard to these developments in the literature. First, the research findings do not always support the direct effect of prior collaboration experience with the development of partner-specific AC, and there have been mixed results (Gulati et al. 2009). For example, Hoang and Rothaermel (2005) evidenced that recurrent alliances between biotech SMEs and pharmaceutical companies have negative effects on joint project performance. More recently, Zaheer et al. (2010) found that there is no significant relationship between pre-existing ties and partner-specific AC.

Second, there are limited insights provided in the literature on whether or how other factors (apart from the pre-existing ties) contribute to the development of AC when a collaboration forms. In effect, it has been presumed that having collaboration experience increases AC. There has been excessive attention paid to the pre-existing relations, and various factors which moderate their effect on AC, but there have been fewer attempts in analysing and investigating the effects of other pre-existing conditions on development of AC. Moreover, AC has been proxied with collaboration experience and pre-existing ties without directly investigating and examining the impact of collaboration experience on each of the dimensions of AC. Therefore, our understanding about the impact of the alliance formation process on the dimensions of AC has remained limited. As an exception, Lin et al. (2012) developed a set of hypotheses to examine the relationship between the properties of collaborations and innovation performance. They found that the proportion of R&D alliances to the firm's alliance portfolio affects recognition of the value of external knowledge dimension of AC in Cohen and Levinthal's (1990) model, the technological distance affects the assimilation dimension of their model, and the R&D intensity of a firm influences the application dimension of AC. Nevertheless, while their model contributes to our understanding of characteristics of collaboration on dimensions of AC, since it uses secondary data and patent data, it remains limited in providing a rich account on how these features of collaboration support the dimensions of AC.

2.3.3 INTELLECTUAL PROPERTY IN R&D CONSORTIA

Knowledge gained from external environment has been viewed as an important source for generating ideas and patents for long (Tushman 1977). A large number of studies have evidenced that partnerships – in the form of strategic alliances, joint ventures, research contracts, etc. - contribute to innovativeness and development of new patents (Mowery et al. 1998, Ahuja 2000, Stuart 2000, Oxley and Sampson 2004, Weck and Blomqvist 2008, Schildt et al. 2012). Recently, in a case study of a European telecom operator, Weck and Blomqvist (2008) found that interactions with R&D consortia, customers, and suppliers positively affect the development of new patents.

Inter-organisational collaborations are found to affect the IP choice mechanisms. Firms become involved in collaborative efforts in order to reap the benefits of specialised knowledge that the partners have and to enjoy gains from interactive learning that are not offered in markets (Sobrero and Roberts 2002). In R&D collaborations, it can be argued, the significance of patenting increases since through patenting, partners define and clarify their rights to emerging intellectual properties and utilise their portfolio of patents for negotiating the terms of ownership of joint R&D outputs, and cross-licensing (Cohen et al. 2002). However, the evidence regarding the significance of patenting in R&D collaborations is not compelling. Arundel (2001) found a weakly significant priority of patenting over secrecy by firms that participate in collaborative R&D, and Cassiman and Veugelers (2002) suggested that R&D collaborations with supplier and customers are negatively related with patenting. Moreover, given the limited power in negotiation of IP rights and due to resource constraints, it has been suggested that smaller firms may be unable to pursue a patenting strategy in their collaborations (Leiponen and Byma 2009). Small firms lack the legal resources for fully appropriating their new ideas, and, as such, unable to enforce their IP rights (Lanjouw and Schankerman 2001). Furthermore, although many authors have argued that partnerships and alliances affect generating new patents, there has been less discussion about the impact of collaborations on joint patenting. For example, Hagedoorn (2003) found that while R&D partnerships may result in filing new patents, there is not any significant relationship between the formation of partnerships and the development of joint patents. He argued that firms avoid joint patenting because of partial ownership of property rights which is not so appealing.

In sum, while extant literature suggests that inter-organisational collaborations contribute to the development of innovations and new knowledge, there is not conclusive evidence about the significance of patenting is appropriating joint R&D outputs. Moreover, there is not much discussion on how IP issues can affect research collaborations, and how patenting strategies differ across different types of research collaborations. Finally, it is rarely discussed how (partner-specific) AC can affect the development of joint patents.

2.3.4 RESEARCH GAPS IN R&D CONSORTIA FORMATION LITERATURE

There are two major gaps identifiable with respect to R&D consortia research. First, although the literature presented above provides some insights into research on the formation of consortia, and the preconditions for formation of R&D collaborations, there has been less empirical evidence on the process of formation of R&D consortia in the extant literature (Doz et al. 2000, Smith Ring et al. 2005). Many authors have focused on the performance determinants of alliances (Das and Teng 2003, Faems et al. 2005, Krishnan et al. 2006) and the type of alliances (Koza and Lewin 1998, Rothaermel and Deeds 2006) while the formation process of R&D consortia deserves more attention as it influences the subsequent creation of knowledge and learning within consortia. The formation process is especially important when it comes to R&D consortia compared with other types of R&D collaboration given the scale of the partnership and the diversity of the collaboration partners. Unlike alliances which form between two parties, R&D consortia involve multiple partners who may belong to different industries and sectors. Such heterogeneity renders the initiation of consortia more complex compared with the dyadic collaborations.

Second, we know little about the effects of the formation preconditions on the three dimensions of AC. Although AC literature has highlighted the role of AC preconditions, the majority of arguments about the nature and impact of these preconditions are theoretically derived from the literature and there is little empirical evidence about the development and the effects of these factors on AC in R&D consortia. Moreover, there is tendency to look into the preconditions of consortia formation only in relation to the identification dimension of AC. For instance, Zahra and George (2002) discussed that prior experience and activation triggers are the main factors that affect the first phase of AC (PACAP), and Volberda et al. (2010) discussed the impact of inter-organisational antecedents on PACAP. Further, although prior work has been focused on AC with relation to dyadic knowledge exchange, when the number of partners increases and the relationships change, the differences between partners intensify and the factors that were identified to be contributing to AC in dyadic relationships can become irrelevant or even counter-productive in R&D consortia which involve multiple partners (Li et al. 2012).

2.4 RESEARCH QUESTIONS

As promised in the beginning of the chapter, after providing a literature review on AC and R&D consortium formation, we would proceed into discussing the research questions. The first research objective was explained as follows:

> ***Research objective 1:*** *To contribute to a contextualised view of absorptive capacity in R&D consortia by 1) identifying the challenges for exploration, transformation, and exploitation of knowledge and 2) identifying the mechanisms that address these specific challenges through 3) opening the black box of the AC.*

Based on this research objective and the research gaps presented above (see 2.2.4), we present the first three research questions:

1- How does AC develop in R&D consortia?
2- What are the AC mechanisms across the exploratory, transformative, and exploitative phases in R&D consortia?

And, the second research objective was presented as:

> ***Research objective 2:*** *To contribute to a more contextualised understanding of the preconditions of formation mechanisms of R&D consortia and to see how these conditions affect the development of AC throughout the collaboration lifecycle.*

Therefore, based on this research objective and the research gaps presented above (see 2.3.4), we propose the second set of research questions as:

1- What are the preconditions for formation of R&D consortia?
2- How do the R&D consortia preconditions affect the development of AC?

In what follows, we present the main aspects of the practice approach as a complementary theoretical view to learning which informs this study. We first discuss the main building blocks of the approach and then we discuss the aspects of the theory which have been critiqued by other researchers.

2.5 THE PRACTICE APPROACH

2.5.1 SITUATED LEARNING AND COMMUNITES OF PRACTICE

Although there are benefits in using a cognitive approach to learning, it cannot be the only source for understanding the dynamics of learning. Common in all positivist epistemologies is the priority assigned to the "truth". Logical positivism aims to identify the "ultimate truth" through observations, atomic facts, and generalizations. Very close to this epistemology are cognitive theories of learning (Fox 1997). In the cognitive theory, learning takes place through teaching, i.e. through the process of sending and receiving knowledge. As such, the main barrier for learning is the lack of capability, motivation, and mentality to learn (or probably to teach). This approach – which Cook and Brown (1999) labelled as the epistemology of possession – has been influential in a large body of organisational learning literature (Arrow 1974, Simon 1991).

The competing epistemology does not presume the existence of a global truth. In contrast to cognitive theories, by dramatically challenging the traditional mind-body and theory-practice dichotomies, practice-based theories question the assumption of considering learning as a set of mental processes at the cognition level arguing that knowledge is context-dependent and needs to be learned in the very local context of practice. Below, we briefly highlight the main differences between cognitive learning theories and the practice-based perspectives.

Table 3 summarises the key differences between the two approaches. In contrast to the cognitive theories of learning, in which mind acquires, stores, and retrieves knowledge, in practice-based theories, knowledge is vested in the local context of knowing. As such, learning is not an outcome of and confined to the changes in cognitive models, their structures, interactions, etc., but it pertains to participation and engagement. It is not a particular activity to which we allocate time and space; it is not an aspect or part of the social world, but it is an ever-contributing aspect of life, and lived experience: "Learning ... is not a separate activity. It is not something we do when we do nothing else or stop doing when we do something else." (Wenger, 1998 p.8)

In the same way, practice theory radically transforms the theory of knowledge from a body of pedagogical facts into locally constructed, mutually perceived, and historically developed practices. Knowledge is situated, contextual, relational and historic (Lave and Wenger 1991, Cook and Brown 1999, Gherardi and Nicolini 2000). Meaning is inseparable from and develops only in relation to its context. "Meaning is not constituted through individual intentions; it is mutually constituted in relations between activity systems and … has a relational character" (Lave 1993 p.18). Knowledge, as a form of meaning, therefore, develops in the context of local communities and is hardly accessible to the people who do not hold any participation in those communities. Such a theory of knowledge questions the divide between knowledge and knowing (Cook and Brown 1999, Orlikowski 2002, Østerlund and Carlile 2005) observed in cognitive learning and views knowing and knowledge as mutually constructed (Cook and Brown 1999).

TABLE 3: THE DIFFERENCES BETWEEN COGNITIVE AND SITUATED LEARNING

Learning	Cognitive	Situated
Knowledge	Canonical/codified/presented in law-like regularities	Tacit/contextual Embedded in practice
Mechanism	Acquisition of information or skills	Transformation of practice/ change in identity
Mode of transfer	Sender-receiver	Interactive-participatory

Adapted from Contu and Willmott (2003)

Lave and Wenger (1991) introduced the notion of situated learning and communities of practice. They argued that learning develops through transformation of identity through engagement in communities of practice. It starts from the peripheral participation of newcomers and continues to full participation and becoming masters in CoPs. Deploying the situated learning approach developed by Lave and Wenger, Brown and Duguid (1991) applied the notion of communities of practice to organisational research in learning and innovation. Drawing on the ethnographic data from Orr's (1990) study of service technicians, they discussed how workplace learning across informal networks can support innovations. They stated that work in organisations is masked by the formal descriptions, while, in effect, learning and innovating relied on the communities of practice which determine the ways people work. However, unlike Lave and Wenger's (1991) account, their story was not about peripheral participation and the trajectory a novice passes in order to become a master, but it was more related to the interactions between CoPs within organisations. This is especially important in the context of organisations since organisations do not deal with coherent crafts which constitute harmonised communities (e.g. tailors in Lave and Wenger (1991)), but they deal with a constellation of different occupational communities.

While in their 1991 book, Lave and Wenger focused on single communities of practice, later contributions of Wenger (Wenger 1998, Wenger 2000, Wenger 2010) concerned the boundaries between the communities of practice and the interactions across them. One of the important aspects of Wenger's 1998 book was its focus on multiple communities and how learning takes place across boundaries. In this book, Wenger argued that limiting learning to a single community of practice does not comply with the considerably specialised reality of the modern world with an enormous number of communities in the landscape of practices and with the multimembership that actors hold in various communities. In fact, he conducted his ethnography among the claim processors in an insurance company. Similarly to any other organisations, claim processors had interactions with other functions within their company which inevitably led into Wenger's exploration of boundaries and interactions between communities of practice.

2.5.2 BOUNDARIES, BOUNDARY SPANNERS, AND BOUNDARY OBJECTS

As discussed, all learning is not limited to individual CoPs, and it also occurs at the boundaries of CoPs. The nature of boundaries and the mechanisms to bridge them have been a subject of query for many scholars. The way the literature looks into boundaries is twofold. On the one hand, some authors have discussed that boundaries need to be protected in order to prevent knowledge spillovers or leakage. Organisations, therefore, create buffers at their boundary encounters to protect their knowledge (Allen and Cohen 1969, Tushman and Anderson 1986). On the other hand, boundaries hold a great potential for learning and it is at the intersection of boundaries that opportunities for delving into new competences emerge. As Nooteboom (2006) articulated, learning is exploitative within the boundaries of CoPs while it is exploratory across them. Wenger (2000) viewed organisations as social learning systems and asserted that the most significant learning opportunities are embedded across the boundaries of CoPs.

In an ethnographic study of a new product development, Carlile (2002) argued that knowledge can be a source of both innovation and conflict. He distinguished between three approaches to boundaries across CoPs. First, he discussed the syntactic approach to boundaries. In this approach, the only problem for knowledge transfer is the language differences between the sender and receiver. Therefore, as long as actors establish a common syntax with identical definition for both parties, they can exchange information. This model built on Shannon and Weaver's (1949) mathematical model of communication where any communication has three elements: transmitter, message, and receiver. Traditional knowledge transfer literature with emphasis on the trilogy of sender, receiver, and knowledge belongs to this strand (Allen and Cohen 1969, Tushman and Scanlan 1981, Szulanski 1996). The second approach relates to differences between meanings across boundaries. At this type of boundary, although the syntax aspect of language is similar, the interpretations may differ. Within CoPs, meaning develops locally, is embedded within the context of the community and is hardly accessible by outsiders. The final type of boundary, as Carlile (2002) discussed, deals with the dependencies and their consequences generated across boundaries. The dependency generated across boundaries originates from the relational properties of knowledge across boundaries. This feature of the boundaries results from the knowledge being at stake and invested in practice. This type of boundary is highly political, and contested. It deals with the question of what counts as knowledge, and who has the right to accept or reject it. This approach to knowledge and learning is rooted in *relational thinking* (Østerlund and Carlile 2005) in which the properties of the social world are only defined in relation to others. As such, not only is knowledge relational, but also its applications, boundaries, and crossing mechanisms.

One of the factors that organisations use for crossing boundaries is the boundary spanners. In the classical organisational learning literature, the importance of boundary spanners and gatekeepers was well recognised (Tushman 1977, Tushman and Scanlan 1981, Tushman and Anderson 1986). Boundary spanners link two different paradigms, environments, or social systems. According to this view, organisations develop gatekeeper roles in order to lubricate the information and knowledge exchange conduits. Moreover, they develop their networks of relations according to the knowledge their respective units need.

Boundary spanning in practice theory, however, is rather different. Apart from their role in information processing and buffering, boundary spanners bring new horizons into CoPs and enable them to comprehend and align those horizons with the current ones. They assist crossing the boundaries between communities of practice and *introduce[ing] elements of one practice into another* (Wenger 2000 p.235). The practice theory discusses that enacting these roles requires establishing legitimacy and flexible identities in relation to the communities that actors belong to.

Boundary objects constitute the other mechanisms for crossing boundaries. Star and Griesemer (1989) introduced the concept of boundary objects as the objects "which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual site use". They may include artefacts, discourses, and processes. However, more than their form and structure, their characteristic of transforming knowledge has been the focus of studies. In the CoPs' language, boundary objects play a significant role in crossing boundaries through the process of reification (congealing into thingness). For example, Wenger (1998) explained how claim processors used claim sheets to communicate their knowledge and help each other understand and comply with the community's needs.

Some studies on boundary objects have stated that boundary objects play various roles in both encountering and bridging boundaries. Carlile (2002, 2004) showed how boundary objects play different roles in bridging syntactic, semantic, and pragmatic boundaries and discussed how knowledge transfers and is transformed by them. Recently, Nicolini et al. (2012) identified three roles for boundary objects as means for motivating collaborations, allowing collaborations across boundaries, and providing infrastructures for joint activities.

2.5.3 CRITIQUES ON COPS

Situated learning and CoPs have received critiques from many scholars. Overall, the strongest critiques lie in three areas including the under-theorised role of power, lack of attention paid to the role of agency, and the confusions between analytical and prescriptive approaches to CoPs.

2.5.3.1 POWER

The literature on CoPs has been criticised by some scholars as having underestimated the role of power. Some authors have argued that in Lave and Wenger's (1991) work, power dynamics between the participants within the community is not discussed to its merits. In Lave and Wenger's (1991) text, power is discussed in a limited fashion. Their story of work relations within CoPs stresses the importance of power dynamics between newcomers and old-timers. When a newcomer wants to join a practice, s/he needs access to practice, which can only be provided by the existing members of the community (the power to give access). Likewise, within a CoP, legitimate peripheral participation and the path to mastery is a political process. The claims to competence and the path that individuals take in order to become competent inevitably involve power dynamics that govern the relationships between community and the individuals. Unless a newcomer's skills and abilities are recognised by other members, s/he cannot engage in more complicated tasks (and become master afterwards).

Despite considering this aspect of power, Lave and Wenger's (1991) theory neither addresses the power dynamics among old-timers or newcomers themselves (Cox 2005) nor does it attend to the power relations between different CoPs. Contu and Willmott (2003) stated that the embryonic appreciation of power relation in Lave and Wenger (1991) does not address the institutionalised context of learning in organisations. Power relations inherent in capitalist work organisations significantly affect learning practices of organisations. Using Actor Network Theory, Fox (2000) contended that the CoPs theory ignores the power relations generated not only through hierarchical forces but also through the network of relations that surround CoPs. The main reason, he asserted, relates to the problematic notion of *community* embedded in the theory because in sociology, attempts to define community have proved controversial (Lindkvist 2005). There is no consensus on how a *community* can and should be defined. The notion of community implies harmony, sameness, and continuity: a friendly and consensual group of people. This has resulted in romanticising CoPs as a group of informal, friendly, apolitical people who purely follow their passion (Cox 2005, Østerlund and Carlile 2005).

Having picked this issue, some authors have attended to the power relations in CoPs arguing that power dynamics within and between CoPs significantly affect the learning processes. Hong and O (2009) demonstrated how power relations between CoPs within an organisation can impede implementations of innovations. Yet, the political aspects of CoPs are still to be further explored.

2.5.3.2 THE LACK OF AGENCY IN LEARNING

The second critique on CoPs relates to the dominance of structured features of learning in CoPs. In situated learning theory, learning entails a gradual move from the periphery of the community into the core within the stable and continuous context of CoPs. In other words, a CoP is a given social setting and learning is the ultimate force, which guides the community. In this sense, a CoP consists of a group of people who know each other long enough to develop communal knowledge and share a practice in a harmonious collection. This assumption "makes it hard to think of individuals as engaged in a process of critical reflective activity" (Lindkvist 2005 p.1196). As a result, the agency of actors and the ways they can develop their learning path is less salient. The theory does not explain why some individuals can progress in their communities quickly while others cannot do so. As such, agency is an underestimated aspect of the theory (Kakavelakis and Edwards 2011).

2.5.3.3 THE NATURE OF THE CONCEPT

There has also been dispute among researchers about the nature of the concept; Lave and Wenger have been accused of being equivocal in their formulation of CoPs as to whether it is a theory that explains how learning happens or an empirical tool for improving learning. Hughes (2007 p.39) highlights the ambiguity on whether the theory *emerges* from the empirical observations or is *projected* on the cases. This concern is then translated into a broader ambiguity about whether the CoPs theory is prescriptive, which dictates how learning should be managed in an ideal world, or is analytical, which explains how learning happens in the real world. The usages advocated by practitioners have favoured the latter. Particularly, the more recent contributions of Wenger (cf. Wenger and Snyder 2000, Wenger et al. 2002) in the field of management have given rise to the prevalence of the prescriptive approach. In this strand, many authors (including Wenger) have discussed the design aspects of CoPs; how CoPs can be initiated, *cultivated,* managed, and monitored within organisations have been the building blocks of the theory.

Critiques have argued that such ambiguity in the functionality of the theory has given rise to uninformed applications of the concept and proliferation of loosely defined approaches to CoPs.

2.5.4 PRACTICE APPROACH IN THIS STUDY

This study is mainly informed by the practice approach into learning, and CoPs remains a theoretical and analytical lens which complements our approach to learning. Therefore, although we remain aware of the main critiques to the CoPs theory, we do not engage in addressing those problems throughout the study. With regards to the critiques on power, we maintain that power is an important element of inter-organisational relations and, as will be shown in chapter 6, can affect the development of AC. However, we do not see power as the main focus of the study and it falls beyond the scope of this study to address that research gap. With relation to the lack of agency, we remain concurred that agency is an important aspect of learning and AC. In fact, as it will be shown in our analysis, we contend that individuals who mobilise their status and linkages to form consortia and to cross boundaries are quite influential in learning in R&D consortia. Again, however, this research does not claim any specific contribution in addressing the gap in the CoPs literature with respect to agency. Finally, as far as the nature of the concept is concerned, this research views CoPs as an analytical lens rather than a prescriptive tool, that is, for us, CoPs is a theory which explains learning in the social world, not a way to establish the right way of learning. Therefore, it is used to the advantage of our theoretical understanding of the interactions that take place in the fieldwork.

2.6 CONCLUSION

In this chapter, we presented a literature review of AC, R&D collaboration formation and the practice-based approach to learning. As a starting point, we explored the origins of AC and made a case that AC follows a cognitive approach to learning. Then, we proceeded to discuss dynamic capabilities and evolutionary approaches to AC. After reviewing the literature, we argued that AC literature is inadequate from three aspects: a) it has mainly followed an epistemology of possession, b) it has been dominated by variance models which reduce AC to a number of input-output relations, and c) it does not take into account the diversity of boundaries in complex settings. Together with the first research objective of the thesis, these research gaps informed the first set of research questions presented in 2.4. Afterwards, we discussed the determinants of R&D collaboration formation and found that resource alignment, activation triggers, and the social networks are the three identified preconditions of collaboration formation in extant literature. Drawing on that, we proceeded to discuss the gaps in R&D collaboration formation. It was discussed that paucity of research on the process of formation of R&D collaboration and especially of R&D consortia makes the area worthy of further exploration. In addition, we argued that the three dimensions of AC can be potentially affected by the (preconditions of) formation process of R&D consortia which is under-researched in extant literature. Together with the second research objective, these research gaps informed the second set of research questions presented in 2.4. The final part of the chapter focused on the practice-based approach as one of the theoretical pillars of the thesis which will be employed as a complementary perspective to the cognitive approach (in chapter 3 we will apply the practice-based approach for building the theoretical framework). Finally, we closed the chapter by discussing the important critiques of the practice-based theory.

Chapter 3. THEORETICAL FRAMEWORK

3.1 INTRODUCTION

In the previous chapter, we critically analysed the AC and collaboration formation literature based on which we identified the research gaps that contributed to the introduction of two sets of research questions. Then, we proceeded to introduce the practice approach to learning and knowing as a complementary view which can inform the analysis of AC. This chapter presents the theoretical framework of the study not only based on the literature that we reviewed in the previous chapter, but also inspired by the initial round of data analysis of the first case study (HOUSE[1]). The first case study, which will be presented in detail in 5.2 was the empirical ground for the development of the theoretical framework. As such, the framework demonstrated in this chapter is not purely deductively developed, but it is a mixture of deductive and inductive theorisations after thoroughly analysing the first case. After the first round of data analysis, this framework remained as the guidance for the rest of the empirical study. However, as will be demonstrated in chapter 7, the theoretical framework was refined and enriched over the later stages of the research.

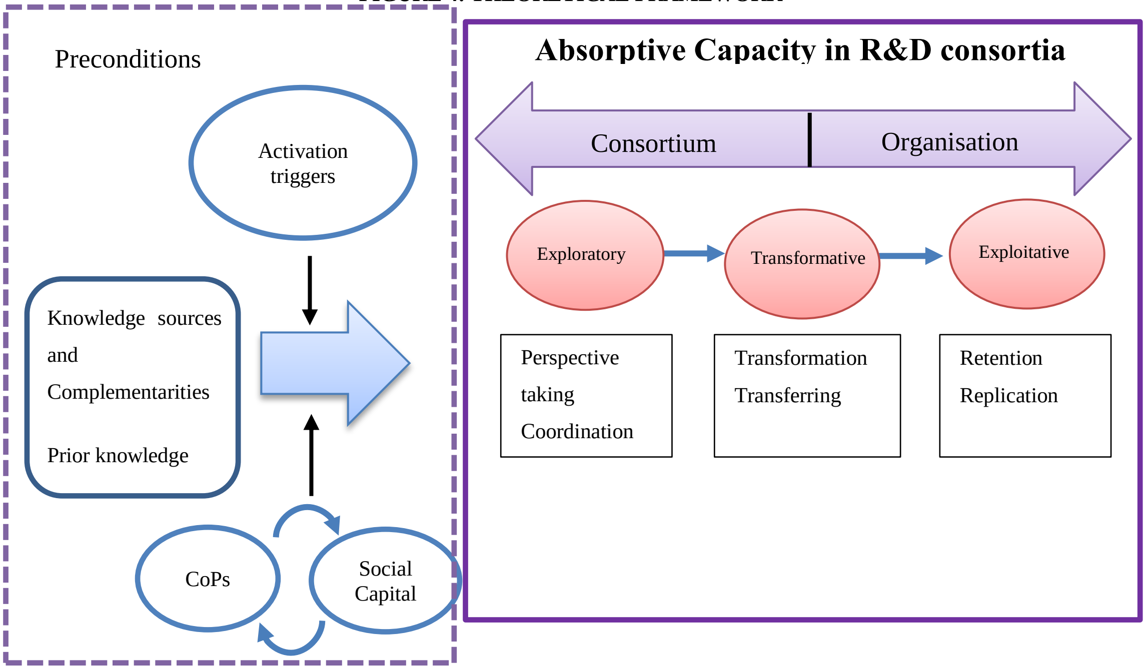
3.2 OVERVIEW

Figure 4 demonstrates the theoretical framework of the study. It aims to provide an overview on how AC operates in R&D consortia. On the left, the preconditions of AC are presented. This part consists of knowledge sources and complementarities, activation triggers, Social Capital (SC), and CoPs. On the right side of the figure, the rectangular demonstrates AC along with its constituents. As the figure portrays, following Lane et al. (2006), we conceptualise AC with its three dimensions

[1] HOUSE was a research consortium aimed at researching and improving the structural and thermal properties of a house made of alternative materials.

(exploratory, transformative, and exploitative). As it will be explained in this chapter, the theoretical framework is focused on the mechanisms that support the three phases of AC. In so doing, we will consider the boundaries in R&D consortia and will explore the mechanisms that are deployed to cross them in the context of R&D consortia.

FIGURE 4: THEORETICAL FRAMEWORK



3.3 PRECONDITIONS

As demonstrated in Figure 4, preconditions of AC include activation triggers, knowledge sources and complementarities, prior knowledge, CoPs and SC. The presence of external knowledge sources has been understood as one of the important preconditions of AC (Cohen and Levinthal 1990, Zahra and George 2002). If there are not enough knowledge sources available within the environment, then internally developing knowledge is the most probable path that organisations can take in developing innovations and solving their problems.

The literature, moreover, recognises the degree of complementarity that organisations can achieve through establishing relationship with the external sources of knowledge as an important precondition for AC (Zahra and George 2002, Lewin et al. 2011, Lin et al. 2012). However, it is argued that having too similar or too different knowledge can obstruct the development of AC (Nooteboom 2000, Ahuja and Katila 2001).

The level of prior knowledge has also been known to be an important determinant of AC. The accumulated level of knowledge affects the search path that organisations take in order to reach new knowledge. Organisational search for knowledge is determined by the prior knowledge and experience that they have accumulated through their previous success (Cyert and March 1963, Levinthal and March 1993). Literature suggests that the previous knowledge that is accumulated by organisations determines not only the direction of future AC, but also the ways through which organisations assimilate and interpret external knowledge.

As suggested in Figure 4, we expect that activation triggers moderate the relationship between complementarities and knowledge sources and AC. The role of activation triggers is noted by many AC researchers. Cohen and Levinthal (1990) highlighted the role of technological opportunities in incentivising firms to invest in R&D. Kim (1998) demonstrated the role of organisational crisis in triggering re-examination of the learning strategies. Activation triggers can be internal – like a firm facing a crisis, or a problem that they need to solve – or they can be external – like a technological shift in the industry in which an organisation is active. Zahra and George (2002) discussed that internal or external stimuli affect the organisational decisions to search for new sources of knowledge. Regardless of the source of activation triggers (i.e. internal or external), they contribute to AC as long as organisations seek for external knowledge in response to those stimuli. Moreover, as activation triggers evolve in response to particular needs in organisations, they determine the direction of the organisational inquiry and, therefore, the sort of complementarities and source of knowledge that an organisation should seek. Putting this in the context of R&D consortia, activation triggers influence AC not only by contributing to the formation of collaborations and the selection of the partners, but also through determining the directions of research.

We are also of the opinion that the formation of consortia depends on the pre-existing SC and CoPs. Following Wenger et al. (2002, p.4), we define a community of practice as “a group of people who share a concern, a set of problems, or a passion about a particular topic, and who deepen their understanding and knowledge of this area by interacting on an ongoing basis".

To begin with, pre-existing CoPs (at the inter-organisational space) can affect the opportunity for forming a consortium. CoPs are especially valuable across the organisational boundaries in assisting organisations to adapt with the environmental changes in fast moving industries. For example, Duguid (2005) explained how CoPs can provide the context for knowledge exchange across organisational boundaries when knowledge becomes sticky and specialised. Therefore, our framework suggests that pre-existing inter-organisational CoPs affect AC in the presence of external knowledge sources, complementarities and prior knowledge. However, although it is not demonstrated in Figure 4 for simplicity's sake, CoPs contribute to prior knowledge as they possess a *shared repertoire* (Wenger 2000) of routines, artefacts, stories and tools which preserve knowledge over generations within and across organisations.

On the other hand, pre-existing Social Capital (SC) contributes to AC by cultivating a favourable context for knowledge transfer through assisting organisations to reach partners who fall beyond their knowledge domain scope. Following Nahapiet and Ghoshal (1998), we define SC in light of its two dimensions of structural capital and relational capital. *Structural capital* entails the impersonal configuration of linkages among actors; it relates to the opportunities actors have to build a relationship (Burt 1992). Prior ties and the frequency of interactions are the most important aspects of structural capital. *Relational capital* reflects the nature and quality of interactions; it relates to the motivational aspects of social capital, including trust and mutual expectations and obligations.

In the above formulation of SC, we follow Nahapiet and Ghoshal's (1998) definition. However, we eliminate the third dimension of their formulation (i.e. cognitive capital). There are two reasons for this move. First, our definition is in line with the narrow view of SC. Adler and Kwon (2002) differentiated between two approaches to SC in the literature: 1) the broad approach which views the resources and abilities possessed by actors as part of the social capital and 2) the narrow approach which does not include the resources possessed by actors as a dimension of social capital. They argued that the broad approach can lose its analytical sharpness as it can encompass other forms of capital such as economic, intellectual, etc. As such, in order to be in line with the narrower view of SC, we do not incorporate the cognitive dimension which is an aspect of the broad view (Adler and Kwon 2002). Second, the exclusion of the cognitive dimension of SC assists us in eliminating the overlap between SC and CoPs. Following this logic, and based on Duguid's (2005) formulation of social capital, we distinguish between CoPs and social capital by the difference they offer in the *ability* dimension. Duguid (2005) argued that while SC provides the conditions for knowledge sharing, it does not necessarily entail the *ability* to share knowledge, and the ability dimension is embedded in the fabric of a practice. Therefore, in our definition SC encapsulates the network of relations and the quality of those relations (e.g. developed trust and mutual expectations), but what is being exchanged through SC is not the matter of discussion. In particular, the ability to learn and exchange knowledge largely falls into the CoPs domain.

Making such a distinction between CoPs and SC is not for the sake of lip servicing the theoretical framework in an academic fashion. It is necessary to our analysis for two reasons. First, this way SC can encompass a wide set of actors ranging from the linkages that organisations make in order to access knowledge in their environment or the goodwill that a set of commercial or non-commercial actors develop throughout a history of relations without necessarily belonging to a similar knowledge domain or following a learning imperative. Second, it helps to keep us focused on CoPs only with respect to their role in encouraging learning and knowledge development (not a bunch of people with extensive social relations).

SC contributes to AC in R&D consortia in two major ways. Firstly, by providing a favourable context of mutual expectations and trust (Nahapiet and Ghoshal 1998, Tsai and Ghoshal 1998, Yli-Renko et al. 2001, Inkpen and Tsang 2005, Thorpe et al. 2005), SC encourages knowledge sharing, transfer, learning, and interacting among partners. Secondly, it facilitates accessing distant domains of knowledge through bridging the structural holes (Burt 1992, Uzzi 1997, Yli-Renko et al. 2001, Kallio et al. 2010). When organisations need to access knowledge that falls beyond the network in which they are embedded, SC helps them to link to new areas. The brokers who are knowledgeable about the current relations and who seek weak ties with other areas can assist in bridging these structural holes. Therefore, they help accessing distant partners.

3.4 ABSORPTIVE CAPACITY

3.4.1 INTRODUCTION

The rectangle in Figure 4 encompasses our formulation of AC. Using Lane et al.'s model of AC (2006), we perceive three dimensions for AC as "(1) recognizing and understanding potentially valuable new knowledge outside the firm through exploratory learning, (2) assimilating valuable new knowledge through transformative learning, and (3) using the assimilated knowledge to create new knowledge and commercial outputs through exploitative learning" (Lane et al. 2006 p.856). However, we add to this model by integrating the previously unattended notion of boundaries in AC and by proposing a micro learning mechanism across the three dimensions.

3.4.2 POTENTIAL BOUNDARIES IN R&D CONSORTIA

As discussed in chapter 2, boundaries play a dual role in the learning context. On the one hand, they protect knowledge leakage. On the other hand, they offer the potential for learning and innovation. Accordingly, specific organisational roles develop in order to buffer organisations from the environment (gatekeepers) or to facilitate the acquisition of knowledge from outside the organisation (spanners) (Allen and Cohen 1969, Tushman and Anderson 1986).

However, in R&D consortia, in addition to organisational boundaries, there are other types of boundaries. Table 4 demonstrates the taxonomy that informs the analysis of the boundaries in the thesis. In line with Akkerman and Bakker (2011), we define boundaries as "sociocultural differences that give rise to discontinuities in interaction and action". In R&D consortia, multiple organisations with various types of expertise collaborate in order to accomplish a set of pre-established tasks in a project. As such, two dimensions matter in understanding the boundaries involved in an R&D consortium: 1) the functionality, i.e. whether the boundary demarcates the domains of competence or differentiates between the organisational identities or the conceptualisations of who members are (cf. Santos and Eisenhardt 2005 formulation of boundaries of competence and boundaries of coherence), and 2) the spatial dimension, i.e. whether a boundary is located at the intra-organisational space, or at the inter-organisational space. At the inter-organisational space, boundaries may appear as disciplinary, or organisational. At the intra-organisational space, boundaries may demarcate functions or separate projects from the rest of organisations. As Table 4 indicates, we differentiate between three types of boundaries: 1) intra-organisational, 2) organisational, and 3) disciplinary.

TABLE 4: TAXONOMY OF POTENTIAL BOUNDARIES INVOLVED IN AN R&D CONSORTIUM

Boundary type	B1: Intra-organisational	B2: Organisational	B3: Disciplinary
Spatial dimension	Intra-organisational	Inter-organisational	Inter-organisational
Functionality	Competence/ hierarchy	Organisational identity	Competence

Intra-organisational boundaries: A project team embraces a subset of actors who are officially involved in R&D consortia. Many organisations use projects to achieve innovations or technological change. However, transfer of knowledge and learning into the wider context of organisations can be problematic (Scarbrough et al. 2004, Swan et al. 2010). Projects necessitate particular governance, idiosyncratic goals and milestones, and a tailored combination of human resources and skills which make them distinct from other types of organising. The temporality of projects, on the other hand, makes it difficult for project-based organisations to sustain the knowledge gained in the projects (Lindkvist et al. 1998, Prencipe and Tell 2001). This is not different for projects taking place at the external boundaries of organisations like R&D consortia. In fact, the knowledge obtained from external projects is even more difficult to transfer and preserve, as individual organisations have limited control over these projects and their governance.

The knowledge that is generated within the context of R&D consortia can be difficult to transfer to other functions within organisations. Functions within organisations can become disconnected from one another due to having diverging interests, incompatible languages, or discordant perceptions of what counts as better for the whole business. For instance, the interfaces between R&D, design, marketing, and manufacturing can influence innovations and new product development (Adler 1995, Song et al. 1997, Hauptman and Hirji 1999, Carlile 2004). Cohen and Levinthal (1990) discussed that the interactions among the subunits in an organisation are essential for developing cross-functional AC.

Apart from the functional differences within organisations, there are also vertical differences within units or subunits. For instance, the boundary between managers and technicians in the same department can hinder the transfer of knowledge that is acquired within the R&D consortia. This boundary deals with hierarchies and power (Fox 2000, Lawrence et al. 2005), i.e. who has the access to knowledge and who has the say on what should be done.

In the remainder of the thesis, as the unit of analysis is R&D consortia, the various types of boundaries that pertain to intra-organisational space are referred to as intra-organisational boundaries, and their specific features (i.e. whether they relate to hierarchical differences or functions) are only discussed with respect to their particular context whenever the findings are presented.

Organisational boundaries: Organisational boundaries have been known both as the source and the barrier for 'external' knowledge acquisition. In this study, we are particularly interested in organisational boundaries in two ways. First, organisational boundaries denote the legal boundaries around the firms – i.e. they demarcate the intra from the extra. This aspect is important in the context of AC since external knowledge, by definition, involves this type of boundary.

Second, by incorporating organisational boundaries into the framework, we aspire to refer to other differences that are not purely limited to the legal boundaries of organisations, but also to the differences that encompass the wider sociocultural context that organisations operate in. In this respect, an organisational boundary may separate a group of organisations who belong to a similar sociocultural context from others. For instance, the university-industry boundary is a prominent type of organisational boundary based on the fact that the two partners have different institutional roots, incentive structures, etc.

Disciplinary boundaries: Disciplinary boundaries constitute the third type of boundary in this study, demarcating the disciplinary differences between actors within R&D consortia. While communities of practice are local with a shared context of mutual interactions, disciplinary domains entail a global dimension of practice without necessarily referring to local *communities.* Drawing on this, we use the notion of disciplinary boundaries in order to refer to the imaginary boundary between practices at the global dimension. For instance, according to our framework, there is a disciplinary boundary between mechanical engineers and material scientists regardless of the organisation they belong to. Similarly, there is no disciplinary boundary between mechanical engineers even if they belong to multiple organisations without any history of pre-existing relationships between them.

In our framework, we assume two features for disciplinary boundaries. First, they only relate to disciplinary differences at the inter-organisational space unless it is mentioned otherwise. The reason is that in R&D consortia, disciplinary differences are more visible at the inter-organisation space compared with the intra-organisational space. The disciplinary differences within organisations are referred to as functional boundaries which go under the broader category of intra-organisational boundaries. Moreover, in this research, we define disciplinary boundaries with respect to the day-to-day practice of partners but not with respect to the background qualifications of individuals. The reason is that in R&D consortia, research areas become very specialised and people with the same background may not necessarily work in the same domain of expertise or disciplines. Therefore, it is their work context which determines their discipline.

3.4.3 LEARNING MECHANISMS THAT SUPPORT AC

3.4.3.1 INTRODUCTION

Lane et al. (2006) combined the insights from learning theories, especially in line with March's (1991) distinction between exploration and exploitation, with Cohen and Levinthal's three AC dimensions of identification, assimilation and application. They attributed the identification of new knowledge aspect of AC to exploratory learning, and the application aspect of AC to exploitative learning. Moreover, referring to the literature that focuses on balancing exploration and exploitation, they proposed that assimilation of knowledge takes place through transformative learning (Garud and Nayyar 1994).

In our framework, we follow Lane et al.'s model. However, being informed by the boundary classifications discussed above, we extend their conceptualisation by offering a set of micro learning mechanisms that support AC at the inter- and intra-organisational levels.

3.4.3.2 EXPLORATORY LEARNING

The first dimension of Lane et al.'s model is exploratory learning, the process that contributes to recognising the value of and understanding new knowledge. It predominantly occurs at the consortium level as it is known to be more relevant across organisational and/or disciplinary boundaries. In a study of optical disk technology, Rosenkopf and Nerkar (2001) found that the level of exploration is highest when technological and organisational boundaries are crossed. Within the practice strand, despite adopting a different angle, authors have supported a similar argument. Within the CoPs, the potential for exploration is weaker as CoPs tend to refine and excel in their prevailing practices. As we move towards the boundaries, the *regimes of competence* weaken and experience begins to diverge from competence: "a boundary interaction is usually an experience of being exposed to a foreign competence" (Wenger 2000). Such discomfort and challenge nurtures the context for innovations, novel possibilities and change. Therefore, across the boundaries of CoPs, the potential for innovations increases (Brown and Duguid 1991) and exploration becomes the dominant logic for learning (Nooteboom 2006).

The theoretical framework posits that *perspective taking* and *coordination* contribute to exploratory learning. As the first aspect of AC in Lane et al.'s (2006) definition relates to recognising and understanding external knowledge, we argue that perspective taking and coordination play significant roles in this phase because perspective taking is required to understand the differences across various boundaries and preparing future assimilation of knowledge and coordination is required for managing the differences at the initial stages of the collaboration, which is essential for delivering the tasks and milestones in the early stages.

Perspective taking refers to understanding and interpreting others' viewpoints, interests, and thoughts through positioning them in relation to one's own knowledge. "This taking of the other into account, in light of a reflexive knowledge of one's own perspective, is the perspective-taking process" (Boland and Tenkasi 1995 p.362). The importance of perspective taking in knowledge transfer across boundaries is well recognised in the literature. Boland and Tenkasi (1995) found that perspective taking is an indispensable aspect of knowledge-intensive firms with horizontal interactions among various specialised CoPs. Examining a multidisciplinary collaboration between cancer specialists, Oborn and Dawson (2010) found perspective taking as a factor deepening the expertise of communities about each other's knowledge.

On the other hand, coordination mechanisms contribute to exploratory learning in AC as they deal with a set of procedures and means for collaborating in distributed work. Coordination mechanisms are the mechanisms that enable collaboration across boundaries even in situations with no consensus (Akkerman and Bakker 2011). Coordination mechanisms facilitate knowledge exchange across organisational and disciplinary boundaries (Jansen et al. 2005). They are useful in two major ways. First, they assist crossing organisational boundaries through harmonising differences and aligning goals. Second, they facilitate crossing disciplinary boundaries through enabling shared language and inducing dialogue between disciplines. The need for coordination across boundaries increases as the work context becomes innovative and complex (Kogut and Zander 1992). For example, by conducting an in-depth case study, Faraj and Xiao (2006) argued that coordination mechanisms are essential to manage distributed expertise in turbulent contexts.

3.4.3.3 TRANSFORMATIVE LEARNING

The second dimension of AC is transformative learning which balances exploratory and exploitative dimensions of AC and gives rise to the assimilation of knowledge. However, while for Lane et al. (2006) transformative learning is limited to combining the existing knowledge with new knowledge (Zahra and George 2002), our theoretical framework suggests that transformative learning can be a far more complicated process. The framework distinguishes between two aspects of transformative learning including 'transformation' and 'transferring'. Transformation includes the mechanisms that give rise to manipulation and modification of existing structures, processes, routines, and practices in order to both *generate* and *accommodate* new knowledge. Transferring refers to the organisational mechanisms employed in order to make the knowledge that is acquired within R&D consortia accessible to and processable in the wider context of organisation across time and space.

In this framework, transformation is close to the notion of adaptation in behavioural theories of learning. Traditionally, adaptation is defined as the ability of a firm to identify and capitalise on market opportunities (Miles et al. 1978). In this sense, adaptation relates to a firm's ability to conform to the uncertainties that environment imposes on them. Recently, some authors have demonstrated that adaptation contributes to balancing exploration and exploitation, contending that adaptation necessitates strategic and structural flexibility in firms in order to achieve such balance. Changing extant processes, resources and routines and continuously establishing new organisational forms enable firms to balance exploration and exploitation (Rindova and Kotha 2001, Staber and Sydow 2002).

