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Is absorptive capacity significant for innovation at firm level?
**A study of the absorptive capacity of engineering and
technology companies in the north west of Ireland**

**A Thesis in partial fulfilment of the requirements for the Degree of
Master of Science in Technology Management**

**Submitted to the National University of Ireland Galway
Faculty of Commerce
Department of Management**

September 2008

by

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A study of the absorptive capacity of engineering and technology companies in the North West of Ireland.

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Signed: Derek Thornton

Date: 1st September 2008

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Abbreviations

ACAP

Absorptive Capacity

HEI's

higher Education Institutes

NPD

New Product Development

R&D

Research and Development

SME

Small and Medium Enterprise

Abstract

The current research literature proposes that absorptive capacity is a crucial dynamic capability in knowledge-based competition (Zahra and George, 2002). Cohen and Levinthal define absorptive capacity as: ‘the ability of a firm to recognise the value of new, external information, assimilate it and apply it to commercial ends’ (1990:128). This study analyses the concept of absorptive capacity in the context of innovation at firm level. The research objective is to examine whether absorptive capacity is significant for innovation at firm level and if it is how firms’ absorptive capacity be enhanced.

This study develops a theoretical framework from previous literature (Cohen and Levinthal, 1989, Zahra and George, 2002, Neely, 1998) and applies this framework to analyse the relationship between research and development, absorptive capacity and innovativeness. A two-stage methodology is used to capture quantitative and qualitative data from engineering and technology based companies in the North West region Ireland. A tool for measuring absorptive capacity is developed, based on previous literature (Nieto, 2004, Schmidt, 2005) and deployed to measure firm absorptive capacity.

The research confirmed the significance of absorptive capacity for firms in knowledge intensive sectors and of the metrics employed to measure research and development. The results reveal the innovative characteristics of firms with high levels of absorptive capacity including intensive engagement with knowledge centres and proactive and open innovation. The research outcomes identify the weakest pillars of firm absorptive capacity in the region studied which have implications for support agencies aiming to enhance firms’ absorptive capacity.

1 Introduction

1.1 Introduction

In a world of greater globalisation and tougher competition, which is increasingly knowledge based, firms strive to learn and to develop capabilities faster than their rivals (Teece and Pisano, 1994). These capabilities need to be dynamic in nature to achieve an edge over competitors (Teece et al., 1997). Dynamic capabilities allow a firm to adapt to changing market conditions. Absorptive Capacity has recently been identified as a crucial dynamic capability in knowledge-based competition (Zahra and George, 2002). Cohen and Levinthal define absorptive capacity as: ‘the ability of a firm to recognise the value of new, external information, assimilate it and apply it to commercial ends’ (1990:128). The use of the concept of absorptive capacity has not been limited to the firm level, it ranges from the level of the individual to that of entire nations (Van Den Bosch et al., 2003).

Despite its relatively simple definition it is not possible to measure absorptive capacity directly and it remains a fuzzy concept. Empirical studies have used proxies to indirectly measure absorptive capacity of firms. Various proxies have been used to capture absorptive capacity in recent empirical studies on the innovation and cooperation behaviour of firms. For example, a recent attempt to operationalise the concept of absorptive capacity at firm level attempts to account for its multidimensional aspects (Schmidt, 2005). Schmidt (2005) summarises the main dimensions of absorptive capacity: R&D activities, Organisational structures, related prior knowledge, individual skills and human resource management practices and suggests appropriate indicators for such dimensions.

The lack of a direct empirical measure of absorptive capacity has caused problems with the comparison of research results. There is also a lack of empirical literature on how a firm can increase its absorptive capacity (Mahnke et al., 2005) or how it relates to more traditional innovation and economic performance indicators. It is commonly contended that greater absorptive capacity results in higher levels of intra-firm and inter-firm

knowledge spillovers, where the latter also includes the transmission of knowledge between firms and other institutions such as universities and public research institute (Abreu et al., 2006).

The literature review in section 2.0 reviews the conceptual and empirical literature related to the concept of absorptive capacity. The research objective is to examine whether absorptive capacity is significant for innovation at firm level and if it is how can firms' absorptive capacity be enhanced. The literature review provides input into how these objectives can be achieved. The research aims in section 2.9 will outline the focus of the research and the hypotheses that are to be tested.

Section 3 outlines the research methodology used in this study in detail. As an outline, the research methodology involved a two-stage data gathering approach. Stage one was a company survey using a self-devised questionnaire which was self-administered by the respondents. The company questionnaire was completed by key company personnel and was the main instrument for data gathering. A significant proportion of the company questionnaire was devoted to the firm absorptive capacity measurement task. This section was adopted from Part II of Nieto's (2005) measures of the firm's absorptive capacity. The company questionnaire also collects general details of the firm, their R&D investment and innovation outputs. In general, stage one collected quantitative and some qualitative data. Stage two of the research methodology involved structured telephone interviews of a selected number of respondents from stage one. In general, stage two of the research methodology collected qualitative and some quantitative data.

Section 4 presents the quantitative and qualitative results from the company questionnaire and the responses from the structured telephone interviews.

Section 5 includes the discussion of the results and hypothesis testing.

Section 6 includes the conclusions from the research and suggestions for future research.

2 Literature Review

2.1 Introduction to Literature Review

In this chapter relevant literature is reviewed on innovation and the concept of absorptive capacity in the context of firm innovative capability for this research study. The literature review is restricted to the application of the absorptive capacity at firm level. The literature sources used in this review were primarily sourced via the online 'E-Resources' material at the University of Limerick and National University of Ireland Galway libraries that were accessed remotely. These readings were complimented with readings sourced through the library at Letterkenny Institute of Technology. Two journals of particular interest for the area of research were 'Technovation' and 'Creativity and Innovation Management'.

2.1.1 Is absorptive capacity important?

In the context of innovation absorptive capacity refers to the ability to assimilate and manage knowledge in order to improve innovation performance and competitive advantage (Abreu et al., 2006). In a world of greater globalisation and tougher competition, which is increasingly knowledge based, firms strive to learn and to develop capabilities faster than their rivals (Teece and Pisano, 1994). These capabilities need to be dynamic in nature to achieve an edge over competitors (Teece et al., 1997). Dynamic capabilities allow a firm to adapt to changing market conditions. Absorptive Capacity has recently been identified as a crucial dynamic capability in knowledge-based competition. (Zahra and George, 2002). The concept of absorptive capacity originates from the field of cognitive and behavioural sciences at the individual level. In recent years researchers have used the ACAP concept in their study of various organisational phenomena (Zahra and George, 2002) i.e. Strategic Management (Nahapiet and Ghoshal, 1998), technology management (Schilling, 1998). This study focuses on the absorptive capacity concept in the context of innovation at firm level and this review is restricted to the absorptive capacity concept at firm level.

2.2 Theoretical treatment of the absorptive capacity concept

2.2.1 Definitions of absorptive capacity

Absorptive capacity at firm level is essentially a firm's ability to deal with external knowledge. The seminal works of Cohen and Levinthal (1989, 1990) offered the highly influential definition of absorptive capacity, it is a firm's ability to: 'identify, assimilate and exploit knowledge from the environment' (1990:569). Mowery and Oxley (1995) offer a second definition of ACAP as a broad set of skills needed to deal with the tacit component of transferred knowledge and the need to modify this imported knowledge. Kim (1997 a, b, 1998) offers a third definition of ACAP as the capacity to learn and solve problems. Other literature such as Lane and Lubatkin (1998) and Van Den Bosch et al. (2003) use the three components proposed by Cohen and Levinthal (1990). Zahra and George (2002) expanded the concept by introducing an additional component – which is: 'a firm's capability to develop and refine the routines that facilitate combining existing knowledge and the newly acquired and assimilated knowledge' (2002:190). Van den Bosch et al. (1999) supplement the ability-based concept of Cohen and Levinthal (1990) and analyse absorptive capacity along the dimensions of efficiency, scope and flexibility.

2.2.2 Innovation and learning - The two faces of R&D

At the level of the firm absorptive capacity is generated in a number of ways. Studies of technological trends have observed that firms invest in in-house R&D to enable them to utilise external information, (Tilton, 1971) i.e. absorptive capacity can be created as a by-product of R&D investment. Cohen and Levinthal argue that: 'while R&D obviously generate innovations, it also develops the firm's ability to identify, assimilate, and exploit knowledge from the environment – what we call 'learning' or 'absorptive capacity' (1989:1). These two outputs from R&D are labelled as the 'two faces of R&D'.

Cohen and Levinthal (1990) distinguish between the internal mechanism of 'learning – by-doing' at firm level with the potential of firms to do something quite different with knowledge acquired externally, facilitated by their absorptive capacity. Technological

opportunity and appropriability are highlighted as the key firm-level determinants of innovative activity and it is proposed that the influence of both of these elements are mediated by the level of firm absorptive capacity.

Cohen and Levinthal (1990) suggest that the second face of R&D;- the ability to learn from external sources explains three phenomena exhibited by firms who invest in R&D:-

1. Why firms may conduct basic research even when the findings spill out into the public domain: termed 'knowledge spillovers'.
2. Why firms may conduct basic research, not solely for explicit results but to retain their capability to identify and exploit useful scientific and technological knowledge generated by universities or government laboratories.
3. Why knowledge spillovers from other companies can be exploited with relative little cost by firms if they have already invested in the development of its absorptive capacity in the relevant field.