Although in our framework we adopt the above features of adaptation, the term transformation is proposed to capture something more than the conventional view of adaptation. First, usually, one aspect of adaptation is its responsive nature, i.e. organisations adapt only in response to external stimuli. This can be due to the fact that adaptation is mainly used in the context of dynamic literature (Teece et al. 1997). In our formulation, transformation refers to the mechanisms which support change but not necessarily in response to environmental stimuli. In particular, transformation is not limited to reactive responses, and encompasses a dynamic, mutual, and interactive process.

Second, while adaptation is an organisational-level mechanism, transformation can have a local aspect. Adaptation takes place at the interface that organisations have with their environment i.e. at the interface of organisations and markets. However, transformation can potentially relate to the boundary crossing mechanisms that support transformative learning. As discussed, across boundaries, there is a higher potential for novelty which, in turn, accompanies the probability for conflict as the local practices become incompatible with each other. In these conditions, a shared context for collaboration is required in order for transformation to take place (Carlile and Rebentisch 2003). Developing such shared context, necessitates deploying mutually accepted methods and practices that facilitate collaborations. Therefore, given the prevalence of various boundaries in the context of R&D consortia, and their level of novelty, knowledge exchange across boundaries may involve some degree of change in existing processes, routines, and methods across various boundaries which are not exclusively defined at the organisational level. Thus, if we extend the notion of adaptation to a mechanism that not only leads into change at organisational boundaries (as adaptation suggests – especially at the interface of organisation and markets), but also supports change at the interface of various (local) boundaries, it can fulfil the main purpose of our framework.

The second aspect of transformative learning relates to transferring mechanisms. Transfer enables organisations to assimilate knowledge in a way that is accessible to the wider context of organisations in time and space. When the R&D consortia are running, there are fewer opportunities to transfer the knowledge to the wider context of individual organisations. However, as a consortium moves towards its final stages, partner organisations start to internalise the knowledge so that it is accessible to others. This process is what we refer to as the transferring dimension of transformative learning. This is an important aspect of transformative learning as it determines the assimilation of knowledge within organisations and can potentially yield future knowledge applications.

Our framework suggests that socialisation and articulation mechanisms are two constituents of transferring. Socialisation enables converting and transferring tacit knowledge through *shared experience* (Nonaka 1994). When knowledge becomes sticky, contextualised, and hard to transfer, socialisation mechanisms are most relevant for transferring. Articulation, on the other hand, reflects the attempts made by organisations to codify the knowledge that is gained from R&D consortia. Articulation can take place through codifying research outputs through documentation, reports, etc. or it can happen through formalising the knowledge within organisational procedures and routines. The importance of articulation as a learning mechanism has been recognised by many authors (Leonard-Barton 1990, Kogut and Zander 1992). Zollo and Winter (2002) argued that articulation facilitates transferring of knowledge. However, they stated that the more important aspect of articulation lies in its contribution to reflection and change. For example, the articulation of experience by groups and individuals can lead into updating and refinement of the operating routines and procedures.

3.4.3.4 EXPLOITATIVE LEARNING

The third and final dimension of Lane et al.'s (2006) model is application of knowledge through exploitative learning in order to create new knowledge and commercial outputs. This aspect of AC, on the one hand, relates to embedding the knowledge within organisations through retention, and, on the other hand, to diversifying its consequents through replication.

Through retention, knowledge becomes vested within the practices and decreases in abstraction as it becomes routinised (Zollo and Winter 2002). The idea of routinisation in organisations resonates with Wenger's notion of reification as the mechanism which objectifies learning. According to Wenger, "reification refers to the process of giving form to our experience by producing objects that congeal this experience into thingness" (Wenger 1998 p.58). It is a powerful aspect of social life allowing actors to encapsulate large amounts of their experience into objects. Creating rules and procedures, producing tools, and routinising knowledge constitute exemplar forms of retention in organisations.

Replication, however, gives rise to new opportunities for application of knowledge. As Zollo and Winter (2002) suggested, retention cannot fix and crystallise knowledge in routines forever. When knowledge is routinised, it can potentially become exposed to new contexts as routines operate in different contexts. This leads into new organisational inquiries, and new absorption cycles. Thus, replication entails the mechanisms that organisations employ in order to apply knowledge in new contexts, which in turn triggers new opportunities for innovation, and may, as well, lead into new problems (Zollo and Winter 2002).

3.5 OPEN INNOVATION IN THE THEORETICAL FRAMEWORK

One of the literature streams related to the management of external knowledge is "open innovation" (Chesbrough 2003). Open innovation research deals with the question of how firms' ability to innovate is affected by their openness. Chesbrough (2003, p.XXIV) defined open innovation as "a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as firms look to advance their technology". This definition of open innovation is widely used in literature and underscores the importance of internal and external ideas in generating value for a firm. This value is created in two ways. On the one hand, in open innovation, added value is generated through integrating external ideas with internal ones. On the other hand, it is gained through deploying mechanisms to channel internal ideas to market. The main point, therefore, is that a single organisation cannot innovate in isolation by only focusing on internal R&D and that it has to interact with different types of partners in order to achieve innovations and to beat the competitors.

In this study, however, we decided not to use the concept for the following reasons. First, open innovation is a rather broad concept which incorporates a wide range of approaches under 'opening up the innovation process' (Dahlander and Gann 2010). Therefore, we found that the ambiguity around the concept may harm the analytical power of the study. Second, the focus of open innovation research is on individual firms as it argues that they can benefit from making their boundaries permeable, and discusses various strategies that they can deploy in their interaction with different partners to maximise their innovation outputs and. However, as the unit of analysis in this study was R&D consortia, and not a single firm, the concept of open innovation could not fit the research objectives. Therefore, in this study, we decided not to employ the concept of open innovation.

3.6 CONCLUSIONS

In this chapter, the theoretical framework for the thesis was presented in detail. As discussed, despite the framework being informed by the literature, it was not purely deductively constructed. The first case study (HOUSE) contributed to the development of this framework. However, in the later stages of the research, the framework was modified and refined through further analysis of the other two cases. A more developed version of the framework will be presented in chapter 7.

The framework consisted of two major parts. First, it encompassed the preconditions of AC including knowledge sources and complementarities, activation triggers, CoPs, and SC. We discussed how these factors contribute to the formation of R&D consortia and AC development. Second, it presented an extended conceptualisation of Lane et al.'s 2006 AC model. In particular, it was argued that a better understanding of AC inevitably involves a refined consideration of boundaries within the R&D consortia. In the framework, we discussed that exploratory learning builds on perspective taking and coordination, transformative learning consists of transformation and transferring mechanisms, and exploitative learning deals with retention and replication.

Chapter 4. METHODOLOGY

4.1 INTRODUCTION

In this chapter, we discuss the methodology that is applied throughout the thesis. First, we describe the research design of the study, the appropriateness of case study strategy, and the sampling approach. We then provide a detailed account of the data collection process including accessing the cases, the retrospective approach to data collection, operationalisation of the concepts, and the sources of data that informed our research. Finally, we present how data was analysed and what data analysis methods we employed in this research.

4.2 RESEARCH DESIGN

4.2.1 CHOICE OF CASE STUDY

In this thesis, we applied case study as the strategy for empirical analysis of the research. According to Yin (2009 p.18) a case study is:

> "…an empirical enquiry that investigates a contemporary phenomenon in-depth and within its real-life context… It copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis".

Yin specifically emphasised that case study should not be confused with ethnography, direct observations, or a combination of qualitative techniques deployed in a research study. It is also clear from Yin's definition that the logic behind case studies is different from the grounded theory in which no prior assumptions for approaching data are permitted (cf. Glaser and Strauss 1967).

Since we are focused on the mechanisms that constitute AC in R&D consortia, a case study strategy fits our purposes well. Compared to other research strategies, like surveys, and experiments, case study is particularly a strong strategy for answering the *how* or *why* questions about a "contemporary phenomenon over which the investigator has little or no control" (Yin 2009 p.9). Easterby-Smith et al. (2008c) argued that case study is useful when an in-depth examination of causalities among concepts and processes is of interest where, through comprehensively analysing the context of the study and giving a rich picture of life and behaviour in groups or organisations, case study provides explanations of those causalities. Given the objective of this doctoral thesis to explore how AC configures in R&D consortia and how formation preconditions affect the development of AC, we contend that case study is an appropriate choice for this research.

4.2.2 MULTIPLE CASE STUDIES

For this thesis, we chose multiple case studies as our approach for conducting the fieldwork. It is usually believed that multiple case studies have the advantage of being more compelling compared with single case studies. However, Yin (2009) argued that the choice of multiple case studies should not follow statistical numeration logic. In contrast to single case studies which ought to be extreme or rare cases, multiple case studies are based on replication logic (Yin 2009). Replication logic, nevertheless, is different from sampling logic where enumeration of the potential pool of respondents is required to conduct statistical tests (Glaser and Strauss 1967, Yin 2009). The appropriateness of multiple case studies is not drawn from their statistical significance but stems from the theoretical variance that they bring to a study. The use of multiple case study design has the advantage of providing theoretical variance and enhancing analytical induction.

According to Yin (2009), multiple case studies can satisfy both literal replication and theoretical replication. Literal replication is concerned with the condition where various cases are selected in order to replicate the same finding, whereas in theoretical replication, cases refer to conditions where discrepancies are analysed in the process of analysis. It is recommended that a study cover both literal and theoretical replications.

4.2.3 SAMPLING STRATEGY

4.2.3.1 INTRODUCTION

Selecting the cases for the research is an important aspect of case study research (Eisenhardt 1989). For this purpose, we first define our sample population. Then, we discuss the sampling logic, or why we selected the three specific consortia in this study.

4.2.3.2 SAMPLE POPULATION

The first step in selecting the cases was to define the sample population. Once the sample population is determined, the limits for generalising the findings will be determined (Eisenhardt 1989). The sample population consisted of R&D consortia. We defined R&D consortia as "a legal entity established by [more than two] organizations that pool resources and share decision making for cooperative research and development activities".

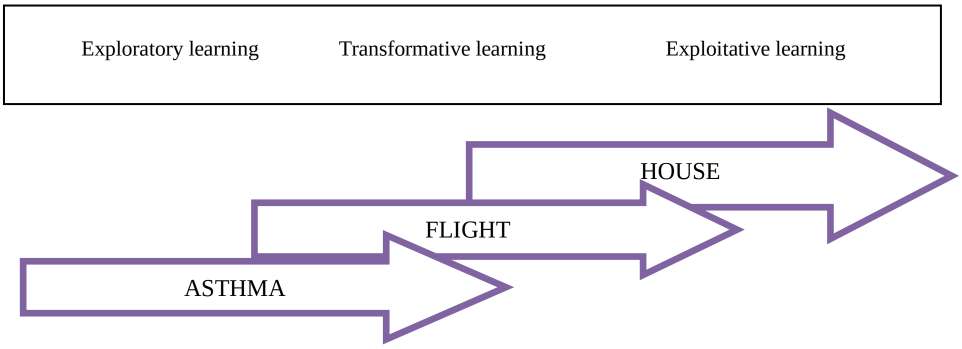
4.2.3.3 SAMPLING LOGIC

In multiple case study design, cases are selected in order to satisfy theoretical reasons instead of statistical ones. In addition, while cases can be selected randomly, it is neither necessary, nor even preferable to do so (Eisenhardt 1989). Random sampling is suitable for the studies that follow statistical sampling rationale. In those types of studies, researchers aim to achieve accurate statistical evidence on the distribution of variables within the population (Eisenhardt 1989). Yin (2009) explained that statistical sampling is not suitable for the case study type of research for two reasons:

> "First, case studies should not generally be used to assess the incidence of phenomena. Second, a case study would have to cover both the phenomenon of interest and its context, yielding a large number of potentially relevant variables. In turn, this would require an impossibly large number of cases – too large to allow any statistical consideration of the relevant variables."

Following a theoretical sampling logic, we selected cases based on the stage of their involvement in their technological innovation trajectory. Doz and Williamson (2002) developed a typology for the stages of R&D alliances. They distinguished between idea stage, experiment stage, venture development stage, and business growth stage of technological innovation trajectory. As mentioned before, one of the main objectives of this research was to improve the understanding of AC in R&D consortia by looking into the exploration, transformation, and exploitation dimensions of AC. The collaboration processes, the governance of the relationship, and the degree to which co-creation of knowledge is formed varies across the phases of the technological trajectory innovation (Doz and Williamson 2002). Inspired by this classification and being driven by our formulation of AC, we selected three cases based on their stage of exploration, transformation, and exploitation (Figure 5). Therefore, although in the three case studies we examined the dimensions of AC, as Figure 5 suggests, each case represents a dominant aspect of AC.

FIGURE 5: THE CORRESPONDING STAGE OF ABSORPTIVE CAPACITY FOR EACH CASE



The first consortium was HOUSE which was a co-funded UK-based R&D collaboration. The HOUSE R&D consortium aimed at researching a house made of straw-bale panels, and it followed on from another collaboration aimed at understanding the functioning of straw-bale panels. The product was becoming very close to the market stage and the partners were keen on testing the features of the house and assessing the preparedness of the product to go to market. Therefore, we categorised the HOUSE consortium as being mainly located within the exploitative learning phase of AC.

The second chosen consortium was ASTHMA, a pan-European co-funded project. The ASTHMA consortium was a collaborative research effort which aspired to understand and address the mechanisms behind the disease of asthma. In drug development procedure, identifying disease mechanisms starts long before the identification of drug targets and drug development. Therefore, collaborative efforts aimed at analysing and understanding the mechanism behind the diseases are increasingly becoming identified as pre-competitive stages (Kamel et al. 2008, Barnes et al. 2009). This research collaboration was far from the market, it did not follow on from a previously-formed consortium, and the partners were experimenting with their ideas, models, etc. Accordingly, we classified the ASTHMA consortium as belonging to the exploratory learning stage of absorptive capacity.

Between HOUSE and ASTHMA, we identified the FLIGHT consortium – a UK-based co-founded R&D collaboration – which did not fall fully into either the exploitative or the exploratory phase. In the FLIGHT consortium, partners had already developed the basics of a new coating technology which was supposed to be applied for titanium landing gears within aircraft. However, as the technology was not mature enough, intense research and experiments were yet to be conducted so that the whole process of manufacturing titanium bearings could become commercially viable. The coating and manufacturing processes had to improve radically in order to meet the highly safety-driven requirements imposed by the aerospace industry. Therefore, the research project was neither purely exploratory nor was it completely exploitative, which is the reason we categorised this research consortium as representing the transformative stage.

By researching three consortia, each at a different stage, we could compensate for the disadvantages associated with not using a longitudinal case study research method by cross-sectional analysis of various stages of the absorptive capacity process (Easterby-Smith et al. 2008a, Vasudeva and Anand 2011). Moreover, given that HOUSE and FLIGHT were completed projects, by analysing the context of these studies in retrospect, we could identify the main aspects of the other dimensions of AC as well as the formation preconditions.

However, it is worth noting that these three stages were never completely divided and they overlapped to a large extent. Although each research consortium mainly represented one stage of three sequential learning processes (Lane et al. 2006), our findings suggest some overlap between the three cases (see Figure 5).

Furthermore, we followed a sequential case selection. A rigorous multiple-case design asks for a sequential process of analysing one case and then selecting the subsequent one since a sequential order will increase the rigour of the study as the findings and conclusions of each case can inform the selection and examination of the following one. The main advantage of this sequential logic is that each new case can address a very specific aspect which was not thoroughly addressed in the previous cases (Leonard-Barton 1990). It means that the selection of each case parallels with data collection and analysis of the previous one. In our data gathering process, in principle, we tried to adhere to this logic in the selection of the cases. The disadvantage, however, was that it could go beyond the resources owned by one PhD student (Yin 2009 p.46). For a three-year PhD programme with a limited amount of time, it was not absolutely practical to follow this logic. Therefore, the processes of conducting case studies and selecting the next cases were not completely distinct, and inevitably there were some overlaps, though this process remained as sequential as possible.

The other criterion for case selection was that we narrowed down the R&D consortia to co-funded collaborations. The main reason for picking this criterion was that co-funded projects offer high impact and high risk. The rationale for co-funding in R&D collaboration is to encourage collaboration in areas that are not likely to form without interventions (i.e. they are risky) and at the same time in the areas that offer radical innovation (i.e. have high impact). Therefore, co-funded projects offer a suitable ground for analysing knowledge exchange and AC.

Although we did not set other criteria for selecting R&D consortia, the three cases varied with respect to their size as well as their geographical diversity. In particular, we found the ASTHMA case as being an exceptionally large one (with more than 50 organisational partners involved), and, as a result, we decided to focus on two of the work packages in the whole consortium. With respect to geographical diversity of the cases, HOUSE and FLIGHT were UK-based consortia while ASTHMA was a European consortium.

Among the three cases, HOUSE and FLIGHT were completed when we started the data gathering process. ASTHMA, however, was in the middle of its lifecycle when the fieldwork began. It should be noted that the HOUSE and FLIGHT consortia continued to subsequent collaborations with almost similar partners (the core partners remained involved in the upcoming collaborations). The same could not be claimed for ASTHMA, as there was still a long way towards the completion of the consortium.

4.3 DATA COLLECTION

In this section, we discuss how we gathered data. First, we describe how we accessed the cases. Then, we explain why we chose a retrospective data collection approach, and finally we elaborate on operationalisations and data collection techniques.

4.3.1 GETTING ACCESS

Getting access to cases is often a practical barrier in conducting case studies. Interesting cases cannot be accessed easily (Yin 2009). Organisations fear leakage of sensitive information and technological and business know-how, and losing their reputation and credit as the result of a research study. In addition, because of the nature of this study which explores the relationships between partners, organisations were concerned about the potential negative impact that such research could have on their interaction with their partners. In order to address these concerns, and to get access to the three R&D consortia cases, we employed a number of strategies.

First, we decided to contact the project managers of the consortia who were responsible for monitoring the project progress. During this process, we emailed the project managers and followed this with a telephone call to illuminate the research goals and inform them about the way research would be conducted. This phase was critical as we had to simultaneously negotiate the level of access to crucial data sources, while not risking the access to the cases. We found this experience extremely important as we could better negotiate the level of access with the project managers for the second and third cases compared to the first one. Then, if asked, a detailed research synopsis was provided to the project managers so that they could figure out the research objectives, methodology, etc.

Second, we had to prepare a memorandum of understanding which included a non-disclosure agreement with the consortium managers to ensure that 1) data collected from their consortium would remain confidential and 2) no publication would be made out of their collaboration without their approval. Finally, in one of the case studies, we were asked to destroy all information gathered about the case after the completion of the research study. We found this arrangement very useful, because upon our agreement to destroy the information, the consortium managers willingly gave away every piece of data about their work without being excessively concerned about sensitive and confidential matters.

Once the access was granted by the consortium managers, the next step was to approach the other partner organisations (since the project managers belonged to one partner organisation and could not speak on behalf of others). For this, we asked the manager to either provide us with the contact details of other partners or introduce us to them so that there was a better chance of getting their consent. This step proved complicated, since the consortium managers were influential people in their respective organisations and could not necessarily guarantee access to other partners. As a result, we had to write to other participants explaining the project goals and objectives, followed by a telephone call so that we could convince them to participate in the study.

4.3.2 RETROSPECTIVE MODE FOR DATA COLLECTION

In case research, data can be gathered in two different ways. Researchers can either follow a real-time sequence of events in a longitudinal approach, or they can rely on the historical accounts of the phenomenon under study. The former is considered longitudinal data collection, whereas the latter is known as a retrospective data collection technique.

For this study, we opted for the retrospective data collection format. There are three main reasons associated with this. First, conducting fieldwork in a retrospective manner has the advantage of identifying the *big picture,* how things unfolded and how they affected the outcomes (Poole and Van De Ven 2004). This was very helpful as we always needed to identify the big picture due to the complexity associated with R&D consortia, arising from the involvement of various, or even conflicting, disciplines, institutional and organisational contexts, and languages which made R&D consortia more difficult to analyse compared with single-organisation case studies. Second, collection of retrospective data is more efficient than that of real-time data. Conducting a longitudinal study necessitates a broader time span, which can easily extend beyond the three-year timeline of a PhD. Collecting longitudinal data, moreover, entails the risk of data overload and collecting much unusable data, while retrospective data collection can be very focused and narrowed down (Leonard-Barton 1990). Finally, retrospective data gathering has the advantage of making participants confident about the data that they are giving away. This was, in particular, relevant with respect to two of the completed cases (HOUSE and FLIGHT) since they had patented the important outcomes of their work, making them less concerned about knowledge leakage. Had they not finished their collaborations, we would never have been as welcomed to study their research.

On limitations, in retrospective data collection through interviews, people may have the tendency to filter out those events that do not fit or may render their story less coherent (Poole et al. 2000). Moreover, it is not always easy for respondents to remember how events unfolded, and confusions about the causality of the relationships between the events is a frequent hurdle (Leonard-Barton 1990).

Efforts were undertaken to address the above disadvantages. The most efficient solution was to triangulate data by mobilising multiple data sources. Therefore, we complemented and triangulated the data gained from interviews with documents and validations from other respondents (Table 5). Combining the different types of data helped with both minimising bias as well as achieving synergy in data (Eisenhardt 1989, Yin 2009).

4.3.3 OPERATIONALISATION

Operationalisation revolved around the major concepts of theoretical interest in this study: AC, CoPs, SC, learning outcomes, and boundaries (see annex-1 for a detailed interview guide).

Absorptive capacity

For asking questions about AC we used the conceptual model of AC proposed by Lane et al. (2006). We defined AC as the "…ability to utilize externally held knowledge through three sequential processes: (1) recognizing and understanding potentially valuable new knowledge outside the firm through exploratory learning, (2) assimilating valuable new knowledge through transformative learning, and (3) using the assimilated knowledge to create new knowledge and commercial outputs through exploitative learning" (Lane et al. 2006). Therefore, AC has the following components:

1. Recognize and understand new external knowledge
2. Assimilate valuable external knowledge
3. Apply assimilated external knowledge

However, since Lane et al. do not provide any operationalisation guidelines, the interview guide was inspired by other available operationalisation guidelines (Flatten et al. 2009, Lichtenthaler 2009).

Communities of Practice

Following Wenger et al. (2002), we define a community of practice as "a unique combination of three fundamental elements: a *domain* of knowledge, which defines a set of issues, a *community* of people who care about this domain, and the shared *practice* that they are developing to be effective in their domain. … Practice denotes a set of socially defined ways of doing things in a specific domain: a set of common approaches and shared standards that create a basis for action, communication, problem solving, performance, and accountability". Usually, empirical research operationalises CoPs rather intuitively as it equates them with functional departments or disciplinary groups. However, by using the above dimensions we do not consider them as given, but we attempt to detect them especially across organisations.

Social Capital

We operationalise SC by its two dimensions of structural capital and relational capital which is based on the definition provided by Nahapiet and Ghoshal (1998). *Structural capital* entails the impersonal configuration of linkages among actors; it relates to the opportunities actors have to build a relationship (Burt 1992). For this dimension, the question refers to pre-existing relationships and the frequency of interactions. *Relational capital* is the nature and quality of interactions; it relates to the motivational aspects of social capital including trust, and mutual expectations and obligations. For this dimension we focused on openness, trustworthiness, and mutual expectations. In order to be in line with the narrower view of SC (Adler and Kwon 2002) (see 3.3), while we applied Nahapiet and Ghoshal's (1998) conceptualisation of SC, we did not incorporate their cognitive dimension of SC.

Boundaries

Following Akkerman and Bakker (2011), we define boundaries as "sociocultural differences that give rise to discontinuities in interaction and action". Therefore, our operationalisation of boundaries was reflected in the challenges that participants faced throughout the collaboration process. Then we used prompts in order to validate the responses of the interviewees. We asked about differences in languages, differences in ways of doing things, and barriers for knowledge transfer, in order to identify the boundaries.

Learning outcomes

We operationalised learning in terms of the outcomes that the consortia generate. We followed Lane et al.'s (2006) conceptualisation of knowledge outputs. In so doing, we distinguished between two types of outcomes, that is, the newly generated technological and market knowledge and the newly developed process knowledge (Lane et al. 2006, Lichtenthaler 2009).

4.3.4 DATA SOURCES

4.3.4.1 INTERVIEWS

The main data collection technique was interviews. We used semi-structured interviews in this study. The overall approach was to interview all the individuals participating in the consortia. However, practically it did not work because some individuals were either reluctant to take part, or had left their organisation after the completion of the projects. In the latter case, we tried to get hold of them and interview them at home, or at their new workplace. This strategy worked for some of the participants, but there were still some participants whom we could not reach. However, we managed to interview the key informants of each consortium for this research[2]. Before conducting the actual interviews and after identifying the informants, we wrote emails to the potential interviewees. In each email, we mentioned the details of the confidentiality agreement and informed them about the anonymity and confidentiality of the interview. The other strategy used to get hold of the participants was to attend events. In particular, for one of the three cases, attending the annual meeting proved helpful in expediting the process of data collection. In this event, almost all participants were present and their interest in having an interview was sought. This was very useful compared with sending an email or giving a cold call since talking face to face with people generated a degree of rapport and cultivated trust that facilitated interviewing them at later stages.

Prior to interviews, desk research was conducted in order to maximise the familiarity with the interviewee's work, their role in the collaboration and to prepare the most relevant questions to be asked of that interviewee.

The interviews were structured in a chronological order starting from the background of the research collaboration followed by questions about the evolution and outcomes of the R&D consortia. At the same time, the interview questions covered a series of themes asking more detailed questions about AC, the role of boundaries, communities of practice, and social capital in the R&D consortia. During the interviews, the questioning approach was to appear rather naïve and less informed about the field so

[2] The details about the cases and the interviewed participants will be provided in the case study reports.

that the respondents could provide a rich commentary. Interviews were recorded, transcribed verbatim, and the transcribed interviews were sent back to the respondents for their validations.

Throughout the fieldwork, we recursively changed the interview questions if: 1) an interview suggested that there were overlooked aspects that needed to be covered by the interview questions, 2) some questions were found irrelevant or were asked in academic language not accessible to participants, 3) some questions were very general and needed to be refined so as to receive more specific replies from the informants, or 4) data analysis of a preceding case study suggested that there were new themes emerging and theoretical framework needed to be refined which then resulted in incorporating new theoretical aspects into the interview questions.

Since not all respondents were engaged in the consortia at equal levels, they had different levels of knowledge about the consortia. Therefore, in order to maximise the use of information extracted from respondents, we utilised two separate sets of interview questions. The first set was developed for those participants who were highly informed about the consortia. That included project managers and/or work package managers in the consortia. From these participants, we asked questions about the overview of the consortium, its formation process, and its evolution. Here, the main objective of the interview questions was to figure out the dynamics of the development of R&D consortia.

Other participants who did not manage the project or were not involved in the consortia on a daily basis were less knowledgeable about the projects as their information was proportionate to their level of participation. Therefore, a separate set of questions were developed in order to address their perspective, which predominantly related to the viewpoint of their participating organisation.

4.3.4.2 DOCUMENTS

Documents were analysed as the second source of the study. We had two sources of documents. We searched through the internet in order to gather the publicly available data. In this way, we could gather 1) the press releases published about the consortia, 2) the presentation videos and TV shows, 3) information about the history of each individual partner, their areas of specialty, their size, and their status in the industry, 4) information about the technology that was developed in the consortium and 5) the co-authored publications coming out of the consortium. Second, we collected documents which were not publicly available. These documents provided a deeper level of understanding about the cases.

These documents were useful for addressing some of the pitfalls of the retrospective data since they provided us with detailed information about the history of events, the structures of the collaborations, the division of labour, and the technical understanding of the technology. This was not achievable in the retrospective interviews because the participant did not fully remember the details of the way things were conducted. At the same time, these documents helped us to triangulate the data gathered from the interviews. If there were instances where written information about division of labour and structure did not comply with the actual narration of the facts by the interviewees, we would explore the case further. Table 5 demonstrates the data sources that were deployed in this study.

As Table 5 demonstrates, there are various types of documents that were used in this study. Descriptions of some of the documents in the table which are not self-evident are as follows. Second-level work plans included the detailed description of the work packages, deliverables, milestones and resource allocation by each partner. The research project summary presented the research experiments in detail and the results of those experiments. Online discussions included the correspondence and email exchanges between consortia partners. Finally, annual meeting presentations included the PowerPoint presentations by individual partner organisations who participated in the research consortia. These presentations covered a summary of what they had done and the main results and challenges ahead of them.

TABLE 5: THE SOURCES OF DATA

R&D consortium	Interviews	Documents that are not publicly available	Other sources
HOUSE	15 interviews	- The second-level work plan - Research Project Summary	- Published case report - Organisation websites - TV shows - Co-authored publications
ASTHMA	23 interviews	- Detailed annual project report - Meeting minutes - Online discussions	- ASTHMA website - EMC[3] website - Presentation videos - Co-authored publications
FLIGHT	11 interviews	- Reports of quarterly meetings - Presentations of quarterly meetings - Second-level project plan - Project timelines and Gant charts - Patents	- Organisation websites - Published case report - Co-authored publications

4.4 DATA PRESENTATION AND ANALYSIS

4.4.1 ANONYMITY AND UNIDENTIFIABILITY

As discussed in 4.3.1, getting access to the cases necessitated ensuring confidentiality and unidentifiability of the participants. For that reason we signed non-disclosure agreements with the consortia managers which resulted in us using pseudo names for the consortia, the participating organisations, and the individual participants throughout the thesis. We labelled the three consortia in accordance with the dominant aspect of their research collaborations (HOUSE, ASTHMA, and FLIGHT). For referring to the participating firms, apart from the pharmaceutical companies, we labelled them based on their main function which represented their role in the consortia (e.g. ARCHITECT, COATING, etc.). Universities and research institutes were labelled according to the order of their appearance in the analysis (e.g. UNIVERSITY A, RESEARCH B, etc.). This was also the case for pharmaceutical companies in

[3] European Medicine Collaboration

ASTHMA where we coded them according to the order that they were presented within the thesis (e.g. COMPANY A, COMPANY B, etc.).

4.4.2 RATIONALE FOR THE PRESENTATION OF FINDINGS AND ANALYSIS

Following Pentland (1999), we distinguished between surface levels and deeper levels of data structure. We used a stage-based method to analyse data. This stage-based approach divided data analysis into two parts. The first part included a detailed description of the cases. This was a thorough presentation of data in a chronological format. In the second stage, we sought to develop a more analytical narrative of the cases by deploying the theoretical framework of the study. At this stage, the focus was to understand the mechanisms underlying the observed phenomena, providing explanations of why findings were similar or different across cases. In this section, we discuss the two aspects of data analysis in detail.

4.4.3 CASE DESCRIPTIONS/ REPORTS

The main purpose of this stage was to present a case study report. Yin (2009 p.50) explained that each case study consists of a *whole* study and must be self-contained, i.e. the facts and data gathered from the case must converge into conclusions from the same case. Although the reports were not necessarily presented in a chronological manner, we attempted to build a story around the cases, which would represent the initiation of the R&D consortia, its structure, and evolution. This can be regarded as a narrative strategy for sense making in process research (Langley 1999). For this purpose, we employed two sources of data: semi-structured interviews and documents. However, given that we were more interested in factual data at this stage, documents comprised the major source of data and the semi-structured interviews were considered as complementary to the documents, either to validate the findings in documents or to further elaborate on them. Therefore, we predominantly cited documents in order to remain objective and to stay as close as possible to the cases. Moreover, only data that were consistent across the sources were used. The objective of this stage was to provide readers with a detailed overview of the different R&D consortia (Yin 2009), preparing them for the more interpretive part of the data analysis.

Finally, we used expert validation for case reports. Upon writing the descriptive case studies, the case reports were sent to the project managers of the three R&D consortia and their feedback informed further refinement of the reports.

4.4.4 ANALYSIS

The analysis part aimed to interpret the stories developed at the previous stage in order to discover the underlying mechanisms and explanations that led into the observed case story. This stage, therefore, explicitly dealt with the research questions that were set for this research.

For analysis, we recruited an inductive approach to data (Eisenhardt 1989) with continuous comparisons between data, analytical interpretations, and theory (Miles and Huberman 1984). However, although we avoided being positivistic by handling data quantitatively (for example, employing content analysis), we did not apply grounded theory (Glaser and Strauss 1967) by being purely inductive. Our approach for data analysis was in-between the two. Template analysis (King 2004 p.256) suggests a useful approach in this regard:

> "…the researcher assumes that there are always multiple interpretations to be made of any phenomenon which depend upon the position of the researcher and the context of the research. Concern with reliability coding is therefore irrelevant; instead issues such as the reflexivity of the researcher, the attempt to approach the topic from differing perspectives, and the richness of the description produced, are important requirements."

Template analysis involves making a coding template identified in the data through recursive reading of the text. Codes can be either descriptive or interpretive (although there is not always a clear distinction between the two). For example, while codes like history of the collaboration or the ultimate goal of the consortium are descriptive ones, codes such as motivation, difference in meanings, tailoring languages, or reconfiguring the boundary are of interpretive nature. While the former group does not require considerable investment by the researcher, the latter group requires more effort to reach clarity in definition and analysis. In template analysis, during the process of coding data, although the codes that are common among most of the interviewees are identified, there are also codes that refer to those parts of data which are observed in a minority set of interviews (King et al. 2002).

In template analysis, the codes are modified in multiple rounds of comparing data and theory until the researcher reaches a confidence point. As an entry point, template analysis allows the researcher to specify themes based on the research objectives and overall directions. Thus, the first set of themes follow the general areas of interest in the research. As our main area of interest revolved around absorptive capacity, social capital, communities of practice, learning outcomes, and boundaries, we started our template with these broad themes. Adding to this, and in accordance with the template analysis technique, we specified a theme for the background and the formation of each case.

Finally, in order to systematise the data coding we used a computer-based qualitative analysis programme, NVivo 8, to code and cross-reference the codes that emerged from the data.

4.5 CONCLUSION

In this chapter, we discussed the methodology of the thesis. Since the objective of the research is to answer *why* and *how* questions, we employed case study research strategy. We opted for a multiple case study design in order to enhance the theoretical variety and analytical induction. We selected R&D consortia cases among the sample population based on a theoretical sampling logic (i.e. cases in exploratory, transformative, and exploitative phases). Once access to three R&D cases was granted, we collected data in a retrospective manner by using both interviews and documents. For interviews, we used the available conceptualisations and operationalisations in the extant literature to prepare the interview guide. Finally, for presenting findings, we employed two distinct stages representing surface level stories and deeper level analysis. First, we presented case reports descriptively for each case. Then, we applied an Nvivo assisted template analysis technique to provide an interpretive account of the cases in order to answer the research questions of the PhD. This involved iterative examination of data and codes in order to reach confidence in our interpretation of data within and across the cases.

Chapter 5. CASE REPORTS

5.1 INTRODUCTION

As discussed in the methodology chapter, the first stage in data analysis relates to providing case reports that give basic information about the cases and prepare the reader for the subsequent more analytical narratives. In this chapter, we present the three R&D consortia cases, exploring their main purpose and background, their funding mechanism and structure, their division of labour, their overall development and success, and the main challenges for learning that they faced. Below, cases are presented in accordance with the chronological sequence of the data gathering process.

5.2 HOUSE: A SUSTAINABLE CONSTRUCTION

5.2.1 BACKGROUND

The HOUSE collaboration was a £2m project under the collaborative R&D scheme of the TSB (Technology Strategy Board)[4]. The consortium started in October 2008 and was completed in March 2010. It was the second project in a series of three successive projects in a broader technological research programme aimed at developing a sustainable construction method. It followed a previously co-funded project by TSB titled PANEL, and was the predecessor of a European funded project named EURO (see Figure 6 and Table 6). For this thesis, we focused on the HOUSE collaboration[5] because the PANEL consortium was relatively old and the EURO collaboration was at its initial phase when we started data collection. Therefore, the best choice for this study was to focus on HOUSE.

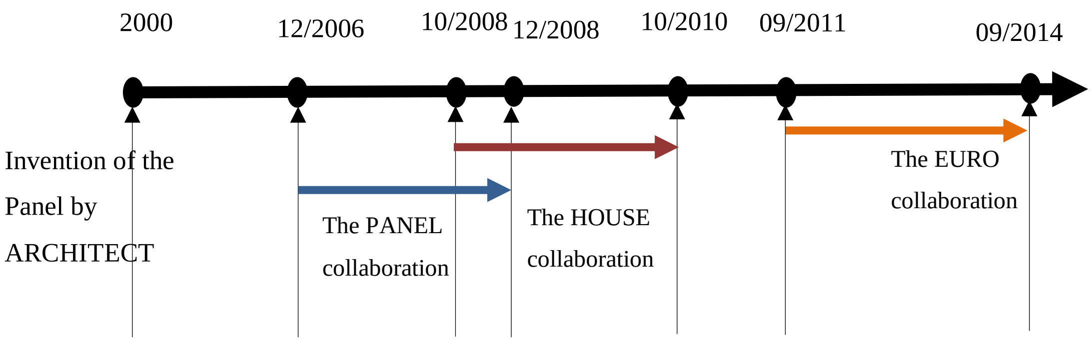
[4] The Technology Strategy Board is an executive non-departmental public body (NDPB) established in 2007 and is sponsored by the Department for Business, Innovation and Skills (BIS)

[5] Project manager and published case studies by TSB

The pre-existing R&D consortium (PANEL) played an important role in nurturing the opportunities for exploring new areas of research, identifying the lacking expertise, and mobilising new partners. During the PANEL collaboration, the key partners identified new questions worthy of further investigation. In particular, they wanted to see how the panel would behave in the more complex context of a house, whether there would be any synergy when multiple panels were used simultaneously, or whether there would be any negative effects. They also aimed at seeing whether the panel would be a reliable load-bearing wall system from a structural engineering point of view. The academic professor of innovative materials explained the importance of the R&D consortium in terms of the opportunities it brought for further understanding of the product in the following terms:

> *This is an exciting product, which has far wider parameters than first realised and could become a key feature in future construction developments. The Panel project enabled us to maximise upon its potential (Academic Professor- UNIVERSITY A).*

FIGURE 6: THE TIMELINE OF THE COLLABORATION



The history of the series of R&D collaborations was an important factor in determining with whom to collaborate. The majority of partners in the HOUSE consortium had participated in PANEL. The decision to retain the same set of partners had pros and cons. On the advantages, partners had developed ways of collaboration, they trusted each other, and they had an understanding about what was expected from their participation. With respect to the disadvantages, however, core partners found the involvement of some partners unnecessary in HOUSE. The inclusion of some partners whose participation was more relevant at the early stages of the collaboration (i.e. in

PANEL) was not as important during the following consortia (i.e. HOUSE and EURO). Consequently, the next collaboration (EURO) did not involve the same set of partners, and the R&D consortium partners were limited to the core partners from HOUSE in addition to a new partner from Europe.

TABLE 6: THE OVERVIEW OF THE THREE PROJECTS

Event	Partners	Funding Scheme	Project budget
Invention of the Panel	Architect	N/A	N/A
PANEL	Architect, Engineer, University, Render, Wood, Agriculture, Research	DTI (Department of Trade and Industry)	£299,000
HOUSE	Architect, Engineer, University, Render, Wood, Agriculture, Research, Constructor	TSB – CollaborativeR&D	£780,000
EURO	Architect, Engineer, University, BB Architect, Panel Ltd.	European Commission's Executive Agency for Competitiveness and Innovation (EACI)	£ 1.9M

It is also important to note the role of the director of ARCHITECT in the formation of the project. First, he had some links with UNIVERSITY A long before the project started. He was involved in teaching at the time. When ARCHITECT, in collaboration with ENGINEER, developed their product and embarked on the research path, he used his linkages within UNIVERSITY A to approach the right department and academics. His credibility and reputation were also important in getting various partners together. Especially for CONSTRUCTOR, who were not part of the pre-existing research collaborations, the main reason for involvement was the reputation of the ARCHITECT director.

Moreover, as the director of ARCHITECT, he actively sought opportunities for further research. In collaboration with the co-founder of the company, he developed a research strategy specifying the research profile that they aimed to achieve. In addition to HOUSE, they contributed to or led many other research projects in their company[6].

5.2.2 THE FUNDING SCHEME

The project was funded by the former Department for Trade and Industry (DTI) and was later governed by the Technology Strategy Board (TSB). TSB is an executive non-departmental public body (NDPB) established in 2007 and sponsored by the Department for Business, Innovation and Skills (BIS). The goal of the organisation is to *accelerate economic growth by stimulating and supporting business-led innovation*[7]. TSB fosters collaboration between various partners in order to increase the chances of stimulating innovation. They offer 50% co-funding to cover transaction costs and aspire to stimulate research that would not have been conducted in the absence of external funding, in order to avoid offering an alternative to private research. The participating firms need to invest in projects by allocating either time or resources. The other qualification is that TSB does not invest in less risky proposals because they do not want to subsidise research which companies would conduct anyhow in the absence of external funding. TSB identifies a number of competition priority areas, which have the highest potential impact. The HOUSE collaboration fell into the *Built environment* category as it dealt with innovative materials for constructing sustainable buildings[8].

5.2.3 THE STRUCTURE AND THE COLLABORATION PROCESSES

The HOUSE collaboration consisted of eight partners including one university, six SMEs and one private research institute[9]. Table 7 shows all project partners with their expertise and roles and their resource contributions to the consortium. Two sets of partners were identifiable. The core partners included ARCHITECT, ENGINEER, and UNIVERSITY A. They had vested interest in researching the area of innovative materials. These partners defined the problem area, and the roadmap to address the research problems. ARCHITECT and ENGINEER had been in close collaboration

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[6] Research Project Sheet Summaries
[7] From TSB website: http://www.innovateuk.org/
[8] http://www.innovateuk.org/ourstrategy/our-focus-areas/builtenvironment.ashx
[9] Second-level project plan

almost since the initiation of their businesses. As the director of ARCHITECT described, they formed a *mirror* and shared a history of development with each other. The interaction with UNIVERSITY A originated from previous ties the ARCHITECT director had with the university. He used to give lectures in the university, though he did not know the professor who eventually became involved in the HOUSE and other PANEL-related projects. Moreover, the interaction between the core partners was not limited to the formal requirements of the project. They were *friends at the social level* (CONSTRUCTOR participant) and were open and trusting with each other. The three core partners believed in each other's competencies in delivering the project tasks and had developed a mutual understanding of what was expected in the context of the collaboration (Director of RENDER, and CONSTRUCTOR participant).

TABLE 7: THE INVOLVED PARTNERS, THEIR EXPERTISE, AND RESOURCES

Partners	Type	Expertise	Main role in the project	Resources
UNIVERSITY A	University	Centre for Innovative Construction Materials	Review of panel materials Testing the features of the house Structural tests Performance tests	Laboratories and test facilities
ARCHITECT	SME	Low environmental impact architect	Designing the prototype Designing the house and commercialising the material Leading the project	Human resource
ENGINEER	SME	Sustainable structural engineering consultancy	Structural design of the prototype Structural design of the house	Human resource
AGRICULTURE	SME	Specialist in industrial use of agricultural crop fibres	Supplying the panels	Panel manufacturing facilities
CONSTRUCTOR	SME	Construction company	Project consultation	Human resource
WOOD	SME	Specialist in the installation of solid timber building structures	Supplying timber	Material – wood
RENDER	SME	Specialist in render and building constructions	Supplying render	Material – render
RESEARCH A	Private research institute	Research institute	Conducting steady state and dynamic modelling studies of prototype building	Modelling software expertise

The rest of the partners were less engaged in the project both from a research point of view and in their resource contribution. For them, the research interest was not at the core of their business. Except for one organisation (RESEARCH A), these partners were either the potential suppliers for PANEL (RENDER supplier, WOOD supplier, and straw supplier) or the potential customer (CONSTRUCTOR). Therefore, their interest in the product related to the commercial success of the final product. RESEARCH A was active in providing a thermal modelling of the house but, like the other minor partners, they did not consider the HOUSE research as core to their interest and it was only secondary to their research activities.

In line with this observation, we found that partners varied in their contributions to AC. As discussed in chapter 3, different dimensions of AC have different characteristics which can be fulfilled by different partners. Table 8 indicates the different roles played by partners in different phases of AC. UNIVERSITY A, ARCHITECT, and ENGINEER were the most contributing partners in the exploratory and transformative phases, and ARCHITECT and ENGINEER were the influential ones in the exploitative phase.