This raises the issue of the path dependent nature of absorptive capacity and the cumulative nature of building absorptive capacity which is dealt with in section 2.2.4.

2.2.3 Potential absorptive capacity and realised absorptive capacity

Following the work of Cohen and Levinthal, Zahra & George (2002) comprehensively analyse the role of absorptive capacity at firm level arguing that: 'empirical studies do not always capture the rich theoretical arguments and the multidimensionality of the ACAP construct' (2002:186) and offer a re-conceptualisation of ACAP. In this study they consider the process of acquisition, assimilation, transformation and exploitation of knowledge as all dimensions of absorptive capacity. This study takes the ACAP concept and subdivides into two categories of ACAP: - Potential and realised absorptive capacity.

Potential absorptive capacity depends on the availability and access to relevant knowledge sources of a firm. Exposure to knowledge does not necessarily lead to potential absorptive capacity development, especially if the sources do not complement the firm's knowledge, Lofstrom (2000). Realised absorptive capacity reflects the firm's capacity to leverage the knowledge that has been absorbed. The proposal of these two types of ACAP add to the theoretical framework of the ACAP concept. This theoretical frame work developed for this research study is presented and discussed in section 2.7.

2.2.4 Path dependent nature of Absorptive Capacity

Cohen and Levinthal (1990) argue that absorptive capacity is path-dependent because experience and prior knowledge facilitate the use of new knowledge. Studies in cognitive and behavioural sciences at the individual level justify this observation (Bower and Hilgard, 1981). As a consequence, absorptive capacity is cumulative. The cumulative nature of knowledge is also related to employees' level of education. The higher the level of education and training an employee receives, the higher his or her individual ability to identify and exploit new knowledge will be. A firms' absorptive capacity is not simply the sum total of the absorptive capacities of their individual employees. Cohen and Levinthal (1990) conclude that it depends on the ability of an organisation as a whole to stimulate and organise the transfer of knowledge across departments, functions and individuals. Firms' absorptive capacities depend on those of their employees, the general level or education, experience and training their employees have has a positive influence on firms' level of absorptive capacity.

Rothwell and Dodgson (1991) found that (small) firms need well-educated technicians, engineers and technological specialists to access knowledge from outside their boundaries. Van Den Bosch et al., (1999) conclude that the absorptive capacity of a firm is determined by its expertise in stimulating and organising knowledge sharing. Daghfous (2004) found that organisational culture, through the empowerment of employees and managers through incentives for knowledge diffusion can have a positive influence on the level of absorptive capacity.

Consequences of the path dependent nature of absorptive capacity are highlighted by Cohen and Levinthal (1990) in technology progressive fields by the nature of the two phenomena of 'lock-out' and 'inertia'. They also refer to two types of firm classifications linked to the aspiration level of a firm and their level of absorptive capacity: - proactive firms and reactive firms. It is suggested that firms with higher levels of absorptive capacity tend to be more proactive, exploiting opportunities presented in the environment, regardless of current performance. Conversely, reactive firms with lower levels of absorptive, it is suggested, tend to be more reactive, searching for replacements only when triggered by failure based on some business performance criteria (profitability, market share etc).

2.3 Previous studies on the determinants absorptive capacity

Research has been carried out studying the effect of ACAP at different levels of analysis. Zahra and George (2002) present a summary of a representative sample of the literature with the three units of analysis of ACAP national, inter-organisational and at the organisational level. In the majority of research the intensity or outputs from R&D activity are featured as a variable in the study. Research also exists examining ACAP in the context of knowledge transfer within organisations and organisational learning. This research review focuses on the research featuring R&D activity as a variable and on research at organisational level.

2.3.1 R&D Intensity as a determinant of absorptive capacity

In the seminal study by Cohen and Levinthal (1989, 1990) R&D intensity is related with ACAP. The results indicated that R&D creates a capacity to assimilate and exploit new knowledge – ‘the second face of R&D’. Veuglers (1997) examines the relationship between external R&D activities and internal R&D expenditures on a cross-section of Flemish R&D active companies. Results showed that R&D cooperation is found to have a significant positive effect on internal R&D but only if the companies have absorptive capacity. Ledwith (2003) examines the networking aspect of innovative capacity and one of the conclusions from this study was that the successful exploitation of partnerships in the context of NPD depends on the absorptive capacity of the firm. Cockburn and Henderson (1998) present a similar result in their study of large pharmaceutical firms: - only firms with absorptive capacity are able to tap into public research laboratories successfully. The study of Nichols-Nixon (1993), based on pharmaceutical companies, concluded that companies with greater ACAP invest more in R&D, co-operate more on R&D and get more out of research alliances. In an Irish context Ledwith (2003) found in her study of electronics firms that the Irish firms reported more frequent interactions with universities than with suppliers on NPD projects. Surprisingly, in this study collaboration by firms with universities or research institutions showed less success than firms who were not collaborating in this way. The need for these firms to increase their absorptive capacity (citing Rothwell and Dodgson (1991)) is suggested as a possible operational solution to this finding.

The studies outlined above suggest two things. Firstly, there appears to be a threshold level of absorptive capacity, above which firms have to reach before they can benefit from R&D collaboration with universities, research institutions or other firms. Secondly, above this threshold level of ACAP the positive outputs from R&D appear as proportional to the R&D investment. The firms studied in the research work outlined above are from the electronics and pharmaceutical sectors, which are knowledge intensive industries:-there is nothing to indicate from these studies if this is significant

factor but it would be reasonable and consistent with the nature of ACAP if it was the case.

The existence of ACAP is not only determined by R&D activities, but also by the organisation and stimulation of knowledge transfer within the firm as well as the employment of qualified personnel. In particular, the stimulation of innovation activities and knowledge transfer is found to be an important building block of exploitive absorptive capacity (Schmidt, 2005).

2.3.2 Metrics for R&D

Schmidt concluded that R&D intensity, which is widely used in the literature as a proxy for ACAP, does not significantly influence ACAP. To expand on this Schmidt study finds that:

R&D expenditures are pre-dominantly a means of developing new knowledge and innovation rather than of building absorptive capacity. Nonetheless, R&D activities help in the long run to build absorptive capacities (2005:22)

This statement appears contradictory on first reading. On examination it is the path dependent nature of ACAP that is the key factor here. What Schmidt is saying is that a firm's current R&D investment primarily benefits a firms' current innovation – the 'first face of R&D'- while current R&D investment helps to develop the firms' ACAP over time. This finding does not contradict the Cohen and Levinthal (1989, 1990) finding on the contribution of R&D to building ACAP, rather it qualifies the Cohen and Levinthal (1989, 1990) finding with respect to the agreed cumulative and path dependent nature of ACAP.

Another striking finding presented by Schmidt is that continuous R&D engagement is found to be relevant to ACAP. A related finding by Abreu et al (2006) was that the presence of a larger share of R&D employees is positively associated with innovation,

particularly for manufactured goods. Abrue et al. (2006) conclude that: 'it is the number of employees rather than the expenditure on R&D that has the greatest effect on innovation' (2006:16). This is consistent with the dual role that R&D employees play proposed by Cohen and Levinthal (1989,1990); contributing directly to innovation but also help to build up the firm's absorptive capacity. A lot of research focuses on research intensity as measures of R&D activity and determinants in empirical studies of ACAP. Moreover, a lot of government agencies supporting innovation use the metric of R&D intensity for targeted funding of programmes to support innovation at firm level. These two findings by Schmidt (2005) and Abreau et al. (2006) suggest other relevant metrics for R&D activity such as frequency and continuity of R&D activity and the proportion of staff involved in R&D.

2.3.3 Optimum absorptive capacity

Mangematin and Nesta (1999) analyse the relationship between the French National Centre for Scientific Research and firms located in the Grenoble area. The results from this work provides insight into the characteristics of firms with considerable absorptive capacity (i.e. ACAP well above the threshold level discussed above) concluding that the presence of considerable ACAP inhibits co-operation on R&D. The implication here is that firms with higher levels of ACAP do not need to collaborate as much as less endowed firms, that they have less to gain from the combined R&D effort and/or these firms do not want to share the fruits of the collaborative effort and want to maximise the return from their own innovative effort.

Stock et al. (2001) examine whether ACAP would be positively associated with new product development performance. From a theoretical viewpoint this association is reasonable because ACAP should lead to better acquisition and exploitation of external knowledge to benefit NPD. Their findings based on a study of firms that developed modems and brought them to market over a period of twenty four years are interesting.

Their results found an inverted-U relationship between ACAP and NPD:

The implication here is that simply devoting a larger proportion of a firm's resources to R&D does not necessarily mean that the products a firm develops will be more advanced. One way to characterise the implication of these results is that there are diminishing returns to investment in learning (2001:88).