TABLE 8: THE IMPORTANCE OF PARTNERS ACROSS THE PHASES OF AC

Partners	Motivation	Importance of phases		
		Exploratory	Transformative	Exploitative
ARCHITECT	To drive market confidence	High	High	High
ENGINEER	To drive market confidence	High	High	High
UNIVERSITY A	Interest in and curiosity about the innovative materials	High	High	Low
RESEARCH A	Not specified	High	Low	Low
AGRICULTURE	To increase their sales as supplier	Low	Low	Low
CONSTRUCTOR	To improve their research profile	Low	Low	Low
WOOD	Commercial interest in the product as a supplier To substantiate how their product performs in straw bale panels	Low	Low	Low
RENDER	To increase their sales as supplier To substantiate how their product performs in straw bale panels	Low	Low	Low

The whole consortium comprised seven work packages including WP1: Material development and testing, WP2: Product design, WP3: Prototype testing, WP4: Prototype building, WP5: High value product manufacture and delivery, WP6: Commercialisation, and WP7: Dissemination activities. Table 9 demonstrates the work packages and their respective leaders.

The consortium partners held quarterly meetings where they had the chance to discuss their progress on their tasks and to share the information and knowledge they had gained during the respective period. The monitoring officer of the TSB attended the quarterly meetings where the progress reports were presented. The three major partners met more often to discuss the details and progress of the projects. Many of these meetings were held on the HOUSE building site. In these meetings, some technical details of the research were discussed and the commercial partners had the opportunity to monitor the progress of the consortium.

TABLE 9: THE WORK BREAKDOWN OF THE PROJECT

WP		Deliverables	WP leader
1.	Material development and testing	Initial report on durability (UNIVERSITY A) Report on experimental studies into straw decay (UNIVERSITY A)	UNIVERSITY A
2.	Product design	Initial design studies (ARCHITECT) Final design details (ARCHITECT)	ARCHITECT
3.	Prototype testing	Report on expt. design (UNIVERSITY A) Report on structural tests (ENGINEERS) Report on performance tests (UNIVERSITY A) Journal article (UNIVERSITY A)	ENGINEER
4.	Prototype building	Prototype design drawings (ARCHITECT) Report on thermal modelling results (RESEARCH A) Prototype build completion (All) Report on 12 months monitoring (UNIVERSITY A)	ARCHITECT
5.	High value product manufacture and delivery	Report on specification for monitoring system (UNIVERSITY A) Report on through-life support protocol (ENGINEERS/ARCHITECT/UNIVERSITY A)	UNIVERSITY A
6.	Commercialisation	marketing plan - house types cost plan (ARCHITECT) Report on commercialisation activities (ARCHITECT)	ARCHITECT
7.	Dissemination activities	Ecobuild 2009 exhibit (ARCHITECT) Insight 2009 exhibit (ARCHITECT) Ecobuild 2010 exhibit (ARCHITECT) Web site delivered (ARCHITECT)	ARCHITECT

5.2.4 THE ACHIEVED OUTCOMES OF THE CONSORTIUM

5.2.4.1 THE CONSORTIUM OUTCOMES

In general, the consortium was successful. The deliverables of the project were all met in accordance with the project plan, the house was built at the university campus and it was fully researched and tested in terms of its design, performance, and structural, thermal, durability, and decay properties. As an outcome of the research, the partners realised that there is synergy between panels when they work together as constituents of a building and that the performance of the house as a whole excelled over that of the individual panels. However, in certain areas, the results were not close to the expectations of commercial partners[10]. This project was recognised as one of the successful collaborative R&D TSB projects and a brief case report was published on the TSB website. Moreover, as mentioned before, the HOUSE project led to further research collaborations at the European level.

5.2.4.2 OUTCOMES FOR INDIVIDUAL PARTNERS

The level of achievement for individual partners varied considerably across the partners, ranging from a partner who realised that they did not fully understand what they wanted out of the project and another who lost interest in the middle of the consortium and stopped attending the quarterly meetings, to the core partners who increased their understanding of the product and improved their collaborative capabilities in addition to commercially exploiting the knowledge gained out of the consortium. Table 10 demonstrates the impact of the participation in the project for each individual partner.

[10] Academic professor in UNIVERSITY A

TABLE 10: THE LEARNING OUTCOME FOR EACH PARTNER[11]

Partner	Outputs and learning outcomes
ARCHITECT	Publications and co-publications Increased understanding of the product Increased collaborative capabilities Increased technical capability to calculate embodied carbon Increased knowledge of how to manage a project New marketing practices (the house as the evidence for their marketing) Increased capability in collaborating with other universities
UNIVERSITY A	Publications MPhil thesis Increased understanding of the way SMEs work The process of negotiating contracts with the partners Improved research profile of the innovative materials department Financial management Increased understanding of the prefabricated straw bale PhD thesis on decay properties of straw
ENGINEER	Co-publications Increased technical capability for doing structural testing Formalising previously ad-hoc design and testing procedures
RESEARCH A	Learning about a new modelling software
RENDER	Better understanding of the render they provided for the panel (information relevant to their product)
AGRICULTURE[12]	Increased understanding of the product Co-publication Identification of a new piece of equipment for cutting straw bale
CONSTRUCTION	To be clear about the project goals before getting involved – as the result of failure

5.2.5 THE CHALLENGES

The HOUSE consortium faced a number of challenges in conducting research in collaboration. First, the level of commitment to the project varied across different partners, which could potentially affect the project completion. Not all contributing partners had clear vision about their contribution to the project. The project was not equally important to all partners, and those parties with higher stakes contributed more enthusiastically to the project.

11 Data presented here is mainly driven by the interviews (and occasionally emails) with the consortium partners.

12 Agriculture is a company owned and run by only one person so every learning is by definition individual

In particular, ARCHITECT, ENGINEER, and UNIVERSITY A were the most passionate partners who took the lead in advancing the project. ARCHITECT and ENGINEER were the inventors of the panel in the first instance and it was in their strategic interest to get the final product to the market. For UNIVERSITY A, the project was a source of funding and they were highly interested in researching alternative materials. On the other hand, for the rest of the partners, the product was not their major focus. Although they contributed to the accomplishment of the project and delivered their tasks, they did not have long-term focus on it.

Another challenge was harmonising language in collaboration between the partners. As the actors belonged to different disciplines and professional contexts, with varying levels of expertise, the collaboration and communication among them could become challenging at times, especially when the level of technicality increased in the respective subject domain[13]. This problem was more evident in quarterly meetings when each partner had to present their progress with the tasks.

The third, and probably the most salient challenge, related to the aims that partners pursued in their participation. From this point of view, academic and industrial partners were particularly different from each other. For UNIVERSITY A, what mattered most was conducting research and finding the answers to the question. In practice, they were not very much concerned about the image of the product, its market success, its presentation, or even its failure in experiments. Conversely, commercial partners were less interested in the scientific understanding of the product and cared more about its market success. Such a difference was a source of conflict in this collaborative research project.

[13] The details will be discussed in chapter 6

5.3 **ASTHMA: A NEW APPROACH TO THE DISEASE**

5.3.1 BACKGROUND

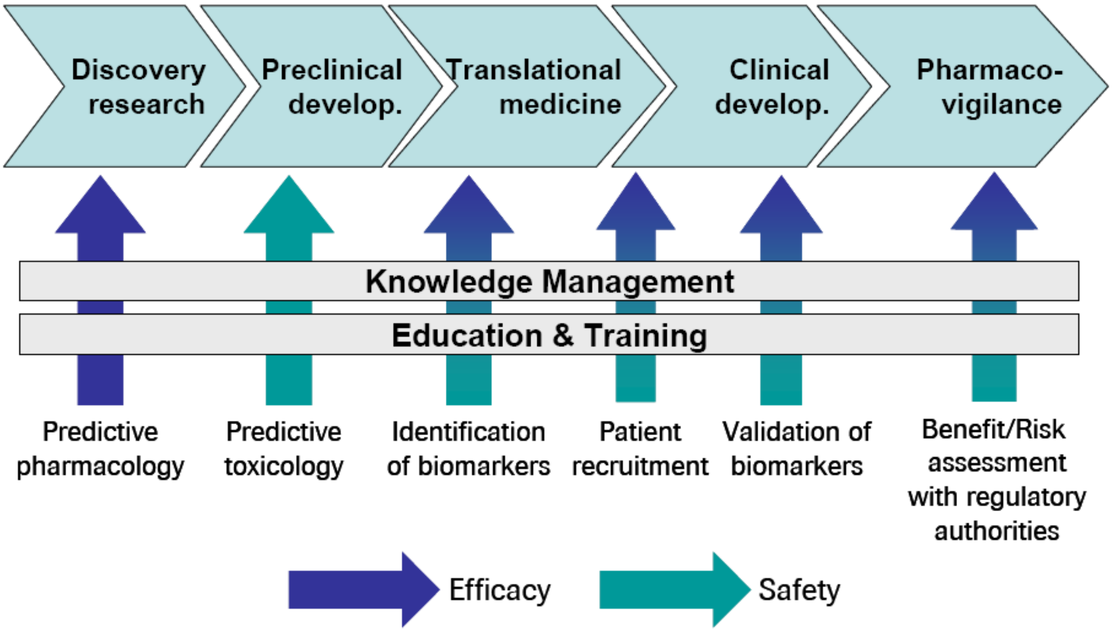
ASTHMA was an R&D consortium aimed at increasing understanding about severe asthma which was a part of a larger European initiative focused on pre-competitive research collaboration in pharmaceuticals. The European Medicine Collaboration (EMC) is the largest public-private pan-European collaborative R&D initiative specifically aimed at accelerating the development of better and safer medicines for patients.

The EMC was launched in order to shorten the time span of drug development and increase the cost efficiency of products. First, it sought to reduce the cost and time spent on a new drug development. The drug development process is very long and costly. On average, it takes 10-15 years for a new medicine to be developed and it costs millions of Euros (Kamel et al. 2008).

Figure 7 demonstrates the key steps in the drug development process. As can be clearly seen in the diagram, this process consists of many steps of screening, each involving a specific set of resources and decisions to make based on the results of experimentations, etc. Each stage is accompanied with a number of bottlenecks which delay the process and incur costs in the development of the final drug (Kamel et al. 2008).

The second issue is the diminishing returns on R&D investments in pharmaceutical companies. Over recent years, increased R&D expenditures have not led into higher FDA (Food and Drug Administration) approvals of New Molecular Entities (NMEs) (new molecular entities) for the large pharmaceutical companies (See Figure 8). Therefore, R&D has become more expensive and involved higher risks. This, in turn, means that individual companies are no longer able to afford the financial investments and associated risks.

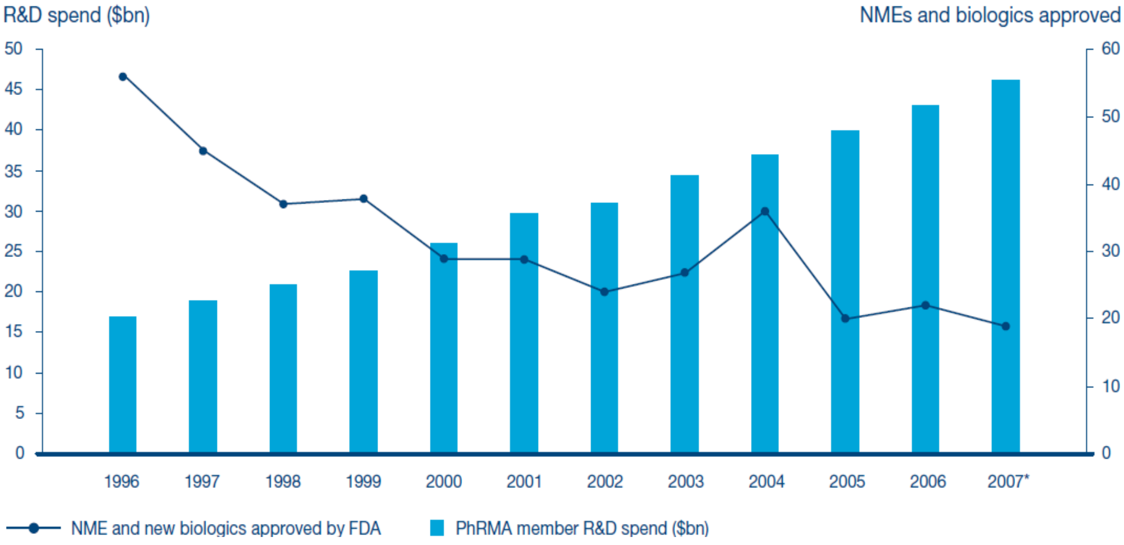
FIGURE 7: KEY BOTTLENECKS IN PHARMACEUTICAL RESEARCH AND DEVELOPMENT



Develop.: development

Source: The European Medicine Collaboration (EMC) Research Agenda

FIGURE 8: DIMINISHED R&D PRODUCTIVITY



NME: New molecular entity; FDA: Food and Drug Administration

Source: PricewaterhouseCoopers (2009)

With the ever-increasing costs associated with drug development in the pharmaceutical industry, the effectiveness of conventional methods of in-house drug development are in question and there is a need to find new ways of gaining sustainable income. In response to these identified needs, the EMC was launched in 2008. The EU FP7 (European Framework Programme 7) contributed €1 billion, which was mainly matched by in kind contributions (mostly consisting of research activities) worth another €1 billion from the member companies of the European Federation of Pharmaceutical Industries and Associations (EFPIA). In addition to the pharmaceutical companies (EFPIA partners), each R&D consortium consisted of a number of applicant partners. Applicant partners included universities, SMEs, patient organisations, hospitals, and regulatory authorities. Once a project application was successful, the funding from the EC (European Commission) was matched by equal in kind contributions from EFPIA partners.

Initiating such a shift to a collaborative approach only became possible in light of two facts. First, it had become clear to the players that the viability of the pharmaceutical industry as a whole would be in jeopardy if companies maintained their closed attitude to research and insisted on developing everything in-house. An alarming evidence for this was the diminishing returns on R&D demonstrated in Figure 8.

Second, the industry was redefining the boundaries of pre-competitive research. The pre-competitive aspects of research do not directly relate to drug development targets upon which companies build their competitive advantage and commercialise their products. Therefore, it is more feasible for pharmaceutical companies to collaborate in the pre-competitive areas. However, the boundaries of pre-competitive research are not clearly defined. Over the last few years, the definition of the pre-competitive research domain has broadened to encompass many aspects which were regarded competitive previously. In fact, the industry has been redefining the boundaries of pre-competitive research and what counted as competitive before may well now count as pre-competitive (Barnes et al. 2009). This shift, therefore, enabled collaboration among pharmaceutical companies without becoming too concerned about the potential negative consequences of working with their rivals.

Thus, the EMC initiative is not about drug development per se, but is concerned with tackling the knowledge gaps that exist across major disease areas[14]. The priorities for research, therefore, include a) enhanced understanding of the history and mechanisms of disease, b) development of relevant pre-clinical and clinical models to allow translational research[15], and c) introduction of new health outcome tools that *reflect the patient's perspective of the disease and treatment, are sensitive to pharmacological interventions and can predict pharmacoeconomic benefit* (Kamel et al. 2008). EMC focuses on five main disease areas: brain disorders, cancer, and metabolic, infectious, and inflammatory diseases.

The ASTHMA consortium, as a part of EMC, fell in the respiratory medicine domain which is one of the Strategic Research Area (SRA) priorities within inflammatory medicine followed by EMC. Ten per cent of asthma patients are not controlled by current therapy and, considering the large number of asthma patients (more than 40 million in Europe), severe asthma is not a negligible health issue. The underlying assumption in the ASTHMA consortium was that severe asthma is caused by different disease mechanisms and the overall aim of the consortium was to better understand the different types of severe asthma. In so doing, partners had to overcome the following bottlenecks[16]:

a) Poor understanding of different phenotypes within the severe asthma population

b) Lack of biomarkers for effectively analysing disease response or the impact of a new therapy on disease throughout the clinical studies

c) The weak linkages between pre-clinical models and clinical data

The main hypothesis of the collaboration was "[t]he use of biomarker profiles comprised of various types of high-dimensional data, integrated with an innovative systems biology approach into distinct phenotype handprints, will enable significantly better prediction of

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[14] http://www.imi.europa.eu/

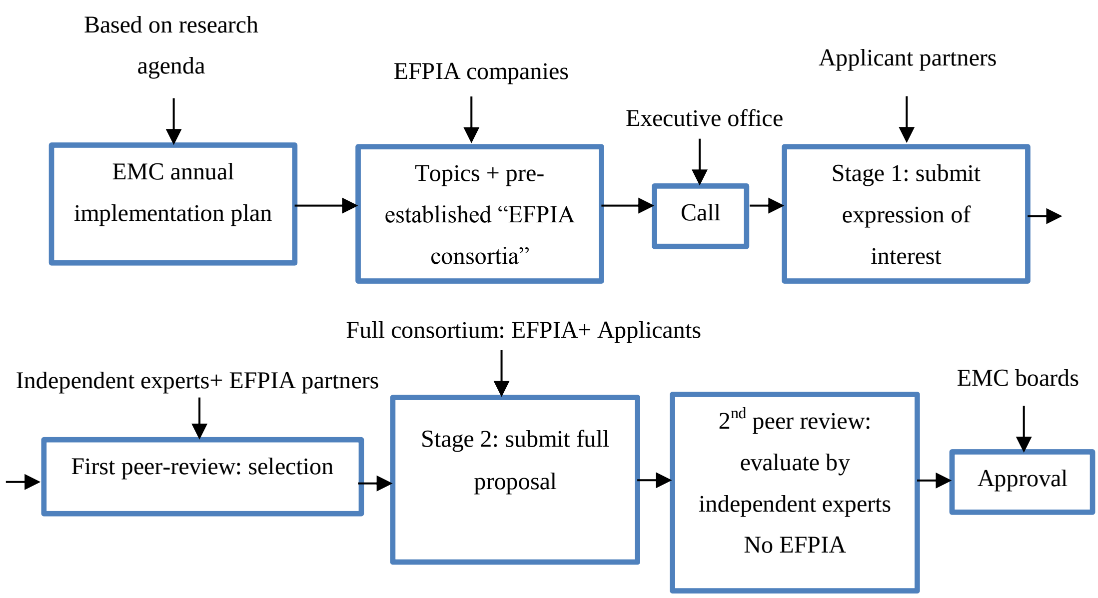
[15] Translational research is used in order to transfer the findings of basic research (e.g. lab experiments) into clinical applications

[16] Presentation by Chris Compton: The EMC Severe Asthma Call: Unbiased Biomarkers for the Prediction of Respiratory Disease Outcomes

therapeutic efficacy than single or even clustered biomarkers of one data type, and will identify novel targets." The main milestones of the consortium included 1) initiation phase 2) foundation study phase 3) data integration methodology 4) handprint discovery and validation phase. When this study was being conducted, the initiation phase was completed and the foundation study phase was ongoing.

Like other EMC collaborations, ASTHMA selection followed the selection procedure demonstrated in Figure 9. However, although Figure 9 demonstrates the formal procedure for formation of consortia, the actual process was not as straightforward. In what follows, we briefly present the process of formation of the consortium.

FIGURE 9: THE EMC CALLS AND ASSESSMENT



Source: (Kamel et al. 2008)

In the first place, using his informal network, the industrial coordinator of ASTHMA mobilised people in the respiratory domain from different pharma companies to determine the companies' research priorities in the field of respiratory disease. In parallel, the applicant partners[17] had already started discussing the research ideas before the call was released[18]. The core academics in the consortium had initial ideas about how asthma research should be developed. These academics had known each other for a long time, and had vested interest in the respiratory research area. They were also members of the European Respiratory Society (ERS) with a shared attitude towards the path respiratory research should take. Once the call was launched, this group of academics took the lead and, with assistance from a bio-pharma consultancy firm, prepared the proposal.

Proposals were evaluated by the EFPIA partners and, among the applications, ASTHMA was selected. Afterwards, the applicant partners met with the pharmaceutical companies to make a full project plan. At this stage, the EFPIA partners' contributions and the resources they would bring to the consortium were determined and a work plan and breakdown of the tasks were specified based on those contributions. Once the project plan was finalised, the consortium started in October 2009. The project timeline was five years and it is expected to be complete in September 2014.

Overall, two distinct networks were involved in the ASTHMA formation process. On the one hand, academic partners had their own network consisting of the centres with interest in the approach. On the other hand, there was a strong network of industrial people who were interested in respiratory medicine within the EFPIA partners, which resulted in the formation of ASTHMA.

[17] Applicant partners were the partners who prepared a research proposal and applied for the projects funded by EC and EFPIA

[18] Manager of the consortium

5.3.2 THE STRUCTURE OF THE CONSORTIUM AND THE SELECTED WORK PACKAGES

5.3.2.1 THE ASTHMA STRUCTURE

ASTHMA was a scalable project. It consisted of partners from academia (20), biopharma industry (EFPIA) (10), patients/care organisations (6), and SMEs (3). The project was broken down into 10 work packages including coordination and management (WP1), consensus generation (WP2), cross-sectional and longitudinal cohort (WP3), bronchoscopy studies (WP4), clinical models (WP5), pre-clinical laboratory models (WP6), omics technologies (WP7), bioinformatics and systems biology (WP8), dissemination (WP9), and ethics and safety (WP10). The consortium mobilised a large base of expertise and resources from various partners. In general, in ASTHMA, three types of expertise were discernible a) clinical experts who were mainly in contact with patients b) scientists (from biologists, to immunologists, to pathologists), c) computer scientists and system biologists and d) managers. Similarly, the work packages were categorised in accordance with these general areas; WP2, 3, 4, 5, 7 were the clinical ones, WPA was managed by scientists, and WPB was run by computer scientists, systems biologists and statisticians. Each work package had an academic lead and an EFPIA leader in order to ensure quality communication between academic and industrial partners. In this study, we selected WPA and WPB as the main empirical focus of the research.

The EMC initiative was a unique form of collaboration in the industry in its own right. First, unlike other collaborations in the pharma industry which take place between large companies and bio-tech SMEs or between large companies and research institutes in a bilateral fashion, in EMC, large pharma companies collaborated with each other (Goldman 2012). Second, EMC built on concrete collaboration between scientists who work on research in the labs. Therefore, interfaces were not limited to distanced licensing or report production, which are the more common forms of collaboration within the industry, but they formed around the intensive interactions between scientists. This meant that pharma companies had to encourage their scientists to get involved in external collaborations.

ASTHMA had a Management Board (day-to-day management), Strategic Advisory Board (external advice), Scientific Board (integrating the 10 Work Packages), Ethics Board, Safety Board, and a General Assembly (representing all partners) [19]. The management board consisted of members from EFPIA and applicant members and the scientific board consisted of all WP leaders including both applicants and EFPIA partners.

5.3.2.2 THE SELECTED WORK PACKAGES

Since ASTHMA was a pan-European project with a high number of partners (more than 40) scattered around Europe and more than 150 participants, and considering the fact that the project consisted of various areas (from clinical and animal models to ethics and knowledge management), it became clear in the early stages of data gathering that pursuing a more specific aspect of the project would enable in-depth analysis and reduce the risk of data overload. Moreover, the size of the two other cases in the study (HOUSE and FLIGHT) were not comparable to that of ASTHMA in any significant way, and it was analytically a better match with other cases to research a smaller part of the project. Moreover, unlike the two other cases in which WPs were run by the same set of participants, the WPs in ASTHMA were rather independent with their own leaders and participants who only belonged to a particular work package.

As a result, a decision was made to narrow down the study to only two WPs within the project. WPA and WPB were selected because of the following reasons: a) the role of companies and their contribution to these WPs were considerably higher compared with other WPs that were mainly managed by universities and research centres, b) these WPs were more advanced with respect to delivering their objectives, and c) they necessitated close collaboration among partners. WPB, in addition, had another interesting factor which led to its inclusion in the research agenda and that related to the significance it held to the whole project. The basic drive of ASTHMA was its systems biology approach assisted by translational research, which meant that large-

[19] Project periodic report – Nov. 2011

scale data drove the analysis in the project[20]. This aspect was a novel dimension of ASTHMA and was the main focus of WPB. WPB consisted of bioinformatics, systems biologists, and statisticians whose expertise was considerably different from the rest of the ASTHMA participants (biologists and clinicians). Therefore, the inclusion of WPB in this study was motivated by its unique nature and the less common interface that it offered in the collaboration.

WPA dealt with the laboratory (animal and pre-clinical) models of asthma. It had two major academic partners (UNIVERSITY B, and RESEARCH B) and five companies (COMPANY A, COMPANY B, COMPANY D, COMPANY E, COMPANY G). After one year of the project, one of the EFPIA partners (COMPANY E) withdrew from ASTHMA due to a change in their research priorities at the corporate level. This incurred adverse effects on WPA as COMPANY E had been one of the major contributors. Moreover, another company's shutting down their respiratory research centre in the UK, relegating their work to a site in Sweden, resulted in some discontinuity in the WPA work[21]. There was also a change in the management team of the WP. The academic leader of WPA was one of the core participants who initiated the ASTHMA proposal. However, at the end of 2011, the first industrial leader of WPA retired and was replaced by a representative from another company.

WPA had two main parts, namely *in-vivo* and *in-vitro*. The objective of the in-vivo part was to establish an in-vivo model of viral-induced exacerbation in asthma and to compare the handprint of this model with human severe asthma and viral exacerbations of asthma. The work package had three main milestones to deliver: 1) developing in-vivo murine models of severe asthma; 2) foundation in-vitro models and 3) handprint discovery. When our study was being conducted, the in-vivo part had been completed. Therefore, a large part of the case report deals with the in-vivo work.

Another aspect of the collaboration in this WP related to two distinct non-invasive imaging techniques (CT scan and MRI) at two of the collaborating companies. During

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[20] In clinical research, using large scale data is rare, and research is conducted only by deploying a limited sample data.
[21] WP academic and industrial leads

the collaboration, these techniques were applied to the chronic House Dust Mite (HDM) model (at COMPANY A and COMPANY B respectively) which resulted in similar outcomes suggesting that the two techniques, despite being different in methodology, may deliver similar results. A joint publication was the result of this collaboration.

WPB dealt with the knowledge management (KM) [22] system and systems biology. The main partners included two companies, one university, and one research institute.

Not being among the core project initiators, the academic lead of the WP was introduced through pre-existing ties that the project manager (i.e. the director of the bio-pharma consultancy SME) had. Initially, ASTHMA decided to outsource the WPB work to a contractor, but due to some serendipitous changes in the project, the management team decided to approach the computer science department in UNIVERSITY B with whom the scientists and clinicians had not worked before.

Within WPB, the KM system an open source software developed by COMPANY C. COMPANY C had invested in translational research and data management within its R&D division. This resulted in the development of a translational medicine informatics infrastructure called TRAMSN (Szalma et al. 2010). COMPANY C agreed to give access to partners in order to work with TRAMSN for conducting translational research within the ASTHMA consortium. Therefore, they assigned UNIVERSITY B to host the system so that other companies as well as research institutes could work with it and analyse their data.

5.3.3 THE MECHANISMS OF COLLABORATION

The ASTHMA project was managed by an SME that specialised in project management of collaborative biomedical research. This SME coordinated and ran teleconferences (TCs), as well as face-to-face meetings in the project. They also developed an online collaboration platform, which enabled interactive task work. Apart from the interactive interface, the platform worked as an information repository

[22] In translational research, knowledge management relates to collecting, sharing, and interpreting large-scale data generated by experimental and clinical trials.

of the projects where all of the reports, presentations, and meeting minutes were available to project participants.

The WPs held monthly TCs in which all partners participated, shared their progress, and made decisions on how to proceed. In addition to the monthly TCs, the whole consortium held an annual meeting where all project participants met. In these meetings, the WPs presented their progress to a larger audience and the integration of the WPs was discussed in more detail. Finally, partners had intense communication via emails and phone calls throughout the collaboration.

One of the common practices in the pharmaceutical industry was the exchange of post-docs between industrial and academic partners. Therefore, the post-docs were also an important factor in the collaboration between the partners because 1) they dedicatedly worked on ASTHMA, unlike other participants, and 2) they had the chance to move freely between partners and specifically at the industry-academia interface. In WPA, a post-doc researcher from RESEARCH B was sent into COMPANY B in order to learn the virus infection technique and combine it with the in-house HDM model they had in RESEARCH B. She spent three months in the pharma company and when she came back to her research institute, she combined the RESEARCH B's in-house model with the virus work. Afterwards, a post-doc was also sent from COMPANY D to RESEARCH B to learn the same virus technique and implement it within COMPANY D.

ASTHMA was a large-scale data-driven consortium, which aimed at enhancing the understanding of asthma mechanisms through classifying data. However, as the research process was scattered across Europe and was conducted by different organisations, the consolidation of data was problematic. A while after the commencement of the consortium, it became clear that in order to be able to collaborate, partners needed to harmonise their methods of working so that they could compare and contrast their research results, experiments, models, etc. As a result, the collaborating organisations had to reconsider their Standard Operating Procedures (SOPs) in order to arrive at a unified form of SOP which, in turn, enabled comparison and consolidation of data between the various partners.

Collaboration was also facilitated because of the presence of research institutes within the consortia. As already mentioned, EMC was one of the first attempts in the pharmaceutical industry to establish a collaboration between large pharma companies. However, despite the fact that EMC research was mainly focused on pre-competitive research, concrete collaboration between partner companies could be commercially sensitive for companies. For example, mobility of scientists between companies, or the way data was being shared, consolidated, stored, etc. could be controversial. Therefore, the presence of research institutes and universities facilitated sensitive transactions between companies. For instance, instead of having the database hosted by one of the partner companies, which would mean giving a rival company access to sensitive data, it was agreed to have UNIVERSITY B host it.

5.3.4 THE ACHIEVED OUTCOMES OF THE CONSORTIUM

5.3.4.1 THE OUTCOMES OF THE CONSORTIUM

When this study was being conducted, the ASTHMA consortium was at the midpoint of its lifecycle. Hence, it is not possible to judge how successful the collaboration has been as the final goals were not satisfied yet. However, the project was moving in accordance with its timeframe and there were no significant delays in meeting the milestones. As the consortium required a large clinical data set, though, there were some delays in data gathering as a whole.

With respect to the two WPs (WPA and WPB) the research project was on track and they had met their milestones. WPA was focused on animal models so it did not rely on patient data and was one of the advanced WPs of the project. On the other hand, since the beginning of the collaboration, WPB was focused on developing the infrastructure for knowledge management and analytical techniques. WPB, however, needed data from all WPs so that it could generate the outcomes at the final stage. Therefore, some delays could be anticipated for WPB.

5.3.4.2 THE OUTCOMES FOR INDIVIDUAL PARTNERS

The outcomes for individual partners were different across the partner organisations. In WPA, the level of engagement from different partners was different and therefore the outcomes were varied. This ranged from COMPANY A, which shut down its respiratory site and transferred the work to another country, to RESEARCH B, which sent a post-doc researcher to learn the virus growing techniques and protocols from COMPANY B. Table 11 presents the outputs and learning outcomes of the project by the time this research was being conducted. WPB relied on data from other partners and the major aspect of the conducted work was to develop the platform for data analysis. In this WP the level of engagement of partners was rather similar. Table 12 presents the outcomes of WPB for individual partners.

TABLE 11: WPA OUTPUTS AND LEARNING OUTCOMES

Partner	Learning outcome
UNIVERSITY B	Learning about systems biology and knowledge management disciplines Learning to work with industry
UNIVERSITY D	Recruiting a post-doc Integrating an inflammatory exacerbation model to their existing line of research Adapting new methods
RESEARCH B	Viral techniques Routines and protocols for new assays
COMPANY A	Trivial – the UK site was shut down Mainly remained at the individual level
COMPANY B	Joint paper on the comparison between MRI and CT scan papers
COMPANY D	Viral techniques Routines and protocols for new assays Getting updated with the latest models and methods
COMPANY G	Developing the network of connections Learning how to collaborate with academia Becoming updated with the new models and techniques

TABLE 12: WPB OUTPUTS AND LEARNING OUTCOMES

Partner	Learning outcome
UNIVERSITY B	Learning how to work with scientists
RESEARCH C	Development of a new platform for interdisciplinary work at the research institute
COMPANY F	Learning about TRAMSN and considering its installation within the company Learning about new models and methods
COMPANY C	Access to leading edge knowledge Developed network Establishing their internal open source platform (GSK) as the standard interface for data in ASTHMA

5.3.5 CHALLENGES

ASTHMA experienced some challenges throughout the collaboration process. First, it was a pan-European project which involved organisations from various parts of the continent, which inevitably made the collaboration difficult.

Second, the variety of types of participating organisations affected the collaboration and knowledge transfer process. As mentioned, the collaboration mainly involved pharma companies, research institutes and universities, as well as patient organisations which had different organisational focus, interests, knowledge base, etc. Given that the study was focused on WPA and WPB, two main areas of difference were evident from the field data. First, the way research is done in universities and companies is different in many respects. Since, for companies, the final goal is to produce a target for market which supposedly has to be screened in various stages, following strict guidelines, abiding to deadlines, and rigorously adhering to safety procedures and standards are common practices in industry. Conversely, in the pharmaceutical research area, academics are not as rigorous. They do not closely follow the deadlines, and are not as concerned about the methodology and rigour of their research. To them, what matters more is the novelty of their publications.

Closely related to this was the stubbornness of academics who did not want to amend their models for conducting research. In academia, research models that are established in a department or research centre play a key role in their long-term research programme. Modifying these research models could be troublesome, making it difficult to persuade academics to do that, while companies were not as concerned about amending, abandoning, and adopting research models, as is common in industry.

Moreover, collaboration between EFPIA companies was not unproblematic. Pharmaceutical companies have always been secretive about their research and opening up does not come naturally to them. At the beginning of the collaboration, the companies showed reservations for sharing knowledge. However, as the project progressed, and partners started to become familiar with one another and developed mutual trust, the hurdles for knowledge transfer between them started to disappear.

The final challenge was rooted in the presence of different disciplines in the consortium. In particular, the interface between systems biology and knowledge management, and the rest of the consortium was problematic. Systems biology and knowledge management were interdisciplinary domains and the participants in this field did not belong to the field of bioscience research in general (the majority of them were computer scientists). Moreover, unlike other participants who knew each other ex-ante (e.g. from conferences, societies, etc.), the systems biology and knowledge management people were less familiar with the rest of the consortium. These hurdles influenced the interaction between the participants.

5.4 FLIGHT: A LIGHT METHOD FOR FLYING

5.4.1 BACKGROUND

The FLIGHT (Lightweight Bearing Technology) consortium was a collaborative R&D project aimed at developing titanium bearings for aircraft landing gears. Conventional steel and bronze bearings are much heavier than titanium alloys and if they are replaced by titanium alloys, the total weight of the aircraft would be reduced by 400kg which results in considerable reduction in fuel consumption as well as negative environmental impacts[23]. However, the wear properties of titanium alloys are weak and bearings in critical parts, such as main landing gears, would quickly wear out.

Having realised the industry's need to move towards lighter aircraft which can be more environmentally friendly and economic, AIRCRAFT, an aircraft manufacturing company, were keen to identify lighter bearing solutions. Therefore, the three partners across the supply chain: AIRCRAFT, the aircraft manufacturing company, BEARING, the bearing supplier company for AIRCRAFT, and COATING, the coating company and the supplier for BEARING, in addition to the department of material science and engineering of UNIVERSITY C, formed an R&D consortium.

The role of COATING in the formation of the consortium was significant. Having identified the opportunity, the R&D head of COATING discussed his ideas with BEARING who then communicated the issue to AIRCRAFT. Afterwards, taking advantage of the funding opportunities provided by DTI (Department of Trade and

[23] FLIGHT project exploitation plan report

Industry), he initiated the writing of a proposal and approached UNIVERSITY C for their input into the proposal.

Once they applied for and won the grant competition, FLIGHT started in July 2006, and the project ended in January 2010 after an 18-month extension. The project goal was to facilitate weight, fuel, and environmental savings in aircraft through enabling the replacement of (heavy) steel bearings with lightweight titanium alloy (Ti6Al4V) bearings. This was to be achieved through the optimisation of existing duplex plasma and Physical Vapour Deposition (PVD) treatments and the innovative development of new duplex processes[24]. One way to increase titanium's resistance under load is to strengthen its surface through coating. The pre-existing coating technology developed by COATING could withstand pressures of up to 80 MPa, but had failed at 100 MPa pressures. Therefore, in order to meet the higher pressures required by AIRCRAFT, an improved coating process was needed which technically meant to reach a 220 MPa resistance level.

5.4.2 THE FUNDING SCHEME

The project was co-funded by the former Department of Trade and Industry (DTI) and was later managed by TSB (see p. 91 for further details) after DTI became a part of BIS.

A number of competition priority areas with the highest potential impact are specified by TSB. The FLIGHT collaboration falls into the *Advanced materials: high performance in extreme and hostile environments* category as it aspired to introduce an alternative material for bearings which were lighter and burnt less fuel. In addition, these lighter bearings eliminated the usage of chrome-plated coating, which was classified as a SVHC (Substance of Very High Concern). As discussed before, TSB foster collaboration in areas with high risk in order to ensure that they are not offering a replacement for private R&D funding. Table 13 shows the distribution of partners' contributions to the project.

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[24] Project completion report

TABLE 13: THE DISTRIBUTION OF PARTNERS' CONTRIBUTIONS

Partner	P. Contribution (£)	TSB Grant (£)	Total (£)	% Grant
COATING	556,915	386,501	943,416	41
AIRCRAFT	70,838	49,162	120,000	41
BEARING	124,354	86,303	210,657	41
UNIVERSITY C	0	230,141	230,141	100
Totals	752,107	752,107	1,504,214	50

5.4.3 THE STRUCTURE OF THE CONSORTIUM AND THE COLLABORATION PROCESSES

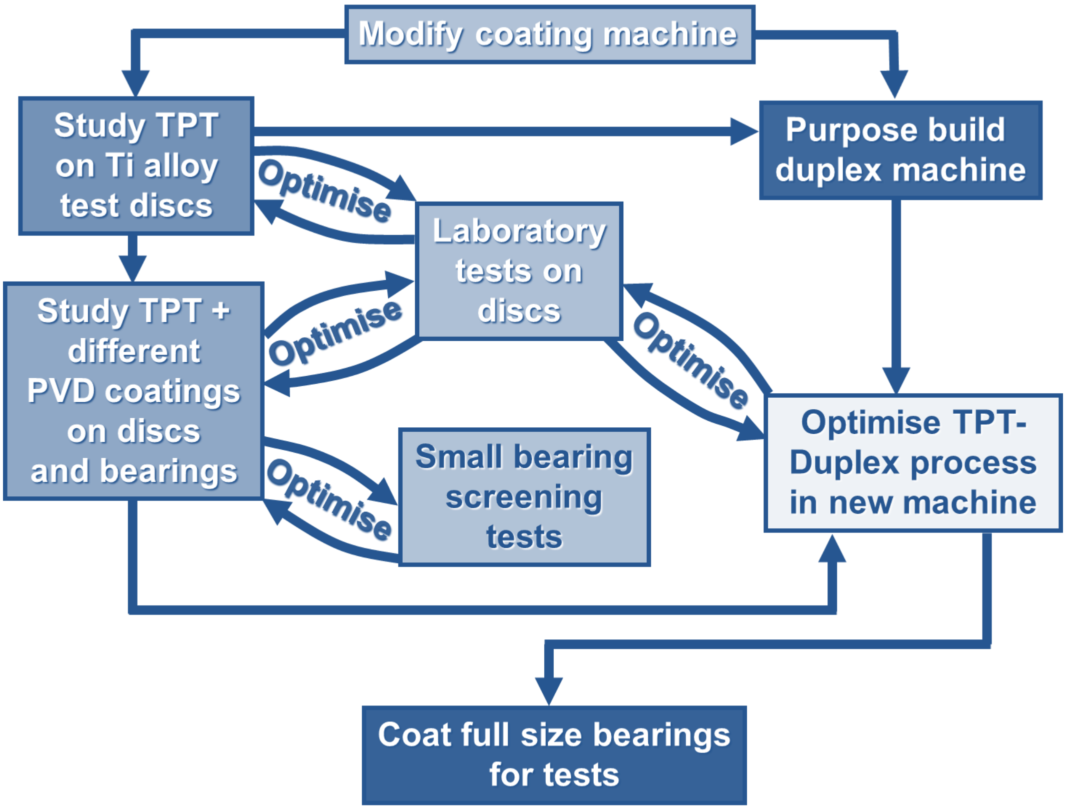
The FLIGHT project was a multidisciplinary research project which involved partners from different organisations with diverse expertise. AIRCRAFT was needed to provide the knowledge about the requirements for bearings in an aircraft, BEARING was needed to provide the knowledge about how to design and manufacture titanium bearings, COATING was needed to provide the know-how on how to coat the titanium alloy bearings, and UNIVERSITY C was needed to provide a deep understanding of the material science involved in the surface treatment process[25].

The overall view of the workflows and technical processes of the work is illustrated in Figure 10. The whole project involved a number of steps. The first stage was the modification of the existing Physical Vapour Deposition (PVD) machine. Then, the partners studied Triode Plasma Treatments (TPT) on titanium alloy discs with the aim of optimising the coating process. The next step was to research TPT plus various PVD coating processes. However, as the pre-existing coating machine was not designed to satisfy the high temperature coating requirements for this project, it was part of the project scope to make a new PVD coating machine specifically configured for this project. Nonetheless, as it was not possible to start building the new PVD coating machine from the outset, during the initial phases of the project, COATING started experimenting with the existing machine so that they could 1) figure out the

[25] Project completion report

specifications of the new machine and 2) efficiently use the time for developing the new coating. At the next step, and when the purpose-built machine was ready, they started researching the duplex TPT coating process for treating the bearings. The detailed breakdown of the project tasks is presented in Table 14.

FIGURE 10: THE TECHNICAL PROCESSES OF THE WORK



Source: Presentation by project manager

TABLE 14: THE STRUCTURE OF THE PROJECT

WP	Deliverables	WP leader	Contributors
1. Benchmarking, experimental matrix, Test sample definition & manufacture	Report on state of the art Report on existing bearings and FEA analysis Experimental matrix – coatings Small bearing test samples test discs	BEARING	All
2. Modify existing the PVD machine for initial experimental TPT & Duplex coatings	Report on specification and design modes required Modified PVD machine Results of initial TPT experiments	COATING	COATING, UNIVERSITY C
3. Optimisation of novel TPT process on Titanium alloy using the modified PVD machine	Report on TPT optimisation	COATING	COATING, UNIVERSITY C
4. Screening testing - using both small test bearings and test discs/pins	Test discs and small bearings coated with a variety of TPT-Duplex coatings Laboratory analyses of TPT-Duplex coated test discs Report discussing which coatings are selected as best for full size bearing trials	UNIVERSITY C	All
5. Full size bearing tests in simulator	Bearing loads specification DTP Test rig design Manufacture test rig Design state of art bearing Steel/Al Bronze Manufacture state of art bearing steel/Al bronze Test state of art bearing Design new bearing (Ti /) Manufacture new bearing (Ti /) Test new bearing	BEARING	BEARING, AIRCRAFT
6. Build purpose-built laboratory/research TPT-duplex processing machine	Specification and design of new machine Completed, fully functional new machine	COATING	COATING, UNIVERSITY C
7. Optimisation TPT-Duplex coatings in purpose built TPT-duplex machine	Full size bearing coated for testing Results of full sized bearing test	COATING	All
8. Protection of knowledge, development of exploitation plan, dissemination	Exploitation plan Patent(s) Presentation, publications	COATING	All
9. Project management	Consortium/ IPR agreement 2^{nd} level plan Quarterly reports and cost claims Final Report	COATING	All

Similarly to all TSB collaborative R&Ds, the partners met on a quarterly basis formally in order to discuss their progress and make decisions on how to succeed to the next stages. The quarterly meetings were attended by an officer from the TSB who monitored the project. In the meetings, each partner gave a presentation on their progress, their achieved results, their challenges, and their expectations from the other partners, etc. The project manager also gave a presentation on the overall progress of the project, expected delays, and modified deadlines for each work package. Partners took turns in holding the meetings on their sites which helped them become familiar with each other's expertise, organisational culture, and climate[26].

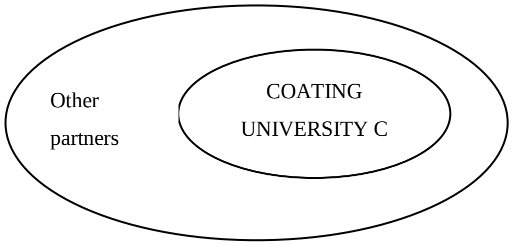
Besides the formal quarterly meetings, the partners arranged technical meetings whenever they wanted to make an important decision that required achieving a consensus among all the partners. As with the formal quarterly meetings, all collaborators – apart from the monitoring officer from TSB – attended these meetings. However, on some occasions, since the meetings could become very technical, not all partners would attend, although they were informed about the outcomes. As can be imagined, the collaboration process also involved exchanging emails and having phone calls.