It is reasonable to compare results from NPD investment with results from R&D investment as the two variables are closely linked. These conclusions suggests that it is not simply a linear relationship between ACAP and investment in R&D as suggested earlier. These conclusions also suggest the possible existence of an optimum level of investment in R&D at firm level which would have implications for the level of firm investment in learning and government agency models for targeting investing in building firm ACAP.

2.3.4 ACAP for different types of knowledge

Schmidt (2005) investigates how firms are able to exploit knowledge from external partners for successful innovation activities. The paper empirically analyses the effects of R&D activities, human resource and knowledge management, and the organisation of knowledge sharing within a firm on the absorptive of innovating firms. Schmidt (2005) distinguishes between three types of ACAP for three types of knowledge, namely absorptive capacity to use knowledge from a firm's own industry, from other industries, and knowledge from research institutions.

Schmidt identifies three types of absorptive capacity:

- Absorptive capacity for intra-industry knowledge (necessary to capture knowledge from sources within the firm's industry)
- Absorptive capacity for inter-industry knowledge (for knowledge originating in other industries)

- Absorptive capacity for scientific knowledge (for knowledge related to cooperation with universities and public research institutes)

The distinction between the three types of absorptive capacity are deemed significant since different types of knowledge sources require different types of absorptive capacity for the knowledge to be successfully assimilated.

Lane and Lubatkin (1998) examine the dynamics of inter-firm learning and conclude that for any particular firm certain characteristics of the external firm from which they are potentially learning effect the level of learning of learning achievable. Certain characteristics of the “student-firm” and the “teacher-firm” have to be similar for learning to occur. These authors propose that one factor which affects this ability to learn from an external partner (“teacher”) is: ‘the specific type of new knowledge offered by the teacher’ (1998:462). Becker and Peters (2000) and Nelson and Wolff (1997) argue that firms need higher absorptive capacities for scientific knowledge than for other types of knowledge. This finding is consistent with the Mangematin and Nesta (1999) finding that firms with higher absorptive capacity have more contacts with research institutes than firms with lower absorptive capacities.

2.3.5 Open innovators, closed innovators and adopters

Abreu et al. (2006) classify firms as open innovators, closed innovators or adopters. Their study examined the effect of absorptive capacity on the probability of firms to use a ‘closed’ or ‘open’ strategy to innovate. A ‘closed’ innovation strategy is based on developing innovative products and processes mainly within the firm, whereas an ‘open’ strategy results from collaborations with other firms, institutions and supply chain partners. ‘Adopters’ are firms who innovate mainly by adoption of external products and/or processes from external sources. The study found that different innovation strategies use different forms of absorptive capacity. Employment of scientists is important for product innovation by closed innovators. This is consistent with the idea that closed innovators require internal capacity whereas open innovators use ideas, skills

and competencies from outside the firm. In the context of firm innovation Freel (2005) examined the relationship between firm innovativeness and firm level training intensity. This study found the most innovative firms train more staff in agreement with Warner (1996) that 'innovation and training in modern economies are inextricably linked'.

2.4 Firm Interaction with Knowledge Centres

Marques (2006) presents a worthy analysis of the role of universities in innovation within the knowledge based economy:

In a knowledge based economy, the university becomes a key player in the innovation system, as both supplier of human capital and as a physical space for new enterprises (2006:535)

Insofar as knowledge is becoming an increasingly important, indeed, crucial, part of innovation, the university, as an institution that produces and disseminates scientific and technological knowledge, is much more important to industrial innovation (2006:535)

Hoffman (1998) highlights the questions being asked about the contribution of HEIs as sources of technology and technical assistance for SMEs in the UK. He cites Tang et al. (1995) and Storey (1992) who suggest a possible inherent mis-match between the interests of the HEIs and the needs of the SMEs. In the context of SMEs : HEIs are only one source of collaboration, but one which is becoming increasingly important for SMEs if they want to target niche or global markets. Decter (2007) examines university to business technology transfer, examining the UK and USA for comparisons. It is an interesting read because it highlights the issues involved at the HEI/Industry interface with some of the key issues relating to motivations and expectations. Some improvement actions are suggested which were surprisingly non-technical in nature:

- The importance of minimising bureaucracy
- The need for better communication and stronger relationships with business

- Better understanding of business by universities

In an Irish context Ledwith (2003) found in her study of electronics firms that the Irish firms reported more frequent interactions with universities than with suppliers on NPD projects. Surprisingly, in this study collaboration by firms with universities or research institutions showed less success than firms who were not collaborating in this way. The need for these firms to increase their absorptive capacity is suggested as a possible solution to this finding. Ledwith (2003) also concluded that networking is sometimes a substitute rather than a complementary process in SME NPD. This could be further investigated. Also, future research into the significance of the absorptive capacity of firms collaborating with universities and the appropriateness of technology coming from the universities and being offered to SMEs is suggested by Ledwith.

2.5 How do you measure ACAP?

The absorptive capacity of firms cannot be measured directly. Empirical studies measure absorptive capacity indirectly. There is no standard measurement method of measuring absorptive capacity in this way. Schmidt (2005) refers to the determinants of absorptive capacity and summarises them as :

- (a) R&D Activity
- (b) Related prior knowledge and individuals' skills
- (c) Organisational structure and human resource management practices
- (d) Networks and alliances with external partners

Schmidt (2005) does not include the fourth group of determinants i.e. networks and alliances with external partners in his research study. The reason for this is that the focus of his study is internal factors. The study emphasises that all the components of absorptive capacity above are relevant to the absorptive capacity of a firm and firms' have to build all the components, up not just a single one.

Cohen and Levinthal (1990) recommend that in order to obtain a measure of a firm absorptive capacity it is necessary to assess the: 'way the communications between the firm and the external environment' (1990:544) are organised and also the 'nature of the know-how and experience within the organisation' (1990:544). They also highlight the importance of considering how the relationship between 'shared knowledge and range of knowledge' among individuals affects the development of organisational absorptive capacity and the 'diversity of knowledge' between individuals (1990:545). Fiol and Lyles (1985) highlight the importance of a firm's strategic positioning as an element determining its ability to learn, stating that the organisation's strategic posture determines in part its capacity for learning.

Nieto (2004) took account of the suggestions from previous studies (Cohen and Levinthal (1999), Fiol and Lyle (1985)) and chose indicators in an attempt to measure each element contributing to firm absorptive capacity.

Nieto's (2004) four categories for measuring firm absorptive capacity include:

1. Links between the firm and the surrounding environment
2. Level of knowledge and experience of the organisation
3. Diversity and overlapping of knowledge structures and
2. Strategic Posture.

Nieto (2004) used eight statement questions in each of five categories. The measures of the firm's absorptive capacity used by Nieto (2004) were used as the basis for developing the measures used in this study. The modified Nieto framework for measuring ACAP is outlined in detail in the Methodology section.

2.6 Conclusions from Review of Literature

The literature review presented has focused on the definitions, theories empirical studies determinants of firm absorptive capacity and the methods used to measure absorptive capacity. A relatively broad framework for absorptive capacity is required to map the determinants and outcome possibilities for ACAP at firm level. Some theoretical frameworks are included in the literature but they are focused on particular aspects of ACAP (Zahra and George, 2002). The literature, however, offers various theoretical elements of the absorptive capacity concept. A theoretical framework has been constructed from elements of the literature that has been outlined in this review. This theoretical framework is used in this research study to research absorptive capacity at firm level. The theoretical framework is a summary of the literature that has been reviewed and a construct that will be employed throughout this research study to demonstrate the research aims, research methodology and the research results. This theoretical framework is presented in section 2.7.

A second theoretical framework on the wider concept of innovation at firm level, drawn from the literature (Neely, 1998) is presented in section 2.8. The purpose of presenting this innovation framework is to demonstrate how the absorptive capacity theoretical framework is placed in the wider context of innovation at firm level bearing in mind that innovation is the reason why absorptive capacity is of importance and the focus of this research. Finally, the aims of this research and the research hypotheses to be tested are presented in section 2.9.

2.7 Theoretical Framework for Absorptive Capacity

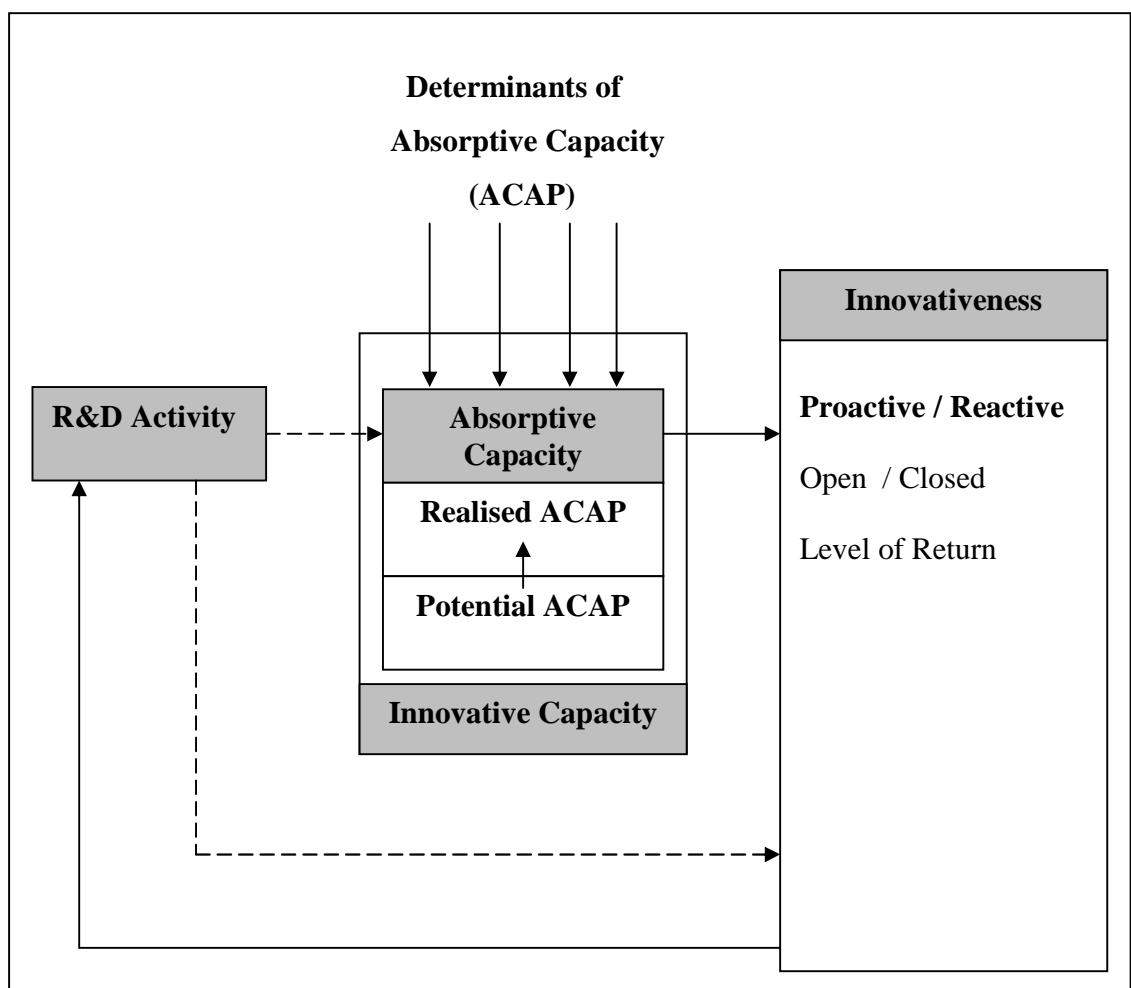


Figure 2.1: Theoretical Framework for Absorptive Capacity at firm level

2.7.1 Description of theoretical framework of absorptive capacity

The theoretical framework in figure 2.2 contains four main components: R&D activity, Absorptive Capacity, Innovative Capacity and Innovativeness with the arrows indicating the primary relationships between the four elements from an absorptive capacity perspective at firm level. R&D intensity is highlighted in the literature as key determinant of ACAP. The ‘two faces of R&D’ (Cohen and Levinthal, 1990) are represented in the framework by the two dashed arrow lines. The effect of R&D on ACAP and on the innovativeness of firms has been identified extensively in the literature. Absorptive capacity is considered by the literature as critical to its innovative capacity (Neely, 1998). Absorptive capacity is presented as an element of a firms’ innovative capability in the theoretical framework. Two types of absorptive capacity identified in the literature – potential and realised (Zahra and George, 2002) are shown as making up the firm absorptive capacity in the theoretical framework. The other determinants of firm absorptive capacity used in the literature are also shown in the framework. The literature also highlighted the influence of ACAP on firms’ innovative traits. The ‘innovativeness’ element of the framework show some of the key firm traits that are of interest i.e. whether firms are open or closed innovators, whether firms are reactive or proactive in their innovative activities.

The framework represents the elements of ACAP that are of interest in this research and it is not intended as a full representation of all the aspects of ACAP at firm level. It is meant to represent the interaction of the core elements identified as inputs to or outputs from a firms’ ACAP and the dynamics of the core elements of the concept. The next section outlines how this framework can be viewed within the wider context of firm innovation.

2.8 Theoretical Framework of Innovation

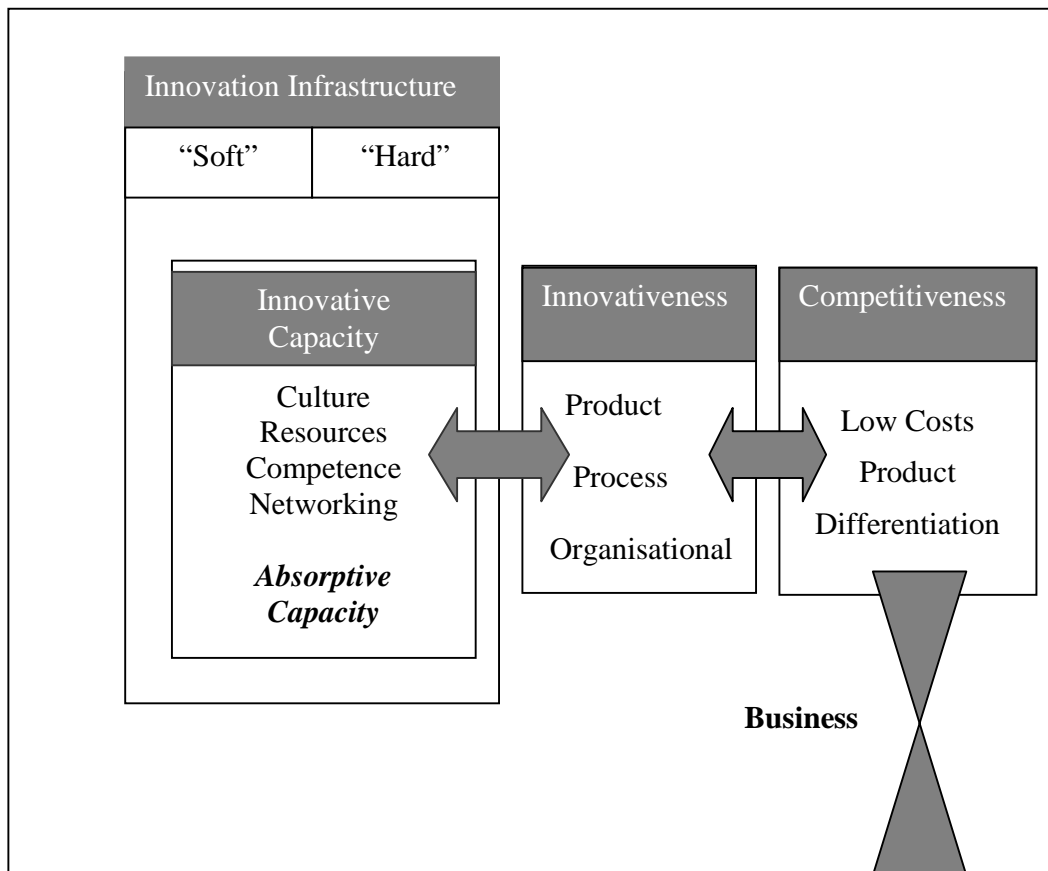


Figure 2.2: Innovative Capacity of Firms (Neely, 1999)

2.8.1 Description of the theoretical framework for innovation at firm level

Absorptive capacity is considered by the literature as critical to its innovative capacity and a firm with a high level of innovative capacity has a higher propensity to innovate. (Neely, 1998).

A theoretical framework of the innovation process at firm level presented by Neely is reproduced in Figure 2.2. The concept of absorptive capacity has been added to this theoretical framework - it is included in the framework as an element of a firm's innovative capability. This is consistent with the absorptive capacity theoretical

framework presented in section 2.7. This theoretical framework is presented as an illustration of the process of innovation and the location of the concept of absorptive capacity within this innovation process framework. The purpose of presenting this theoretical framework is to explicitly present the context for this research on ACAP.

A brief description of two key elements of the innovation framework:

Innovation Infrastructure

The availability and efficiency of the infrastructure available to a firm is key to its business activities. The soft infrastructure includes: skilled labour pool, knowledge base of the region, buyer-supplier networks, training consortia, business support agencies et. Hard infrastructure includes transport and communications infrastructure.

Innovation Capacity

Innovation capacity is built upon four interrelated dimensions: culture, resources, competence and networking. Firms differ in terms of their excellence in managing these four interrelated dimensions. A firm's absorptive capacity is one of the factors that determines a firm's ability to manage these four interrelated dimensions. The differences between firms in managing these four dimensions manifest themselves in the level of innovativeness achieved by firms.

A virtuous cycle is implied by the framework. High levels of innovativeness results in competitive advantage in the marketplace which manifests in enhanced business performance which allows the firm to devote more resources to innovation .

2.9 Aims of Research and Hypotheses

The subject of this research study is on innovation at firm level. In particular the focus is on the absorptive capacity of firms which has been proposed as a key component of firms innovative capacity (Zahra and George, 2002). This research study examines the relationship between R&D intensity and the level of absorptive capacity of companies. The study also compares the innovation profile and innovation performance of companies with their absorptive capacity. The study compares the general findings with the results from previous studies. The study seeks to identify any results and possibly recommendations that would be useful for institutions or agencies seeking to improve the level of ACAP of firms in the region. This could take the form of learning from companies with high levels of ACAP or identifying elements of ACAP weak due to regional deficiencies that would merit attention or appropriate intervention.