Within the collaboration, the relationship between COATING and UNIVERSITY C was very intense. Throughout the project, they formed a smaller circle within the collaboration (Figure 11). This linkage was very strong because 1) both partners belonged to the same knowledge domain (surface engineering), meaning that they dealt with similar problems, challenges, etc. in their research process, and 2) they had a long-standing relationship with each other, which was not limited to this project. The two partners had collaborated on other grounds prior to the formation of FLIGHT.

Finally, partners, and especially AIRCRAFT, arranged multiple visits to other partners' sites in order to investigate their equipment and ensure that their test designs and testing procedures met the aerospace standards. As the end user of the product, AIRCRAFT were concerned about the rigour and processes of research in the collaboration.

[26] Project manager

FIGURE 11: THE INTERNAL CIRCLE IN THE FLIGHT CONSORTIUM



Source: Based on the hand drawing of the academic in UNIVERSITY C

Table 15 indicates the partners' motivations and their relevance to each dimension of AC. As it is evident, partners pursued different motives to participate in the consortia and their role varied across the three phases of AC. In the exploratory phase, UNIVERSITY C and COATING were the most active organisations, in the transformative phase, all partners were involved, and in the exploitative phase, COATING, BEARING, and AIRCRAFT were the most visible ones.

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TABLE 15: THE IMPORTANCE OF PARTNERS IN PHASES OF AC

Partners	Motivation	Importance to phases		
		Exploratory	Transformative	Exploitative
COATING	Developing the coating technology that is applicable on titanium bearings	High	High	High
UNIVERSITY C	Interest in and curiosity about the new coating technologies	High	High	Low
BEARING	To increase their capability to supply AIRCRAFT	Low	High	High
AIRCRAFT	To respond to the market need for lighter planes	Low	High	High

5.4.4 THE ACHIEVED OUTCOMES

5.4.4.1 THE CONSORTIUM OUTCOMES

The project did not meet its desired target on a full size A++ (an aircraft model) bearing in a simulator. Two bearings with the developed treatment failed early in the test. The main reason behind the test failure was technical. The coating was not done properly for the final test samples. As a result, the new treatment did not produce the same surface modifications as it did when applied to bushes (small bearings) for the lab tests. Time pressure of the project was a contributing factor. In the aircraft industry, deadlines are very tight and difficult to extend. Accordingly, the project was *wrapped up in a rush*[27]. Close to the final stages of the project, the purpose-built PVD coating machine was still not completed due to technical reasons like staff change in COATING, and the ambitious timing for the machine building. Consequently, the full-scale bearings were treated in two stages, in two different machines. This led to inaccurate coating of the bearings resulting in the premature failure of the full-scale bearings[28].

Moreover, the changes in the scope of the project incurred challenges for the consortium. Halfway through the project, the partners decided to move away from A++ to A+ (a smaller model of aircraft) as they had missed the deadline for A++. This shift raised some problems for BEARING. Although the shift did not imply significant amendments for other partners, it induced a serious challenge for BEARING as they had to make many changes in design and manufacturing of the bearings which was problematic[29].

In spite of the failure of the final tests, the project was considered as being rather successful since the newly developed processes/treatments could withstand 270 MPa in laboratory trials on bushes (small bearings), AIRCRAFT placed orders worth more than £20 million for BEARING[30], and some of the new processes were applied to medium-sized bearings and performed to AIRCRAFT's satisfaction. Compared to the state-of-the-art technology with 80 MPa pressure capabilities for the titanium alloy bearings, the bearings in this project could withstand 150 MPa, which is a considerable improvement. As a result, the Main Landing Gear (MLG) bearings and torque strut bearings on the new A+ were made of titanium alloy treated with the processes

[27] Project manager, and academic lead
[28] Project completion report
[29] R&D head of BEARING
[30] Project completion report

developed in the FLIGHT project. Moreover, the partners agreed on continuing the work in order to meet the desirable specifications after the project's completion.

5.4.4.2 OUTCOMES FOR INDIVIDUAL PARTNES

Given that FLIGHT formed around a supply chain, the achievements for different partners in the consortium were mixed. Table 16 presents the outputs and learning outcomes for individual partners within the R&D consortium. Below, we elaborate on the role of each partner within the consortium and discuss whether/how they gained benefit from their participation.

TABLE 16: THE LEARNING OUTCOMES FOR EACH PARTNER

Partner	Number of participants[31]	Outputs and Learning outcomes
COATING	8	Co-publications Patents Development of TPO (triode plasma oxidation) Building a new PVD coating machine Development of a new control software Changing the quality management practices Understanding how a large company like AIRCRAFT works
BEARING	7	Patents Development of test rigs and test facilities Development of existing processes for shapes and finishes of the bearings New bearing generation design
UNIVERSITY C	3	Co-publications PhD thesis completion Joint patents with COATING Link their research to market needs Increased understanding of titanium surface coating Understanding the commercial aspects of the research collaboration Enhanced coating tribological tests equipment
AIRCRAFT	3	Getting an understanding of different research cultures across the supply chain

COATING: COATING was a surface engineering and coating company offering ultra-hard coating, heat treatment and vacuum brazing services. It was an SME with 63 staff members. COATING was a physical vapour deposition (PVD) and nitriding coating market leader in the UK and an expert in plasma-based surface treatment processes.

[31] The numbers provided here are based on the second-level project plan. However, in practice, some of the individuals were not involved in the project and/or left their company after a while.

COATING also built industrial scale coating machines. The R&D expenditure of the company was £300,000 annually. For the FLIGHT project, they had the know-how to produce a new coating process required for achieving the high-load pressure bearings.

COATING was the lead partner of the project and the head of the COATING R&D department was the project manager. Throughout the project, COATING developed and tested a number of new coating processes, which were novel in the technological domain. For one of the processes, COATING filed a patent together with UNIVERSITY C. As part of their contribution to the FLIGHT consortium, COATING, moreover, were responsible for building a new PVD coating machine since FLIGHT required coating of *large* bearings in *high* temperatures which fell beyond the specification of the existing PVD coating machines that COATING already possessed. In order to build the machine, COATING started by experimenting with and modifying the existing PVD machine. To this end, they had to increase the chamber shield temperature resistance. In so doing, they conducted a series of experiments. First, they tried graphite shielding which failed as graphite absorbed moisture once the doors of the machine opened. Then, they utilised multi-layered metal shield with gaps between the layers which proved successful.

The process of building the new machine induced a number of additional explorations, which did not directly relate to FLIGHT. Along with designing and building the new machine, the engineering department of COATING programmed new software for controlling the power supply of the machine. This was different from the previously used analogue and digital controlling systems at COATING. It was based on network interfaces and could considerably decrease the waiting time for coating operators in the company by automating the coating process.

After the completion of the project, and together with UNIVERSITY C, COATING researchers published a number of journal articles and presented in a number of conferences. Moreover, immediately after the completion of the FLIGHT project, one of the researchers in COATING was funded by COATING to do her PhD at UNIVERSITY C.

Participation in the project, and closely collaborating with the commercial partners, increased COATING’s knowledge about the requirements of coated bearings. In particular, COATING gained an insight about the *workings,* and *driving forces and requirements of* AIRCRAFT [32]. The whole experience of collaborating with a very large company like AIRCRAFT was completely new for COATING and gave them an appreciation of how such large companies work, what their concerns are, and why they are rigid in processes[33]. Towards the end of the project, the quality management department of COATING was trained by the AIRCRAFT quality management department. As a result, some of the quality management processes were modified so that COATING could become an accredited supplier of AIRCRAFT[34].

BEARING: BEARING were a market leader in landing gear bearings, and suspension and tram coupling bearings. They were a supplier for a number of aircraft manufacturers.

Recognising the market trends in the industry with a shift from conventional metal bearings to lighter weighed materials, and having closed down another site due to metal bearings being non-profitable, BEARING had strong momentum to get engaged in the FLIGHT project[35][36]. They considered the collaboration as an *intelligent shift*[37] because the technology was so advanced and not easily replicable by international competitors with cheap prices.

BEARING's involvement in the project embraced three main aspects. First, in collaboration with AIRCRAFT, they developed the design specifications of the bearings. In contrast to their previous collaborations with AIRCRAFT whereby they would receive the design specifications from them in a document, in this project, they developed the design specifications collaboratively with AIRCRAFT.

[32] Project completion report
[33] R&D head – COATING
[34] Researcher in COATING, internal presentation – Airbus
[35] Project manager
[36] Technical manager of BEARING
[37] Technical manager of BEARING

Second, BEARING worked on Development Test Plans (DTP) and manufacturing test rigs for the bearings. This was done through closely collaborating with AIRCRAFT in order to ensure that the testings met their standards[38].

Third, BEARING conducted Finite Element Analysis (FEA) which is to calculate and analyse the load distribution pressure. This was also done by having AIRCRAFT's advice throughout the process. Although FEA calculations became very complex due to the shape of the grooves and had to be abandoned after a while, the calculations largely informed the whole research programme[39].

Finally, although the project could not fully meet its objective, BEARING were able to win three of the six bids they made for A+ bearing [40]. This meant that they received orders from AIRCRAFT worth in excess of £20 million.

UNIVERSITY C: The department of material science and engineering at UNIVERSITY C had academics with expertise in coating technologies who were well known in surface engineering research globally. The academic partners who participated in the project had been in this domain of expertise for around 20 years[41]. They had previously worked with COATING and had known them for a long time. In the FLIGHT project, they offered a range of equipment and analysis competencies not available to industrial partners. Three academics were involved in the project: a professor, a senior lecturer, and a PhD student.

The academics' primary role was to provide scientific understanding of the project, conducting tests and advising on the choice of coating techniques. In other words, their role was 1) to provide the theoretical and conceptual understanding of the project, 2) to interpret the test results (conducted by themselves or other partners) which would result in 3) modifying the conceptual part.

They employed a PhD student on the project who developed his thesis around it. However, they could publish out of the project only once the project was completed,

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[38] Second-level project plan
[39] Minutes of the 7th quarterly meeting
[40] FLIGHT final project report
[41] Senior lecturer in surface technology

although it was *frustrating* (PhD researcher, UNIVERSITY C) that they could not publish anything during the project work. Moreover, they filed two patents jointly with COATING[42]. They also modified the coating tribological test equipment designs, with enhanced instrumentation and operating procedures in their labs[43]. After the completion of the project, identifying further knowledge gaps, the PhD student continued researching the areas that did not fall into the project timeline[44].

AIRCRAFT: AIRCRAFT was a leading aircraft manufacturer whose main drive for getting involved in the FLIGHT collaboration was their interest in reducing the weight of the aircraft. Despite technical failing of the tested bearings, they utilised the technology for A+ wing landing gear attachment bearings. This decreased 50kg per set of bearings and contributed to the performance of the aircraft and the fuel burn over the aircraft lifecycle. Concurrent to conducting this study, AIRCRAFT were conducting the final set of tests on the bearings treated by this technology in order to assess their compliance with the safety standards of AIRCRAFT. Once these tests are passed, AIRCRAFT will confidently apply the technology for the bearings[45].

As the end user, AIRCRAFT pursued a specific goal for this project. Being a large company and given the high safety standards that AIRCRAFT followed, they were very restricted in the way they expected the research process to run. Consequently, they collaborated very closely with COATING, BEARING, and UNIVERSITY C to ensure that the processes and research procedures were rigorous enough for AIRCRAFT purposes. As already mentioned, they closely collaborated with BEARING for test design, and designing of the bearings[46]. They insisted on making procedures *scientific* as opposed to *empirical* and developing a *full testing programme to prove the capabilities*[47].

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[42] Project completion report
[43] Project completion report of UNIVERSITY C
[44] The PhD graduate of UNIVERSITY C
[45] Project completion report
[46] Minutes of the 7^{th} quarterly meeting
[47] Internal AIRCRAFT presentation

5.4.5 CHALLENGES

FLIGHT experienced some challenges throughout its development. First, it revolved around different disciplines which entailed different languages and perceptions about the project. The three main disciplines in the collaboration included surface engineering, aerospace manufacturing, and bearing manufacturing. Although the three disciplines had some basics in common and were not completely different, expectedly, in such a narrow research domain, their knowledge became very specialised which implied difficulties in communication between the partners. For instance, not knowing how much work is involved for an experiment, AIRCRAFT (aerospace specialists) disagreed with the pace at which the testings were conducted by surface engineers. On the other hand, AIRCRAFT used many abbreviations in their reports which were exclusively used in the aerospace industry, making it difficult for other partners to understand.

Second, different organisational contexts affected the collaboration between the parties. The consortium consisted of a University (UNIVERSITY C), an SME (COATING), a subsidiary of an international company (BEARING), and a large aircraft manufacturing company (AIRCRAFT). Such variance in organisational contexts affected the collaboration among parties. Being a large company with high levels of safety standards, AIRCRAFT were very organised and inflexible with respect to their deadlines, procedures, etc. In aircraft manufacturing, planning is based on programmes (aircraft projects). This means that any planning inevitably serves a final product manufactured and assembled by following strict deadlines. Consequently, although the project was a research project, from the very beginning AIRCRAFT wanted the collaboration to be focused on a specific application for A++.

Other partners were less familiar with such a strict approach, and although they made efforts to keep the end user satisfied, they could not easily meet their requirements. The fact that AIRCRAFT required the product to be aimed at A++ especially gave rise to conflicts as BEARING wanted to develop a broader approach for their bearing manufacturing so that it could fit other applications too. When the research project did not meet the deadlines for A++, as AIRCRAFT expected, they had to shift the direction of the project to A+, which implied switching into a different research path especially for bearing manufacturers as they had to redesign and modify their test design and test rigs. However, being the end user, AIRCRAFT had the final say on what direction the project would take.

Finally, the development of the new PVD coating machine necessitated intensive interactions between the R&D department and the engineering department. However, the engineering department was not officially involved in the consortium which meant that the R&D division of COATING was the only interface between the machine building and the consortium. This meant that there were delays in communication between the machine building team and the R&D consortium.

5.5 CONCLUSION

In this chapter, we provided structured information about the three cases studied in the thesis. The aim was to provide a general understanding of the cases before going into deeper analysis over the next chapter. First, we discussed the HOUSE consortium which aimed at researching the performance and properties of a house constructed with alternative materials. Then, we presented ASTHMA, a pan-European research consortium which was aimed at developing and improving the understanding of severe asthma, and two of its WPs. Finally, we provided information about FLIGHT, a research consortium focused on developing light-weight bearings for aircraft. In all cases, we explored the background of the formation of the consortia, the funding mechanisms, the structure of the collaboration and the division of labour between partners, the mechanisms that were employed for collaboration, the learning outcomes and outputs of the project, and the challenges in the collaboration. In the next chapters, we further discuss our findings by deploying the theoretical framework of the study.

Chapter 6. ANALYSIS AND DISCUSSION

6.1 INTRODUCTION

In the previous chapter, the background and descriptive stories of the three cases were narrated. As our methodology suggest, after presenting a descriptive account of the cases, we seek to answer research questions through applying the theoretical framework developed in chapter 3. The aim is to unravel the underlying mechanisms that contribute to the formation of R&D consortia and the development of AC (in accordance with the research objectives). In what follows, first, we explore the observed boundaries within the three R&D consortia. The understanding of the boundaries within the R&D consortia will then be the basis for the analysis of consortium formation and AC dimensions. Afterwards, we discuss the formation preconditions and how they contribute to the development of AC. In the last part of the analysis, the dimensions of AC in R&D consortia will be discussed in three separate sections (exploratory, transformative, and exploitative learning). In section 6.5, we collate the elements of the study discussed separately throughout the chapter into one single model. In doing so, we will revisit the theoretical framework and will refine and improve it based on the findings. The chapter concludes with offering a summary of the findings.

6.2 BOUNDARIES

6.2.1 INTRODUCTION

In 3.4.2, we discussed that an understanding of boundaries is essential for unpacking AC and exploring the dynamics of consortia formation. In this chapter, we will empirically identify the different types of boundaries within the three R&D consortia. This piece of analysis is essential before attending to the two main research objectives, i.e. analysing the dynamics of the formation of consortia and the constituents of AC as the primary research objectives. In what follows, we explore disciplinary, organisational, and intra-organisational boundaries in the three examined R&D consortia.

Given the fact that AC relates to the ability to intake knowledge from the external to the internal, it may involve boundaries that can impede or enrich knowledge transfer. On the negative side, boundaries can hamper the knowledge exchange through the differences they impose on actors whether it relates to the differences between the disciplines, or to the interests followed by organisations, or to the intra-organisational boundaries separating those who are involved and engaged within the consortium from the rest of the organisation. On the positive side, boundaries bring opportunities for learning. While, within boundaries, the opportunities for learning can be limited to incremental improvements in the existing processes, and procedures and practices, across them, there is higher potential for radical innovations.

In what follows, we provide evidence on the existence of boundaries and the way they were manifested in the examined consortia. This will later inform the analysis of AC.

6.2.2 DISCIPLINARY BOUNDARIES

The first type of boundary deals with the differences between the disciplines that are present within R&D consortia. Since in the examined consortia the individual participants were from different areas of expertise, the disciplinary boundaries were salient in interactions, especially at the initial phases of the collaboration when shared technical languages and terminology were not adequately developed. In this study, disciplinary boundaries relate to the area of expertise that each partner belongs to in their work context, and therefore, they can be different from the background of individual participants. Although background similarities may facilitate communication between partners, when it comes to very narrow areas of specialisation (which is the case in knowledge-intensive R&D collaborations), their differences become salient. Below, we discuss the disciplinary boundaries within the three studied R&D consortia.

The HOUSE consortium involved partners from different disciplines. There were structural engineers, architects, agricultural engineers, and mechanical engineers involved. Such disciplinary differences triggered challenges during collaboration. An agricultural engineer explains his experience of such a barrier:

> *I come from agriculture where the whole world of architecture and construction is new to me. Certainly at first, there were words and terminology that I did not understand....*

A structural engineer who was involved in the project also agreed with the existence of such boundaries between disciplines:

> *....for example, between me and John and Jack [pseudo names], because obviously we were all from a structural engineering background, I think we could maybe talk at a slightly more technical level. ... So there was a level of technical language that sometimes didn't get across.*

The same level of difficulty was observed in knowledge transfer between the mechanical engineers who were in charge of developing the thermal model of HOUSE and the rest of the consortium. Since their domain was very specialised other partners had difficulty in comprehending their work on occasions (MPhil researcher).

ASTHMA consisted of three identifiable disciplinary groups: 1) clinicians, 2) scientists and 3) computer scientists and systems biologists. However, since our case study focused on two of the WPs, which did not involve clinicians, we can make no claims about the absence or presence of any boundaries around them. Accordingly, the more evident disciplinary boundary lay in the differences between (biological) scientists, on the one hand, and systems biologists and computer scientists on the other.

In one of the sessions of the ASTHMA annual meeting, where all the consortium participants attended, WPB – which was mainly run by systems biologists and computer scientists – presented their progress along with their approach for data analysis. Being focused on data analysis techniques, these presentations were different from those of the other WPs. In the evening, over dinner, people started to express doubts about those presentations. The discussion went on to state that they did not understand what the WPB participants said, suggesting that they could have simplified their language for the presentations. Also, as one of the interviewees explained:

> *In terms of technical languages, I think WPB is the one with which I am least familiar. So I think statisticians, data people, IT people have their*

> *own language which unless you are analysing data, or handling data on a regular basis, that could be quite far really. (WP4 leader)*

However, the differences were not limited to the languages, but they also related to the meanings. The meaning of data, experiment, and research was very different for scientists and systems biologists and knowledge management experts. The main focus for systems biology and knowledge management is on analysing and working with large data sets which is a relatively new area in biologic research (Calvert 2011); it is not aligned with conventional medical research, which uses limited data samples, and it is *an absolutely different mindset* (WP3 academic leader). On the other hand, generating a very limited amount of data by scientists required weeks of experimenting which is very different from what systems biologists and statisticians expected. Therefore, the meanings as what counts as relevant 'data' were very different.

In the FLIGHT project, the four partners belonged to the three disciplinary areas of (i) coating technologies and surface engineering, (ii) bearing manufacturing, and (iii) aerospace manufacturing. The project manager explained this as a barrier:

> *…the main barrier is that we have our area of expertise and along with that goes a certain amount of language which then people who are not in the area wouldn't really understand. Because we are all at the leading edge of our expertise, to go back to basics and explain it to other partners who have nothing to do with your area of expertise will be there forever. (The project manager)*

Being specialists in surface engineering, COATING and UNIVERSITY C shared a similar domain of expertise and could understand each other very well and, in some circumstances, they would not involve other partners if their discussions were very technical:

> *…if it was something very technical, specifically about the process, then it meant that we would have more and closer discussion with UNIVERSITY C rather than involving BEARING and AIRCRAFT, although we would let them know… (Research scientist A – COATING)*

Moreover, the disciplinary differences also would translate into differences in meanings of research. First, there was a difference in the approach to testing. In academic research and surface engineering literature, the reliability of test samples (i.e. how many times a certain test piece can endure a certain amount of load over a certain period of time) was not of interest. However, in aerospace, reliability was a critical aspect. Merely testing whether a test piece endures a certain amount of load over a certain period of time does not guarantee that it can meet the high safety requirements needed in aerospace. Second, there were differences between surface engineers and aerospace experts with respect to their ways of doing things and how research was being conducted. Therefore, the meanings of research varied because of the differences in requirements, and methods.

> *…in surface treatments, there are some standard tests for adhesion of coating and specific loads and specific magnification that you use. Obviously, because AIRCRAFT are related to aerospace, they are much more restricted in things. (Research scientist B – COATING)*

6.2.3 ORGANISATIONAL BOUNDARIES

Organisational boundaries related to the differences between organisational contexts in the R&D consortia. The findings suggest that organisational differences can affect the collaboration in two major ways. First, different organisations, because of their orientations, aims, strategies, and goals may approach collaboration objectives differently. Second, specific organisational contexts may accompany particular practices and routines within organisations, which can impede collaborations and reduce efficiency.

In the HOUSE collaboration, potentials for conflict, misunderstanding and differences were observed across the boundaries between academics and industrial partners. These two groups of partners saw the project goals and objectives slightly differently. For academic partners, the main interests included research, development of the understanding of the product, and filling their knowledge gaps in alternative materials. For the commercial partners, on the other hand, the project was about gaining market confidence through research, and reassuring the customers about the product.

A post-doc researcher who later had a chance to work within ARCHITECT (one of the commercial partners) explained how the fact of belonging to the academic side of the collaboration affected the perceived goals of the project:

> *There were times that I always concentrated on the research parts and so that could sometimes influence a little bit how I saw the goals of the project and it would have been presumably the other way around for commercial organisations.*

This point was further confirmed by the project manager – who was the research director of ARCHITECT:

> *…there was obviously difference of focus between the commercial partners and the academic partners… the academic culture of being very rigorous, very wordy, and very accurate, whereas our culture is slightly more risk taking, very much more market focused, much more commercially focused; whereas academic wording is towards finding the right answer, whatever that answer may be, our approach is about making sure that we use that answer to enhance what we are trying to do. (Research director of ARCHITECT)*

Likewise, in ASTHMA, the most visible organisational boundary was that between academic and industrial partners. The differences revolved around the following factors. First, while industrial partners were very rigorous and restricted in their methodologies, conducting studies, and meeting deadlines, academic partners were less so. In the pharma industry, it is very well appreciated that pharmaceutical partners need to meet the standards and restrictions set by regulatory bodies. As a result, in many studies, companies are accustomed to following very detailed and rigorous procedures. However, in academia, due to being more interested in novel ideas and publications, the deadlines and work procedures are not as rigid. The academics would follow *shortcuts* (Industrial lead of WPA).

Second, industrial partners were more receptive to change in their models and methodologies compared with the academics. In biological studies, models constitute the basis for interpreting and analysing data obtained from in-vivo and in-vitro experiments. In industry, models and methodologies change frequently. New models replace the older ones and the older methodologies become obsolete when better ones are introduced. This is, however, different in academia. Academics have less flexibility with respect to their models. In academia, research programmes and long-term research strategies revolve around the models developed in a department or by a researcher. Therefore, it is of considerable importance to researchers to stick to those models as they will be publishing based on them.

> *One of the things that became fairly obvious was that it was not going to be possible to get every lab to do exactly the same thing. It just wasn't going to happen! It's a cultural thing. Each of the academic labs has built up expertise and knowledge and their publications are based around their laboratory, the way they do particular lung functions. …People are very unwilling to change, and you see this all over academia. People won't change the methodology. (WPA industrial scientist)*

Apart from the industrial-academic divide in the consortium, there was an expectation that the companies would have reservations about exchanging knowledge with each other, as they were competitors. Prior to the formation of this consortium, the instances of collaboration between pharmaceutical companies were rare. Historically, pharmaceuticals are very secretive about what they do so to protect their competitive advantage over their rivals. When ASTHMA started, the participating scientists were secretive on exchanging knowledge:

> *Prior to the symposium, the companies were secretive and COMPANY E was the most secretive one. (The former industrial lead of WPA)*

Surprisingly, the competition element was not limited to the companies. Academics also saw themselves as rivals. Within ASTHMA, academics with close research interests were collaborating, and given that this project could provide them with access to huge amounts of data, there was potential for publishing articles out of it.

> *We are competitors between universities in terms of scientific novelties, originality and publications. So having the most original and novel research is an element of competition between centres. (Project coordinator)*

Organisational boundaries were evident in the FLIGHT consortium too. A set of differences that caused tensions throughout the project resulted from the differences in the interests that various partners followed in FLIGHT. UNIVERSITY C were keen on publishing which was not allowed until the end of the project due to the restrictions imposed by the collaboration agreement. AIRCRAFT were interested in the end product, its compliance with safety standards, and they wanted it immediately:

> *…they just wanted a solution to the problem: Can we replace steel with titanium? [Laughing](Anonymity retained)*

Because of safety reasons, AIRCRAFT were very accurate in their testing processes and would not accept tests conducted by other partners unless they monitored and checked their testing procedures. Other partners, however, were not as concerned. From the AIRCRAFT point of view, the consortium partners' research mentalities and their tendency to stick to their conventional way of doing things[48] was a barrier in the accomplishment of the project goals. Adopting a more scientific method was more critical in the FLIGHT consortium because partners were developing a new technology (Head of the structure stress department at AIRCRAFT). Historically, bearings were developed empirically, i.e. their design was not based on detailed scientific calculations. However, AIRCRAFT did not accept empirical design of the bearings for this new technology (which was based on titanium nitride coating). New technology necessitated more rigour in order to avoid risks:

> *With the old technology, we did not need this [finite element analysis[49]]. Based on the historical data we say we are flying with this technology for fifty years so the risk is minimum. With new technology we spend a lot of time making sure all the testing has been validated before it is implemented in the final aircraft production line. (AIRCRAFT, head of structure stress department)*

This divergence in viewpoints resulted in tensions throughout the project as BEARING found the AIRCRAFT pressure excessive throughout the collaboration.

In general, the organisational boundaries presented in this section show that the differences in the contexts of organisations can result in tensions and difficulties in the transfer of knowledge. They also suggest that in the context of R&D consortia, these differences can lead into discrepancies in meanings. In particular, we found that the meaning of 'research' could be different between the partners. Although all partners in the R&D consortia believed that they were participating in 'research', their interpretation of what counts as research was different. In HOUSE, for academics, research meant thoroughly analysing the product while for commercial partners it

[48] Internal presentation – AIRCRAFT

[49] Finite Element Analysis (FEA) is the calculation method used for measuring the surface of bearings and its hemispheric shape

meant ensuring the market. In ASTHMA, research for academics meant novelty while for industrial partners it meant rigour and reliability. In FLIGHT, for AIRCRAFT research meant a tightly defined process with clear inputs and outputs while for others it was a more flexible process with considerable uncertainties.

6.2.4 INTRA-ORGANISATIONAL BOUNDARIES

Embedding the knowledge that is gained within R&D consortia into organisations and applying it is an essential aspect of AC. In this section, we discuss the intra-organisational boundaries within the HOUSE and FLIGHT consortia. However, as ASTHMA was at its midlife point when this research was being conducted, there were fewer attempts to transfer the knowledge into the wider context of individual partners. Therefore, the evidence for intra-organisational boundaries in ASTHMA was minimal.

In the HOUSE project, among the core partners of the consortium, ARCHITECT and ENGINEER indicated that the knowledge does not reach other organisational members effortlessly. In some cases, it was important for collaborators to be able to spread the knowledge within their companies.

The research director of ARCHITECT stated:

> *I suppose people who were not involved in the research... are probably not that familiar with the results. So… I wouldn't say it has become an integral part of everyone's knowledge stream, but those who were involved in jobs within this area would have a much better understanding following this research. Some of them are actually focused on PANEL in their daily jobs but they were not part of the project. Those who are working with PANEL and with PANEL products within ARCHITECT will have a pretty good understanding of performance credentials based on this research, definitely.*

A similar point was made by the director of ENGINEER:

> *I think it is fair to say that there are a few individuals in the practice [ENGINEER] that are more involved in PANEL than others.*

In the same manner, the FLIGHT consortium involved intra-organisational boundaries. First, as the exploitation would not happen until and unless the developed technology was proved as being technically and commercially viable, the knowledge remained very much limited to the project team:

> *Internally it is not easy to download that [knowledge] to production and to sale... but there was not any need to do this until the end of the project and after we made sure that the product is working. Then we could inform marketing people. (The R&D head of BEARING)*

COATING entailed a similar type of boundary. The knowledge about the technology was limited to the project team in the first instance and to the R&D department in the second. It was not until towards the end of the project that the other parts of the company became informed about the project as they intended to put the technology into production. Moreover, as part of their project commitment, COATING was supposed to develop a PVD coating machine which necessitated involvement of the engineering department of COATING. However, as the engineering department was not officially part of the project, their interactions with the consortium were mediated by the R&D department of COATING. In fact, FLIGHT was not the main focus of their daily activities. Therefore, there was an intra-organisational boundary between the R&D and engineering departments in COATING which had to be overcome.

In AIRCRAFT, for constructing any new aircraft, a number of meetings were held routinely. This helped with updating others with the progress achieved in FLIGHT. Therefore, the project boundaries within AIRCRAFT were less of an issue.

> *It is an ongoing internal process that we have. It is like our own R&D. We have basically gate reviews like tier 01, tier 02, tier 05, tier 06, tier 07. Tier 07 is where we deploy it into the product. So, to see if the maturity is there, those are the criteria we go through. (AIRCRAFT, head of structure stress department)*

The three cases suggest that disciplinary, organisational, and intra-organisational boundaries play a role in interactions between partners. The disciplinary and organisational boundaries mainly affected language and meaning differences, and intra-organisational boundaries affected the communications that were needed both to address the requirements of the R&D consortia and to apply and embed the knowledge within individual organisations.

6.3 FORMATION PRECONDITIONS

6.3.1 INTRODUCTION

This section responds to the research question of the thesis addressing the preconditions of the formation of R&D consortia (which relate to research objective 2[50]). Conducting a cross-case analysis, in this chapter, we will attempt to identify the formation preconditions of R&D consortia. This section considers formation in a broad sense, which is not merely captured in the signing of a contractual agreement, but is a process starting from the initial moves for forming a consortium, even prior to the formal collaboration, through to the initial stages when the consortium becomes operational.

In what follows, we discuss how activation triggers, complementarities, and the pre-existing SC and CoPs contribute to the formation of R&D consortia. Then, we explore the main factors that contribute to the development of shared space once R&D consortia start legally. Finally, the three cases will be compared with respect to their key structural features, boundaries, and the pre-existing SC and CoPs.

6.3.2 ACTIVATION TRIGGERS

Activation triggers are the internal or external factors that make organisations respond accordingly. Our findings suggest that environmental and regulatory forces and external funding constitute activation triggers.

In our quest, one of the main drives for the formation of the three consortia was environmental shifts, which included both competition and regulatory forces. The FLIGHT collaboration was pushed by the competitive industry requirements for lighter aircraft. With the high level of competition among the major players in the aerospace industry, there was significant pressure on manufacturers to reduce cost. Lighter aircraft meant less fuel consumption, which entailed lower costs for AIRCRAFT in the long term. Being keen on achieving this aim, AIRCRAFT were encouraging their

[50] We start the analysis with research objective 2 because it is in line with the chronological order of events.

suppliers to identify a lighter solution for their compartments[51]. One option was using titanium. BEARING, as an AIRCRAFT supplier, were eager to move into titanium bearings in order to beat the market and be able to outperform other suppliers. It was pressure from the customer (i.e. AIRCRAFT) (technical manager of BEARING). COATING were interested in expanding their coating capabilities in the aerospace industry, and they saw the opportunity to get involved in this collaboration as beneficial for gaining competitive advantage over their domestic and international rivals. As the R&D head of COATING stated:

> *…we are very pleased to be coating these bearings with advanced processes and coatings, which you wouldn't find in China for example...*

In addition to the market pressure for moving into lighter bearings, there was a regulatory thrust for the development of Titanium Nitride (TiN) materials to be used for coating purposes. In addition to fuel consumption reduction, switching into TiN coating conveyed less environmental hazards. Conventional coating techniques involve cadmium and chrome, which are identified as SVHC (substance of very high concern) under European Chemical Agency (ECHA) standards. The use of alternative coating techniques (like TiN) could potentially resolve this issue.

The ASTHMA collaboration formed as part of a broader EMC scheme, which was based on the assumption that close collaboration between academic and industrial partners will help to overcome the bottlenecks in the drug development processes. The changing landscape of the industry and the diminishing returns on pharmaceutical R&D investments in Europe led to questioning the effectiveness of internal R&D efforts. It had become clear that the pharmaceutical industry would not survive if companies maintained their closed, secretive attitudes to R&D and developing everything in-house. In the course of explaining the importance of collaborations for innovation in today's pharmaceutical industry, the industrial lead of WPA explained:

[51] AIRCRAFT internal presentation

> *...industries had to learn from the past, from being secretive, [that] doing everything in-house limits the science you do and probably limits innovation. So the idea was collaboration drives innovation, and if collaboration means with other companies, so be it.*

It is worth mentioning that we do not intend to argue that ASTHMA (or EMC in general) was the first instance of collaboration within the pharmaceutical industry. In fact, in the pharmaceutical and biotechnological industries, collaborating with universities, research institutes, and biotech SMEs is routine. However, the difference for ASTHMA was that 1) unlike conventional forms of collaboration within the pharmaceutical industry, which usually consist of public-private or company-SME collaborations, in ASTHMA, the large pharma companies collaborated with each other[52], and 2) the form of research collaboration was participatory. By the latter point we mean that in conventional collaborations, industry faces a problem and gives a grant to university to work on it and return with a solution. Therefore, the collaboration is minimal, interfaces are limited to business developers and lawyers who deal with IP issues, and the outcome is a report or a series of findings that university or bio-tech SMEs provide to the industrial partner. However, in ASTHMA the collaboration entailed mutual engagement. Partners worked together in order to address a problem or a research issue.

Furthermore, there was a shift in the attitude of the industry towards what counts as pre-competitive and what counts as competitive. The pre-competitive aspects of research do not directly relate to the drug development targets upon which companies build their competitive advantage. Being focused on researching and understanding the disease mechanisms, ASTHMA was considered a pre-competitive research project. However, the definition of pre-competitive research has been changing over the last couple of years to include aspects which were considered competitive. In fact, the industry is redefining the lines between the two (Barnes et al. 2009). Things that once were considered as belonging to the competitive phase are no longer so considered. This was the case in the ASTHMA consortium too:

[52] Project coordinators

> *...previously, just identifying what you should target with your drug was considered as competitive. A lot of the bigger companies are moving away from that and saying what is competitive is our compound, how it works. What is pre-competitive is making the targets. That is a pre-competitive field. So, in other words, they should all work together for finding the targets and compete on how the targets are blocked. So that is the shift in the landscape, which is making collaboration such as this [ASTHMA] much more possible because we not only have the academic-industry collaboration, but, equally as important as this, companies work together in a bigger and broader way than they probably ever did before and that is also very interesting. (project manager)*

At various points in the interviews, informants agreed with this statement, stating that this shift was, especially for industrial partners, tangible in the consortium. Becoming more collaborative, sharing knowledge and cooperating with other industrial companies as well as abandoning the previous assumptions about the advantages of remaining closed and secretive was a well-established need for the industry.

The HOUSE consortium was a rather different one. At a higher level, the whole construction industry was moving towards more environmentally friendly solutions. Constructing buildings with smaller carbon footprints was a new direction that had interested many organisations. The inventors of PANEL (ARCHITECT and ENGINEER) aimed to commercialise it. However, in order to enter the market, the product had to pass a number of standards and regulatory screenings. This, in turn, meant to research, test and improve the product:

> *…the collaborative research was about how we could demonstrate that this system was accurate to build… What we wanted to do was to commercialise the system. (Director of ARCHITECT)*

At a lower level, however, the collaboration was a development of a previous research project (PANEL). The whole research programme focused on developing an alternative for conventional construction methods. During the PANEL project, a number of questions had been raised which required further research by partners. Therefore, the HOUSE project was a natural continuation of the previous phases.

In summary, the competition pressure within the aerospace industry intensified the efforts for developing lighter solutions for aircraft (Wilson et al. 2009), the changing landscape for the pharmaceutical industry made companies tap into collaborations in areas that, in the past, had been less plausible to collaborate in (Barnes et al. 2009), and the increasing environmental and economic pressures (including rising energy prices) opened an avenue for potential demands for straw bale housing which is one of the promising options for future housing (Seyfang 2010). The three cases, thus, suggest that environmental dynamics as well as regulatory forces are important in the formation of the collaborations.

Finally, the three cases show that the presence of external funding affected the formation of the R&D consortia. As these projects involved high levels of risk and uncertainty, it would have been highly unlikely for the partners to form a research collaboration without external funding. External funding in the three cases lowered the transaction costs between the partners so that they could collaborate.

6.3.3 COMPLEMENTARITIES AND SUPPLEMENTARITIES

Complementarities and supplementarities between partners' expertise were the other factor in determining the formation of consortia. The three consortia demonstrated a degree of complementarity/supplementarity.

The HOUSE collaboration consisted of academic and commercial partners. While academic partners were more focused on the research aspects of the consortium, the commercial partners explored the market opportunities and market needs of the product. Moreover, the three core partners ARCHITECT, ENGINEER, and UNIVERSITY A represented a triangle of expertise in design, structural engineering, and alternative materials. They were complementary to each other and as the Architect director specified:

> *ARCHITECT is an architectural practice and so we bring design capability and building experience together to inform how they might be deployed in buildings, and ENGINEER obviously bring all of the structural engineering capability because we want the panel to be not just an internal panel but a structural panel. And then the reason for doing research with UNIVERSITYA is Prof. Mark Dash [pseudo name] was expert in the use of what we call alternative material, non-conventional material… So we had a very good triangle of complementary skills.*

In ASTHMA, one of the overarching findings was that collaboration was sought in the areas that involved complementarities. In the first place, the applicant partners approached the centres that could bring *something new to the table (Project coordinator)*. Then, once the consortium was formed, in the course of breaking down the work and assigning the tasks to each partner, the WP leaders tried to mobilise the expertise from different partners with varying focus. A core member of the ASTHMA consortium corroborated this idea of how important it was to select partners that could add value to the consortium:

> *We established the principles of the consortia, which I think is key, and we decided that one of those principles was to bring in people who would have genuine interest in participating, would have something concrete to bring. So they wouldn't just be calling upon centres for the sake of internationalism and politics and so on. We selected centres where there would be really added values for having those centres participating (WP7 academic lead).*

As such, ASTHMA was not merely about task accomplishments, but it entailed an element of complementarity and synergy. Later, such an approach became beneficial for partners when they started the project as new opportunities for learning were created because of the differences in the approaches, methods, and practices (WPB, COMPANY F representative).

In contrast to the other two collaborations, which had a fixed set of partners from the outset, within ASTHMA, the identification of complementarities and forming new linkages was an ongoing process throughout the collaboration. This was because, with the progress in the collaboration, new areas of research and new questions were identified which necessitated approaching new partners. Therefore, although ASTHMA retained their overall composition of partners, they approached new departments or individuals within existing collaborators to fill the knowledge gaps. For example, a need for having a human model in WPA after the first phase of analysis resulted in approaching the human model group within UNIVERSITY D (a pre-existing partner).

Although complementarities (bringing dissimilar resources) were the major drive among the applicant partners at the industry-university interface, supplementarities (bringing similar resources) were the main drive among the pharma companies (EFPIA), where achieving economies of scale was the main thrust. As mentioned in 5.3, the pharma companies were concerned about the increasing cost and risk of developing new MNEs. Therefore, the collaborative approach was primarily about avoiding redundancies within the industry. For instance, development of a knowledge management system in one company (COMPANY C) meant that others did not need to go through that route again and could utilise that system to advance their research.

In FLIGHT, apart from the university, the partner organisations belonged to a pre-existing supply chain. Accordingly, the expertise within the collaboration was vertically scattered along the supply chain. While UNIVERSITY C's contribution was to provide scientific understanding of the coating process and surface engineering, COATING had the expertise in coating equipment and coating machines in addition to their knowledge about the different surface treatment processes. BEARING were experts in the designing and manufacturing of bearings, and AIRCRAFT were aerospace specialists. These types of expertise were needed in order to achieve the collaboration targets. The technical manager of BEARING explained the importance of the complementarities among partners in the following quote:

> *The main drive behind it [the consortium] is that AIRCRAFT is the end-user and from the customer perspective, they were the driver behind it because they set the requirements. They scoped out what their need was. We, as a bearing manufacturer, brought the technology to the table in the design. COATING as a specialist in coating could bring their expertise on different coating techniques, and UNIVERSITY C provided the technical metallurgical experience and knowledge from a material perspective. So, for a four-tier partnership, you had the customer, the manufacturer, the processor, and an independent third party to provide the technical oversight.*

Although all interviewees agreed that it was important to have all partners on board, they did not equally agree that AIRCRAFT contributed to the process of research. At times, the technical contributions of AIRCRAFT seemed to be questioned:

> *…their contribution was a little bit different… They were almost the client, because their contribution was more: "This is what the component will need to sustain, this is where the component needs to fit, this is the geometrical envelope". I can't recollect a clear instance where AIRCRAFT said, "OK, from the technical side we will handle this…"* (Anonymised)

However, by combining the different viewpoints of the partners, it appears that AIRCRAFT's role cannot be underestimated. The fact that they were not very much involved in the research process does not mean that they were redundant in the collaboration. The suppliers found their knowledge of the requirements of the bearings, the features and the volume of their future demand, etc. crucial to the whole collaboration. Had AIRCRAFT not contributed to the project, the collaboration would not have achieved its objectives. As the R&D head of COATING mentioned:

> *...just no way could we have possibly done it without the others. We all needed each other to get to the goal…*

This finding suggests that complementarities are not limited to the technological knowledge that parties provide, but they can equally deal with market knowledge (Kogut and Zander 1992).

In general, the three cases suggest that resource complementarities and supplementarities contribute to the formation of a collaboration. In HOUSE, both technical knowledge and market knowledge complementarities between partners contributed to the collaboration. In ASTHMA, complementarity drove the collaboration between academic and industrial partners and between applicant partners. However, the main resource alignment force between the EFPIA companies was supplementarity in order to achieve economies of scale. Finally, in FLIGHT, technical and market knowledge complementarities were observed within the consortium.

Therefore, the type of resource alignment (i.e. complementary or supplementary) between the partners is related to the motivation behind the collaboration. When a consortium forms in order to achieve innovations and to beat the competition (HOUSE and FLIGHT), seeking resource complementarity is dominant. In these conditions, if the product is close to market stage, market knowledge complementarities can be relevant. On the other hand, when the primary goal of R&D consortia is to achieve economies of scale and risk sharing (ASTHMA), seeking supplementarities will be the dominant logic (Table 17).

Our findings, moreover, suggest that disciplinary boundaries induce technical knowledge complementarities, and organisational boundaries induce both technical and market knowledge complementarities. On the other hand, findings suggest that when there are no conspicuous differences across organisational and disciplinary boundaries (e.g. the EFPIA companies offered similar types of expertise in the consortium), supplementarities are the main drive.

TABLE 17: RESOURCE ALIGNMENT IN THE CASES

Consortium	Resource alignment	Knowledge type
HOUSE	Complementary	Technical knowledge Market knowledge
ASTHMA	Complementary/Supplementary	Technical knowledge
FLIGHT	Complementary	Technical knowledge Market knowledge

6.3.4 THE IMPORTANCE OF INNOVATION CHAMPIONS

The importance of innovation champions is discussed in a large body of literature (Howell and Higgins 1990, Shane et al. 1995, Chesbrough 2003). In all three researched consortia, there were individuals who played a significant role in the formation of the consortia.

In the HOUSE collaboration, the directors of ARCHITECT and ENGINEER were the key individuals in fostering the formation of the consortium. They were the visionaries of the research path around their pre-existing product (PANEL) and were reputable in the sustainable construction industry for their research activities. Their role was substantial in initiating the research collaboration.

In ASTHMA, individuals noticeably contributed to the formation of the consortium. On the industry side, the industrial coordinator had a substantial role in defining the area of research and mobilising other industry members to define the research interests in the industry, bringing together individual companies with an interest in asthma in order to issue the call for proposals. He said:

> *I was involved in getting an initial group of pharma companies together who had an interest in respiratory medicine to identify potential respiratory calls...*

A COMPANY C representative mentioned:

> *John Smith [pseudo name] has a very strong network in the industry which has been an important factor both in the formation of the consortium and in retaining its achievements.*

On the other hand, a set of key academics were important in initiating the consortium. In addition to developing the first ideas about the consortium, the core applicant partners contributed to the formation of the consortium by finding and involving others through their own network. They were highly reputable in the respiratory domain, and their publications were read by academics and scientists within companies. Therefore, their presence as the core group who initiated the idea encouraged other research centres to join the consortium (Academic professor – RESEARCH B).

In FLIGHT, the project leader who was the research director of COATING played a substantial role in initiating the consortium. Although there was a need to move into lightweight bearings in the aerospace industry, and this is what AIRCRAFT enthusiastically followed, the very commencement of the collaboration was accelerated by the R&D head of COATING. He identified the funding opportunity, discussed the idea with BEARING and proposed to start an R&D consortium with AIRCRAFT in order to address their needs.

> *...COATING were working on TiN which we already had tried as an initial solution for the problem, but it did not seem like it was a really good solution nor had we any information to justify to customers [AIRCRAFT] that we should proceed with that type of technology. Jonathon [the research director of COATING] put together various other coatings that might be an improvement on the TiN and also a way of improving the TiN side. ...He mostly drove finding the funds and finding the vehicle for doing the research. So when he did find it, we joined the consortium (The R&D head of BEARING)*

The three cases suggest that these individuals who actively promoted the collaboration shared a number of traits. First, they had extended pre-established linkages, on which they could capitalise in order to attract others into the collaboration. They were mainly well known and reputable scientists/practitioners in their domain of expertise. This was reflected in their roles and positions in the professional communities in which they held membership (e.g. the importance of the coordinator of ASTHMA in respiratory society). Therefore, other researchers/scientists were eager to develop ties with them or strengthen their pre-existing relationships. In the next section, we elaborate on this point by putting this finding in the context of SC. Second, these individuals had a vision about the research paths that the consortia should take. They were not only familiar with the knowledge domain but they also had initial ideas about the opportunities that could assist them in starting the consortia. For instance, as the findings suggest, the directors of ARCHITECT and ENGINEER in HOUSE, and the R&D head of COATING took advantage of funding opportunity and catalysed the formation of the consortium.

6.3.5 THE ROLE OF SC AND COPS

Not all determinants of formation of collaborations were limited to the initiatives taken by individuals and to activation triggers. The findings suggest that SC and CoPs encouraged the formation of R&D consortia. In the following section, we elaborate on the role of these factors in the formation of R&D consortia.

Based on what was proposed in the theoretical framework, the main dimensions of SC for this study consist of the structural dimension and the relational dimension. *Structural capital* is the configuration of linkages among actors; it relates to the opportunities actors have to build a relationship (Burt 1992). *Relational capital* is the nature and quality of interactions and relates to the motivational aspects of social capital including trust, mutual expectations and obligations. Moreover, we defined a community of practice as "a unique combination of three fundamental elements: a ***domain*** of knowledge, which defines a set of issues, a ***community*** of people who care about this domain, and the shared ***practice*** that they are developing to be effective in their domain".

SC was an important determinant for the HOUSE consortium. HOUSE was initiated following on from a pre-existing collaboration (PANEL) with almost the same set of partners. Investigating the case, one can realise that both dimensions of SC existed prior to the formation of the consortium. Structurally, all partners had either weak or strong pre-existing ties. ARCHITECT, UNIVERSITY, and ENGINEER had closely collaborated before and almost all partners had collaborated in the previous R&D consortium. Relationally, the partners had developed mutual expectations and trust among themselves.

In PANEL, partners had identified their knowledge gaps and the areas worthy of further exploration that would transcend the scope of PANEL. Therefore, they rolled into the new consortium. Through former collaboration, the developed SC among the partners enabled them to start HOUSE smoothly and without having to pass a phase of getting to know each other. Apart from one partner organisation that was completely new to the consortium, the rest of the HOUSE collaborators had participated in the PANEL consortium. They were *friends at the social level* (Director of RENDER) and were open and trusting towards each other. They believed in each other's competencies and in delivering the project tasks, and they had developed a mutual understanding of what was expected in the context of the collaboration (Director of RENDER, and the representative of CONSTRUCTOR). As a result, when they started the HOUSE collaboration they were notably harmonised and compatible with one another. CONSTRUCTOR were the only partner who could not meet the expectations of the consortium and their role was reduced after a while. It was mainly due to the fact that they had not developed a history of mutual expectations and they entered the consortium without having a clear idea about their commitment. The representative of CONSTRUCTOR described the relationship between the rest of the partners as being friendly and trusting.

> *…they were a very tight bunch and they got on well and they worked well together. It is because of the relationships that already existed, that people weren't only working for a project …they have all had a long working relationship together so this is not the first time they have collaborated. So they all know each other and know how they work...*

This finding suggests that strong pre-existing SC can make the entrance of new partners difficult as they will have to develop their SC from the beginning which can be time-consuming and costly.

As the findings suggest, the core three partners (ENGINEER, ARCHITECT, and UNIVERSITY A) shared the features of a CoP (domain, community, practice) to a certain extent. First, they all belonged to the domain of sustainable construction. They were passionate about the area and they identified with the field. Their shared curiosity and interest in the domain of sustainable construction was not limited and temporal to the HOUSE project. It existed prior to it and it continued afterwards. Second, they shared a common practice. Although they belonged to different disciplines, they had worked on PANEL for a long time. They had a background in architecture or structural engineering with specific interest in innovative materials, which constituted their specific practice. Finally, they belonged to a wider community of people interested in research in sustainable construction and innovative materials.

While SC underlines the linkages, i.e. who knows who and how well people/organisations are connected to one another, the CoP element in the R&D consortium determines the research and learning directions. In HOUSE, some partners were interested in the collaboration and the research project in general, but researching PANEL and HOUSE did not constitute the core of their interest. They were not closely following the progress of the final product and its compliance with housing standards. Hence, their participation was limited to successfully accomplishing the tasks that they were assigned. This implies that SC was not a justified determinant of the formation of the consortium.

In the succeeding research collaboration (EURO), the CoP decided not to include the suppliers in order to be more focused on research. For instance, the director of ENGINEER described the contribution of RENDER to HOUSE as being trivial, and as the research continued, they needed to consider other *potential partners* compared to the existing ones[53].

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[53] This was also confirmed by the project manager

[...for example]with RENDER, we pretty much knew that it works fine in some way, it was more of a supply from RENDER to the project, so in some ways, RENDER wasn't quite as key to the last project as they had been in previous research.

As such, although the pre-existing SC guided the formation of a research consortium through increasing the level of trust between partners and making the collaboration run *smoothly* (mechanical engineer in RESEARCH A), it was not effective in guiding the research directions. This means that although SC is important in formation of R&D consortia, it should not be considered as the ultimate determinant. On the other hand, the CoPs perspective assists consortia partners in evaluating research needs and developing methods to acquire knowledge.

The ASTHMA consortium was initiated through two distinct social networks. On the one hand, the pre-existing social network of the current industrial coordinator was instrumental in the formation of the call for proposals by the EFPIA partners. On the other hand, the applicant partners exploited their social network in order to approach potential contributors. When the main applicants determined what they needed and how they wanted to conduct the research, they approached other research centres by utilising their pre-existing SC to call for partners.

So even before the call was published, when they had the information on the call that was coming out, [they] met and brainstormed the whole conception of the project. Now, at that time they had already talked to a number of people, in fact 95% of the consortium was already identified at that point based upon their existing and previous collaborations. (Industrial coordinator)

You start with who are the key people you need. Do you know them? And most of them you know or, between the four of us [the main applicants], we knew quite well... it's mostly personal contact; you know people either directly or indirectly through colleagues. (Academic lead of WPA)

However, the network they utilised was not limited specifically to the respiratory domain. From the very beginning, the core applicant partners anticipated that the implementation of their approach would require expertise from the systems biology and knowledge management area. Therefore, they utilised their network in order to access such expertise:

[We] involved somebody who was not previously in the practice and that group but had himself developed some interest in respiratory disease, but he was a systems biologist, which is using systems modelling to understand biology, and I had met him through the previous application we worked on. So that was somebody that my connection brought into the consortium. (Project manager)

Therefore, the pre-existing SC was important in two ways: first, in initiating the call for proposals by pharmaceutical companies (EFPIA) who were interested in respiratory disease, and second, in facilitating the identification of new applicant partners who then became part of the consortium.

The formation of the ASTHMA consortium was also accelerated through the pre-existing CoP which constituted the core of the consortium. First, the core partners belonged to the respiratory disease domain. They were all interested in the area, they were members of the European Respiratory Society (ERS), and they had similar ideas about the approach that should be taken for analysing asthma. When asked about the core set of people who initiated the consortium, the WPA academic lead responded:

I knew Philipp, and Andrew [pseudo names], and we were all in the same sort of area. We do the same sort of research, we go to the same meetings and, you know, we're competitors, but you do talk to each other and you go for beer and dinner and stuff...

This CoP informally initiated ASTHMA even before the call was published:

…they [core applicants] knew that EMC were having this call that was focused on severe asthma and they all had interest in severe asthma research-wise. So the three formed a group to come up with an idea... (Industrial coordinator)

This point was confirmed by other interview participants: that the core applicant members had a pre-existing established research area and research interest and also shared a similar approach towards conducting the research (using large-scale data to redefine asthma as a disease). This initial CoP worked as a focal point for the whole consortium, facilitating others' joining and collaborating.

The FLIGHT consortium had a similar development history, with one important difference, and that related to the fact that three out of four consortium partners belonged to the supply chain. Therefore, SC was developed between the partners in pairs beforehand. Previously, COATING had worked with UNIVERSITY C for many years in joint research projects, and BEARING, on the other hand, had a long standing relationship with AIRCRAFT:

> *As a supplier to AIRCRAFT, we have been working with them since the late 70s, early 80s, and as a manufacturer, we have been supplier to AIRCRAFT or its supply chain for the last thirty years. So our relationships with AIRCRAFT has been developed and evolved over many years.*

Therefore, the pre-existing relationships can be clustered into three dyads: UNIVERSITY C-COATING, COATING-BEARING, and BEARING-AIRCRAFT.

However, unlike the relationship between COATING and UNIVERSITY C, which was based on close research activities, COATING's relations with BEARING were primarily limited to the buyer-supplier type:

> *…we have been working with BEARING on a commercial basis. They sent stuff, we coated and sent back, but we didn't know them really. (R&D manager – COATING)*

From the expertise point of view, the metallurgy department of UNIVERSITY C and the R&D department of COATING belonged to the same domain. Both parties were expert in a very narrow branch of surface engineering of light alloys. They had, moreover, worked together for a long time before this project, with ongoing research interactions. Therefore, in the CoPs language, they constituted a pre-existing CoP. This point was further confirmed by looking into the co-authored papers. Six out of the seven published articles about the consortium outputs in peer-reviewed journals were co-authored by the same set of authors consisting of the two research scientists and the R&D head of COATING on the one hand, and the PhD researcher, Principle Investigator (PI), and a professor within UNIVERSITY C. The partners found this pre-existing CoP a strong point of the collaboration (Academic partner in UNIVERSITY C, the research scientist in COATING and the PhD researcher in UNIVERSITY C). A PhD researcher explained the significance of a pre-existing relationship with COATING:

> *…from the start, I think that [the existence of this relationship] was a big plus for this project, a very strong background, a very strong connection. We knew each other, we could communicate very easily, we could share data and information freely.*

The presence of such an established CoP helped the consortium in two major aspects. First, it accelerated the formation process. COATING and UNIVERSITY C took the lead in writing the proposal for the project and applying for the funding. Second, the fact that throughout the collaboration, they could easily communicate, collaborate and be on *the same page* (Research scientist A at COATING) made the collaboration process very efficient, especially given the fact that COATING and UNIVERSITY C had to exchange ideas and test pieces, and their results, frequently.

In summary, in this section, we attempted to discuss the important roles of SC and CoPs in the formation of R&D consortia. It was discussed that SC can assist formation of R&D consortia by offering developed trust, mutual expectations, etc. whereas pre-existing CoPs facilitate formation of R&D consortia through offering shared research interest and language. It was, moreover, discussed that although SC can contribute to the formation of R&D consortia, it cannot be as an effective determinant for forming these collaborations as CoPs.

6.3.6 THE ROLE OF SHARED SPACE IN A LONGER TIME HORIZON

Thus far, we have discussed about the preconditions of consortia formation. However, formation is not limited to a single point in time. It is a process starting long before the actual contracting and it continues long after that. Although there are some factors which affect the formation of consortia, in the course of time, the very formation of consortia affects the arrangement of the partners. In this section, we will seek to address such dynamics by employing the notion of 'shared space'.

We define 'shared space' as the conditions that cultivate the opportunity for participation across organisational and disciplinary boundaries in pursuit of shared meaning while distinguishing the participants from those who are not engaged in a similar pursuit. Shared space involves a mixture of conditions that allow participants to a) interact throughout (but not limited to) the R&D consortia and b) weaken the boundaries so as to form CoPs at the inter-organisational space. We put the findings of the case studies in a broader context in order to shed light on what characteristics of R&D consortia contribute to the formation of shared space. In what follows, by discussing these characteristics, we will attempt to unpack the concept of shared space.

The findings suggest that the development of shared space relies on 1) configuration of boundaries, 2) structure and governance of consortia, and 3) boundary spanners and boundary objects. Below, we will elaborate on these factors.

Configuration of the boundaries and governance of consortia: The three cases varied in the configuration of their boundaries. In 6.2, we elaborated on the differences between the three cases with respect to their boundaries. The HOUSE consortium dealt with both disciplinary and organisational boundaries. In ASTHMA, WPA and WPB mainly dealt with organisational boundaries while disciplinary ones were less prominent; the FLIGHT collaboration involved both types of boundaries.

The three cases demonstrate some differences with respect to their structure and governance of the consortia. ASTHMA was a horizontal collaboration as it was a pre-competitive collaboration and the collaboration involved pharmaceutical companies, universities and research institutes, SMEs, and patient organisations. On the other hand, FLIGHT was almost a vertical collaboration among the supply chain members. Between the two, one can put HOUSE which had a hybrid structure. In addition to the members of the supply chain, HOUSE involved other partners including UNIVERSITY A, RESEARCH A, ARCHITECT, and ENGINEER. The two latter SMEs did not manufacture anything, but they were mainly involved in design aspects of the project.

Our findings suggest that the formation of shared space becomes easier in horizontal collaborations. In the HOUSE collaboration, the interactions and research interests did not become aligned in vertical relations. However, the alignment of research interests and intensity of interactions were noticeable between UNIVERSITY A, ARCHITECT, and ENGINEER (all in horizontal relationships).

Likewise, in FLIGHT, the formation of shared space was more noticeable along the horizontal relations. As discussed, UNIVERSITY C and COATING had intensive research collaboration throughout but not limited to the project. This was not the case in the vertical relationships. Between COATING, BEARING, and AIRCRAFT, the relationship was task-oriented and demand-led.

At the beginning, in ASTHMA, the shared space was limited and there were not many chances for knowledge sharing:

> *At the beginning of the consortium, we found a couple of examples where one company would not have disclosed that they had done a certain part of the work, but another company was actually repeating it within the consortium. We could have saved doing that work, if we knew that, but that sort of thing is not happening right now. (COMPANY D representative)*

Being predominantly horizontal, however, ASTHMA offered the most favourable condition for development of shared space. One of the characteristic features of ASTHMA was its facilitation of collaboration among the scientists per se. In ASTHMA, scientists and operational people who worked at the labs were directly connected. Because scientists were interested in science, and pushing its boundaries, as soon as they were connected through ASTHMA, they found knowledge- and experience-sharing with their counterparts in other organisations pleasant (COMPANY A representative, Professor at RESEARCH B).

As discussed, unlike many other collaborations in the pharmaceutical industry which involve business developers, IP lawyers, or clinical research directors, ASTHMA connected operational people who were in the lab and this was found to be an important factor by our informants. A recurrent finding in ASTHMA was the 'surprise' element. As explained before, in ASTHMA companies had not collaborated with each other previously and the interfaces with academic partners were not as developed. Although the core applicants had known each other for a long time, in such a large consortium, many of the participants did not know each other ex-ante. However, almost all interviewees mentioned that they were 'surprised' about the ease of communication and the absence of reservations. When asked about the reason, interviewees highlighted that the participants were operational people, or scientists who worked in the lab, and could easily exchange knowledge.

> *... I found [ASTHMA] very open and constructive, and a bit of surprise to be honest. I collaborate occasionally with companies and sometimes they are very, very protective and this is actually a different structure… I think it is probably important that we now deal with people who are actually on the floor in the lab doing their experiments and who share the information. Normally, that is not how far we get. Normally we talk to the clinical research directors who realise and know if they have got a medication. [Academic – WPA - UNIVERSITY D]*

In an illustrative example, in the course of a TC meeting, scientists from COMPANY E were talking about the virus exacerbation model that they had worked on previously. While they were explaining their study and their experiments and results, COMPANY B scientists stood up *curiously* stating that they had also gone through a similar process, reaching the same results. Later on, this led to data integration from both sides, which then resulted in making a decision on whether that research path should be followed (story told by project manager and a WPB participant).

This finding suggests that although organisational boundaries were expected to be difficult to overcome in ASTHMA, connecting scientists who shared similar interests, passion, and language assisted the development of a shared space, weakened the organisational boundaries, and facilitated knowledge sharing. One explanation is that in horizontal relations, belonging to similar knowledge domains, scientists can form inter-organisational CoPs which, in turn, facilitate and accelerate knowledge sharing. In other words, as scientists follow similar research interests irrespective of their organisational context and interests, once they connect, they follow what interests them.

However, our findings underline that knowledge does not leak without triggers. In the case of ASTHMA, at the higher level of governance, in the EFPIA companies, the EMC initiative was supported and the governance mechanisms of the consortium were agreed upon at that level. Having such support from senior managers at the higher level facilitated the development of openness. Moreover, the contractual settings at the EMC level facilitated knowledge sharing between participants without reservations about sharing sensitive knowledge (WPA industrial lead). Finally, the pre-competitive nature of the collaboration meant that participants had minimal reservations about sharing and interacting with other partners as they knew which pieces of knowledge were sensitive and which were not (COMPANY A representative).

The other factor in the formation of shared space within ASTHMA was the role of public organisations which reinforced trust development among participants, ensuring non-commercial use of data. Research centres and universities contributed to overcoming the boundaries between companies by playing a role that we label ‘trust hubs’. Two specific findings corroborate this argument. First, the public institutes could host data-related activities like platforms, software, and company databases. In WPB, there was a time when COMPANY C decided to share their open source software (TRAMSN[54]) with other companies so that they could utilise it and analyse their data through it. However, as other companies would not agree to their data being hosted by their rival (COMPANY C), they decided to install the database at UNIVERSITY B before they could input their research data into it and analyse it (COMPANY C representative).

The second way that public institutes bridged the boundaries between companies was through facilitating mobility of individuals. As discussed in 5.3, in WPA, COMPANY B had expertise in virus growing which both RESEARCH B institute and COMPANY D needed to learn in order to accomplish their ASTHMA tasks. To this end, a post-doc was sent from RESEARCH B to COMPANY B for three months in order to learn the technique[55]. However, since COMPANY D was a pharmaceutical company and a competitor to COMPANY B, it was impossible to send a post-doc researcher from COMPANY D to COMPANY B. To overcome this issue, after the RESEARCH B post-doc researcher returned from COMPANY B, COMPANY D sent a post-doc to RESEARCH B in order to learn the technique. Once the technique was learned, he returned to COMPANY D to implement the virus work[56]. Therefore, COMPANY D learned the virus technique indirectly from COMPANY B and through RESEARCH B. The two examples are illustrative of the way that public institutes could facilitate interaction between companies.

[54] TRAMSN is the open source software which is adopted for KM in ASTHMA

[55] This was unique in its own right. Usually, companies fund a post-doc to go to research institutes, while in this case, COMPANY B funded a post-doc from RESEARCH B to go to COMPANY B for three months.

[56] WPA leader, Post-doc researcher in RESEARCH B, and COMPANY D representative

Yet, ASTHMA faced some hindrances for developing shared space as well. One of the pitfalls of ASTHMA and especially WPA was the ever-changing combination of participants, especially in industry. There were two factors contributing to this. First, according to the terms and conditions of the consortium contract, the EFPIA companies were not obliged to sustain their participation in EMC in general, and in ASTHMA in particular. Therefore, pharmaceutical companies had the option to leave the consortium whenever they decided. As a result, COMPANY E withdrew from the consortium after they reassessed the strategic importance of the respiratory area based on which they decided to limit their respiratory research. COMPANY A, moreover, shut down their UK respiratory site which meant that the existing participants from COMPANY A had to move to Sweden or change their role/job. As a result, none of the COMPANY A WPA participants stayed in the collaboration. These changes had negative effects on the collaboration. Second, the high rate of workforce mobility within the pharmaceutical companies (which is quite usual in the pharma industry) and constant change in the organisational priorities damaged the development of shared space.

> *…it was some surprise that, particularly in the commercial companies, persons and positions are changing so rapidly… Some of the companies are also changing priorities during the course of the project which has led to unexpected reductions in commitment and resources... (Project coordinator)*

Such rapid changes within the companies prevented the formation of the shared space. Ongoing changes meant that there were always new participants assigned to the WPs who replaced their predecessors which, in turn, entailed updating the newcomers, building the mutuality of expectations from scratch, and even re-agreeing on already-made decisions. Moreover, it meant that people had to become familiar with each other and understand each other's expertise which could potentially delay the development of the desirable shared space.

The findings about shared space can also be explained in light of power relations. In horizontal relations, as partners are at the same level, power relations are more symmetrical which decreases tensions between partners, resulting in more attuned knowledge sharing. However, as the collaborations become vertical, there is higher possibility for power asymmetry. Among the three cases, FLIGHT demonstrated conspicuous asymmetric power relations. AIRCRAFT was the end user imposing their demand on the consortium partners. Such a superior position hindered the learning between partners and directed research along a route that it would not have taken in the absence of their pressure. For instance, it restricted the research to be focused on only one application which was not favoured by other partners (this aspect of power asymmetry will be further explained in 6.4.2).

This does not mean that all collaborations should be horizontal, but it means that when collaborations are vertical, the power asymmetry can destabilise shared space and extra efforts are required to compensate for this.

Boundary spanners: Boundary spanners significantly contributed to the development of shared space in the studied R&D consortia. They had dual membership in more than one world which equipped them with the abilities to establish connections between different aspects of the collaborative work.

In HOUSE, the director of ARCHITECT had a peripheral membership in academia as he participated in academic events on a regular basis and he had taught within the university before. In addition, two individuals played a significant role in facilitating interactions between partners. First, during the collaboration, an MPhil student was sent to ENGINEER in order to help with some testings throughout the process. This helped communications between the consortia members, which required having ability to work with both sides or having two 'mindsets':

> *...for me it was interesting how the structural engineers [in ENGINEER] …approached the research and Sam and UNIVERSITY A approached the same problem from structural engineering. It is quite hard to give you definite examples but it was more like language they used, or where different people's passions lay… and obviously I was kind of in the middle of it. I was kind of bouncing between [ENGINEER] and [UNIVERSITY A]. So I almost had two different mindsets.*

Second, there was a post-doc researcher involved in the consortium who was heavily involved in the daily life of the project, which meant that she had extensive interactions across various boundaries.

In ASTHMA, there was a dedicated boundary spanner at the interface of WPB and the rest of the consortium. He was a former post-doc student in the computer science department of UNIVERSITY B who was hired by COMPANY C afterwards. He was very much involved in ASTHMA and was praised for his contributions to ASTHMA in catalysing interactions between the project participants[57]. During the interview, when asked whether there was a challenge in understanding the differences between the disciplines in WPB and the rest of ASTHMA, he pointed out:

> *…I think you may be talking to the wrong person because I am someone that enjoys trying to learn languages of many other disciplines and so I am not sure that's a challenge for me as an individual. Let me give you an example: I personally read out and said to everyone in WP7, "What data are you doing? How has it been generated?" I spend a little bit of time with all of them and put in the effort to learn about their platforms so I can have a conversation now between WPs with people from WP7.*

Interestingly, he did not even consider himself as a good programmer:

> *I may have spent all my academic life in computer science; I am not a very good programmer. I have a skill set which allows me to move technology transfer and knowledge transfer between different disciplines.*

In other words, instead of being deeply focused in a specialised area (computer programming in this case), he could situate himself in an in-between position which, in turn, facilitated crossing the boundaries between computer programming and pharma-related disciplines. In addition, there were others who had interactions across different boundaries. In particular, post-doc students were mobilised between organisations in order to transfer knowledge between partners.

The FLIGHT consortium use of boundary spanners was minimal. Although the research scientist in COATING was sponsored to do a PhD in UNIVERSITY C, it only happened after the project was completed. However, the intensive interactions between COATING and UNIVERSITY C compensated for the absence of dedicated boundary spanners in this research consortium.

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[57] In the ASTHMA annual meeting, he won the prize for his contributions to industry-academia crossing

In general, the findings indicate that the presence of boundary spanners was crucial in the R&D consortia, but our informants agreed that further usage of dedicated boundary spanners, especially in ASTHMA which was a significantly dispersed collaboration, could benefit the consortia.

Boundary objects: The other element that showed as being relevant in the formation of shared space was boundary objects. We defined boundary objects as “plastic artefacts that inhabit several intersecting social worlds and satisfy the information requirements of each of them” (Star and Griesemer 1989 p.393). Boundary objects played two types of roles within the R&D consortia. First, emails, phone calls, and teleconferences enabled the consortia partners to communicate and remain updated with the project progress. In HOUSE and FLIGHT, emails and phone calls were utilised extensively. ASTHMA, moreover, adopted a web-based communication platform which allowed them to communicate, keep meeting minutes and presentations, and follow the project progress. This was a necessary boundary object in ASTHMA because, given the size of the consortium, the conventional communication methods could not be efficient:

> *I think having a good collaboration platform [was important]. We have a website which is a central repository for minutes from the meetings, agendas for the next meetings, data that people have submitted. So it is quite easy to track what has been done in the past. So that is a very useful tool. Otherwise, you end up with information scattered around emails and various inboxes around the world and it is very difficult to track the information you want. So having the right collaboration tool is quite a good thing to have (WPA, industrial leader).*

The general trend among the cases was that in the smaller consortia (FLIGHT and HOUSE), emails and phone calls were used efficiently while in ASTHMA, which was a sizeable consortium with a considerable number of partners across Europe, the regular communication systems could not be as efficient. Therefore, utilising a platform in which every participant could log in and monitor the activities, progress, meeting schedules and minutes, etc. was a more effective communication channel.

Apart from the communication channels, which were specifically designed for communication purposes, the role of other boundary objects, which facilitated communications across boundaries, were as significant. These objects were not particularly designed to enable communication between partners but they would provide the grounds for interactions between the partners.

In the HOUSE collaboration, partners circulated drawings among themselves to communicate ideas, leave comments, etc.:

> *I think drawings are always useful to easily communicate ideas and you can always sketch onto drawings as well. So what I would do in a meeting with John and Jack [pseudo names] is obviously sketch... So they were useful to sitting around the table and flashing ideas almost, or pencil an actual plan. (MPhil student – University)*

The other boundary object was the thermal model that RESEARCH A developed within the consortium. A mechanical engineer from RESEARCH A explained how the model induced close collaboration and transferring and harmonising of data requirements:

> *I had a few meetings with John and Sarah [pseudo names] from UNIVERSITY to discuss what our modelling was and what data we were collecting and how I could better use that data to help me improve my modelling... I didn't know what data they were collecting, and they didn't really know initially what sort of data they needed to collect. So it was sort of working together to find out what information I needed, what information they could easily measure and then using that together to benefit the modelling. (Mechanical engineer in RESEARCH B)*

Finally, the house itself played a significant role in encouraging dialogues among the project participants. First, it meant different things to different partners. While for academics it was *a research house (MPhil student),* it was a *show home (director of ENGINEER)* for commercial partners. Therefore, it was a point both for revealing the differences between the partners and for reconciling those differences. Because of the selling features that HOUSE represented for commercial partners, they would become concerned about any experiment that could potentially distort this image. Therefore, on many occasions partners had discussions on how to conduct an experiment without harming the image of HOUSE. While sometimes consensus could not be achieved and one partner had to give way to the other, on other occasions, HOUSE could afford to be tested without compromising its image as a marketing symbol.

A story told by one participant clarified this point:

> *I can remember one conversation I had with him [Director of ARCHITECT] regarding structural testing when we developed this idea that we were going to use a scaffolding frame and then he was very sceptical about the structural testing... That is the opinion I got. I think he was interested from the point of view he realised that this work needed to be done to an extent, but I just found it interesting that he was sceptical about it. …Also it is very interesting because I said that John [pseudo name] was concerned that we didn't damage the house which I completely agree with. We didn't, obviously, want to break windows or even crack the render, but he was very concerned, but kind of expressed his concern one day and then on a different occasion he would say actually HOUSE is almost there to… not quite as a selling feature, but it is meant to tell us a story, to tell us the story that they are doing the thermal tests and equally the story of me doing the structural test could be apparent. ...there was a time when we were thinking rather than actually pushing the house, of pulling the house, and one way that we were going to do it was effectively apply FRP strips to the floor and the roof and basically link the strips… Eventually we didn't do it and we found a less intrusive way or less destructive way of doing it which was basically pushing it, and the way we did that was removing the cladding panel and then just loading the strength to the floor and roof plates.(MPhil researcher- UNIVERSITY A)*

This story illustrates how HOUSE as a boundary object opened the floor for discussion among the partners, and afforded to accommodate of a solution which was mutually acceptable: it could accommodate the differences by accommodating non-intrusive testing.

In ASTHMA, within WPA and WPB, all participants belonged to similar disciplines. The majority of partners in WPA included scientists with shared technical language. However, as mentioned before, WPB especially was a different WP from others in ASTHMA – WPB participants belonged to the domain of systems biology and computer science which was far from the conventional research domain in the industry. As a result, its interface with others was potentially difficult to coordinate. Therefore, a specific data platform was utilised in order to enable communication with other WPs without any need for understanding the underpinnings involved in data processing which was the concern of WPB. The KM software, for instance, provided a user-friendly interface for scientists to input their data into the system and obtain the results.

> *...what they've done is produced an interface on* TRAMSN[58] *so that it's very simple, it's like a tick box or drop down menu. I worked on a subset of patients who had this lung function or these specimen accounts and I wanted to see how that relates to gene expression profiles in blood. I can do that just by putting these into boxes, and the data comes out so I can then ask secondary questions which may be, "What are the effects of steroids on that?" So this is all real-time questioning, and a huge amount of computer power behind it. I don't understand any of it but I think the real key... [is] its interface that I can use: I can ask questions in my own terminology, I don't have to go to someone else who has to interpret my question to interrogate the database and come back five, ten days later with the answer. So we can just ask questions as they interest us. So it's how it works. Behind the screen, I don't know. (WPA academic lead)*

Two other boundary objects in WPA included Computed Tomography (CT scan) and Magnetic Resonance Imaging (MRI) techniques used in different companies. While in COMPANY B, MRI was the main device for imaging of lung functioning and chronic asthma in mice, COMPANY A utilised micro CT. During the WPA meetings, project participants learned about this difference. Then, they started to explore whether and how the two techniques compare. Afterwards, the project participants from COMPANY B and COMPANY A collaborated in order to analyse how such a difference affected the outcomes of their research experiments. A joint publication was the result of this effort.

In the FLIGHT consortium, test pieces and photos played significant roles in facilitating communication and exchanging interpretations between the partners. Partners circulated the test pieces among themselves so as to know about the status of the coating, its wearing and failure (Technical manager at BEARING). Many of the test pieces were sent to UNIVERSITY C to be analysed. On other occasions, partners would use photos of the test pieces. Figure 12 demonstrates one of the photos which was taken from the test pieces:

[58] TRAMSN is the open source software which was adopted for KM in ASTHMA

…for me, pictures work better than words. So if we were at BEARING what they would do was that they would take pictures of the testings that they were doing, they would explain exactly what they were doing… The pictures showed the results of the tests. (Research scientist A at COATING)

FIGURE 12: PHOTOS OF WORN BEARINGS USED IN A QUARTERLY PRESENTATION

At other occasions, when the test results were important to partners, they would talk over the actual test pieces immediately after the test was conducted. Being present at the same time and in the same environment would enable partners to discuss the various aspects of the testing in detail, share their interpretations, and exchange ideas about the reasons and potential solutions:

…we tested a medium bearing which could be tested under the high loads at BEARING. …this was programmed into the system on the test gear at BEARING and we went along and witnessed this… and so I suppose we came to appreciate by watching that a huge load was involved, and these tests went on for a few weeks and then we heard that the bearing had failed and so we all went back to BEARING to have a look at the failed bearing. We watched as it striped out from the test equipment and we all looked at the failed bearing surface and discussed what we thought was the reason for the failure. So it was beneficial to all be together to witness the test itself and to look at the failed bearing itself. You could have sent around a photograph by email to each of the partners and said, "What do you think of this?" but the fact that we were all there together looking at it, exchanging ideas, [was helpful]. AIRCRAFT was there saying that it failed because of such and such, so because of our know-how and because of BEARING's know-how, they were able to say, "Well, hang on, it is probably because this grease groove here has got too sharpened an edge on it and we need to take that edge off because it has been digging in. We need to take that edge off and redo the test". And we were able to say,

"Yes, with a sharp edge like that if the housing of the bearing is distorting such that the edge is digging into the coating, then you can't expect the coating to survive", whereas AIRCRAFT would say, "Well, you know it has failed because it is just worn out" and they wouldn't know how it could be avoided – they would have some idea. [R&D head of COATING]

Other forms of boundary objects which were used the consortia included project plans and milestones, Gantt charts, meeting agendas, etc. These forms of boundary objects were universally used in all of the three consortia. They were particularly useful in coordinating organisational boundaries and mainly served the interests of the industrial partners in coping with the relaxed attitude of the academic partners.

In general, those boundary objects which dealt with managerial coordination among partners (e.g. milestones, Gantt charts, agendas, etc.) were mainly useful for crossing organisational boundaries, while objects which were exposed to analysis and testing (e.g. test pieces, analytical models, drawings, samples, etc.) supported the interaction across disciplinary boundaries.

In addition to the factors that were discussed as contributing to the formation of shared space, the findings suggest that there are dynamics involved between SC, CoPs, and the formation of R&D consortia on the one hand, and the development of shared space on the other. Although a threshold level of pre-existing SC and CoPs is essential for formation of R&D consortia, the very formation of consortia provides opportunities for furthering SC among a set of actors beyond the core group of initiators encompassing a broader set of project participants. On the other hand, once R&D consortia form, the floor opens for people who belong to similar knowledge domains with a shared learning imperative to collaborate and form a shared space.

6.3.7 CROSS-CASE COMPARISON

Table 18 categorises these differences into collaboration type, participation scope, focus, history, purpose, boundary focus, SC, and CoP aspects.

TABLE 18: THE VARIOUS ASPECTS OF THE THREE CASES

	HOUSE	ASTHMA	FLIGHT
Collaboration type	Hybrid	Horizontal	Vertical
History	Continuation	Unprecedented	Unprecedented
Research aims	Improving the performance of the product Complying with standards	Discovering the underlying mechanisms of severe asthma by using large data samples	Development of new titanium bearings
Purpose of collaboration	Market assurance Filling knowledge gaps	Risk sharing Community development Economies of scale Filling knowledge gaps	End-user involvement Filling knowledge gaps
Resource alignment	Complementarity	Supplementarity/complementarity	Complementarity
Boundary focus	Synergising	Attenuating organisational boundaries Disciplinary synergising	Synergising
SC	Pre-established between the majority of partners	Pre-established within industry and academia separately Emerging at the interface of academia-industry	Pre-established at dyads within the supply chain Emerging at other interfaces within the supply chain
Pre-existing CoP	The core partners within the three consecutive consortia	The core applicant partners within the respiratory domain	COATING and UNIVERSITY C surface engineering scientists

The first difference between the R&D consortia originates from the type of collaboration. The FLIGHT collaboration was vertical, ASTHMA was horizontal, and HOUSE was hybrid. FLIGHT was vertical because it was mainly organised around the supply chain. It consisted of the end user (AIRCRAFT), the first-tier supplier (BEARING), the second-tier supplier (COATING) and a university (UNIVERSITY C). ASTHMA was horizontal because it was a pre-competitive research collaboration and it included universities, research institutes, companies, patient organisations and SMEs. Finally, HOUSE was hybrid because it consisted of supply chain partners and a research institute, university, and two SMEs who provided architecture and structural engineering advice to the project.

The three cases also varied with respect to their history of formation. The HOUSE collaboration followed from a previous collaboration between almost similar organisational partners, while FLIGHT and ASTHMA did not enjoy the same conditions. In FLIGHT, despite the presence of pre-existing relationships at the individual dyads, partner organisations had not worked together as a group beforehand.

The cases followed different purposes too. HOUSE was focused on gaining market assurance by thoroughly analysing the various aspects of the product, improving its weaknesses and reinforcing its strengths; the ASTHMA consortium was mainly initiated to decrease the risk and costs of drug development, to avoid redundancies in the industry, and to encourage the formation of a wider community for research in pharmaceuticals. As the EMC mission statement specifies: “EMC aims to build a more collaborative ecosystem for pharmaceutical research and development (R&D[59])”. Finally, FLIGHT aspired to address the requirements of end user and shortcut the relationship between the end user and second-tier supplier.

Variance in purposes and type of collaboration translated into difference in resource alignment strategies in the three consortia. For HOUSE the formation was driven by resource complementarities (in market and in technical knowledge) between the partners. In ASTHMA, both complementarity (dissimilarity of resources) and supplementarity (similarity of resources) drove the consortium formation. Among the EFPIA partners, supplementarity of resources was the main reason for collaboration as they wanted to decrease the costs and risks associated with development of new NMEs. On the other hand, seeking complementarities was the dominant logic within the rest of the consortium (between applicant partners and at the interface of applicants and EFPIA companies). Finally, in FLIGHT, the complementarity between partners was the major thrust. However, while at the interface of the end user and the rest of the consortium, complementarities dealt with market knowledge provision, technical knowledge complementarities were dominant among the other members.

The boundary focus was also different between the cases. The FLIGHT and the HOUSE collaborations were not designed for crossing boundaries per se. The actors were specialised in their respective areas, and the boundary crossing rationale was to cultivate synergy between the partners. This does not mean that the boundaries were

[59] EMC webpage – mission statement

not crossed within the collaboration, but it means that the collaboration was not primarily designed to do so. This dimension relates to the objectives of the consortia. For the HOUSE and FLIGHT collaborations, the main focus was to achieve a commercially viable product/process. In doing so, partners had to collaborate across boundaries in order to utilise each other's expertise, resources, etc. Therefore, the consortium outcomes originated from the synergic effects generated across the boundaries. Although such collaboration necessitated having meaningful communications and interactions across the identified boundaries, the ultimate goal of the consortium was not to remove these differences and build a new form in the long term. For example, the FLIGHT consortium was not meant to enable the bearing manufacturer (BEARING) to develop a coating process, although the boundaries affected the communications and alignment between partners. Conversely, ASTHMA was designed to attenuate the traditionally established boundaries between academia and industry and between the industrial partners so as to collaboratively address the commonly faced problems in the industry as a whole and to benefit the whole community. In fact, one of the main goals of EMC was to build the research community at the European level.

In conclusion, the three cases shared different levels of pre-existing SC and CoPs. HOUSE had the highest level of SC as partners had collaborated previously , and the consortium incorporated the supply chain members. FLIGHT ranked second because of the inclusion of the supply chain members, and because of pre-existing relationships between partners in pairs prior to the consortium. Finally, SC was least developed in ASTHMA due to the lack of prior collaboration between academic and industrial partners, in general.

As far as CoPs are concerned, the conspicuous CoP within HOUSE was that consisting of the set of participants from the core partners. In ASTHMA, the CoP encompassed the core applicant partners with similar interest in the respiratory domain, and in FLIGHT the CoP involved the research scientists in COATING and in UNIVERSITY C who had similar interest in and approach towards surface engineering. The findings suggest that boundaries matter in the development of new CoPs. When boundaries are impermeable and historically established through the differences between industries, professions, institutional contexts, etc., there are more barriers in place compared with the conditions where such strong boundaries do not pre-exist. Therefore, as collaborations move from vertical to horizontal, there are more chances for the development of new inter-organisational CoPs in the long term.

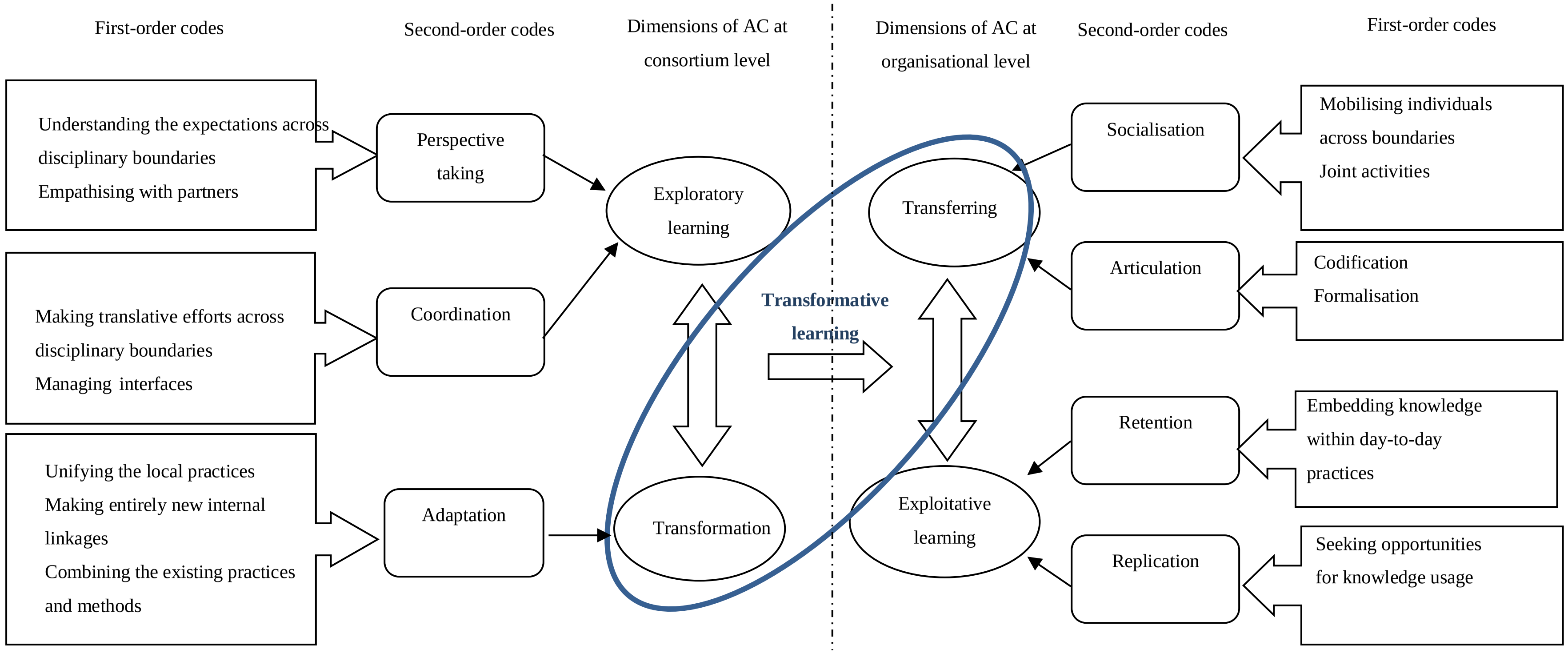
6.4 ABSORPTIVE CAPACITY

6.4.1 INTRODUCTION

Thus far, we have elaborated on the preconditions of formation of R&D consortia and the importance of the formation of a 'shared space'. This section examines the three dimensions of AC, i.e. *exploratory, transformative,* and *exploitative.* Once the dimensions of AC are figured out in this chapter, we collate the big picture of the findings in 6.5.