The key research questions, research aims and hypotheses to be tested are presented in section 2.9.1 to 2.9.3. Section 2.10 maps the research aims and hypothesis onto the absorptive capacity theoretical framework that was developed in section 2.7.

2.9.1 Research Questions

The key research questions of this research are:

1. Is firm absorptive capacity significant for innovation at firm level?
2. If absorptive capacity is significant for innovation at firm level how can it be enhanced?

2.9.2 Research Aims

The key aims this research study are as follows:

- Aim 1: To collect (qualitative and quantitative) data on the innovative capacity traits and innovation performance of engineering and technology firms in the north west of Ireland.
- Aim 2: To obtain a quantitative measure of the absorptive capacity of engineering and technology firms in the North West of Ireland.
- Aim 3: To identify any relationships between the company innovative capacity traits and innovation performance and their relative levels of absorptive capacity.

2.9.3 Hypotheses

The following Hypotheses will be tested:

- Hypothesis 1: Companies with higher levels of R&D intensity have greater absorptive capacity.
- Hypothesis 2: Companies with higher levels of absorptive capacity tend to be proactive and open in their innovation while companies that have a modest absorptive capacity tend to be reactive and closed in their innovation.

2.10 Mapping of Research Hypotheses

Figure 2.3 presents the research hypotheses mapped onto the absorptive capacity theoretical framework. Hypothesis 1 involves the relationship between R&D activity, in particular, R&D intensity and absorptive capacity. Hypothesis 2 involves the relationship between firm level absorptive capacity and innovative traits of firms.

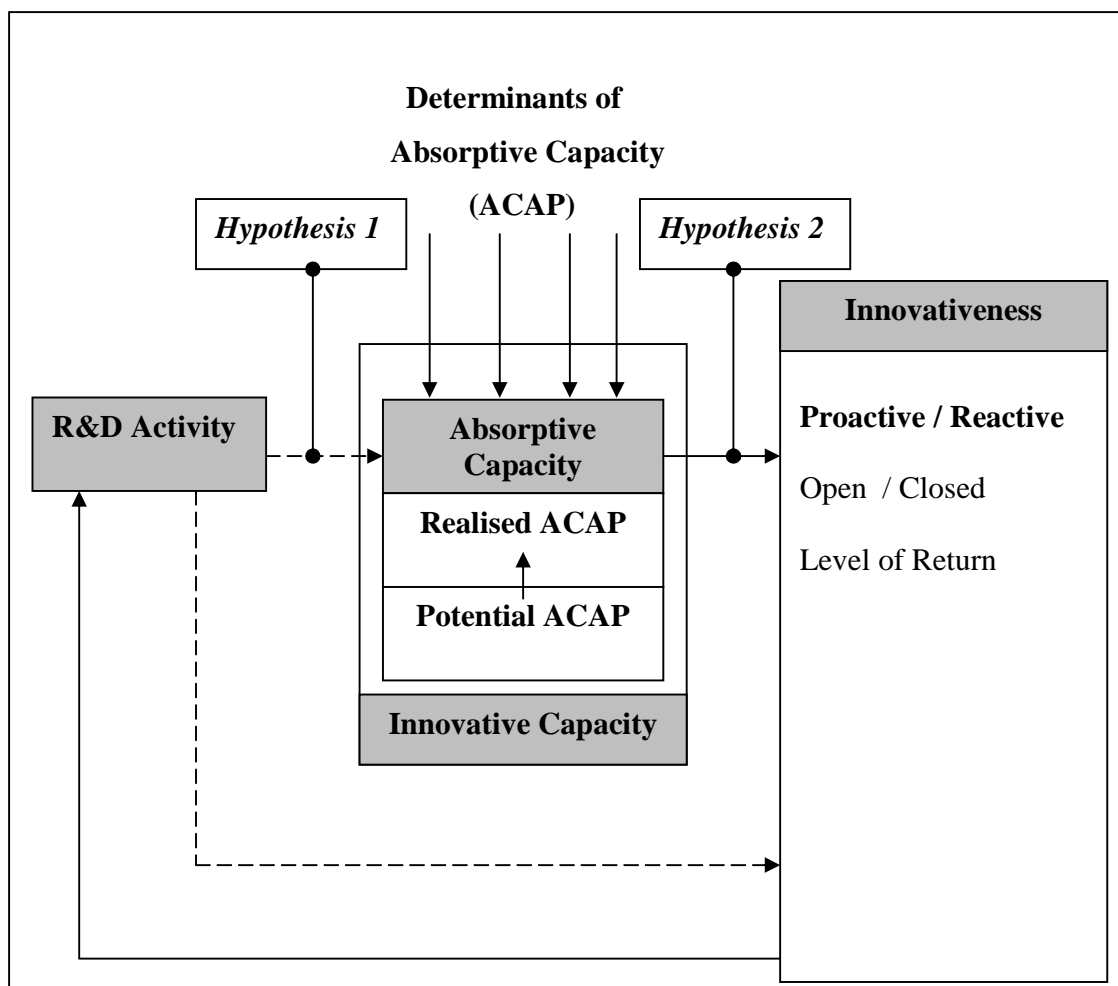


Figure 2.3: Research Hypotheses Mapped onto Theoretical Framework

3 Methodology

3.1 Summary of methodology

A detailed description of the methodology is given in section 3.3. A two stage research methodology was used. Stage one consisted of a company questionnaire which captured quantitative and some qualitative data. Stage two consisted of a structured telephone interview which followed on for a selection of companies who had completed the company questionnaire. The structured telephone interview captured qualitative and some quantitative data. Summary of company data:

Stage One: Company Questionnaire

Number of Companies sent Company Questionnaire	75
Number of Completed Questionnaires received	15
Response Rate	20%

Stage Two: Structured Telephone Interview

Number of Companies Interviewed	6
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3.2 Choosing the Research Method

The factors considered in choosing the research method can be summarised as:

3.2.1 Company innovation profile – suitability for research questions.

Companies engaged in R&D and companies involved in innovation in general were the companies most relevant for this research. The concept of absorptive capacity and its relationship with R&D and collaboration activities at company level cannot be adequately studied for companies involved in neither activities. Because of this it was initially considered focusing attention exclusively on companies who had been involved in the IntertradeIreland technology transfer FUSION programme. Involvement in this

programme is an indicator of a desire to innovate and collaborate. Following initial exploration it was discovered that companies involved in the FUSION programme were a common target for research surveys etc. and would probably not be that responsive because of this. The study group was chosen as clients of a technology support centre (EPICENTRE) at Letterkenny Institute of Technology. The EPICENTRE provides technical support and specialised expertise and mentoring in new technologies for companies in the North West of Ireland. The companies using the EPICENTRE services satisfied the criteria for company engaged in R&D and/or innovating. The manager of the EPICENTRE agreed to facilitate this research with his client companies.

3.2.2 Efficiency of data collection method

It was important that the method of gathering data was efficient from a man-hour perspective. There were very little resources available apart from the Authors' time to collect the necessary data. Also, due to the relatively short time scale of the project a one off snapshot of data collection would only be possible. A survey of client companies of the EPICENTRE was chosen as the most efficient method of data collection.

3.2.3 Access to companies - Probability of company response

Access to FUSION programme companies was possible because the companies involved were published. However, it would essentially have been 'cold calling' to these companies which would have taken more time and with a lesser chance of response. The EPICENTRE client companies could be approached via email from the EPICENTRE. The email could be sent from the manager requesting the assistance of the client companies in the research. This was essentially the equivalent of an introduction of the researcher to the client companies, increasing the likelihood of response.

3.2.4 Validity of collected data.

It was decided to obtain a better understanding of the makeup of the client EPICENTRE companies to enable the survey questionnaire to be customised to suit the company size etc. A questionnaire was compiled for the manager of the EPICENTRE to complete. This yielded information about the size of client companies, client company sectors and activities and the services delivered by the EPICENTRE to the client companies. The client companies were revealed to be primarily SME's or micro-organisations. The following extract from the questionnaire response is a good summary:

'EPICENTRE focuses on the delivery of technology solutions. Overall the client is looking to either start a new business or increase productivity through new technology or improvements to existing systems in place'

This proved useful in designing the company questionnaire, for example there was no point asking about communication between departments when companies have only six employees. It also verified that the client companies are engaged in innovation. The 'EPICENTRE Questionnaire is included in Appendix A.

3.2.5 Suitability of collected data for analysis and testing of the hypothesis.

It was initially decided to carry out a company survey using a self administered questionnaire. It was believed that a well designed questionnaire would be capable of obtaining relevant and suitable data to analysis and testing of the research hypothesis. Following discussion with my thesis supervisor who suggested follow-up interviews with a selection of the companies it was decided to use a two stage approach as the research methodology. Stage one : Self –administered questionnaire to companies and Stage two : Structured telephone interviews with a selection of the companies that took part in stage one.