Figure 13 demonstrates the structure of data gathered from the field. For our data analysis of AC, we took Lane et al.'s (2006) model with its three dimensions of AC (exploratory, transformative, and exploitative) as our departure point. Then, we analysed data and grouped the findings into first-order codes which are presented at the two sides of the figure. Then, the codes were aggregated to the second-order codes extracted from the literature which represent the micro learning mechanisms that support AC in R&D consortia.

FIGURE 13: DATA STRUCTURE



6.4.2 EXPLORATORY LEARNING

6.4.2.1 INTRODUCTION

Exploratory learning relates to identification and understanding external knowledge. In what follows, we present the two aspects of exploratory learning, that is, 'perspective taking' and 'coordination', within the three case studies. We will also provide explanations about what determines perspective taking and coordination.

6.4.2.2 PERSPECTIVE TAKING

The findings suggest that *perspective taking* (Boland and Tenkasi 1995, Oborn and Dawson 2010) at organisational and disciplinary boundaries contributes to exploratory learning. It is the initial step where participants 1) make their perspectives clear and accessible to others, and 2) endeavour to understand the perspectives of partners and own them. In other words, perspective taking is about being capable of putting oneself in others' shoes and making attempts to make one's position transparent to others.

In our researched cases, at disciplinary boundaries, perspective taking related to appreciating the complexity of one's own technical language which was crucial for making 'conversations' comprehensible. At organisational boundaries, it related to realising and accepting the different work contexts and empathising with the limits that those differences would incur. The most significant organisational boundary related to the differences between commercial and academic partners. For commercial partners, perspective taking meant to be able to think and to behave differently within the consortium compared with their day-to-day environment, and for universities, it meant to learn about the restrictions and time pressures within the industry, to identify the reasons behind these differences, and to empathise with the partner.

In HOUSE, perspective taking was evident at both types of boundaries. At the disciplinary level, structural engineers, especially, were aware that they should take into account the technical complexity of their language:

> *…what I found interesting... is what level of technical ability you assume people have because obviously you can't necessarily pitch it so that everybody understands everything, everybody knows everything. (MPhil student)*

At organisational boundaries, university partners, in particular, tried to *empathise* (Academic professor at UNIVERSITY A) with the SMEs, to understand their limited resources and the time horizon that could work for them. A post-doc researcher explained how important research findings were for commercial companies. She explained that the research outcome depended on the research methodology and commercial partners could potentially lose their competitive edge against their competitors in the industry because of inferior research outcomes and despite their superior product. This was not something easy to appreciate for academic partners and required time:

> *I think it is very difficult for a commercial company when they know that people are not necessarily going to look back at the research ... and I think that is something that I really learned to appreciate... that was a very interesting issue that I didn't wholly appreciate before. (Post-doc researcher)*

In ASTHMA, perspective taking happened at disciplinary boundaries as well as at the organisational ones. Collaboration between WPA and WPB required WPA scientists to provide data for the KM system. However, at times the expectations of WPB could turn unrealistic as they did not know the actual implication of their requirements:

> *I had one person from the computer department who wanted [a large data set to make the system work]; I brought him down to my lab and said, "Let's actually see what you have asked for these experiments, let's go and do one part of that huge experiment you asked for. They have been working flat out for a week with a hundred floss of cells and yet this is a tiny fraction of what you ask for. You've got to realise that we can't physically do that."(WPA academic leader)*

On the other hand, the academics and industrial partners had to understand, empathise, and become flexible in order to be able to work with their counterparts. This meant, for each partner, to appreciate the differences and to understand the reasons behind them. From the academia point of view, it entailed becoming more receptive to the industrial way of doing things:

> *...we as academics learned the strict way of commercial thinking and I think that commercial colleagues got very much involved into the academic way of working which, even though it is less strictly planned, may also have benefits in terms of openness, flexibility, creativity. So that*

> *is something that we learned both ways… Companies are used to comply with very strict and final deadlines and very concrete deliverables because that is what they do towards their senior management whereas academics are usually question-oriented rather than deliverable-oriented. So what we as academics learned from our commercial partners is just to think more strictly in timelines, deliverables, etc. (Project coordinator – UNIVERSITY D academic)*

From the industry point of view, empathy, diplomacy, and flexibility were the main factors contributing to perspective taking. Perspective taking involved accepting the fact that a consortium is running in a different setting from their routine industrial activities, which required behaving differently during collaboration with partners in the consortium. This, in turn, meant loosening the strict logic of following procedures rigorously in order to be able to interact and collaborate with academic partners within the consortium. When asked about how industrial partners coped with the academic perspective, the industrial lead of WPA explicated the importance of perspective taking:

> *Diplomacy and tact, and that is really important... if you are working on a project within industry, you have got time pressures, and the project leaders of those things are very hard-nosed, very driven, very time-urgent, very organised, and want to see everything moving as fast as possible. If you try to apply that into consortia, where different people want to do different things, it does not work. You have got to be a little more relaxed, you have got to be a bit more diplomatic, and slowly guide people to a work plan which you think is going to deliver your own resource, but if you apply the hard-nose industry way of doing it, you will probably cause so many arguments that the group will disintegrate. (WPA – industrial lead).*

Similarly, in the FLIGHT consortium, in order to cross the various kinds of boundaries, partners had to put themselves in the others' position. Across the disciplinary boundaries, it was important to understand what information, data, test results, etc. could be communicated. As the R&D head of COATING said:

> *…UNIVERSITY C and COATING have been working together on coatings for many years and so we probably have our own language as well, and it is a speciality, what we do, so when we meet with other partners and start talking about how we adapted the coating and how we changed the process, it can be very baffling for them and very difficult to follow.*

At the organisational level, AIRCRAFT was a completely different organisation among the partner organisations, with its large scale of operation and strict safety and testing environment. Therefore, it took some time for partner organisations to learn about the differences that AIRCRAFT had:

> *I suppose the scale of the operation was very, very big, and the very high levels of testing and safety testing and the very precise way in which the whole company and the people within it were organised... Obviously it was a highly health and safety critical application, being in aircraft. We were a relatively small company with around 60 people and things were more structured – they are structured here but they are more structured there – and it has a say on their language. So people very rigidly follow the procedures. They have a particular route to follow and if they want to move off that route, they have to get permission, and it was just helpful to understand that is how they work there and that is how they had to work there, so what we were doing needed to fit in with that. (R&D head of COATING)*

Yet, the findings suggest that perspective taking was not mutual. AIRCRAFT was not willing to take perspectives from the rest of the partners. As one of the informants explained:

> *I think most of the time they [AIRCRAFT] thought that their language was different from ours… I'll give you an idea: we want to try ABC, but we cannot because it is too far off from what they have already certified and it will take them a year to certify it within a big business like aerospace and so … we could understand what certifications are involved, what approval systems through high people in the system are involved... So I think we were understanding. …[but] sometimes, they misunderstood our interest in trying to be interested in pure science… Sometimes, I think they were not thinking that we were getting the point. (Anonymity retained)*

Interestingly, the head of the structure stress department of AIRCRAFT believed that UNIVERSITY C and COATING were interested in research and had less interest in the industrial applications:

> *...it becomes difficult because the problem with COATING and UNIVERSITY was that they were very research oriented and they really started doing their research on that particular area, not looking at the broader picture and saying, "This is where we need to stop" or "We need to direct you in this direction and instead of doing 50 coatings, we need to narrow it down", and that became a challenge as we went through. (Head of the structural stress department, AIRCRAFT)*

In fact, AIRCRAFT focused more on *challenging* partners instead of accepting their viewpoints easily. It was evident in the meeting minutes of the consortium that AIRCRAFT continuously raised issues and asked for clarifications, scientific reasoning, failure reports, etc. At many points, they would ask the partners to send the reports of their work one week ahead of the quarterly meetings[60] so that they could fully analyse the progress:

> *If the testing they did was incorrect, we would challenge them on the testing: Why did they do that? What were its benefits? What were the other processes that we were using in the composition of the coatings? We would ask them questions and challenge them, saying, "What is the reason for it?" "What is the benefit for it, and how can it help us in the long run?" (Head of the structural stress department, AIRCRAFT)*

This piece of finding suggests that perspective taking can be asymmetric at times. In this case, although perspective taking played a role, it was not mutually developed among the partners. All partners had to take perspective from AIRCRAFT, and appreciate their requirements, concerns, etc. while AIRCRAFT were reluctant to do so. Furthering the analysis, the role of power that AIRCRAFT could exercise over the other partners within the consortium was conspicuous. *Giving way to AIRCRAFT* (R&D head, BEARING), *addressing their concerns* (R&D head, COATING), *fulfilling their [AIRCRAFT] requirements* (PhD, UNIVERSITY C), and *pushing them [suppliers] to improve their capabilities* (AIRCRAFT representative), represent the power that AIRCRAFT held over its collaborators. This piece of finding suggests that when power relations become asymmetric, perspective taking can become asymmetric too.

[60] Meeting minutes of the 3rd quarterly meeting

In general, findings suggest that perspective taking is an important aspect of AC in R&D consortia since an effective and meaningful collaboration necessitates a level of perspective taking at organisational and disciplinary boundaries.

6.4.2.3 COORDINATION

The other aspect of AC in the exploratory phase was coordination. Across the boundaries, there are two options for managing the differences and communicating with the partners: either boundaries can be crossed by efforts made to coordinate the differences without having to change the configuration of existing boundaries, or partners can develop new practices which are considerably different from their pre-existing ones and thus change the boundaries. Coordination mechanisms deal with the former category. At coordination, dialogue between partners is deployed as long as it is necessary (Akkerman and Bakker 2011), i.e. coordination mechanisms maintain the flow of work across diverse perspectives or practices. As the data suggests, translative efforts and alignment of interests constituted coordination in the researched R&D consortia.

Translative mechanisms were concerned with the routines and processes that made dialogue comprehensible across the 'disciplinary' boundaries. While perspective taking across disciplinary boundaries related to appreciating the differences across disciplines, translative mechanisms helped with overcoming those differences through developing shared language. In the HOUSE consortium, at the disciplinary boundaries, partners tailored their languages in order to be accessible to others. In particular, the structural engineers simplified their language during their presentations in the quarterly meetings, making it comprehensible to the rest of the consortium members. A structural engineer pointed out how they tailored their language (which was used within their discipline) when they wanted to talk at their collective meetings, although they had their own intra-disciplinary meetings.

> *...it [our language] was always maybe tailored or changed when we were in the [quarterly] meeting so that everyone could understand what everyone was saying… [MPhil student]*

The other mechanism was to focus on the results rather than the scientific underpinnings of the project. In the HOUSE collaboration, particularly, the work conducted by RESEARCH A was difficult to understand in its details. Therefore, the partners would settle with the understanding of the results instead of having a detailed appreciation of their findings and their model. It was neither necessary nor beneficial to comprehend the detailed technicalities of the work thoroughly.

> *It is the results of what they have been looking at that I want to know and if I can understand the results, that is fine. (Director of AGRICULTURE)*

In ASTHMA, and particularly within WPs, individual participants were experts in similar areas, although there were some differences in their areas of expertise, which did not affect the communication between the individuals. Therefore, the disciplinary boundaries were less of an issue. However, at the interface of the WPs, having dialogue was not as effortless:

> *There are many specialists who know their own thing but there have been problems to make sure that there is a helicopter view of how all these should relate with each other, really, and that is one of the challenges... there is still need for coordination across WPs. (WPB participant)*

Within WPA and WPB, all participants belonged to similar disciplines. The majority of partners in WPA were scientists with shared technical language, and WPB participants belonged to the domain of systems biology and computer science. However, as mentioned before, WPB especially was a different WP from others in ASTHMA. As a result, its interface with others was potentially difficult to coordinate. Therefore, a specific data platform was utilised in order to enable communication with other WPs which eliminated the need for understanding the underpinnings of data processing. The KM (TRAMSN) software, for instance, provided a user-friendly interface for scientists to input their data into the system and obtain the results (see 6.3.6 for a detailed explanation of the role of KM software).

Likewise, in order to address the disciplinary differences, translative efforts were important in FLIGHT. In this consortium, this was achieved through 1) explaining in detail what each partner was doing without presuming any pre-existing knowledge with an open platform for discussion and clarification, and 2) simplifying the language so that it was comprehensible for other partners.

In the following illustrative quotes, interviewees explain how they were able to solve the problems associated with language difference:

> *AIRCRAFT tend to use their own acronyms or their own language if you like. They have so many processes and procedures which are all aerospace type of things. So they just shorten them to three letters. When AIRCRAFT people talk – just through habit – they tend to fire off a few of these things. We found it difficult to follow what they were saying. We picked up some of it and when they were reminded, they remembered that we were not able to follow them. So they tried to include what they were talking about rather than using acronyms, using the full descriptions of what they were talking about. ...even after using the full names, if there were parts that they thought that we were not familiar with, they would explain that as well. (R&D head of COATING)*

This point was further corroborated by the PhD researcher at UNIVERSITY C:

> *I think the fact was that each of us was ready to explain as much detail as was being asked for and provide as much simplification as was needed. So over a month, I am pretty sure that everyone was much more on the same line because people actually bothered to explain themselves properly, which was very good. (PhD researcher at UNIVERSITY C)*

While making the details accessible to others and showing willingness to explain as much was requested within the consortium was an important aspect of translative efforts, at some points, a degree of simplification would be necessary. Accordingly, focusing on the results was also important to facilitate communication across the disciplinary boundaries.

> *I wouldn't have expected anyone at the table apart from COATING to understand, really, certain technical language, and that is why you would avoid it, or you would simplify it, or if most of the time there wasn't scope to discuss certain technicalities, you would talk about the results… and you would avoid saying exactly why. (PhD researcher at UNIVERSITY C)*

On some occasions, when COATING and UNIVERSITY C found it difficult for others to grasp details of their findings, they would meet separately to discuss the findings in detail beforehand. Then, they would reformulate it for the other partners during the actual meetings. This way they could present the findings in a more *general way without all the technical details [R&D head – COATING]* for other consortium partners.

Coordination mechanisms were also used in order to provide interface across organisational boundaries. In HOUSE and FLIGHT, partners held quarterly meetings to discuss their progress, set milestones, and plan for the next periods. In both cases, there were also informal meetings that occurred outside the formally organised quarterly meetings. In the HOUSE consortium, a full-time post-doc researcher was employed on the project and she was responsible for coordinating partners and research throughout the collaboration. In FLIGHT, in quarterly meetings, apart from the presentations by each partner which addressed the work progress, the consortium manager gave a presentation about the overall progress of the work, discussing the milestones and delays of the whole project. Moreover, in the FLIGHT project, partners held the quarterly meetings in turn. Therefore, the partners had the chance to visit each other's sites which helped with understanding their differences. Like HOUSE, FLIGHT used a full-time PhD researcher to work on the R&D consortia and to coordinate research among partners. In ASTHMA, given the size and scale of the project, a separate organisation (a consulting SME) was in charge of managing the whole consortium. This company would run the TCs, online and face-to-face meetings, writing down and archiving meeting minutes and monitoring the progress of WPs. Moreover, ASTHMA used full-time post-doc students in WPs who were in charge of coordinating partners (especially with relation to academic-industry interfaces).

In this section, we discussed that the exploratory learning dimension of AC built on two mechanisms of perspective taking and coordination. It was suggested that perspective taking in disciplinary boundaries relates to becoming aware of one's own technical language complexity and relates to appreciating and empathising with differences across organisational boundaries. On the other hand, it was discussed that across disciplinary boundaries, coordination involves making translative efforts and across organisational boundaries it is concerned with aligning organisational interests.

6.4.3 TRANSFORMATIVE LEARNING

6.4.3.1 INTRODUCTION

The primary quest of this section is to understand the notion of transformative learning in AC which relates to assimilating acquired knowledge. In so doing, we distinguish between two aspects of transformative learning, namely transformation and transferring.

We contend that transformative learning consists of two sets of mechanisms of transformation and transferring. Lane et al. (2006) define transformative learning as a mechanism that links exploratory learning into exploitative learning. Therefore, on the one hand, it entails change, adjustment, and combination of pre-existing routines and processes across various boundaries in order to assist exploration at the consortium level. On the other hand, it deals with the mechanisms that handle the temporal and spatial differences between exploration and exploitation phases. While we call the former mechanisms ‘transformation’, we label the latter ones ‘transferring’.

Among the three dimensions of AC, transformative learning occurs at the intersection of inter-organisational and intra-organisational space. The inter-relations between transformation and transferring render transformative learning simultaneously inter-organisational and intra-organisational. Therefore, spatially, transformative learning cannot be attributed to the either of these areas and can be perceived as an interface-level dimension.

The rest of the section is organised as follows. First, the characteristics and mechanisms underlying transformation are discussed. Then, transferring mechanisms are presented. Finally, the dynamics of transformative learning are examined.

6.4.3.2 TRANSFORMATION

The main mechanism supporting transformation was adaptation (see 3.4.3.3 for a detailed discussion on adaptation). Adaptation entails changes in existing behaviour in response to external stimuli. Our findings suggest that adaptation involve unifying the local practices through combining the features of the different functional groups, modifying them, or making entirely new internal linkages.

In general, ASTHMA was a large-scale, data-driven research project. However, when it came to the data, a number of difficulties existed. First, clinical and non-clinical data were gathered in different ways by different partners. In medical studies, the ways data are gathered by research institutes and companies are specified by Standard Operation Procedures (SOPs) and Case Report Forms (CRFs). Having these differences would hamper the comparison and integration of data between partners. Therefore, in ASTHMA, in order to collaborate effectively, the existing SOPs needed to be harmonised.

> *...by defining all our methodologies in the project not only in animal labs but also in the clinical arenas, we now have commonly agreed standard operating procedures (SOPs) on how to use a questionnaire, how to perform lung function, how to draw blood, etc. The SOPs have been compiled into a big document that changes practices in all our institutes, because sticking to this collaboratively agreed methodology is of great benefit. (Project coordinator)*

However, the SOPs were not new and they were mainly the outcome of putting *certain SOPs together (WP3* leader*).* Partners shared their experience and the rationale for their SOPs. Then, through discussion, the new SOPs were introduced by combining the existing ones.

Adaptation was not limited to SOPs and CRFs, and animal models needed to be matched as well. The analytical models were different between various partners. In WPA, collaboration between partners in research entailed designing and conducting experiments, comparing results, and making plans for the next round of work. However, like SOPs, in order to compare the results, it was necessary to have similar models:

> *The idea is that everybody working in the same model, either in-vivo or in-vitro model, should be using the same protocols for collecting samples for the model. So all the samples collected from any of the members can be compared one to the other... We started collaborating with COMPANY G. Obviously, they had their model. So we started using their protocol but then we modified their protocol because we did a lot of work on the model and there were things that you could do better. Then, we put them in common and now they started following things that we set up. So I think that is the way it goes, which is you need to follow a protocol and, at the moment, everybody follows a similar protocol for everything. Otherwise, we wouldn't be able to compare anything. [COMPANY D representative]*

Therefore, partners changed their models in order to become unified in what they do so that they could start comparing their results effectively.

In FLIGHT, partners modified their tests because of AIRCRAFT requirements. AIRCRAFT asked partners to conduct a 'reproducibility' test, which investigates how many times a sample can endure load. This was not usual practice for academia or among other firms, but was crucial for AIRCRAFT in order to ensure safety. For academics, it was a completely new concept: *In literature, it is not usually specified how many tests were conducted* (PI from UNIVERSITY C). Therefore, because of AIRCRAFT requirements, UNIVERSITY C and COATING repeated tests and measured the average results instead of conducting tests and measuring the results merely once. Close collaboration enabled this change in practice: *we collaborated on something which was going to be used by the partners. What came out of the project was immediately used (PI from UNIVERSITY C).*

COATING modified their standard testing procedures to meet the aerospace industry's requirements. Working on a treatment for AIRCRAFT required adhesion tests with higher magnification in comparison with their routine tests. In the following quote, the senior researcher at COATING explains how they moved from their conventional way of doing things into new practices within this collaboration.

> *...sometimes we had to change some practices and do higher loads for titanium; they wanted high adhesion and we had to look at higher magnification in order to see the slightest effects in the coating, or lack of adhesion. So basically, we have new practices that are only used for this AIRCRAFT process for these bearings...*

Towards the end of the FLIGHT project, AIRCRAFT asked COATING to allow a quality check by AIRCRAFT so that they could become an accredited supplier. As a result, in a two-day training programme, the quality control people from AIRCRAFT went to COATING in order to observe the coating process during the first day, and to discuss the results and finalise the standards on the second day. It was a collaborative process though:

> *…it wasn't a unilateral thing. It was an interactive process. We developed a standard that we wanted to work with all the way. (Senior researcher at COATING)*

In addition, COATING adapted its coating machine to comply with consortium requirements. In order to coat bearings in accordance with the specific application requirements of FLIGHT, a new coating machine had to be designed and built which could coat at higher temperatures and accommodate larger bearings. However, before building the new machine, in order to determine its exact specifications, COATING had to modify and experiment with their existing machine. After undergoing a number of modifications, the existing machine was temporarily used for coating smaller bearings. Once the specifications of the new machine were established, COATING started building the new coating machine.

This adaptation process necessitated internal collaborations within COATING. There were, however, some problems in collaboration with the engineering department. The engineering department was not directly involved in the consortium, and their interface with FLIGHT was limited to the R&D department. The absence of direct contact between the engineering department of COATING and FLIGHT inhibited the smooth transformation of the machine. Therefore, there were delays in the construction of the machine, which incurred an extension on the FLIGHT collaboration:

> *I think if there is one thing that I would do differently it is that I would involve the engineering manager in the meetings we had with the partners because… that was a part of the proposal, and instead of just having Jonathon to manage the project and me to do all the experimental stuff, it would be good to have an engineering manager reporting on the machine build, because it is not my expertise, and it is not [the R&D manager]'s either, and I think that would have been beneficial because there were delays, there were problems. …It would have been good if the engineer manager could have explained to the partners what type of challenge we were facing. I think that was missing. (Research scientist A, COATING)*

This finding suggests that adaptation necessitated continuous interaction at the interfaces as it required extra efforts owing to alterations in existing arrangements, routines, or procedures.

As for BEARING, they had to build new titanium bearings, which were different from their conventional steel bearings. This entailed changing their existing production processes so that they could process titanium materials.

> *There were a lot of new processes for titanium, for actually machining the titanium and getting it to be nice and spherical. It is not easy to machine. …We were trying to machine with grinding and we finally developed an off-turning technique to allow us to finish them with titanium. (R&D manager, BEARING)*

Forming entirely new internal linkages was the other aspect of adaptation. In the three R&D consortia, on various occasions, partners formed entirely new internal linkages in order to respond to the requirements posed by R&D consortia. In particular, whenever participants found gaps in their knowledge which could not be addressed by their existing expertise, they tended to form new internal linkages. Through forming such linkages, organisations filled the knowledge gaps that they faced within their collaboration. Below, a number of instances when new internal linkages were formed are presented.

In the HOUSE consortium, the academic lead of the project initiated some internal collaborations with the biology department and physics department of the university in order to analyse the decay and thermal properties of HOUSE, respectively. These were entirely new internal linkages, which did not exist previously within the university (Academic professor at University A).

Likewise, ASTHMA triggered internal collaborations in some organisations. The very prominent example was the introduction of the department of computing science at UNIVERSITY B to the project. Prior to the collaboration, the respiratory department had no close ties with them. However, because systems biology and knowledge management were important aspects of the ASTHMA research agenda, the respiratory department established new linkages with them, which then resulted in their WPB leading:

> *Within here [University B], we have had great interaction with our computing people who are involved in knowledge management and that has been a great bonus for us and now, we are much more into a systems biology approach to disease, which has been a big bonus. (Academic lead of WP3)*

The same thing was found in UNIVERSITY D. ASTHMA triggered new internal linkages:

> *The project has reinforced and created new collaborations.... For example, in my case this concerns electronic nose technology, which is an instrumentation to do exhaled gas sampling from patients and examine whether the gas mixture is telling us something about the presence and severity of disease. The technical demands are such that we now collaborate with the department of analytical chemistry and other chemical and physics experts, which we did not in the past. So it has created new collaborations which are being used for other projects. So it has expanded. (The project coordinator – UNIVERSITY D)*

Although the FLIGHT consortium triggered collaborations within each partner organisation, it did not involve unprecedented collaborations internally. In COATING, the R&D department collaborated with the engineering; in BEARING, the R&D department collaborated with production, and in AIRCRAFT, the stress structure department collaborated with the R&D department, engineering department, and finance department, but these linkages were part of their routine jobs.

As findings suggest, forming entirely new internal linkages was more often seen in universities than in firms. A potential explanation for this can be that universities are structured around individual disciplines where academics work in isolation and remain constrained to their respective subject domain. In contrast to firms, which usually have a multifunctional structure and do collaborate across departments and functions in order to deliver a product or service, there is usually no need for academics to collaborate across their immediate disciplines. Yet, the inter-disciplinary nature of the examined R&D consortia, and their focus on satisfying the requirements of industrial partners, encouraged universities to form entirely new linkages. If it was not for the consortia, these internal linkages would never have been formed.

In summary, our findings suggest that adaptation is the mechanism that supports transformation. It is mainly driven by the needs and requirements that develop at the consortium but in order to be able to cope with them, individual organisations will have to develop a flexible interface to modify their existing practices, routines, processes, or linkages. It was, moreover, discussed that adaptation requires interfaces both within and between organisations so that changes can take place. Having sustained interaction with the partners and frequent interactions with internal collaborators is important for adaptation.

6.4.3.3 TRANSFERRING

6.4.3.3.1 INTRODUCTION

As discussed in 6.4.3.1, transferring deals with the mechanisms for moving from exploration phase into exploitation phase in a temporal and spatial sense. While change and adaptation are the main aspects of transformation, moving knowledge in space and time is the dominant element of transferring. Moreover, in contrast to transformation mechanisms, which mainly develop in response to inter-organisational (consortium) level stimuli, transferring mechanisms predominantly develop in response to organisational needs (e.g. a need to exploit knowledge, to expand research, etc.). However, although these mechanisms are driven by internal needs, they are not limited to intra-organisational activities and in many instances, a successful transfer starts at consortium level and continues into the organisational level.

In what follows, in two separate sections, we elaborate on articulation and socialisation mechanisms that constitute the transferring mechanisms (see Figure 13).

6.4.3.3.2 ARTICULATION

Articulation is one of the main aspects of learning in organisations. When knowledge is articulated, it becomes detached from its social context and can be accessed by the wider community. A range of observations within the three case studies suggest that articulation assisted transfer of knowledge through codification and formalisation. By codification, we mean putting knowledge in the form of documents, reports, presentations, etc. By formalisation, we mean putting knowledge in the form of instructions or manuals in order to make it routinised within organisations.

In HOUSE, the two forms of articulation were present. For ARCHITECT, calculating the embodied carbon was a new capability that they developed as a result of participating in the HOUSE consortium. Based on the techniques that they learned within the project, they developed a software package which allowed them to design and develop 3D models (formalisation):

> *In fact that [the knowledge to calculate embodied carbon] is now built into a parametric software that allows us to design and generate 3D models and produce all schedules and materials and fabrication drawings, and in that it also auto-calculates the captured carbon, and that has helped us to secure work and interest in our products with potential clients and future clients interested in their carbon footprint as well. (Director of ARCHITECT)*

Once developed into a new software package, the knowledge on calculating embodied carbon became accessible to others. Other architects could utilise the software without having detailed knowledge about how the software was developed or what were the underpinning formulas for calculating embodied carbon.

ENGINEER formalised their structural testing processes so that the rest of the company could refer to those instructions and follow the testing procedure closely. This codification helped them to eliminate their ad-hoc procedures for conducting tests because engineers could refer to the codified procedures in order to conduct their testing.

> *This project has more formalised how we do tests whereas previously it was a series of more ad-hoc tests that we were going to carry out, and getting confidence on where it is going, and now we are going to formalise that into design manuals on how everyone can take it for themselves and almost design it themselves. So it is kind of formalising a lot how research works so we can use that for further designing buildings. (Director of ENGINEER)*

As far as ASTHMA was concerned, one of the regular practices within the industry was to adopt and change SOPs and protocols that they used for conducting experiments, getting samples, handling data, etc. Accordingly, formalisation is an ongoing aspect of the pharmaceutical industry.

In addition to formalisation, other forms of articulation were used within the industry. For instance, making reports after participating in a project was one of the mechanisms to preserve knowledge for use by others within COMPANY B. In COMPANY B, people were required to write down a report upon the completion of any project. This helped the companies to retain the knowledge gained out of ASTHMA:

…it is all documented and a paper will be written… Upon completion of any study, we have to complete a report, and the report will contain full protocols, full data, full results and conclusions. [COMPANY B imaging expert]

Moreover, the virus model accompanied a number of protocols which were brought to the institute by the post-doc researcher (formalisation). The head of the Department of Airway Immunology in RESEARCH B explained:

It was one of the first projects with viral infection and we built in a new infection facility. It was a very high security level in the institute. It was one of the first projects that were really done in this new facility. So a lot of routines... how to deal with such a viral infection, things like that were established in here, based on the way COMPANY B is dealing with it.

In the FLIGHT consortium, formalisation was a significant aspect of articulation. When this study was being conducted, COATING was in the process of documenting the project findings and developing manuals for production people so that they could perform the task.

We have written details on how to handle the bearings, how to clean them, how to gig them into the chamber. We are in the process of writing down details on every aspect of how to do this process, how to produce the coatings. (R&D head of COATING)

The engineering department of COATING had also documented every detail of the software that they developed to handle the new machine. This would enable others to pick up on the details and use the software loops for other purposes in the business:

We have brought some new software loops and we can use those on other projects. It can easily be copied and pasted onto new machines... As far as the software is concerned, everything is annotated. In theory, any competent software engineer should be able to pick up the code and be able to work on it with very little concern to the company. I think everything is fairly documented. (Engineering manager, COATING)

Expectedly, codification was one of the major mechanisms for universities for disseminating knowledge. Publishing articles and reports based on their project participation and findings was one of the major forms of codification we observed in universities. These publications, however, were not predominantly limited to universities and many of them were written in collaboration with other partners. Therefore, they provided accessibility to knowledge for companies too.

In summary, articulation contributed to maintaining and preserving knowledge within companies or universities in order to make knowledge accessible to others across time and space. However, there were differences between the two forms of articulation. On the one hand, it regarded record keeping including writing reports and project summaries, publishing peer reviewed journal articles, etc. This form of articulation was passive and could not lead into exploitation without making efforts to put the project outcomes into practice. On the other hand, the other form of articulation dealt with the efforts made to ensure that knowledge is formalised so that it can be replicated in the day-to-day life of organisations. The findings suggest that the latter form is more effective in transferring as it not only gives access to knowledge, but it also provides a basis for the rest of the organisation to embed the knowledge into their routine activities.

6.4.3.3.3 SOCIALISATION

Socialisation relates to the process of transferring (tacit) knowledge through shared experience (Nonaka 1994, Jansen et al. 2005). The following section elaborates on the observed instances of socialisation.

Mobilising individuals across boundaries: Making boundaries permeable by mobilising individuals was one aspect of socialisation. One of the common findings in the three cases was mobilisation of postgraduate and post-doc students between universities and firms. Mobilisation of these individuals across organisations made boundaries permeable and expertise accessible by other organisations.

In HOUSE, the MPhil student was sent to ENGINEER for a short time. In ASTHMA, post-docs were considered important actors who facilitated transfer of knowledge across partner organisations. In WPA, a post-doc was sent from RESEARCH B into COMPANY B to learn virus modelling, and then a post-doc from COMPANY D joined RESEARCH B temporarily to learn that model and take it back. Therefore, even COMPANY D, which is a rival pharmaceutical company to COMPANY B, could access COMPANY B’s expertise through funding a post-doc within RESEARCH B which played the role of an intermediate organisation.

Such new knowledge could not be transferred in vacuum. The post-doc researcher from RESEARCH B had to be situated within Company B. When asked why she did not only ask for the manuals for conducting virus work she emphasised that such knowledge is not easy to transfer through a codified manual or a set of instructions:

> *…reproducing something that is written on paper, every scientist would laugh, or not – it's not as easy as it sounds. So, let us say, you have a recipe and you try to cook it but, always, something is like "How do you handle this?"*

Engaging in joint activities: The other aspect of socialisation related to engaging people in joint activities. In the HOUSE collaboration, socialisation was one of the main mechanisms. ARCHITECT used four forms of socialisation. First, they used what they labelled as *active secondment,* which is using job rotations for people to work on the projects related to the panel:

> *…what we call an 'active secondment' route is that people from ARCHITECT come and work inside the PANEL business on specific projects. We also jointly bid for work. …So currently we have two or three people from ARCHITECT working on PANEL projects over and above the PANEL team.*

Second, towards the end of the project, ARCHITECT employed the post-doc researcher in order to utilise her expertise:

> *What we did not want to do was to lose the benefits and so we offered her [the post-doc researcher] the opportunity to come and work with us to continue along these lines. She worked extending some of the activities that we were doing with HOUSE research, but also then worked with Mary on what it was that we were doing in generalised research as well.*

Third, they involved other employees of ARCHITECT in the HOUSE consortium by encouraging some form of engagement in research. Either they brought along some non-participants to the quarterly meetings in order to engage them with the project and make them more knowledgeable about HOUSE or they asked some people to observe and record testings. This way, they could ensure that the knowledge of the project was not limited to the official participants and was spread across the business.

Finally, they had a unique arrangement in their business to retain knowledge generated from the projects within their company. They organised internal communities in the company, each of which represented the whole business, in order to keep everyone updated about the projects the company was involved in. These communities were a mixture of people from different practices in the company. They included senior and junior architects, landscape experts, and administrators. Therefore, they formed a *slice* (ARCHITECT director) of the business in order to make sure everyone was informed about the areas that ARCHITECT was involved in.

In ASTHMA, the mobility of the workforce within companies adversely affected the transfer of the project knowledge into organisations. With the high rate of change in staff, in many cases, the opportunities for embedding knowledge within the organisations did not form. For example, COMPANY A closed down its respiratory site within the UK, assigning the Swedish site to do the research, but none of the UK participants moved into the Swedish site, leaving a hole in the company's knowledge about the research conducted within ASTHMA. In the following quote the COMPANY A representative states that it is not possible to transfer that knowledge only through exchanging data and without utilising joint engagement:

> *…If we look at what we have left out of ASTHMA, we have some data stored in various areas but interpreting that and knowing what those studies were requires the people who initially did it to say, "Yes, this, this, this and this." If those people are not available then you can't do anything but start from scratch. …so the loss of expertise and knowledge is a huge problem. [COMPANY A representative for WPA]*

Therefore, the remaining data was not useful on its own. The individuals needed to be around long enough to discuss data face to face with others, provide interpretations and engage with others in working with the data.

In the FLIGHT consortium, the importance of engaging in joint activities for transferring knowledge was evident. The participants from COATING explicated that knowledge is tacit and transferring it (especially to production) requires R&D scientists to be around enough in order to ensure the new technology becomes fully operational (Research scientist B – COATING). A similar point was raised by the R&D head of COATING:

> *...actually, if those involved suddenly disappear I think the company couldn't carry on with it. It needs us to be around long enough to transfer it into production, and to have production become skilled at carrying it out really. If we leave before then, it will be difficult for the company to carry on.*

When this study was being conducted, the R&D department of COATING was in the process of transferring the knowledge to the production department. Therefore, they needed to train operators on how to coat titanium bearings. This training, however, could not be in the form of codified instructions because it was required to be done through mentoring and jointly doing the process:

> *You can't just sit down in a room in front of the screen and explain it. You need to do that, and then you need to actually do it with them, and then have them do it while you watch, and of course put checks in place to make sure that they can check and we can check that what they are doing is producing what is required; and then, as they become experienced in it, we [R&D] can withdraw and then get on with it and if they have got any problems, they come and ask us and at that stage it will be passed over to production. (R&D head – COATING)*

The importance of engaging in joint activities for transferring knowledge was also observed within UNIVERSITY C. On the other hand, in UNIVERSITY C, as the PhD researcher was technically and operationally involved within the project, he was very knowledgeable about its technical details. However, immediately after the completion of the project, he left the university. This caused a level of knowledge loss because he was the one who had worked with the coating machines on a daily basis. Therefore, whenever he visited UNIVERSITY C, he would dedicate half a day to teach people how to work with the machines:

> *...the fact that I am not there does have some loss. Because if I am there, I can show them how to do specific tests or treatments. ...there is no one to show them - from a practical perspective, there is really no one because I was actually the person who was handling the machine. When I left, certainly there was a problem with UNIVERSITY C... Every time I visit, I spend half of my visit there training people on using this or that machine… Obviously, if I was there, much of the knowledge that I had acquired during FLIGHT would have been of direct benefit to the group. (PhD graduate at UNIVERSITY C)*

In summary, the findings suggest that socialisation mechanisms are more relevant when knowledge is tacit and contextual. In these conditions, knowledge is difficult to transfer in codified form because the more important aspect of learning lies in the meanings associated with data, manuals, or information. The case of virus work in RESEARCH B and the coating machine in UNIVERSITY C corroborate this point.

6.4.4 EXPLOITATIVE LEARNING

6.4.4.1 INTRODUCTION

The last dimension of AC relates to exploitative learning, which relates to the application of knowledge. In the following section we discuss retention and replication as the two mechanisms of exploitative learning and discuss their determinants.

6.4.4.2 RETENTION

Retention occurs when the outcomes of projects become completely operational and get embedded within the day-to-day routines of organisations.

In ARCHITECT, as constructing buildings with PANEL had become an ongoing aspect of their business, they utilised what they learned in their day-to-day business.

> *As ARCHITECT who work on PANEL-related projects, we are involved in using that product in our work. So in terms of giving us confidence to talk about this product with clients it has been fantastic. It has given us a set of results that we can volt and we can ensure clients with. It has obviously massively increased our knowledge and understanding of using straw as well, which was relevant especially when we were working in projects that involved PANEL. (Research director – ARCHITECT)*

Within ASTHMA, some organisations adopted new routines and SOPs for clinical and non-clinical data gathering:

> *We made ASTHMA our standard. So some things have changed here, and because of the project. I think this will occur in most of the institutes. Our standard operating procedures (SOPs) can also be used by other investigators in our institute, in small studies. It has really provided great benefit to harmonise the methods. (Project coordinator – UNIVERSITY D)*

The same happened in UNIVERSITY B:

> *The SOPs and the approaches we're taking have, where possible, been adopted [within UNIVERSITY B]. (Academic lead of WPA)*

In FLIGHT, when partners were asked about the ways their organisation was using the acquired knowledge, they replied that the knowledge was *embedded* or was going to be *embedded* within their organisation. This was particularly true for BEARING and COATING whose utilisation of knowledge relied on putting it into production.

> *...it is now embedded within the organisation. The actual technology which was arrived at from the collaboration is now part and parcel of the technology that this company continues to develop, continues to work on. (Technical manager of BEARING)*

For COATING, the outcome of the consortium was a number of new coating processes which were completely new to the company. Therefore, for exploitation, it was necessary not only to routinise these coating techniques within the production line, but also to ensure that the interfaces with the quality department were established appropriately and quality testing procedures were followed closely. (Research scientist B – COATING)

6.4.4.3 REPLICATION

In parallel with retention, replication constituted the other aspect of exploitation (3.4.3.4). Replication related to applying knowledge in areas that fell beyond the original purpose of the consortium. In the HOUSE collaboration, partners applied the knowledge gained from this collaboration into other applications. ARCHITECT developed capabilities to calculate embodied carbon for other projects that they commissioned.

> *…we were taking the knowledge that we learned out of this project and applying it to some other work... and in particular how we calculated the embodied carbon, and, in fact, we have been paid by clients to do that. (Director of ARCHITECT)*

They also used their knowledge about the product to apply for the next funding application:

> *We have a project in the office at the moment which is the HOUSE development [EURO] so all that background research on how to use the product is completely there. (Research director of ARCHITECT)*

UNIVERSITY A applied this knowing to inform the lectures that they gave in their courses, and to engage students in the research process which took place within the consortium. After the completion of the project, the house was used as a case study for undergraduates and students who had to model it as their coursework.

> *[For one undergraduate module a] case study [was] done within the department looking at making thermal models of the house... (Post-doc researcher)*

Replication was a mechanism for ENGINEER too. Engineers used the testing capabilities that they had developed through the HOUSE project in order to achieve a wider accreditation for their practice.

> *As structural engineering, we have to submit calculations to building control. We have a duty to care for our clients as well. We have to ensure that we have these tests carried out and these tests are partly informing part of a wider accreditation which we are applying to get for PANEL at the moment through BMTRADA[61] so we can get HBC approval and that is all part of what this research is about. (Director of ENGINEER)*

In the FLIGHT collaboration, replication was also notable. Among the commercial partners, COATING and BEARING were keen to develop a broader technology base out of the collaboration. COATING aimed to diversify the exploitation of the technology and apply it to other areas like biomedicals:

> *…we are finding that with this new coating machine we are able to address the needs of other customers and other end-users to produce even more new coatings that we weren't able to do before. (R&D head of COATING)*

In the process of developing the new coating machine, the engineering department of COATING refined and improved their prevailing control and supply power system. They developed a new software programme for controlling the machine, and introduced a new power supply system (network power supply instead of their pre-existing digital and analogue power supply systems).

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[61] A multi-sector certification body accredited by United Kingdom Accreditation Service (UKAS)

> *[We] wanted to introduce some automation to the machines as most of the machines we have on the shop floor are completely manual. We wanted to be able to introduce some control loops to make the process a little less complicated for the operators... We have now the confidence to go through that route. (Engineering manager of COATING)*

For UNIVERSITY C, there were two aspects. First, the PI used what he learned from the project as teaching material in undergraduate and postgraduate courses. Second, they utilised the credit they had gained out of this collaboration in order to apply for other grants (Project PI, UNIVERSITY C). The knowledge affected the other collaborations that UNIVERSITY C initiated:

> *Certainly the know-how helped in, for example, other projects. For instance, although not directly in UNIVERSITY C but in collaboration with UNIVERSITY C, over the last couple of years, we have been doing research that was certainly affected by FLIGHT. [For instance, using] nickel instead of titanium would need to change a lot of things but the know-how originated from FLIGHT. (UNIVERSITY C PhD student)*

For AIRCRAFT, although the technology was initially developed for the landing gears of A++, they applied the technology in other areas:

> *We have applied [the technology] to engine pile on bearings applications. …We are looking at flat bearings as well... So we have got a baseline for this coating technology. This is just one coating. We would say yes, it has got a limitation of up to that level of 150 but we would consider cropping it a little bit lower and that is why we size it.*

In summary, exploitative learning encompassed retention and replication as the two major mechanisms. Through retention, the acquired knowledge became embedded in the day-to-day work context of the organisations and through replication it became diversified across the work contexts within organisations.

6.4.5 THE ROLE OF IP

As far as the IP issues were concerned, the three cases varied with respect to the importance of IP throughout the research collaboration. In the HOUSE collaboration, concerns for IP were minimal. From the very beginning of the project, the partners did not expect any IP to arise during the collaboration (Director of ARCHITECT) because their research was less about developing new technology, product, or process, as it was about ensuring markets and complying with regulatory requirements. The only patent in the HOUSE collaboration was the one developed prior to the collaboration and was jointly owned by ARCHITECT and ENGINEER. They had filed a patent for the PANEL product which was a straw-based panel with viable thermal and physical properties.

Patenting was not an issue in ASTHMA either. There were two factors contributing to this fact. First, ASTHMA was aimed at developing a new understanding of asthma disease. The collaboration involved researching large scale data sets gathered from asthma patients and clustering those data based on the properties of data. Therefore, as ASTHMA was mainly focused on understanding the mechanisms of asthma disease – a stage far from drug development where targets are identified and potential drugs are developed – it did not involve patenting. Secondly, ASTHMA was a precompetitive collaboration which aspired to strengthen collaboration within the industry in the long run which meant transforming competition to collaboration. What counts as precompetitive has been a question in the industry. According to some researchers, the pharmaceutical industry has been redefining the boundaries between competitive and precompetitive stages in order to enable joint efforts (Barnes et al. 2009). This, in turn, means making internal knowledge publicly available in the expense of waiving the advantages of keeping it internally. Making information publicly available means that there are not any opportunities for developing patents.

Despite the two points raised above about the unimportance of IP in ASTHMA, it is worth noting that in the ASTHMA collaboration, biotechnological SMEs, which are more likely to be concerned about IP rights in precompetitive stage, did not play a significant role. This is an important aspect in discussing IP because for biotech SMEs, IP is crucial and can affect their commercial viability. In some of the other EMC projects, SMEs played a more substantial role. Therefore, speculatively, IP issues affected the way collaborations run even in precompetitive stages.

Perhaps, among the three cases in this study, IP issues were most prominent in FLIGHT. In particular, two patents were developed during the FLIGHT collaboration. First, COATING and UNIVERSITY C jointly filed and were granted a patent for a coating process called “TPO[62]”. TPO was a coating process for titanium bearings and demonstrated superior wear and thermal properties compared with other methods. Second, BEARING filed two patents for their processes; one for the improved titanium bearing coating and the other one for the aerospace bearing component. While the latter patent clearly differed from TPO, the former had some overlaps with TPO. A correspondence between the R&D head of COATING and the technical manager of BEARING revealed this problem. The correspondence showed that the two parties tried to minimise the overlap between the two patents. They agreed that while the patent for COATING was a process patent, the patent for BEARING should be filed as a product patent. AIRCRAFT did not have any contribution to the patenting process and did not file any patents in this collaboration. However, they thought that it could be better if they had jointly filed patents with COATING and BEARING who were their suppliers:

> *…a big issue would be joint patent agreement and having that established from day one. I think that was a big challenge we had originally for not getting the overall patent application for all three of us instead of BEARING doing it on their own or COATING doing it on their own. We tried, but it was difficult I think. At the end of the day it could be a big benefit for us. The problem for BEARING is that they might supply this technology to our competitors potentially. If it was a joint patent between all, then they could not sell it to competitor. (Head of the structural stress department, AIRCRAFT)*

Although partners had an agreement not to supply the technology to the competitors of AIRCRAFT, AIRCRAFT was still interested in having a joint patent because it could be much stronger for them (*Head of the structural stress department, AIRCRAFT).* Moreover, in FLIGHT, patents affected how partners collaborated. For example, it was not until COATING filed the patent for TPO that UNIVERSITY C were allowed to publish their findings about the TPO process.

Putting the evidence from the three cases together it seems that patents are likely to be important at the transformative phase (for which FLIGHT was the representative case).

[62] Triode Plasma Oxidation

For example, HOUSE was very close to commercialisation and the project was focused on 'demonstrating' how viable a panel-based construction can be which meant that inventions and patent development were less important. Conversely, as ASTHMA was in the precompetitive phase (exploratory), patent issues were not still so relevant. However, this claim should be taken into consideration with caution because, as the findings suggest, the cases had very different conditions with reference to their patenting. For example, although ASTHMA did not generate any patents, it cannot be argued that patents are irrelevant in exploratory phase of AC because it was mainly because of the peculiar features of ASTHMA – which was to understand the disease mechanisms – patents did not turn out to be important.

Finally, in line with Leiponen and Byma (2009) and Arundel (2001), we found that when appropriation of new knowledge is crucial (as it was in FLIGHT), following a secrecy strategy was dominant. However, our findings suggest that in R&D consortia, secrecy can be used as a complement, and not a substitute, for patenting. In FLIGHT, in the beginning, partners followed a secrecy strategy through agreements and through limiting university partners in their publications until they filed and were granted patents.

6.5 AN EXTENDED MODEL OF ABSORPTIVE CAPACITY IN R&D CONSORTIA

6.5.1 INTRODUCTION

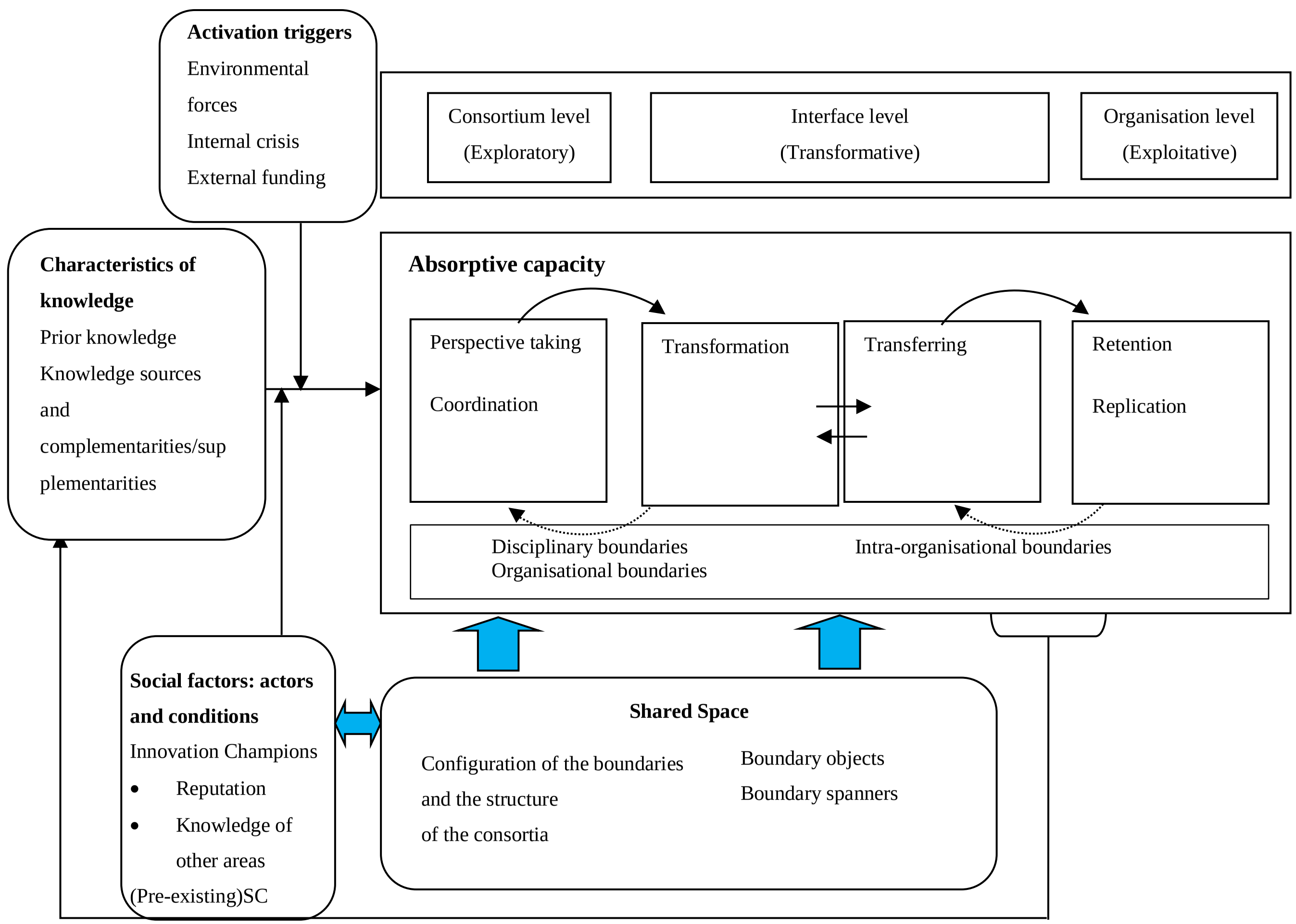
Thus far, we have discussed the elements of AC based on Lane et al.'s (2006) model with the three mechanisms of exploratory, transformative, and exploitative learning. By deploying a practice lens and examining the boundaries that were involved in R&D consortia, we analysed the findings across the three case studies. We identified the underlying mechanisms of AC and discussed the preconditions of the formation of R&D consortia.

In this section, we provide an overview of these findings and explain how the various elements of the study link together to form a bigger picture (see Figure 14). In this way, we refine and enrich the theoretical framework presented in chapter 3 (Figure 4).

In the remainder of the chapter, we go through the elements of the model and discuss the causalities between its constituents in detail. Section 6.5.2 discusses the role and importance of the characteristics of knowledge, section 6.5.3 reviews the role of activation triggers, section 6.5.4 explores the role of innovation champions and (pre-existing) SC and CoPs in the formation of consortia, section 6.5.5 discusses the mechanisms that constitute AC in R&D consortia, section 6.5.6 reviews the importance of the formation of shared space in AC in R&D consortia, and section 6.5.7 elaborates on the importance of individual organisations across the phases, classifying them according to their contribution to AC.

Figure 14 unpacks the variables within the model and portrays the constituents of AC in more detail. It presents AC as a linear sequence of three learning macrophases (exploratory learning, transformative learning, and exploitative learning) unfolding at three different levels (consortium, interface, and organisation). Although the sequence of the phases is presented linearly, the process is likely to proceed in multiple iterations both across (as indicated by (dotted) arrows) and within phases (not illustrated in the figure for simplicity). Moreover, while the figure suggests that there are three separate levels (consortium, interface, and organisational) and learning phases (exploratory, transformative and exploitative), levels and phases have overlaps in reality, and the separations made in the figure are only for simplicity's sake.

FIGURE 14: AN EXTENDED MODEL OF AC IN R&D CONSORTIA



6.5.2 CHARACTERISTICS OF KNOWLEDGE

In the literature review chapter, we discussed that the AC literature is significantly influenced by a cognitive approach to knowledge and learning referred to as the *epistemology of possession* (Cook and Brown 1999). We then speculated that a practice approach with a closer attention to boundaries would offer a more compelling account of AC. The finding suggested that a practice approach can only complement the extant cognitive view but cannot fully replace it. In particular, it was found that characteristics of knowledge (prior knowledge, and knowledge sources and complementarities/supplementarities) are important preconditions for R&D consortia formation and AC. A practice approach was more useful in order to understand the dynamics across boundaries and the ways contextualised knowledge can be 'absorbed'. In what follows, we discuss the role of prior knowledge and complementarities/supplementarities which are the main elements of the cognitive view.

Prior knowledge: Our findings indicate that the constituents of the cognitive approach to AC do play a role. In particular, we found that prior knowledge determines the direction of organisations' future inquiries or the choice of collaboration partners in the formation of R&D consortia. In all three cases, prior knowledge facilitated the commencement of R&D consortia which is in line with the Cohen and Levinthal's (1990) and Zahra and George's (2002) argument that pre-existing knowledge affects the direction of future knowledge acquisitions by AC.

Complementarities/supplementarities: In line with a number of scholars (Zahra and George 2002, Todorova and Durisin 2007), we found that complementarities (dissimilarity of resources) between the knowledge sources have significant impact on the choice of partner organisation. We found, moreover, that in addition to complementarities, supplementarities (similarity of resources) (Das and Teng 2000) can play a role in formation of R&D consortia. Our findings suggest that supplementarities can play a role in the formation of R&D consortia when the purpose of R&D collaboration is to achieve economies of scale and to avoid redundancies. Among the three cases, ASTHMA demonstrated a degree of supplementarity because, for the EFPIA partners (pharma companies), the main reason behind the collaboration was to reduce costs for research and to share risks in the long run. In general, complementarities formed around disciplinary and university-industry boundaries while supplementarities formed by connecting partners in similar disciplines from different companies.

6.5.3 ACTIVATION TRIGGERS

In all cases, activation triggers consisted of environmental and regulatory forces, internal crisis, and external funding. In line with previous studies (Kim 1998, Zahra and George 2002, Todorova and Durisin 2007), we found that activation triggers affect the development of AC through encouraging the formation of collaborations. The formation of the research consortia was facilitated by the existence of external stimuli or internal crisis which encouraged partner organisations – individually or collectively – to embark on collaborations. The pressure to have innovations and to comply with the standards of the industry in HOUSE and in FLIGHT forced partner organisations to form consortia. For ASTHMA, the diminishing returns of R&D investments were the main element that pushed the pharmaceutical companies to form the R&D consortia. Therefore, it was an internal trigger at the industry level.

In particular, funding bodies played an important role in determining the research area, the composition of partners, and the governance of consortia. HOUSE and FLIGHT were co-funded through the R&D collaborative scheme of TSB. TSB identified the areas of research with high priority, encouraged public-private R&D collaborations, and one of its funding conditions was that collaborations should involve academic and industrial partners. ASTHMA was part of a European initiative (EMC) which was sponsored by EFPIA – the federation of large pharmaceutical companies – and the European Commission. EMC aimed at fostering public-private partnerships to enhance knowledge transfer and co-creation in life sciences and EFPIA, as one leg of the funding, would identify the areas of significance for the industry. One of the important features of EMC was the opportunities it offered for collaboration between large pharmaceutical companies. Without the initiative it would be impossible for pharmaceutical companies to engaging in collaboration with their rivals. As discussed, the presence of public organisations facilitated the interactions between large pharma companies.

In the case studies, we found that the governance[63] of the consortia affected the development of AC and the success of the consortia. The governance of a network determines how resources are managed and how individuals are mobilised throughout the collaboration. Since HOUE and FLIGHT were cofounded by TSB collaborative R&D scheme, they offered rather similar governance structures. The TSB procedures for collaborative R&D projects were standardised and the decision making processes and the way the consortia were administered were similar. In these consortia, partners were required to hold quarterly meetings in which each partner presented their findings and progress. They were moreover required to develop reports for each quarterly meeting. The manager of the consortia was also required to give presentations about the overall progress of the consortia, the milestones and the steps that had to be taken. Moreover, to ensure the progress of the consortia TSB would have a monitoring officer present at quarterly meetings. Once the projects finished, the contributing partners were required to write a full report of their achievements in the project, the way it helped their business and their plans for further exploiting the technology.

ASTHMA was rather different. The governance of the consortium had different levels. First, each WP had its academic and industrial lead. Then, there were a management board consisting of three EFPIA and three non-EFPIA members, and a scientific board comprising the leaders of WPs who reported to the management board. Finally, at the highest level, the consortium was monitored by the EMC's governing board and scientific committee. Therefore, only one of the funding legs had direct role in monitoring the collaboration. Unlike EFPIA who had representatives at the operational level (e.g. industrial leads at WPs), European Commission did not have any representative to monitor the collaboration at that level. Thus, the TSB funding body seemed to be more involved in monitoring the governance of the consortia compared with EC in ASTHMA. This had pros and cons. On the negative side, TSB collaborations entailed a degree of unnecessary bureaucracy which could become counter-productive at times. On the positive side, the fact that TSB projects were

[63]Here we refer to governance in terms of the way a consortium is being managed and decisions are made. We do not use governance to refer to choices between equity-based and non-equity-based collaborations as the three R&D consortia are co-funded R&D collaborations.

monitored very carefully enhanced their delivery of their milestones and timely completion of the projects.

In sum, not only funding bodies facilitated the formation of the consortia by allocating funds for collaborations but they also did determine the area of research, the governance of collaborations, the composition of the partners, and the way they were being managed. These aspects affected the development of AC within R&D consortia by facilitating knowledge exchange among partners, increasing the level of trust and incentivising the development of shared space (which will be discussed in 6.5.6).

6.5.4 SOCIAL FACTORS: ACTORS AND CONDITIONS

Innovation champions: Innovation champions played a significant role in the formation of R&D consortia. All three cases benefited from the presence of individuals who were capable of initiating the research ideas and searching for connections across various disciplines and organisations. Not only were these individuals knowledgeable about the area that they belonged to, but they also had the reputation, legitimacy, and prior linkages to initiate the collaborations. The roles of the director of HOUSE, the R&D head of COATING and the academic and industrial coordinators of ASTHMA were significant in the formation of R&D consortia.

Pre-existing CoPs: The pre-existing CoPs were influential both in formation of R&D consortia and in advancing the research in later phases of the collaborations as they had vested interest in the knowledge domain which could facilitate learning within the R&D consortia. The CoP of respiratory experts in ASTHMA, the CoP of surface engineers in FLIGHT, and the CoP of alternative material experts in HOUSE enthusiastically engaged in research in the R&D consortia.

These findings illuminate the role that CoPs can play beyond their organisational territory. Although existing literature highlights the importance of CoPs to learning and innovation within organisations, there have been fewer studies exploring the role of CoPs across organisations. Being highly driven by in-depth analysis of organisational contexts, features of *habitus* (Bourdieu 1977), and cultures (Orr 1990, Cook and Yanow 1993, Weick and Roberts 1993), CoP theorists (or those who adhered to the practice theory) had predominantly focused on learning context within organisations (Brown and Duguid 1991, Boland and Tenkasi 1995, Wenger 1998, Gherardi and Nicolini 2002, Bertels et al. 2011). This, in turn, implies that CoP researchers, or practice theorists, have been less focused on the ways external knowledge can be acquired from the environment. Our findings add to the current debates about the CoPs and their role by demonstrating how they can assist organisations in identifying new opportunities for research and learning across organisations and their contribution to the formation of R&D consortia.

Pre-existing SC: Our findings, moreover, demonstrate the importance of pre-existing SC in the formation of R&D consortia. In all three cases, a subset of partners had worked together previously, developed trustworthiness towards each other, and had defined mutual expectations before the collaboration started. However, as discussed, the level of SC varied across the three cases. The HOUSE consortium had the highest level of pre-existing SC with partners already collaborating on a preceding consortium and having long-lasting relationships. FLIGHT ranked second as SC had developed at dyads prior to the collaboration but not at a shared level across all partners. Finally, being a large-scale collaboration, ASTHMA possessed the lowest level of pre-existing SC as the academic partners and industrial partners had not had much interaction hitherto. Lower levels of pre-existing SC entailed difficulties in running the consortium during the initial phases.

These findings illuminate the role of SC in the development of AC. The importance of socially enabling mechanisms in transferring and circulating knowledge among people within organisations has been discussed by AC researchers (Zahra and George 2002, Jansen et al. 2006). However, as Todorova and Durisin (2007) proposed, these mechanisms can be equally effective in recognising external knowledge because, through mobilising social capital, actors can also identify knowledge in their environment. Our findings validate Todorova and Durisin’s (2007) proposal that social ties facilitate recognising knowledge.

At the same time, however, our findings challenge the ultimate effectiveness of SC because we found that substantially developed SC can lock partners into a set of familiar collaborators hampering their abilities for searching and identifying new partners. Although highly developed SC facilitated starting collaborations, the higher levels of SC were found to be accompanied by risk averseness and lack of novelty. The pre-existing relations in HOUSE resulted in partners' not searching for new collaborators and tapping into new areas of research. Conversely, the ASTHMA consortium offered a lot of opportunities for learning and novelty due to the absence of pre-existing SC in many areas. However, underdeveloped SC meant that partners had difficulty during the early stages of consortia for effectively collaborating and sharing knowledge. Thus, our findings suggest that a threshold level of pre-existing SC is needed for starting an R&D consortium. If pre-existing SC is too underdeveloped, there will be problems in identifying new knowledge domains and potential partners. Conversely, if SC is highly developed, there will be a risk of involving some partners who do not necessarily contribute to the consortium.

Our findings, moreover, shed light on some doubts cast in the literature about the effectiveness of pre-existing ties in the development of partner-specific AC (Hoang and Rothaermel 2005, Zaheer et al. 2010). For example, examining the context of pharma-biotech collaborations, Hoang and Rothaermel (2005) found that pre-existing ties do not translate into higher levels of (partner-specific) AC. Our study offers an explanation for this phenomenon by proposing that strong pre-existing relations (SC) can contribute to the development of AC only if they offer learning opportunities (through inter-organisational CoPs). Hoang and Rothaermel (2005) had focused on pharmaceutical-biotech collaborations which are mainly task-based collaborations in which partners work independently, that is, biotech SMEs develop a new product and pharmaceutical companies use it commercially without engaging in collaborative work. In these conditions, the developed SC intensifies the work specialisation and separation, and hampers engagement in joint projects since parties trust each other and know how to work in isolation. As a result, AC suffers because there are no grounds for acquiring knowledge. Thus our findings suggest that pre-existing SC contributes to the development of AC if it is accompanied by the opportunities for learning developed through the formation of inter-organisational CoPs.

6.5.5 ABSORPTIVE CAPACITY

Our analysis of AC focused on disciplinary, organisational and intra-organisational boundaries and the way they can be bridged in throughout the R&D consortia lifecycle. We analysed the three dimensions of AC (exploratory, transformative, exploitative) and examined their underlying mechanisms as well as their inter-relations.

Exploratory learning: The exploratory learning dimension of AC, according to Lane et al.'s model (2006) (which we adopted in this study), enables recognising the value of external knowledge (Cohen and Levinthal 1990, Todorova and Durisin 2007, Lewin et al. 2011) or acquisition of new knowledge (Zahra and George 2002). Our findings demonstrate that at the exploratory learning phase, perspective taking and coordination at organisational and disciplinary boundaries are the two most important aspects of AC within R&D consortia which predominantly develop at the consortium level. We foud that perspective taking (Boland and Tenkasi 1995) allows partners across organisational and disciplinary boundaries to empathise with the limitations, constraints, and pressures that *others* experience, making them receptive to buy in contrasting attitudes. We found, moreover, that coordination constitutes another aspect of exploratory learning. Coordination mechanisms facilitated effective communication and collaboration across organisational and disciplinary boundaries without transforming or changing the prevailing state of the boundaries (Akkerman and Bakker 2011). Across disciplinary boundaries, coordination entailed deploying translative efforts and across the organisational boundaries, it entailed making the interests of partners aligned.

Our findings complement the existing body of knowledge by enriching our understanding about the ways through which external knowledge can be identified. First, the existing literature mainly focuses on search routines for identifying new knowledge. While we agree that search is an important aspect of AC (as it was in our cases when partners were looking for partners to form a consortium or to find a specific technique in solving a problem), we maintain that it is mainly useful in the initial steps of identification of external knowledge and usually when knowledge is decontextualised or not vested in practice. When knowledge becomes contextual, as our cases suggested, 'meaning' can become contested across disciplinary and organisational boundaries rendering search mechanisms blind to identifying new knowledge as they cannot detect the differences in meaning. For example, what "research" meant in industry was different from what it meant in academia. Similarly, the meaning of “data” was different for statisticians compared with biological scientists. While the former group expected large scale data sets, the latter could only produce limited data out of an experiment which took about two weeks. Therefore, in these conditions, search mechanisms per se do not assist identification of external knowledge simply because the subtle differences in meanings are not identifiable through search routines. By discussing perspective taking, our study offers a complementary mechanism to search which is important when meanings vary.

Our findings complement the existing research on AC by explicating the role of coordination mechanisms in the exploratory phase. The importance of coordination has been highlighted by some authors in AC research (Van den Bosch et al. 1999, Jansen et al. 2005) who assert that coordination capabilities (cross-functional interfaces, participation in decision making, and job rotation) contribute to AC. However, while their focus is on intra-organisational coordinative capabilities, we found that coordination capabilities are just as important in inter-organisational relations, and that they co-develop with perspective taking. Through perspective taking, partners find out their differences and develop strategies to manage those differences through coordination. On the other hand, coordination mechanisms reinforce perspective taking by facilitating interactions between partners.

Transformative learning: Following Lane et al. (2006), we defined transformative learning as the mechanism for assimilating new knowledge. According to our findings, transformative learning comprised two facets primarily developed at the interface level. On the one hand, it involved transformation, which entailed the changes made to cope with the requirements of the consortium. On the other hand, it included transferring mechanisms, which enabled transfer of knowledge between partners within the consortium and to the broader context of individual organisations.

As for transformation, the more important aspects related to changing the existing practices and structures in order to ‘adapt’ with the requirements of the consortium. Among the three R&D cases, FLIGHT and ASTHMA demonstrated a higher level of adaptation when the collaboration was running than the HOUSE consortium. A possible explanation for this could be the novelty of the collaboration. FLIGHT and ASTHMA were more novel collaborations, which incurred significant changes on the collaborating partners, compared with HOUSE. Therefore, transformation was a significant aspect in FLIGHT and ASTHMA. However, in HOUSE, the product was very mature and close to the market. Therefore, the partners could collaborate and exchange knowledge without significantly changing their existing structures, practices, etc. This finding suggests that transformation is a contingent dimension of AC. In the contexts with lower levels of novelty, there is less need for significant transformation of existing practices within organisations. In these settings, the transformation phase is bypassed and partners exchange knowledge without notably altering their ways of doing things. Conversely, in more novel contexts, transformation becomes an indispensable aspect of AC.

This finding contributes to our understanding of ‘transformation’ mechanisms in AC literature which is a rather contested dimension (Todorova and Durisin 2007, Sun and Anderson 2010, Lewin et al. 2011). Zahra and George’s formulation of transformation is based on the knowledge content, i.e. they argue that transformation relates to combining new knowledge with existing knowledge. However, as discussed, we maintain that the more relevant aspects of transformation relate to modifying the prevailing boundaries and practices. This argument is in line with Todorova and Durisin’s (2007) proposal that the transformation dimension of AC only operates when existing structures are unable to absorb new knowledge but adds to it by stating that transformation not only happens through change in structures but also through changes in existing practices and routines.

The findings also suggest that transferring mechanisms constitute an important aspect of transformative learning. Transferring mechanisms facilitated knowledge exchange among partners and into the wider context of individual organisations. We found that transferring consists of socialisation and articulation mechanisms. Socialisation relate to the process of transferring (tacit) knowledge through shared experience (Nonaka 1994, Jansen et al. 2005), while articulation relate to the efforts organisations made to codify and/or formalise knowledge. Socialisation was particularly useful when knowledge was contextual and situated. For example, mobilising researchers among partner organisations in order to gain knowledge from each other or conducting joint activities to make knowledge accessible across the wider context of individual organisations supported socialisation. These mechanisms were also important in internalising the knowledge within the individual organisations because when the research consortia were approaching their last phases and research outcomes were being finalised, the individual organisations could transfer the knowledge into their wider work context. As the findings indicate, limited transferring capability is detrimental to AC because the knowledge will be lost without being sufficiently internalised by the partner organisations.

The findings, moreover, suggest that articulation constitutes the other side of transferring. We found, however, that not all forms of articulation are equally useful. Organisations that formalised their consortium experience into models, SOPs, and procedures, which were routinely used afterwards, were more likely to exploit that knowledge compared to those who prioritised codification in the form of reports, presentations, etc. One explanation can be that formalisation facilitates reproductions of knowledge within organisations, which is the basis for actors' participation in the knowledge (re)creation process. Therefore, articulation is an important mechanism for internalising knowledge not only through its outcomes (like reports, minutes, articles, presentations, etc.), but also through the process of formalising in the forms that can be later routinised within organisations.

Finally, we ascribed the development of transformative learning to the interface level because it related to the interactions that take place at the interface of organisation and consortium. It was not a purely organisation-level dimension because it related to interacting with the consortium-level requirements, and it was not a purely consortium-level dimension because it related to the ways that organisations mobilised their resources to participate in collaborations and to internalise the knowledge.

Exploitative learning: Following Lane et al. (2006), we defined exploitative learning as the ability to use assimilated knowledge and to create new knowledge and outputs. Our findings suggest that exploitative mechanisms mainly involve retention and replication which develop at the organisational level. Retention regards embedding knowledge within the day-to-day practices of organisations. This is the final stage for application of knowledge when it becomes stored in collective routines in organisations (Zollo and Winter 2002, Jansen et al. 2005) which can be in the form of operational routines or artefacts that are used as the outcome of collaboration. In

HOUSE, ARCHITECT used the research outcome to inform the marketing of the product; in FLIGHT, COATING and BEARING embedded the outcomes in their production line; and in ASTHMA, partner organisations started to globalise the SOPs and research methodologies across their organisations (although ASTHMA was at its midlife point when this research was being conducted).

In addition, exploitative learning involved replication. Our findings suggest that the very application of knowledge across various contexts within organisations inspires opportunities for new forms of knowledge to emerge, which may be far from the original usages of the absorbed knowledge. We labelled this aspect of AC within our analysis ‘replication’ and we found that replication diversifies knowledge application within organisations. In HOUSE, the developed 3D carbon calculation software assisted ARCHITECT to give service to their clients in areas which were different from PANEL-related products, and in FLIGHT, we found that the research findings led into exploring the appropriateness of the new treatment technique for medical devices. Our findings suggest that replication depends on the managerial efforts made to explore the possibilities of applying knowledge to different areas, and to utilise cross-functional interfaces.

6.5.6 SHARED SPACE

Our analysis suggests that AC in R&D consortia relies on the development of what we labelled as ‘shared space’. We defined ‘shared space’ as the conditions that cultivate the opportunity for participation across organisational and disciplinary boundaries in pursuit of shared meaning and joint interpretations.

The bottlenecks for collaboration were across disciplinary and organisational boundaries within R&D consortia because of the differences in languages, meanings, interpretations, and interests across those boundaries. Opening up the bottleneck, at least, necessitates developing shared language in less complex situations and developing shared methods, practice, procedures, etc. in novel contexts. Shared space, therefore, was needed to provide the conditions for overcoming the differences. It transcended the boundaries of individual organisations, providing the opportunity for partners to participate, and to tap into the joint effort, in order to interact, exchange, translate, and transform their knowledge. Shared space provided the participants with a locally developed means of identifying differences and negotiating solutions, especially in the highly complex context of R&D consortia.

The idea of shared space resonates with the notions of trading zones (Kellogg et al. 2006) and joint fields (Levina and Vaast 2005) in the existing literature. Kellog et al. (2006) discussed how shared space (trading zone in their language) cultivates a basis for interaction and knowledge transfer when values, norms, interests, and languages differ or how it helps with identifying and confronting divergent areas and bringing the possibility for adaptation in practices (O'Mahony and Bechky 2008, Mørk et al. 2012). Similarly, Levina and Emmanuelle (2005) discussed that the emergence of joint fields enables actors to develop mutual interest while protecting their distinct organisational interests. However, while trading zones refer to 'coordination structures' and 'joint fields' to the joint context of practices and the symbolic capital that actors can mobilise across those contexts, 'shared space' relates to the opportunities that actors are given to participate and learn, which is in line with the practice-based theorising that views learning as a form of participation in the social world (Wenger 1998, Handley et al. 2006). Bellow, we discuss the main features of shared space.

Configuration of boundaries and the structure of consortia: The findings suggest that when only one of disciplinary or organisational boundaries is present, chances are that shared space forms more easily. In other words, organisational boundaries weaken in the absence of disciplinary boundaries. If a consortium is vertical, the formation of shared space will be difficult as disciplinary boundaries will add to organisational ones. Conversely, if a consortium is horizontal, then the formation of shared space will be easier because lack of disciplinary boundaries facilitates bridging the organisational ones.

The three researched cases varied with respect to their consortium structures. While ASTHMA and HOUSE were rather horizontal collaborations, FLIGHT was vertical. In FLIGHT, both disciplinary and organisational boundaries were present. In ASTHMA, owing to its horizontal configuration, the domains of expertise were not drastically different, which meant that fewer efforts were needed to harmonise the collaboration during the early phases of the consortia. The absence of disciplinary boundaries within WPs in ASTHMA facilitated the interactions between the consortia participants.

Apart from the disciplinary differences, there is another problem associated with vertical collaborations. Our findings suggest that vertical collaborations can involve power asymmetry across organisational boundaries. When collaborations are horizontal, each partner can exert limited control over the others due to lack of resource dependence. However, in vertical collaborations, end users in the supply chain have more control over the others (Christensen and Bower 1996, Danneels 2003). If one partner possesses more power over the others, the potential for tensions increases as there is less willingness from the powerful partners to empathise with the others. On the other hand, although the overruled partners may abide with the requirements of the powerful partner, they are not likely to take perspectives, mutually negotiate meanings, and interact empathically. Therefore, when power relations are asymmetric, the likelihood of the formation of shared space will decrease. Among the three R&D consortia, FLIGHT demonstrated asymmetrical power relations while in the two other consortia, power relations were rather symmetrical. As discussed, the asymmetric power relations in FLIGHT adversely affected the development of shared space as all partners had to comply with AIRCRAFT's requirements categorically.

Therefore, our findings further refine the understanding about the role of power in AC. While the role of power has been discussed in some of the contributions in AC embryonically (Todorova and Durisin 2007, Easterby-Smith et al. 2008a), we add to this aspect of AC research by suggesting that it is through destabilising/stabilising shared space that power relations affect the development of AC.

We, moreover, found that the governance[64] of the networks and the way they were organised mattered in the development of shared space. One particular aspect of the governance in ASTHMA impeded the formation of shared space. In ASTHMA, and in EMC in general, pharmaceutical companies were not committed to sustaining their participation in the consortium. Therefore, industrial partners could withdraw at any point or shift their human resources contribution to the collaboration which resulted in rapid and constant change in the configuration of the consortium. Such a rapid change impeded the development of shared space as partners had to develop mutuality and trust and update the newcomers following each alteration.

There was another aspect regarding the governance of the consortia. The governance of the three cases facilitated movement of researchers between university and industrial partners. As discussed, in ASTHMA, partners could utilise this mechanism more frequently and post-doc researchers could move between companies, research institutes, and universities. This in turn led to research institutes playing an intermediary role for transferring knowledge between companies. Moreover, research institutes offered the hosting of sensitive data from rival pharmaceutical companies, hence the reason we labelled this specific role of research institutes 'trust hubs'.

In summary, we found that the governance of networks played a significant role in the development of shared space through regulating the frequency and type of interactions between the consortia partners, through facilitating the movement of participants across different organisational contexts, and through affecting the stability of the arrangement and configuration of the consortia partners.

Boundary spanners: The findings of the study revealed that boundary spanners significantly contribute to the development of a shared space. They facilitated interactions among partners and assisted the transfer of knowledge. The post-doc researcher in the HOUSE consortium and the representative of COMPANY C in ASTHMA were the two boundary spanners who had intense interactions with multiple partners. In FLIGHT, although there were interactions between partners, we did not observe a dedicated boundary spanner.

We found that the role of boundary spanners excel their ability to transfer and exchange knowledge across organisational boundaries. Above their ability to transfer and translate knowledge across boundaries, the boundary spanners had the ability to participate in different communities and to establish legitimacy within those communities.

This finding is in line with the recent developments in AC literature that highlight the role of boundary spanners in AC beyond their information processing role. Although Cohen and Levinthal (1990) had discussed the role of boundary spanners in AC, their primary focus was on transmitting and transferring the information from outside the organisation. Recently, some authors have paid attention to the other characteristic of boundary spanners by exploring the capabilities that they demonstrate to bridge the organisational and disciplinary boundaries. For example, Jones (2006) found that boundary spanners link organisations with the external knowledge environment through using their individual agency and through accumulating legitimacy across communities. Similarly, Easterby-Smith et al. (2008b) demonstrated how the agency of boundary spanners and their power relations affect the identification of external knowledge.

Boundary objects: The other key factor in the development of the shared space was the deployment of boundary objects (Star and Griesemer 1989). We defined the boundary objects as the plastic artefacts that “inhabit several intersecting social worlds and satisfy the information requirements of each of them” (Star and Griesemer 1989 p.393). According to Carlile (2002), a good boundary object contributes to the development of a shared language, facilitates identification of differences across the boundaries and, eventually, contributes to the transformation of knowledge across different contexts. Therefore, by providing a cross-boundary means for interpreting and applying knowledge, boundary objects attenuate the potential resistance of actors to engage and interact with each other.

In our research, two sets of boundary objects were found as important. The first set of boundary objects were mainly utilised in order to connect people to each other. They included emails, phone calls, TCs, shared databases, etc. which mainly assisted communications between partners without significantly affecting the meanings and languages across boundaries. A second group of boundary objects contributed to marking the differences in meanings across various boundaries and to providing joint interpretations. In the HOUSE consortium, the house itself, through which both academic and industrial partners represented their knowledge in a way that could eventually lead into consensus, played a key role in the development of the shared space. In ASTHMA, the models (for disease and virus), SOPs, and the data analysis software, which acted as the interface between biological scientists and statisticians, facilitated crossing organisational and disciplinary boundaries. Finally, in FLIGHT, site visits and the test samples contributed to the development of shared interpretations and joint goals. Test samples were important for knowledge exchange as partners discussed interpretations of the test results when they talked over samples. Site visits were equally important as they enabled partners to get an appreciation of how different partners vary in their focus, requirements, etc. (perspective taking). They especially helped in understanding why AIRCRAFT were so restricted and rigid in their focus and their desired research direction.

We are not the first to recognise the importance and role of boundary objects in collaborative work processes. The findings of this study are in line with the various scholarly studies which have explored the role and importance of (boundary) objects (Boland and Tenkasi 1995, Carlile 2002, Oborn and Dawson 2010, Nicolini et al. 2012). However, while existing research has been more focused on the role of boundary objects within multidisciplinary work environments, this study specifies that boundary objects can be as important for bridging organisational boundaries within R&D consortia since they can facilitate perspective taking, coordination, and transformation across organisational boundaries.

6.5.7 INDIVIDUAL ORGANISATIONS

As consortium was the unit of analysis, the main focus of the thesis was on R&D consortia instead of individual organisations. Therefore, we did not explore the role of individual organisations within R&D consortia to their merit in the above sections. However, various organisations played different roles in the development of AC in R&D consortia. Together with the previous sections in which we developed a model of AC in R&D consortia, this section provides a complementary account of why and how AC is affected by individual organisations within R&D consortia.

As indicated in Table 8 and Table 15, the significance of organisations across the three phases of AC varied. Some organisations were actively engaged in all dimensions of AC, and others only engaged minimally across the three phases. The former group had strategic interest in the collaboration and actively sought to turn knowledge into application, while the latter group mainly participated to only accomplish their tasks and to observe the collaboration.

Individual organisations had different drives for participating in the consortia and different capabilities to contribute to them. Therefore, it is important to see how and why they were different and how these differences affected the collaborations. This is especially important in our analysis as individual organisations considerably affect the transformative and exploitative dimensions of AC.

Our analysis suggests that the organisations which participated in the R&D consortia can be grouped into innovators and scanners. Table 19 presents a classification of organisations in the R&D consortia. Among the firms, innovators had certain features with respect to their contribution to the R&D consortia and their AC. As regards the purpose of participation, innovators were the ones with the motivation to beat the competitors and to create new knowledge. Participating in collaborative research enabled these firms to gain competitive advantage over their rivals, either through excelling over others with their enhanced level of knowledge or through closely collaborating with customers/end users (e.g. ARCHITECT and COATING). Conversely, the scanner firms were less driven by competitive forces and their primary focus was to keep their knowledge up to date within the industry (e.g. RENDER and CONSTRUCTOR). Among academic partners, scanners primarily joined the consortia in order to keep up to date with the leading-edge knowledge (RESEARCH A), while innovators endeavoured to promote their school of thought and to establish long-term relationship with the industrial partners (e.g. UNIVERSITY A and UNIVERSITY C).

TABLE 19: SCANNERS AND INNOVATORS AMONG FIRMS

	Scanners		Innovators	
	Firms	*Academics*	*Firms*	*Academics*
Purpose of contribution	Keeping up to date with leading-edge knowledge	Keeping up to date with leading-edge knowledge	Beating the competitors Complying with standards and regulators' requirements Complying with end users' needs	Developing and promoting their school of thought and research interests Establishing long-term relationship with industry
Building external linkages	Maintaining linkages within industry	Being part of the research community	Becoming prominent player Developing joint capabilities	Enhancing reputation within industry and academia Expanding industrial network
Scope of contribution to the project	Short-term: Task accomplishment	Short term: Task accomplishment – Projects as funding source	Long-term: Project as part of a bigger innovation trajectory	Long-term: Enhancing knowledge in the respective research domain – Project as the opportunity to get to real world
	Deployed AC mechanisms			
Level of transformation	Low	Low	High	Medium
Transferring mechanism	Mainly codification	Mainly codification	Mainly formalisation and socialisation	Mainly formalisation and socialisation
Usage of exploitative mechanisms	Low	Low	High	High

As regards building external linkages, the first priority for scanner firms was to *retain* their linkages within the industry, whereas the first priority for innovators was not only to become a prominent player in their industry, but also to develop joint capabilities which they could exploit collaboratively later. Among academics, scanners sought to remain part of the research community, while innovators focused on enhancing reputation both within industry and academia and on expanding their linkages.

In the same way, the scope of contribution was different for scanners and innovators. Although we focused on research consortia, which inevitably have a given project lifetime, different partners pursued long-term or short-term goals out of the collaboration. For scanners, the scope of the collaboration was limited to the project lifecycle. Once they finished the task, there were not many other issues to explore.

Conversely, innovators pursued long-term objectives out of the collaboration. For them, the research consortia constituted only a part of their wider innovation trajectory which they would follow at later stages and outside the consortia.

The participating organisations also varied with respect to their level of transformation. We found that innovators were more likely to change their existing processes, procedures, routines, etc. in response to the adaptive pressures imposed by consortia whereas scanners were not and did not have to be as flexible because their objective was not to embed the knowledge generated within the consortia into their business.

Finally, we found that scanners and innovators deployed different transferring mechanisms. For scanners, the main mechanisms for transferring, if any, included articulation usually in the form of reports, published articles, project briefings, etc. and it rarely involved formalisation of new processes or routines within the organisations. Conversely, innovators deployed a more diverse portfolio of mechanisms for internalising knowledge. They used both socialisation and articulation mechanisms.

In general, the differences between individual organisations affected the transformative and exploitative dimensions of AC. Innovators were more likely to have transformations and to use formalisation mechanisms for internalising the knowledge obtained from the consortia, whereas scanners were less inclined to apply knowledge as a part of their day-to-day processes and routines.

6.6 CONCLUSIONS

In this chapter, we presented the findings of the case studies by applying the theoretical framework developed in chapter 3. However, through analysing the data, we further refined and enriched the theoretical framework, and developed a new model which we presented in Figure 14. In this chapter, we first investigated the various boundaries that were present in the R&D consortia. Then, replying to the second research objective, we discussed the formation preconditions of R&D consortia in 6.3. In 6.4, replying to the first research objective, we analysed the dimensions of AC in R&D consortia, and in 6.5, we presented an extended model of AC in R&D consortia where we discussed how findings related to the extant literature.

The main findings of the chapter include:

- We found that activation triggers, knowledge complementarities and supplementarities, innovation champions, and (pre-existing) SC and CoPs affect the formation of R&D consortia.
- We examined and analysed the dimensions of AC. We found that the exploratory dimension of AC relates to perspective taking and coordination and mainly unfolds at the consortium level, the transformative dimension relates to adaptation, articulation, and socialisation and mainly unfolds at the interface level, and the exploitative dimension relates to retention and replications and mainly unfolds at the organisational level.
- Viewing formation of R&D consortia beyond a single point in time, we found that the emergence of shared space is an important factor in facilitating collaboration in the long run. We discussed that the development of shared space depends on the configuration of boundaries and the structure of the consortia, and the presence of appropriate boundary objects and boundary spanners. We found that the emergence of shared space contributes to AC through facilitating perspective taking and coordination in the exploratory phase, and through accelerating adaptation, articulation and socialisation in the transformative phase.
- We found that there is a direct relationship between the formation of a shared space and the ease with which partners move from the exploratory learning phase of AC to the transformative learning phase.
- We found that participating organisations vary with respect to the AC mechanisms that they deploy in R&D consortia. We identified scanners and innovators in this study and argued that innovators are more likely to succeed in fully embedding knowledge in their collaborations whereas scanners are less likely to engage in transformation and in embedding knowledge in their organisations. We posited that the variance between individual organisations should be viewed as complementary to our model for AC in R&D consortia (Figure 14).

Chapter 7. CONCLUSIONS AND IMPLICATIONS

7.1 RESEARCH OBJECTIVES AND RESEARCH QUESTIONS

In this study, we pursued two research objectives. First, we aimed to contribute to a contextualised view of AC in R&D consortia. The research questions associated with this objective included:

1- How does AC develop in R&D consortia?
2- What are the underlying mechanisms of AC in R&D consortia?

Second, we sought to increase our understanding of the preconditions of AC which a) give rise to the formation of R&D consortia and b) support AC throughout the consortium. The research questions associated with this objective included:

3- What are the preconditions for formation of R&D consortia?
4- How do the R&D consortia preconditions affect the development of AC?