3.3 Description of Research Method

A two stage research methodology was chosen. Stage one consisted of a company questionnaire. Stage two consisted of a structured telephone interview. The rationale behind this research methodology is that stage one would serve the purpose of gathering quantitative information about the companies and stage two would gather more quantitative information about the companies innovation activity and behaviour. The company questionnaire requests general company information and information about the company's innovation profile, innovation inputs and outputs with particular focus on R&D. The key purpose of the company questionnaire is to obtain a measure of key indicators of firm absorptive capacity.

Figure 3.1 overleaf summarises the nature of the research data that was collected at stage one and stage two of the research methodology in relation to theoretical framework and the key elements: R&D activity, firm absorptive capacity and firm innovativeness. Section 3.3.1 and Section 3.3.2 present the two stages of the research methodology in detail.

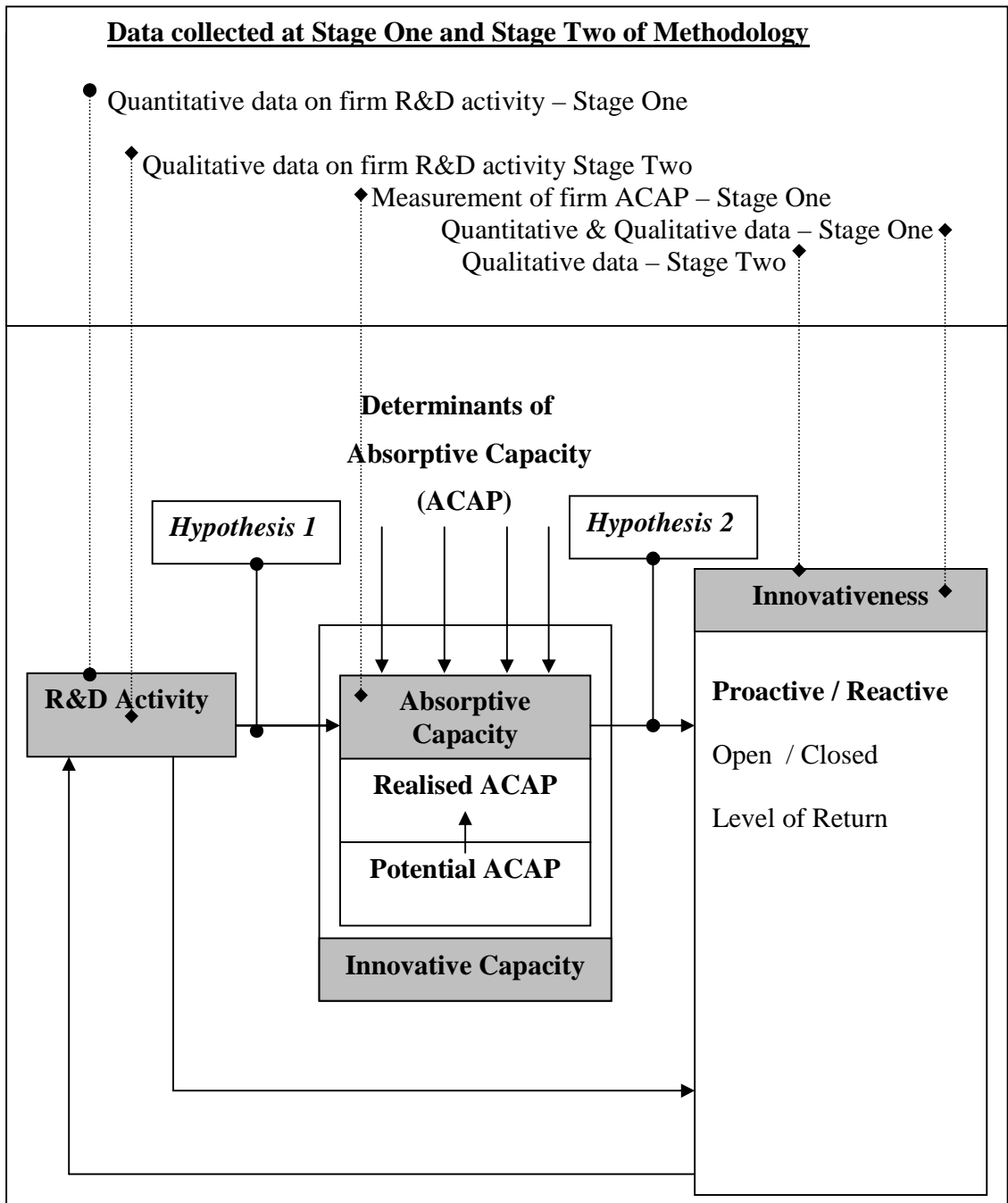


Figure 3.1: Research Hypotheses Data Mapped onto Theoretical Framework
 (See Section 2.6.1 for details of Theoretical Framework)

3.3.1 Stage one – Company Questionnaire

Theoretical Background

A snapshot measurement of the absorptive capacity of the firms is obtained using a measuring tool that is developed based on appropriate variables that have been identified as key indicators of absorptive capacity from previous theoretical and empirical works (Nieto, 2004, Schmidt 2005)

In this study it is required to have R&D effort and expenditure (which has a strong correlation with innovative effort) independent from the measure of absorptive capacity. The Nieto (2004) framework does just that whereas the Schmidt (2005) framework does not. For this reason and the because of the simplicity of the structure of the Nieto (2004) framework it has been used as the basis for the measurement of absorptive capacity in this study.

The Nieto (2004) measurement framework has been modified to suit the respondent companies in this study. This involved removing some of the questions mainly because the questions were not relevant to small companies i.e. communication between departments etc. The strategic posture questions were effectively re-written for this research study. The resulting measurement framework used in this study has seventeen questions compared to the thirty two used by Nieto (2004). The scores from the seventeen questions are added up with equal weighting to each question. This is in consistent with the assertion by Schmidt (2005) that all three components in his framework were relevant. This assertion has been extended to all five components in this study. The questionnaire structure is outlined in detail in Section 3.3.1.1.

3.3.1.1 Company Questionnaire Design

A copy of the company Questionnaire is in Appendix A. The company questionnaire is made up of a word document of seven A4 sheets. The word document uses table as the general question format and text boxes are extensively used to facilitate respondents typing responses and choosing from options. 'Questionnaire Guidelines' are included at the beginning of the questionnaire thanking respondents for 'taking the time to complete this questionnaire' and indicating that completion of the questionnaire would take 'approximately 10 minutes to complete. Respondents were advised that 'All responses will be treated with the strictest confidence and no company names will be used in the research report. Finally, respondents were requested to email completed questionnaires to the authors email address.

This questionnaire will be referred to as the company questionnaire in this text or 'CQ'. The CQ consists of three sections: - Section A, Section B and Section C. Section C is subdivided into four subsections labelled Section C1, Section C2, Section C3 and Section C4. Each section has a number of questions which are number, starting at number one in each section. In this way specific questions can be referred to i.e. question 1 in section one is referred to as question A1 etc. Questions in section three, with the four subsections are referred to as follows: Question one in subsection C1 is referred to as question C1-1 etc. I will now describe each of these three sections in detail and outline the questions contained in each of the three sections.

Section A

This section relates to 'Company Information' and consists of seven questions. The first five questions are for completion by respondents:- questions A1 to A5.

'Title/Position of Person completing this questionnaire'.A1 . 'Age of your company'.A2. 'Number of Employees'. A3. 'Core Area/Sector of Business activity'.A4. 'Core Company Activities'.A5.

A6 is a Yes/No question to whether the company exports (reference 29 pg 12). A7 prompts the respondent to put a tick in the relevant box which indicates the correct company turnover from a choice of seven, ranging from 'less than 10,000 Euro' to 'More than Fifty Million'.

Section B

This section relates to 'Company Innovation and R&D' and consists of five questions

In questions B1 and B2 the respondents have to choose from options presented. B1 requires the respondents to choose from three statements the statement that is the closest to describing their company's method of innovation. (reference 29 pg 12) The three statements essentially refer to Exclusively Internal Innovation, Collaborative Innovation and Adoptive Innovation. 'How often does R&D activity take place at your company'. B2. Respondents have four options to choose from for B2: - All the time, Occasionally, Rarely or Never.

B3 requests respondents to provide 'the typical amount you spend on R&D activity as a percentage of annual Turnover'.

In questions B4 and B5 respondents fill in company performance information relating to the previous three year period. B4 requests the 'number of new or improved products and/or services introduced to the market by your company'. B5 requests 'the percentage of current turnover generated by new or improved products and/or services which have been launched by your company'.

Section C

Section C is the part of the questionnaire that measures the absorptive capacity of the respondent companies. Section C consists of four subsections:- Section C1, Section C2, Section C3 and Section C4. Subsection C1 relates to 'External company Links'.

Subsection C2 relates to ‘Company Knowledge and Experience’. Subsection C3 relates to ‘Diversity of Company knowledge’. Subsection C4 relates to ‘Company Strategic Posture’.

The subsections consist of four questions, with the exception of Subsection C4 which has five questions. All the questions in Section C comprise of individual sentences that are presented to respondents.

In subsections C1 , C2, C3 and C4 the respondents are requested ‘For your company indicate the level of agreement (on a scale of 1 to 5) with the following statements’. The four statements are presented below this instruction with a scale labelled from numbers 1 to 5 and indicating that 1 is ‘Totally Disagree’ and 5 is ‘Totally Agree’. Respondents put one tick in the box on the scale at the appropriate level of agreement from 1 to 5.

In subsection C5 the respondents are requested ‘Please assess the level of priority (on a scale from 1 to 5) the following objectives would have in your company strategy’. The five statements are presented below this instruction with a scale labelled from numbers 1 to 5 and indicating that 1 is ‘Very Low Priority’ and 5 is ‘Very High Priority’. Respondents put one tick in the box on the scale at the appropriate level of priority from 1 to 5.

Company Questionnaire wrap-up

Finally, respondents are asked if they ‘would be willing to answer a few additional questions by telephone interview’ and to leave their contact details if so.

Respondents are thanked for their completion of the questionnaire and requested to e-mail the completed questionnaire to the appropriate email address which is supplied in hypertext.

3.3.1.2 Administration of Company Questionnaire

The company questionnaire was emailed to the manager of the EPICENTRE with a draft of the covering letter to accompany the questionnaire. The questionnaire was emailed by the EPICENTRE manager to all EPICENTRE client companies (Approximately 75 in total) with a brief explanation of the purpose of the questionnaire and encouraging recipients to complete the questionnaire and to return to the researcher. It was deemed important that the questionnaire was sent by the EPICENTRE manager to the EPICENTRE clients, rather from the researcher, to increase the likelihood of the companies completing and returning the questionnaire.

3.3.2 Stage Two – Structures Telephone Interviews

The telephone interviews were carried out following the company questionnaires and were with respondents to the company questionnaire. A selection of respondents were chosen for telephone interview based on their expressed willingness to be interviewed (indicating this on the company questionnaire) and based on their absorptive capacity score from the company questionnaire.

The interviewees were contacted at the telephone numbers they previously provided. The interview times were not pre-arranged. The interviewees were thanked for filling out the original company questionnaire, reassured of the confidentiality of their contribution and asked if they could answer a few additional questions. The interviewees were informed that the interview would take approximately ten minutes but it would depend on their responses. If it was not a convenient time a future interview time was agreed where possible.

The interviewer proceeded to explain that there were nine questions and that some of the questions were based on the responses made by the interviewee in the company questionnaire. The interviewer also informed the interviewee that they would be taking notes of the responses and also encouraged the interviewee to stop them at any time if any clarification of the questions was needed etc.

The structures telephone interviews were based on nine prepared questions. The questions were both open and closed in nature. The nine questions will be referred to as T1 to T9 to distinguish them from the company questionnaire questions. The first question, T1, asked the interviewee to classify the competitiveness of the business sector that their company operated in on a scale of 1 to 5, with 1 indicating very low competition and 5 indicating very high competition. Any additional comments by the interviewee were also notes. In view of the response made by the interviewee to question B2 regarding the intensity of R&D at their company (All the time, Occasionally, Rarely, Never), the interviewees were asked in T2 ‘What is your motivation to do R&D?’ Only companies who have indicated that they never carried out R&D were asked T3 ‘How do you innovate’, otherwise interviewees were asked T4. T4 required interviewees to classify the nature of their R&D activity under one of two options ‘Proactive or Reactive R&D’. A brief description of the meaning of the two types of R&D activity was provided.

In view of the response made by the interviewee to question B1 regarding their company’s method of innovation (Exclusively Internal Innovation, Collaborative Innovation or Adoptive Innovation), company’s who had an exclusively internal method of innovation were asked in T5 ‘Why this way? Any reasons/barriers for not collaborating externally’. This question was teased out with the interviewee. T6 asked ‘Who do you collaborate with’ for companies who answered ‘Collaborative Innovation’ to question B1 in the company questionnaire. Again, an open discussion on this topic was encouraged between the interviewee and the interviewer.

The interviewer referred to the score of 1 to 5 the interviewee had provided for question C1-4 in the company questionnaire before asking question T7. The interviewer asked the interviewee ‘Why/Why not interaction/collaboration with external bodies (Universities/Government agencies). T8 involved the interviewer requesting the interviewee to rate a number of information sources as Not Relevant, Relevant or Very relevant for their company in the context of triggering/supporting innovation. Interviewees responded to nine sources of information prompted by the interviewer.

Finally, Referring to the sources of information in T8, T9 involved the interviewer asking 'How do you use the internal/external information to improve your business'. The interviewee was prompted if necessary by the interviewer if they used any formal or informal processes/tools to facilitate same.

3.3.3 Piloting of Company Questionnaire

The company questionnaire was self devised. The *first draft* was forwarded to an experienced Occupational Psychologist who has a lot of experience of evaluation and the use and design of questionnaires. The feedback received on the first draft was as follows:

There were too many questions and some of the questions were too heavily loaded requiring respondents to make up to twelve ratings of various aspects of their business. It was believed that the questionnaire was too long and respondents might struggle to complete or lose interest.

It was suggested that a simpler layout would flow better for respondents completing the questionnaire and the format of two columns on each sheet with questions on the questionnaire was found to be confusing.

These comments were taken on board. The format was simplified and the number of questions in the company questionnaire was reduced significantly. The following eight questions were removed or modified at this stage from Sections A and Section B of the company questionnaire. These eight questions and the reasons for removing or modifying the questions are outlined below:

1. 'Company goals for the near future', (Seven options to choose from)

This company goals was essentially covered in Section C4 of the questionnaire – 'Company Strategic Posture'.

2. 'Markets you currently compete in or are currently preparing to compete in'.

This question was replaced with a simpler question A6 'Do you Export?' with a Yes/No Option

3. 'Approximate percentage of total man-hours spent on Research and Development',

This question was replaced by question B2 'Please indicate the typical amount you spend on Research and Development activity as a percentage of Annual Turnover'

4. 'Please choose the frequency of introduction of new or improved goods and/or services in the last three years' (with options Continuously, Frequently, Regularly, Rarely, Never)

This question was removed - too detailed for the scope of the study and research aims.

5. 'Please state the number of process innovations introduced in the last three years',

This question was removed – it was decided that no distinction was to be made in this study for simplicity and feasibility between product and process innovations.

6. 'Please choose the frequency of introduction of new processes in the last three years' (with options Continuously, Frequently, Regularly, Rarely, Never)

7. 'Your Motivation / Reason to innovate' (with options) was removed.

This question was move to stage two of the research methodology and modified to present as an open question.

8. 'Relevance of Information Sources of Information' (Sources listed to be rated by respondents)

This question was move to stage two of the research methodology

A *second draft* of the company questionnaire was presented to the manager of the EPICENTRE for feedback. The purpose of this was to obtain feedback about the questionnaire and in particular the suitability of the language used for the EPICENTRE clients. The feedback received was as follows:

1. To change the five point scale being used: 'Totally Dis-Agree, Mainly Agree, Agree a Little, Mainly Agree, Totally Agree'.
2. To remove footnotes in questionnaire as they were not required.

This advice was taken on board, footnotes were removed and five point scale terms and format modified.

3.3.4 Piloting of Structured Telephone Interview

The Structured telephone interview was piloted with an experienced Occupational Psychologist who has extensive experience of structured telephone interviewing. The interviewer went through a mock telephone interview with the prepared questions. The feedback from this exercise included the following points:

1. The need to build up a rapport with the interviewee as much as possible early on and to put them at their ease, while re-assuring them of the confidentiality of the data collected.
2. The benefit of gently probing the interviewee to explain their responses, where appropriate, or to elaborate on their responses.

3.3.5 Limitations of Research Methodology

1. The company questionnaire was self-administered. There is a possibility of bias in responses, in particular to rate company activities and successes higher than they are.
2. The telephone interview is recognised as not the most robust method of capturing qualitative data.
3. The number of responses (at 15) to the company questionnaire is relatively low.
4. The measurement of firms' absorptive capacity depends on the respondents understanding of certain terms: R&D, Innovation etc. This understanding will vary with individuals.
5. The firms are all engineering and technology based firms in the same region. However the sectors of operation can still be quite different with different levels of knowledge intensity.

4 Results

4.1 Results from Stage One: Company Questionnaire

The nominal results from the company questionnaire are presented first for the three questionnaire sections:

Section A	Company Information,
Section B	Company Innovation and R&D
Section C	Measures of Company Absorptive Capacity

Section C is made up of four sub-sections for the four elements of company absorptive capacity:

C1	External Company Links
C2	Company Knowledge and Experience
C3	Diversity of Company knowledge
C4	Company Strategic Posture

Analysis of the company questionnaire results is presented in section 4.2.

Some comments on the results presented overleaf:

Table 4.1 in Section 4.1.1 overleaf presents the company information for the companies who completed the questionnaire. The codes (from letter 'a' to letter 'o') in the second column of the table are the company labels used in this research study. These are used in the results section. The sectors that the companies operate in are listed in the third column. 'Engineering' is listed for traditional engineering activities, primarily manufacturing based with some design element. The last column refers to the position of the individual who completed the questionnaire.