To address these research questions, we examined three cases of R&D consortia, and presented findings in chapters 5 and 6 in detail. In what follows, first, we answer the research questions by synthesising the findings. Then, we move onto discussing the particular theoretical and methodological contributions of the study. The chapter ends by discussing the limitations of the study and potential avenues for future research.

7.2 SUMMARY OF MAIN FINDINGS

7.2.1 RQ1: HOW DOES AC DEVELOP IN R&D CONSORTIA?

Our analysis suggests that AC in R&D consortia is a multidimensional and multiphased concept which unfolds at the consortium, interface and organisational levels. The exploratory dimension of AC mainly develops at the consortium level. At the early stages of R&D consortia, partners have limited understanding about each other's capabilities, resources, etc., and interactions between consortium partners are crucial for developing an interim understanding about how to organise collaborative work which, in turn, leads to a deeper engagement during the later stages of the consortia. We found that when consortia form, if there is little pre-existing history of relationships, crossing boundaries will be difficult, which hampers the exploratory dimension of AC because of the time required for perspective taking and coordination to unfold. Pre-existing SC and CoPs can facilitate perspective taking and coordination mainly by contributing to the development of shared space.

At the transformative phase, AC develops at the interface level. Although in the exploratory phase, partners can collaborate in R&D consortia without undergoing significant changes, if collaborations necessitate a deeper engagement of partner organisations, the partners will have to transform their prevailing structures, practices, and routines in order to respond to their environment (consortia). At this stage, the collaborations involve interactions and confrontations between the organisational level and the consortium-level interests and requirements. The transformative dimension of AC facilitates overcoming the confrontations through continuous comparing of the two levels, i.e. what is in the consortia which challenges the organisations, and vice versa. Therefore, it develops at the interface level between organisations and consortia.

In the transformative phase of AC, organisational and disciplinary boundaries need to become more permeable. The presence of shared space is critical in this phase. While in the exploratory phase, shared space enables parties to interact and coordinate, in the transformative phase, shared space enables partners either to modify structures and processes at the boundaries and/or to transfer knowledge into their organisational context. At this stage, shared space not only provides the basis for interactions but also the platform for participation and adaptation across boundaries. Moreover, the boundary objects which contribute to transformation and interactions are more crucial compared with the ones that facilitate communications and coordination.

Finally, the exploitative dimension of AC is characterised by its minimal interface with the consortium and its development at the organisational level. This aspect of AC deals with applying the knowledge gained from the consortia within organisations and developing new applications through transferring it across intra-organisational boundaries. At this stage, organisational and disciplinary boundaries become crystallised and the boundary-crossing mechanisms mainly relate to the intra-organisational realm. Therefore, the main mechanisms to internalise knowledge are developed at the organisational level which means that shared space has limited impact on the exploitative aspect of AC. In this phase, organisations may deploy independently developed routines and mechanisms to utilise the knowledge that is acquired within R&D consortia.

7.2.2 RQ2: WHAT ARE THE UNDERLYING MECHANISMS OF AC IN R&D CONSORTIA?

To answer the second research question, using Lane et al's (2006) framework, we attempted to unravel the constituents of AC in the exploratory, transformative and exploitative phases. We found that the exploratory phase is driven by perspective taking and coordination, the transformative phase is driven by transformation and transferring, and the exploitative phase is driven by retention and replication mechanisms. Below, we further elaborate on those findings.

First, investigating the exploratory learning across disciplinary and organisational boundaries, we identified perspective taking and coordination mechanisms as the major constituents of the exploratory dimension. Through perspective taking (Boland and Tenkasi 1995) partners across organisational and disciplinary boundaries empathise with the limitations, constraints, and pressures that *others* experience in the consortia, making them receptive to buy into the contrasting attitudes and angles about the research. Moreover, we identified coordination as the other constituent of exploratory learning. The role of coordination within R&D consortia is twofold. On the one hand, it involves translation across the disciplinary boundaries and aligning meanings across organisational boundaries. On the other hand, it refers to harmonising collaboration in R&D consortia, setting shared goals, and aligning interests.

In general, we are convinced that overcoming language and meaning differences through translation across disciplinary boundaries is easier to achieve compared with overcoming the meaning variances across organisational boundaries, though the latter is more important to accomplish. A potential explanation could be that people are more likely to be aware of their disciplinary differences when they collaborate within R&D consortia. Hence, they reflect on their specialised languages, making them accessible to others. However, as organisational identities are deeply rooted within the local practices that actors have, it is more difficult for partners to reflect on and address them.

In our investigation of transformative learning, we identified transformation and transferring as the two underlying mechanisms. First, it was found that transformation comprises adaptation which is the mechanism used by partners to respond to the requirements of R&D consortia. Second, transformative learning comprises transferring. This mechanism relates to transferring knowledge between partners and to the broader context of the individual organisations not only spatially, as the concept of transfer suggests, but also temporally as consortia move from exploratory phase into exploitative phase. In our findings, the two dominant aspects of transfer included socialisation (through conducting joint activities and mobilising individuals across various boundaries) and articulation (through codification and formalisation). Moreover, we found that the two mechanisms of articulation (codification and formalisation) have different enduring effects on preserving knowledge. When articulation is the result of formalisation (documenting knowledge in the form of manuals and procedure), the knowledge is more likely to become stored within organisations compared with codification (e.g. turning knowledge into a report or presentation). Further, we found that articulation is complementary to socialisation and neither of the two could replace the other. Although articulation is needed to preserve the knowledge for future use, when knowledge became complex, socialisation is a more relevant mechanism for preserving external knowledge.

The final dimension of AC in R&D consortia is exploitative learning. We found that retention and replication form the two complementary facets of exploitative learning. We demonstrated that exploitative dimension is not limited to *applying* knowledge but also involves storing the knowledge in routines and processes within organisations which can be replicated spatially and temporally. We found that the replication of routines and processes across the organisational contexts gives rise to new enquiries and challenges which can lead into further explorations.

7.2.3 RQ3: WHAT ARE THE PRECONDITIONS FOR FORMATION OF R&D CONSORTIA?

The three cases examined in this thesis demonstrated similar preconditions in the formation of R&D consortia. First, we found that knowledge complementarities/supplementarities and prior knowledge play a key role. Prior knowledge and complementarities/supplementarities are important in specifying the type of partners that were sought within R&D consortia. Second, we found that activation triggers in the form of internal problems and environmental pressures are influential in the formation of R&D consortia. However, although activation triggers play a significant role in the formation of consortia, they can only trigger collaboration in the presence of actors who actively formulate the problem and initiate the collaboration. We found that innovation champions' contribution to the formation of R&D consortia through mobilising their reputation and social networks and bringing various partners together to form the collaboration. In addition, pre-existing SC influences the formation of R&D consortia. SC enables partners to identify who they will be collaborating with and facilitated the formation of collaboration through reinforcing trust between partners. Finally, our findings underline the significance of CoPs in the formation of R&D consortia. Pre-existing CoPs are influential not only in initiating the R&D consortia but also in pushing the research throughout the collaborations.

7.2.4 RQ4: HOW DO THE R&D CONSORTIA PRECONDITIONS AFFECT THE DEVELOPMENT OF AC?

As the number of partner organisations increases, R&D collaborations grow in their complexity (Smith Ring et al. 2005, Li et al. 2012) because partners with diverse sets of priorities and heterogeneous sociocultural contexts need to collaborate around a narrow set of objectives. Such complexity affects AC throughout the consortia's lifecycles.

The findings suggest that the preconditions of R&D consortia have enduring effects on the development of AC. The roles of the preconditions do not disappear once the consortia form and they remain just as important during the later stages of collaboration and they influence the development of AC. We found that the R&D consortia preconditions affect the development of AC through the effects they have on the formation of shared space. We defined 'shared space' as the conditions that cultivate the opportunity for participation across organisational and disciplinary boundaries in the pursuit of shared meaning and joint interpretations. Pre-existing SC facilitates the development of shared space through reinforcing mutual trust which in turn enables actors to participate and interact across organisational and/or disciplinary boundaries. However, while higher levels of pre-existing SC enable the formation of R&D consortia, lower levels of SC are accompanied by slower formation of collaboration among partners, especially during the initial phases of R&D consortia. We discussed that high levels SC level can attenuate the learning opportunities as the partners fall into the comfort zone of only collaborating with familiar partners and working independently which limits the opportunities for participation in a shared space. Moreover, the presence of pre-existing inter-organisational CoPs facilitates collaboration between partners because pre-existing CoPs have similar research interests and repertoire of methods and routines with a shared vision about how the research should be done.

In addition to these factors which predominantly count as the formation factors, the governance of R&D consortia plays a significant role in the development of shared space. Although governance is not a precondition for formation of R&D consortia, it gradually develops during the initial stages of the consortia and it affects the development of shared space which then influences AC. Our findings suggest that shared space forms easier if the governance of the consortia facilitates the mobilisation of individuals across various boundaries and if it limits the rapid changes within the consortia. Finally, we discussed that the ex-ante configuration of boundaries affects the development of shared space. Absence of disciplinary boundaries within R&D consortia facilitates the exchange of knowledge between partners. When the consortia partners belong to similar disciplinary domains, new CoPs can develop easily which then facilitates the formation of shared space and knowledge exchange among partners.

7.3 CONTRIBUTIONS

7.3.1 THEORETICAL IMPLICATIONS

7.3.1.1 INTRODUCTION

In the above section, we discussed the main findings of the study with relation to the research questions. In what follows, we weave these findings together and compare them with the extant literature in order to discuss their significance. Overall, the theoretical contributions of the thesis can be classified into two groups. The first set of contributions concerns the development of our understanding of AC in R&D consortia. The second set of contributions relates to the development of our understanding about boundaries in inter-organisational relations. Table 20 demonstrates an overview of these theoretical implications.

TABLE 20: THEORETICAL IMPLICATIONS OF THE STUDY

Contribution	Details
An enriched understanding of AC in R&D consortia	-A model of AC in R&D consortia with three phases and three levels -The role of shared space in the development of AC -The role of adaptation as a mechanism that makes AC a dynamic capability which can break path dependencies
An enhanced understanding of boundaries in inter-organisational relations	-The synergic effect between disciplinary and organisational boundaries and the importance of organisational boundaries within a single disciplinary domain

7.3.1.2 AN ENRICHED UNDERSTANDING OF AC IN R&D CONSORTIA

The first contribution of the study lies in conceptualising and developing a multiphase and multilevel model of AC in R&D consortia. In the extant literature, authors have either viewed AC as an organisational capability limited to firm boundaries (Cohen and Levinthal 1990, Van den Bosch et al. 1999, Zahra and George 2002) or a relative capability pertaining to the features of dyadic relations (Dyer and Singh 1998, Lane and Lubatkin 1998, Nooteboom et al. 2007). However, there has been little development about how AC unfolds in multilateral settings like R&D consortia. This study addresses this research gap by exploring the formation process of R&D consortia and investigating the development of AC in R&D consortia across phases and levels.

We contend that taking into account the ecologies of complex innovations (Dougherty and Dunne 2011), and the heterogeneity of boundaries (Santos and Eisenhardt 2005), conceptualising AC as a purely organisational or dyadic capability is rather simplistic and we contend that AC in R&D consortia is a multilevel concept. It develops at the consortium level through exploratory learning, at the interface level through transformative learning and at the organisational levels through exploitative learning. This multilevelledness make the concept far more complex compared with the previously developed single-level conceptualisations as organisations have limited control over the consortium in which they operate. When it comes to consortia, individual organisations are less influential in managing the project, controlling resources and coordinating interactions compared with their internal affairs. This, in turn, means that an important aspect of AC is the capabilities that develop at the consortium level and in collaboration with other partners.

This study, moreover, contributes to our understanding of how AC unfolds across different phases in R&D consortia and how the requirements may change across those phases. This provides an enriched understanding of the learning mechanisms that support the exploratory, transformative, and exploitative learning phases of AC. The existing body of knowledge is equivocal in identifying, analysing, and developing how AC relates to learning. This study contributes to this gap by providing a detailed account of the learning mechanisms that constitute AC in R&D consortia. In the exploratory phase, partners have little familiarity with each other, the scope of research is not fully determined and there are reservations about knowledge sharing. Therefore, disciplinary and organisational boundaries are strong and difficult to cross. The main requirement, hence, at this stage is to intensify the interactions so that trust develops among partners, enabling them to take perspectives. Moreover, since at this phase consensus cannot be easily generated, efforts are made to unify syntaxes and align distributed work for coordination. In the transformative phase, collaboration requires deeper engagement of participating organisations and involves transformation and transferring. This may involve modification of the prevailing practices which takes place through transformation and/or transferring knowledge between partners and into the organisations through transferring. At this phase, partners need to become flexible with respect to their established practices, attitudes and structures so that boundaries start to become more permeable. Therefore, at this phase merely having harmonisation does not suffice. We found that this shift becomes feasible only in the presence of appropriate boundary objects which are flexible enough to make adaptation possible, and of individuals who can move freely across boundaries in order to engage in shared experience with the other partners. Finally, at the exploitative phase, individual organisations internalise knowledge within their organisations through retention and replication. The main requirements lie in sustaining efforts to apply knowledge within organisations through embedding knowledge in ongoing routines or in artefacts on the one hand, and to expose it to different contexts by encouraging application of knowledge in different areas in the organisations, on the other hand.

A second contribution has to do with the role of shared space in the development of AC. Shared space is a field in which partners engage, interact, negotiate, coordinate, and exchange. As discussed in chapter 2, one of the pitfalls of the extant AC research is the dominance of *epistemology of possession* (Cook and Brown 1999) which overlooks the role of 'meaning'. Utilising the notion of shared space enables us to explore the role of meaning which is one of the least attended aspects of AC research.

Overlooking the importance of meaning mainly affects our understanding about the *assimilation* dimension of AC. For example, although assimilation is one of the three dimensions of Cohen and Levinthal's (1990) paper and other conceptualisations (Transformative learning (Lane et al. 2006), or transformation (Zahra and George 2002, Todorova and Durisin 2007)), we know little about how assimilation works, and what its underlying mechanisms are. Cohen and Levinthal (1990) do not explain its mechanisms, and Zahra and George (2002) and Lane et al. (2006) limit transformation to the ability to *combine* new knowledge with existing knowledge. Often, in empirical studies, assimilation is referred to as the abilities to analyse data, disseminate knowledge, and integrate new knowledge with existing knowledge. This is not because assimilation is not an important aspect of AC, but mainly because there is not much to say about assimilation should 'meaning' not be taken into consideration.

This study suggest that shared space affects exploratory learning and transformative learning (which embodies assimilation in our formulation of AC) dimensions of AC through providing opportunities for members across various organisational and disciplinary boundaries to participate in and to develop shared meanings, shared methods, and shared repertoire. Moreover, our findings suggest that shared space is determined by the configuration of boundaries, the structure and governance of consortia, and the presence of appropriate boundary objects which facilitate the negotiation of meaning across those boundaries.

A third contribution of the thesis pertains to increasing the understanding of AC's path dependency which is compatible with the understanding of innovation. Classically, AC is considered as a path-dependent concept in Cohen and Levinthal's original work (1990). Cohen and Levinthal attribute the path dependency of AC to the accumulation of knowledge stock, that is, AC is determined by the knowledge that is accumulated hitherto in organisations. Therefore, AC is cumulative and future ACs are determined by former ACs. There is, however, a contradiction between the path dependency of AC and its support for innovation. Path dependency accompanies a certain level of continuation which limits the possibilities for innovation and change in a significant way. This is at odds with arguments which consider AC as a determinant of innovation (Cohen and Levinthal 1989, Cohen and Levinthal 1990, Oxley and Sampson 2004). Should AC be purely path dependent, there is no room for innovation and change as the main function of innovation is to break path dependencies (Augsdorfer 2005).

Extant literature provides limited understanding of how path dependency of AC can be reconciled with innovation. Often, path dependency is discussed in the theoretical (part of) studies and there is hardly any evidence on how AC can contribute to breaking/maintaining path dependencies. In theoretical contributions, path dependencies have accumulative properties. In Zahra and George's (2002) AC model, path dependency is attributed to the experience accumulation of firms (cf. Zahra and George, 2002 p.193). Experience accumulation determines the acquisition and assimilation of knowledge through affecting the locus of search. For Lewin et al.

(2011) path dependency of AC is reflected in the history of development of the routines that constitute AC[65].

This study adds to these developments by introducing, examining and differentiating between the mechanisms that give rise to breaking path dependencies on the one hand, and the mechanisms that reinforce path dependencies on the other hand. We discern the mechanisms for knowledge storage (transferring, retention, and replication – presented at the right side of AC in Figure 14) from the mechanisms that lead into change in the prevailing practices (perspective taking, coordination, and transformation – presented in the left part of the AC rectangle in Figure 14). As suggested in the model, transferring and exploitative mechanisms contribute to the knowledge storage, which is then fed back into the level of prior knowledge. As the model suggests, knowledge storage can relate to the efforts made to codify and archive knowledge through articulation or to share the experience through socialisation. These can lead to embedding the knowledge in routines, practices, and artefacts within communities of practice through retention and replication (Brown and Duguid 1991, Lave and Wenger 1991). Therefore, these knowledge storage mechanisms enlarge the organisational memory (Walsh and Ungson 1991). Moreover, in this way, our findings shed light on the feedback loops that Todorova and Durisin (2007) introduced (the knowledge which is stored in routines and processes feeds into new enquiries). Although we did not explore the feedback loop per se (i.e. from exploitation to exploration), we identified the mechanism (i.e. replication) that can potentially support its development.

On the other hand, the findings suggest that exploratory learning and transformation mechanisms contribute to modification and change when organisations deal with novel contexts. When AC relates to less novel contexts, external knowledge can be acquired without breaking the path dependency. AC transfers knowledge from the external environment to the internal space of organisations without imposing radical changes within organisations. In less novel contexts AC reinforces the path dependency and

[65] In this study, Lewin, A. Y., Massini, S. and Peeters, C. (2011). Microfoundations of Internal and External Absorptive Capacity Routines. *Organization Science*, **22**, pp. 81-98., view path dependencies as a reflection of how routines of AC develop and change. Therefore, learnings that lead into change in routines are considered an integral part of the path dependency of AC.

adaptation mechanisms are less likely to be triggered. Yet, when the context and content of inquiry grow in novelty, as is usually the case in R&D consortia, prevailing practices become incompetent in handling the new knowledge, and the differences across communities generate negative consequences which render the transformation of ongoing practices inevitable so as to accommodate new knowledge (Carlile and Rebentisch 2003). Through perspective taking and coordination, participants appreciate the scale of required change, and through transformative learning they implement it.

Thus, by incorporating the two aspects of change and accumulation, our reformulation of AC stays in line with the original formulation of AC as a path-dependent concept, but provides a complementary explanation about the mechanisms that trigger innovations and change. Exploratory and transformative learning contribute to breaking path dependencies, especially when the knowledge context and content grow in the level of novelty, and transferring and exploitation contribute to preserving path dependencies, especially when new knowledge is compatible with the existing framework. Therefore, AC is neither purely path dependent, nor it is purely path breaking, but it builds on the combination of the two. Such a formulation of AC is in line with the notion of dynamic capabilities as higher-order capabilities which generate and modify the operating routines/capabilities (Zollo and Winter 2002, Winter 2003, Minner et al. 2008).

7.3.1.3 AN ENHANCED UNDERSTANDING OF BOUNDARIES IN INTER-ORGANISATIONAL RELATIONS

Apart from the contributions that this study makes to AC literature, we are of the opinion that the contributions are not limited to AC research and can be viewed in a broader research domain that explores the learning dynamics across boundaries. The findings of this study suggest that any understanding of inter-organisational learning, especially in R&D consortia, requires taking into consideration the diversity and complexity of multiple disciplinary and organisational boundaries.

Resource-based theory has explored the transactions that occur across organisational boundaries which is most visible in ideas like resource complementarities and knowledge combinations (Kogut and Zander 1992). On the other hand, practice-based theory has predominantly focused on the learning that occurs across practices within organisations and particularly by exploring the boundaries between occupational groups (McGivern and Dopson 2010, Oborn and Dawson 2010, Barrett et al. 2011, Nicolini et al. 2012).

This study suggests that none of the above approaches can explain inter-organisational learning independently. Organisational boundaries were inadequate in explaining the barriers in knowledge exchange, because we witnessed instances where knowledge exchange took place smoothly across organisations. In ASTHMA, biologists could easily share knowledge regardless of their organisation because they were all *scientists* and interested in the same set of research issues. In FLIGHT, COATING and UNIVERSITY C remained on *the same page* (Research scientist A – COATING) with a low level of conflict as they belonged to the same discipline of surface engineering. What Brown and Duguid (2001) identify as the *network of practice* (communities of practice at a global level) closely relates to this finding. They argue that across organisational boundaries, networks of practice (e.g. engineers) start exchanging knowledge and that is why knowledge leaks beyond firms.

However, this is not the whole picture of what our findings suggest. As often as we observed knowledge sharing across organisational boundaries among people belonging to similar disciplines, we witnessed the opposite. There were occasions when organisational boundaries became dominant although people belonged to similar disciplinary domains. In ASTHMA, there was a noticeable divide between academic and industrial partners who belonged to the same disciplinary boundaries. In HOUSE, structural engineers in UNIVERSITY A and their counterparts within ENGINEER (an SME) had trouble harmonising the research directions. Moreover, many of the discontinuities in knowledge flow that we observed within the cases pertained to the organisational differences.

This study suggests that any understanding of knowledge exchange in (multidisciplinary) R&D consortia requires taking into consideration disciplinary and organisational boundaries. Ignoring either of the two types of boundaries may result in limited understanding of boundaries in inter-organisational collaborations. This study suggests that there is a synergy between organisational and disciplinary boundaries.

The absence of disciplinary boundaries attenuates organisational boundaries, and vice versa.

7.3.2 MANAGERIAL AND POLICY IMPLICATIONS

The study also entails implications for consortium managers and policy makers alike. First, it suggests that owing to the diversity and heterogeneity of specialisations and organisational contexts, any R&D consortium inevitably deals with multiple boundaries. Understanding the configurations and the dynamics associated with these boundaries is important for the development of AC in R&D consortia, both for consortium managers and partner organisations. From a policy point of view, this means that more concrete policy interventions are required when the level of heterogeneity increases. As the diversity augments, more efforts will be needed to form research consortia.

Second, the study indicates that when organisations seek to become involved in collaborative R&D projects, they are more likely to succeed if they weaken the disciplinary boundaries, unless they are aiming to engage in multidisciplinary research. For example, ASTHMA suggested that connecting scientists across organisations was more effective than connecting scientists from one side to business developers or IP lawyers from the other side (a common practice in the pharmaceutical industry). Although this approach comes with the risk of spillovers, especially in collaborative R&D projects, it should be the dominant approach if partners seek to become deeply involved in knowledge sharing. To take the implication further, it would be even more desirable if the collaborations were not only to take place between people from the same discipline, but also from the same practice (in our definition a subset of disciplinary domain which includes specific characteristics of that broad domain: a potential CoP). For instance, our analysis of ASTHMA and FLIGHT revealed that connecting scientists who worked in *the lab* was advantageous as they were not concerned about anything other than the science itself.

The third implication is the inclusion of research institutes if the initiative is to encourage collaboration among companies. When companies participate in R&D consortia, the rivalry between them might turn into a drawback for knowledge exchange. As discussed, the inclusion of public institutes facilitates the knowledge exchange as they act as ‘trust hubs’ ensuring non-commercial use of knowledge by competitors. Therefore, research consortia aiming to involve collaboration between competitor companies can benefit from the inclusion of public institutes not only because they possess leadingeedge knowledge, but also because they can mediate the relationship between companies and facilitate the formation of shared space.

Fourth, the findings suggest that the development of shared space entails enforcing stability in configuration of the consortia. Rapid changes in the configuration of the consortia and changes in the priorities that each partner organisation pursues can destabilise the development of shared space. Preserving the stability of shared space is crucial during the exploratory and transformative phases of AC. It is important in the exploratory phase because it contributes to perspective taking and coordination. It is important throughout the transformative phase because transformation requires continuous interaction and participation so as to implement changes. Therefore, foreseeing the commitment of partner organisations throughout these two phases, not only in terms of the amount of the resources that they contribute, but also in terms of preserving the configuration of those resources throughout the consortia, is crucial.

Fifth, the findings suggest that individual organisations should pay particular attention to the interface that they develop with the consortium. Developing a flexible interface with dedicated boundary spanners who can continuously connect the consortium with the organisations is critical. This is particularly important in exploratory and transformative learning in which partner organisations modify their pre-existing structures and processes in order to comply with the consortium requirements. Taking perspective of the other partners and accommodating others’ viewpoints rather than focusing on one’s own purpose of participation, and the ability to respond in a timely manner to the requirements of the R&D consortia without compromising internal priorities, are among the key managerial implications of the research.

Finally, the study suggests that organisations should dedicate sufficient resources for transferring and exploitative mechanisms. Some organisations prioritise the delivery of the consortia outcomes, moving from one project into next tasks, projects, etc. In some instances, they may even lose the people who were involved in the collaborative efforts because of downsizing, retirement, staff mobility, etc. post-collaboration. In order to preserve the knowledge within organisations, and probably when an R&D consortium is finalising its experiments and freezing its findings, it is important to focus on transferring. These mechanisms ensure the dissemination of knowledge within the organisation through articulation and socialisation. The case studies imply that it can even be a good practice for organisations to temporarily employ the knowledgeable participants from other organisations, especially universities and research institutes, in order to embed their knowledge within their own company. This is a crucial step for organisations as there can be a tendency to roll from one project to another without ensuring that the knowledge reaches the department, division, or groups which can capitalise on and use it. For managers, the warning is not to build their business models purely based on external collaborations or projects, but to consider the ways through which knowledge can be internalised for application. From a policy point of view, this means evaluation measures should not be limited to the outcomes of R&D consortia but should as well take into account their impact on the development of capabilities of individual organisations in the course of participation in research collaboration. Too much emphasis on the outcomes of joint efforts in collaborations may encourage organisations to complete their task without allocating sufficient time, or investing adequate resources, to embed the knowledge within their organisation and to develop their capabilities. This policy implication relates to the concept of behavioural additionality (Buisseret et al. 1995, Metcalfe and Georghiou 1997, Gök and Edler 2012) which discusses the impact of policy interventions on the behavioural characteristics of participating organisations rather than the output they generate. From this point of view, this study suggests that behavioural additionality of a policy intervention can be evaluated by the extent to which it triggers the dimensions of AC (and especially transferring mechanisms) in consortia and in individual organisations.

7.4 LIMITATIONS AND FURTHER RESEARCH

7.4.1 LIMITATIONS

This study does come with a number of limitations. First, given that AC deals with three phases of exploratory, transformative, and exploitative dimensions, a longitudinal study could add value to the thesis. However, because of the time limit (the data gathering process took around 18 months) and financial resource constraints (partially funded international student), the subsequent changes in processes and structure were not taken into consideration after the data gathering was completed. Moreover, given the confidential nature of R&D consortia, it was not feasible to access cases prior to their IP filings. We found the partner organisations more willing to open up once their collaboration was complete and data was no longer sensitive.

Second, it was considerably difficult to establish access because of two obstacles. Getting access to cases was built from scratch without capitalising on any pre-existing contacts. This made the process for identifying and approaching potential cases very challenging. As a result, we could not access the cases that we would have done in an ideal situation. Moreover, considering the fact that R&D consortia involved participation from multiple organisations, accessing the participants from each organisation entailed dealing with a new organisational *boundary* and passing through a new gate because getting the consent from the consortia managers did not automatically translate into getting access to various partner organisations. In fact, it resulted in not being able to interview some of the informants whose opinion could have been important.

The third limitation of the study relates to the generalisability of the findings. Qualitative research has been mainly criticised for its limited power of generalisability. However, as discussed in the methodology chapter, we attempted to keep the diversity of the cases in three different sectors with three different levels of maturity in their technological path in order to enhance their theoretical generalisability (Yin 2003).

Maxwell (1992 p.293) defines generalisability as "the extent to which one can extend the account of a particular situation or population to other persons, times, or settings than those directly studied". According to Lewis and Ritchie (2003) generalisability in qualitative research has three aspects: 1) *representational generalisability* which refers to the correspondence of the sample with the population 2) *inferential generalisability* which refers to the applicability of the findings to other settings and 3) *theoretical generalisability* which refers to the broader theoretical propositions and statements. With respect to the representational generalisability, as is usually the case in case study research, our sample is very small compared with the population. Therefore, the research provides limited representational generalisability. Inferential generalisability pertains to the correspondence between the 'sending context' in which research has been conducted and the 'receiving context' in which the new research is going to take place. This type of generalisability is difficult to anticipate by the researcher as it mainly needs to be investigated by the reader in accordance with their peculiar research needs (Seale 1999, Lewis and Ritchie 2003). However, we could anticipate that the findings of the study are applicable to multidisciplinary collaborative research schemes which involve firms, universities, and research centres. The third form of generalisability relates to the theoretical generalisability of the research. It relates to 'seeing particular cases as opportunities for further refining our hitherto conceptualiszations of general processes' (Tsoukas 2009, p.286). The theoretical generalisability was the most significant aspect of this study. By comparing the empirical findings and the existing theoretical body of knowledge, this research aimed to understand AC development in R&D consortia. In all these conditions '[t]he particular is not subsumed into the general; it rather further specifies the general'(Tsoukas 2009, p. 298). The multilevelledness of AC, the importance of shared space in the development of AC, and the mechanisms for transformation were among the main theoretical refinements that this study suggested. These aspects that form the theoretical contribution of the study can be potentially generalised to other settings. However, further empirical studies are needed in order to make judgements about the relevance of these findings. Based on this idea, the next section presents the areas that are seen as potential domains for further research.

7.4.2 FUTURE RESEARCH

This study offers a number of avenues for future research. First, as the study was limited to three cases, future research can explore larger samples in other sectors to see whether the findings are replicable. We encourage researchers to examine the model developed in this study in large-scale samples. In particular, it would be interesting to use quantitative methods to examine the reliability of the model that we developed in chapter 6 (Figure 14).

Second, although in this study we addressed the differences between the partner organisations, it was not the major focus of the research to do so. Future research may examine the factors that lead into differences among partner organisations with respect to the benefits that they draw from R&D consortia. However, this does not mean a return to the accounts of AC which view it as a purely organisational capability, but to explore the concept from the relational point of view in the context of the network that organisations are situated in. Such an approach calls for exploring the institutional context of the relations between organisations as well as taking into consideration the resources and capabilities of single organisations. This, in turn, may translate into deploying practice theory in combination with the resource-based view, and institutional theory in order to analyse AC of organisations.

Third, in this research we chose R&D consortia as the unit of analysis. Therefore, we did not focus on the portfolio of R&D collaborations/consortia of individual organisations. Clearly, many organisations actively participate in a number of (R&D) collaborations. Speculatively, AC can vary across these collaborations. Therefore, by switching the unit of analysis from R&D consortia to collaborative R&D portfolios, future research can explore the variance and configuration of AC across the collaboration portfolios.

Finally, it is common for individual departments within companies, especially in the large ones, to collaborate internally with other departments in order to solve a particular problem. However, the difference between the nature of knowledge transfer between internal departments compared with knowledge transfer to an external environment is under-explored. By comparing AC of the same department across internal and external relations, future research can explore how intra-organisational context compares with inter-organisational context and how the two contexts can affect the formation and development of AC of a focal department.

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APPENDICES

ANNEX-1: INVITATION LETTER TO PROJECT MANAGERS

Dear ______

I am writing to ask if you would consider taking part in a research study I am conducting to explore success factors of inter-organisational R&D collaborations. This study is a doctoral research project supervised by Professor Jakob Edler and Dr. Khaleel Malik from the Manchester Institute of Innovation Research (http://research.mbs.ac.uk/innovation/) at Manchester Business School. Having done some desk research about your research collaboration, and given that in the **A** project [X], you work on cutting edge research areas, I believe that your collaboration is very interesting to be researched.

Collaboration and partnership in R&D is becoming increasingly prevalent in pharmaceutical industry, for all kinds of reasons (learning, pooling complementary assets, costs, etc.). Recently, the concept of "open innovation" has been used to characterise the increased need for collaboration. However, while open innovation is widely used across organisations, and our knowledge about open innovation business models is becoming fairly mature, research confirms that the potential of open innovation and collaboration is not fully realised, and in many instances, these collaborations fail to achieve their objectives. This study intends to look at the structural and social pre-conditions that enable firms to reap the benefits of inter-organisational learning in R&D collaborations.

In particular, we are interested in looking into organisational learning in R&D partnerships from the lens of two very important and substantial learning dynamics in organisations namely: *Absorptive Capacity* and *Communities of practice.* In brief, absorptive capacity is the ability to identify, assimilate and apply external knowledge and communities of practice include those people interested in a learning area and collaborate in order to solve genuine technological, scientific or practical problems.

We believe that by participating in case studies, firms (and other organizations) can actually learn about those preconditions and in doing so improve their collaboration management in the future. We are also happy to provide you with a copy of the PhD thesis on completion as this will contain a variety of different company experiences that should hopefully give you some interesting and informative insights into this subject area, or organising seminars based on early research findings.

The case study will mainly involve interviewing key informants of the project (based on their availability and their consent to be interviewed). Interviews will be around the major preconditions of successful R&D partnerships and participants' explanations of their collaboration experience.

I look forward to hearing from you and my supervisors and I are happy to give you further information

Yours Sincerely,
Omid Omidvar

ANNEX-2: INVITATION LETTER TO INTERVIEW PARTICIPANTS

Dear ______

I am writing to ask if you would consider taking part in a research study I am conducting to explore success factors of inter-organisational R&D collaborations. This study is a doctoral research project supervised by Prof. Jakob Edler and Dr. Khaleel Malik from the Manchester Institute of Innovation Research (http://research.mbs.ac.uk/innovation/) at Manchester Business School. Having done some desk research about your collaboration, and given that in the [project name] , you work on cutting edge research areas, I believe that your collaboration is very interesting to be researched. I have had an interview with the [project manager] before and received useful information about the collaboration and have realized that you were an important participant. Hence, this email.

This study intends to look at the structural and social pre-conditions that enable firms to reap the benefits of inter-organisational learning in R&D collaborations. In particular, we are interested in looking into organisational learning in R&D partnerships from the lens of two very important and substantial learning dynamics in organisations namely: Absorptive Capacity and Communities of practice. In brief, absorptive capacity is the ability to identify, assimilate and apply external knowledge and communities of practice include those people interested in a learning area and collaborate in order to solve genuine technological, scientific or practical problems.

If you agree with being interviewed, your permission will be sought to record it. We might also ask you for a follow up interview at a later stage, should there be any issues requiring clarification and given you remain interested.

Obviously, your participation is entirely voluntary and there is no requirement for you to take part. If you do agree to take part, you will be free to withdraw at any time and if you are concerned about any of the questions in the interview, you can skip those questions or choose to stop the interview at any time. The study is confidential, and no individual who is interviewed or observed will be identified in any way in any analysis or project report.

I look forward to hearing from you and we are happy to provide you with further information.

Yours Sincerely,

Omid Omidvar

ANNEX-3: PARTICIPANT INFORMATION SHEET

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please ask if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

Who will conduct the research?

Omid Omidvar- Manchester Business School- Manchester Institute of Innovation Research- The Harold Hankins Building- Room 7.09- Manchester Business School- Oxford Road- University of Manchester M13 9PL, UK.

Title of the Research

Knowledge acquisition and learning in R&D partnerships: The role of absorptive capacity and social capital

What is the aim of the research?

The aim of this research is to analyse how organisations develop social and organisational capabilities in R&D alliances in order to be successful.

Why have I been chosen?

Participants are chosen based on their expertise and their knowledge of the area

What would I be asked to do if I took part?

In the following interview/survey, you will be asked several questions about this topic which you should answer based on your knowledge of the area. You will be asked for permission to record the interview.

What happens to the data collected?

Data will be transferred into data analysis software, and will be used merely for academic purposes. This data will help the researcher to find answers to the questions he has developed for his research.

How is confidentiality maintained?

Your answers will be confidential and the results will be published anonymously. Furthermore, data will be stored on a personal computer and won't be accessed by others.

What happens if I do not want to take part or if I change my mind?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time without giving a reason and without detriment to yourself.

Will I be paid for participating in the research?

No.

What is the duration of the research?

It consists of an hour interview

Where will the research be conducted?

UK- R&D alliances in medium-high tech companies

Will the outcomes of the research be published?

The outcome of the research might be published in academic journals, but data will be presented anonymously, and research participants will remain unidentifiable.

Contact for further information

Omid Omidvar
Email: omid.omidvar@postgrad.mbs.ac.uk
Mobile: 07832980894
Phone: 0161 275 5935

What if something goes wrong?

You can contact Omid Omidvar
Email: omid.omidvar@postgrad.mbs.ac.uk
Mobile: 07832980894
Tel: 0161 275 5935
If a participant wants to make a formal complaint about the conduct of the research they should contact the Head of the Research Office, Christie Building, University of Manchester, Oxford Road, Manchester, M13 9PL.

ANNEX-4: CONSENT FORM

If you are happy to participate please complete and sign the consent form below

Please Initial Box

1. I confirm that I have read the attached information sheet on the above project and have had the opportunity to consider the information and ask questions and had these answered satisfactorily. ☐

2. I understand that my participation in the study is voluntary and that I am free to withdraw at any time without giving a reason ☐

3. I agree with using a digital audio recording device during the interview ☐

I agree to take part in the above project

Name of participant	Date	Signature
______________________	______________	______________________
Name of person taking consent	Date	Signature
______________________	______________	______________________

ANNEX-5: INTERVIEW GUIDE

Project informants

	Focus of questions
Variable	Interview question
	• Purpose of interview (number of organizations/ persona) • Confidentiality and right to quit • Approximate length • Any questions • Permission to record • Signing consent form
General	Please can you tell me about the collaboration? - What were the areas of collaboration? - How it worked? How was it organized? What was the research problem/question? How novel is the project? How did you start? How are the project teams configured? From which divisions? What specialties they have? When did you start? What were the main reasons for collaboration in this project? What technological/commercial knowledge were you looking for? To what extent have you achieved what you were looking for? Why? How? Has this collaboration led to further involvement in other projects? Why? How? Why? What were your main objectives to join the consortium as an organization? What are the main objective of different groups for joining the consortium?
SC	Who were the core team that initiated the work? Why? How? What were their motivations? How did the core people in the collaboration get together How knowledgeable were the core members about each other before getting involved in the project? How much does the core team have in common (history of relations, knowledge stock, shared practices)? Did the new collaboration create entirely new linkages? How has the relations between the participants changed throughout since the beginning of the project? How did you find the motivation of partners? Who were the most motivated participants (individual/organizational)? Why? How? To what extent have you found the parties competent/reliable in delivering their

	task? Do they keep their words and promises? Do parties trust each other? How have you found the level of accountability and participation in teamwork in the project?
Boundaries	What are the main challenges in the collaboration process across the consortium? What are the challenges you face when transferring knowledge across the consortium? - Organizational - Practices - Across work packages What objects were used for knowledge transfer (e.g. websites, models, drawings, etc.)? How did you use them? What mechanisms/ activities did you use to share knowledge with partners? Why? How? How might you improve the knowledge sharing in the collaboration?
CoPs	What are the drivers of research in the collaboration? To what extent are people passionate about the research problem? Which partners are more motivated? Why? Did group members share the same understanding of the project goals, needs, etc.? Do you have sufficient shared language in the project? If not, did you achieve this and how? Did participant belong to similar knowledge domain and specialties?
Learning outcomes	Is there anything that you would do differently? How have the practices changed since the initiation of the project? Any patents generated in the project? What knowledge was/is going to be generated in the collaboration? How? What are the new practices generated in the collaboration? How has the project changed the practices in your organization? How do you identify and evaluate arising research problems in collaboration to further work on?
	• Is there anything else you want to add? • Participation in a follow up interview • Supporting data (internal company papers/ presentations/ industry reports)- ask for the confidentiality • Transcript to be sent for verification • Name other individuals who I might want to talk to • Thank you

Company informant

	Focus of questions
Introduction	• Purpose of interview (number of organisations/ persona) • Confidentiality and right to quit • Approximate length • Any questions • Permission to record • Signing consent form
General	Please can you tell me about the collaboration? - What were the areas of collaboration? - How it worked? How was it organized? - When did you start? What was the research problem/question? How did you start? -conferences How it worked? How was it organized? What was your role/contribution in the project as an organisation? How novel is the project? What were the main reasons for collaboration in this project? What technological/commercial knowledge were you looking for? Why did you decide to participate in the collaboration? To what extent did you achieve what you were looking for? Why? How? What did you do in the collaboration (organisational/ individual)? How? Has this collaboration led to further involvement in other projects? Why? How?
Pre-existing	What is your role in your company? who else was participating from your company in the project? Why? How do you identify and use new external knowledge general? How knowledgeable were you about this research area before taking part in the project? What about your organisation?

Boundaries and boundary crossing	What are the challenges you face when transferring knowledge across the collaboration? What are the boundaries? - Organisational - Language - Disciplinary What objects were used for knowledge transfer between partners (e.g. websites, models, drawings, etc.)? How? What mechanisms/ activities did you use to share knowledge with partners? Why? How? How might you improve the knowledge sharing in the collaboration? Did the R&D collaboration result in internal collaborations within your company? To what extent are other people in your unit/organisation (non-participants) informed about the project? How? Why?
CoPs	How much do you identify with the project? How close is the project to your areas of professional and business interest? Why? How? What about others? How the way you do things in general is similar or different from the way project expects you? How did you find the motivation of partners? Who were the most motivated participants (individual/organisational)? Why? How? To what extent have you found the parties competent/reliable in delivering their task? Do they keep their words and promises? Do parties trust each other? How have you found the level of accountability and participation in teamwork in the project? To what extent are people passionate about the research problem? Which partners are more motivated? Why? What are the drivers of research in the collaboration?
AC/learning outcomes	Did you have to change any structures within your company in order to work in the project? -Have any processes/practice changed within your organisation because of the project? How do you apply the knowledge you gained from the project? Do you apply it elsewhere? How has your participation in the project enhanced/ hindered your capabilities (e.g. technical capabilities, marketing capabilities, knowledge in the area, collaboration capabilities, etc.) in your organisation? Why?

	How did the project affect your practices in your organisation? What are the new practices/processes generated in the collaboration? What did you learn from the project? What knowledge was created as the result of the project? How did this project affect the position of your organisation in the industry? How has your knowledge increased in the collaboration? What will your organisation lose if those who participated in the project leave the company? Why? What knowledge was/is going to be generated in the collaboration? How? What are the new practices generated in the collaboration? Is there anything that you would do differently?
	• Is there anything else you want to add? • Participation in a follow up interview • Supporting data (internal company papers/ presentations/ industry reports)- ask for the confidentiality • Transcript to be sent for verification • Name other individuals who I might want to talk to • Thank you!

ANNEX-6: MEMORANDUMS OF UNDERSTANDING

-ASTHMA

This agreement is made the …. Day of 2011 between:

1) Omid Omidvar, PhD researcher at Manchester Business School- University of Manchester, his supervisors Prof. Edler and Dr. Malik (the research team); and

2) The ASHTMA consortium.

The “research team” will not publish anything about the “ASTHMA” consortium unless it is reviewed by the ASTHMA consortium. “ASTHMA consortium” has the right to review and withhold items before publishing.

-FLIGHT

This agreement is made on … Day 2012 between:

1) Omid Omidvar, PhD researcher at Manchester Business School- University of Manchester, his supervisors Prof. Edler and Dr. Malik (the research team); and

2) The FLIGHT consortium.

The “research team” will not publish anything about the “FLIGHT” consortium unless the FLIGHT consortium manager reviews and agrees it. Publication of papers involving findings regarding the FLIGHT requires written approval by the FLIGHT manager. Prior to publication, all information coming from FLIGHT has to be considered confidential, which means restricted to the research team only, and the “research team” will destroy/delete all copies of the FLIGHT reports at the end of the project.

ANNEX-7: LIST OF THE NON-PUBLICLY AVAILABLE DOCUMENTS USED IN THE ANALYSIS

Documents from HOUSE

- Research Project Summary - December 2010
- Second-level plan
- Research_Project_Sheet_Summaries

Documents from ASTHMA

- Project proposal
- Access to the online data storage platform containing meeting minutes, project timelines, and presentations

Documents from FLIGHT

- Second-level project plan
- Project Gant charts
- Quarterly meeting minutes
- Quarterly meeting presentations
- Informal meeting minutes
- Project completion reports by all partners
- Exploitation plan
- Patents
- Titanium bearings advancement-Internal presentation-FLIGHT