Section B results in Section 4.1.2 show a 80:20 split between collaborative innovators and internal innovators with none of the fifteen companies primarily engaged in technology adoption or licensing. Section B results also reveal that two thirds of the companies surveyed innovate 'All the time' and 87% of the companies surveyed export their products and services.

4.1.1 Section A Results: Company Information

Company		(Question A-4)	(Question A-3)	(Question A-2)	(Question A-1)
No.	Code	Sector	Company Size	Company Age (Years)	Respondents' Position
1	A	Engineering	S	10	Managing Director
2	B	Engineering	S	25	Director
3	C	Engineering	S	4	Marketing Manager
4	D	Avionics	S	1	Managing Director
5	E	Renewable Energy	S	2	Managing Director
6	F	Medical	M	14	Director
7	G	Medical	S	2	Director
8	H	Engineering	S	22	General Manager
9	I	Marine Engineering	S	22	Director
10	J	Electronics	S	6	Managing Director
11	K	Software	S	10	Software Designer
12	L	Printing Technology	S	17	Senior R&D Engineer
13	M	Engineering	S	34	Engineering Manager
14	N	Software	S	4	Director
15	O	Engineering	M	15	Managing Director

Note : S = Small (<50 Employees), M=Medium (<250 Employees)

Table 4.1: Section A Results - Company Information

4.1.2 Section B Results: Company Innovation and R&D

Question B-1: Company's Method of Innovation

Which one of the following three statements is the closest to describe your company's method of developing new products and/or processes i.e. your company's method of innovation?

20% Innovation developed exclusively within the company

80% Innovation developed mainly within the company but based on collaboration/interaction with other firms/institutions/partners

0% Innovation developed mainly through adoption and/or licensing from other firms/institutions/partners

Question B-2: Intensity of R&D

How often does Research and Development activity take place at your company?

67% All the time

27% Occasionally

6% Rarely

0% Never

Question A-6: Do you Export?

87% YES

13% NO

Comments on Results presented in Table 4.2 overleaf

Table 4.2 overleaf presents the quantitative data on company R&D and innovation. Company turnover is presented in column three. The questionnaire requires companies to indicate the approximate company turnover by indicating the company turnover within ranges of values presented. Mid-range values are included in Table 4.2 based on the respondents indicated company turnover. R&D intensity is presented in column four: - expressed as company expenditure on R&D as a percentage of company turnover/Sales. This is an established metric for R&D intensity used in the literature (Cohen and Levinthal (1989, 1990), Nieto (2004) . Company ‘g’ recorded the highest R&D intensity at 75%. This is a small new company in the medical technology sector with a small turnover so the high figure is understandable. Four companies are around the 20% level of R&D intensity:- company ‘n’ (25%), company ‘e’ (20%), company ‘f’ (16%) and company ‘o’ (15%)., with the rest of the companies 5% or lower. Company ‘h’ is the only company with 0% R&D intensity. The average R&D intensity is approximately 8% ignoring the 75% figure for company ‘g’ as an outlier.

Column five in Table 4.2 includes the responses to question B4 on the company questionnaire: ‘Please state the number of new or improved products and/or services introduced to the market by your company in the last three years (or currently working on)’. Company ‘k’ and company ‘b’ have the highest number of new or improved products and/or services at ten and nine respectively. Company ‘c’ and company ‘h’ recorded zero. The average number of innovations over the fifteen companies is 3.2. Care must be taken when examining the results of the number of company innovations indicated by the number of new products etc as it is left to the respondents to interpret what a new product entails etc. and/or the difference between levels of improvements i.e. radical improvement versus incremental etc. Care is needed in drawing conclusions from this particular metric due to this inherent weakness in the data.

Column six in Table 4.2 includes the responses to question B5 on company questionnaire: ‘Please state the percentage of current turnover generated by new or

improved products and/or services which have been launched by your company in the last three years'. The two software companies indicated that 100% of company return was from new products, perhaps not surprising in the context of the sector of operation. Three companies: company 'c', company 'f' and company 'h' indicated zero return from new products, having invested 3%, 16% and 0% of company turnover on R&D. Care must be taken when examining these results due to the time lag between investments in R&D and the returns.

Section B Results: Company Innovation and R&D

<i>Company Labels</i>			<i>R&D Intensity</i>	<i>Innovation Outputs</i>	
No.	Code	Company Turnover (Millions of Euro)	Company Expenditure on R&D (As % of Turnover)	Number of New/Improved Products/Services	Company Return on New products
1	a	15	2	3	15
2	b	7.5	4	9	22
3	c	0.5	3	0	0
4	d	0.1	N/A	1	N/A
5	e	0.1	20	2	50
6	f	2.5	16	2	0
7	g	0.1	75	1	90
8	h	7.5	0	0	0
9	i	2.5	4	5	25
10	j	0.1	3	3	20
11	k	2.5	5	10	100
12	L	2.5	5	2	3
13	m	7.5	5	3	10
14	n	0.5	25	3	100
15	o	7.5	15	4	12

Table 4.2 Section B Results – Company Innovation and R&D

4.1.3 Section C Results: Measures of Company Absorptive Capacity

The measures of company absorptive capacity consist of the presentation of seventeen statements to respondents to consider. The seventeen questions are divided into four categories which represent four different determinants of absorptive capacity:

- Section C1: External Company Links
- Section C2: Company Knowledge and Experience
- Section C3: Diversity of Company knowledge
- Section C4: Company Strategic Posture.

For Section C1, Section C2, Section C3 :The respondents are asked their company's 'level of agreement (on a scale of 1 to 5, where 1 = Totally Disagree, 5 = Totally Agree)' with each of the statements in turn. For Section C4: The respondents are asked their company's 'level of priority the following objectives would have in your company strategy' (on a scale of 1 to 5, where 1 = Very Low Priority, 5 = Totally Very High Priority)' with each of the statements in turn. The level of agreement of the companies with the seventeen statement questions are indicators of a company's absorptive capacity. The rationale is that the higher the level of agreement with the statements– the higher the absorptive capacity for the company. The one exception to this is question C3-3 'The Company specialises in a small number of technologies'. There is a negative relationship between absorptive capacity and specialization, absorptive capacity positively associated with knowledge diversity. The way this is treated in the results is that the respondents scores are reversed i.e. if they chose a rating of 5 then a rating of 1 was recorded with the results etc. All 'level of agreement scores' (with question C3-3 adjusted) for the seventeen questions contribute to the total or accumulative company absorptive capacity score, this is referred to as the 'Aggregate Absorptive Capacity' score in the results.

Comment on Results from Section C1: External Company Links

The results are presented in Section 4.2.3.1 for section C1. The highest scoring company is the electronics company 'j' with a score of 4.75 indicating strong ability to collaborate with external partners. The lowest scoring companies are engineering companies 'b' and 'h' both with 2.25 indicating limited external links. The mean score across all the companies is 3.5.

Comment on Results from Section C2: Company Knowledge and Experience

The results are presented in Section 4.2.3.2 overleaf for section C2. The highest scoring companies are the electronics company 'j' with a score of 4.75 and the avionics company 'd' indicating strong internal competencies. The lowest scoring company is engineering company 'h' with a low score of 1.75 indicating limited internal competencies. The mean score across all the companies is 3.6.

Comment on Results from Section C3: Diversity of Company Knowledge

The results are presented in Section 4.2.3.3 overleaf for section C3. The highest scoring company is the engineering company 'c' with a score of 4.5 indicating existence of diverse knowledge in-house. The lowest scoring company is engineering company 'h' with a very low 1.75. The mean score across all the companies is 3.4.

Comment on Results from Section C4: Company Strategic Posture

The results are presented in Section 4.2.3.4 overleaf for section C4. The highest scoring companies are the electronics company 'j' with a maximum score of 5.00. The software company 'k' are next with a score of 4.8. The lowest scoring company is engineering company 'h' with a score of 2.4. The mean score across all the companies is 4.15. Company strategic posture is a measure of a firms ambition and aspiration levels. The questions in section C4 ask companies to rate their company's level of priority on the objectives presented. By scoring five on all five objectives it could be argued that it was inconsistent because not all objectives can have top priority. There is a possible problem in the interpretation of this question by some respondents rating the objectives stated are important for their company rather than rating their relative importance as requested. It could also be indicative of a lack of explicit strategic focus in certain companies if all stated strategic objectives are given equal priority. This problem could possible be designed out of the questionnaire by better clarification to respondents.

4.1.3.1 Result from Section C1: External Company Links

Figure 4.1 shows the mean rating obtained for all companies on the 'external company links' ACAP indicator. The mean rating for the four questions are presented below for each company. The four 'External Company Links' questions requested 'the level of agreement (on a scale of 1 to 5, where 1 = Totally Disagree, 5 = Totally Agree) with the following statements':

Question C1-1: The company is well aware of technologies/products being developed by its competitors

Question C1-2: The company conducts frequent market research so as to be aware of customer needs

Question C1-3: The company has developed new products and/or processes in collaboration with other companies/organisations/institutes etc

Question C1-4: The company normally goes to other bodies (Universities, Institutes of Technology, Government Agencies etc.) to find out about fresh opportunities for introducing new products

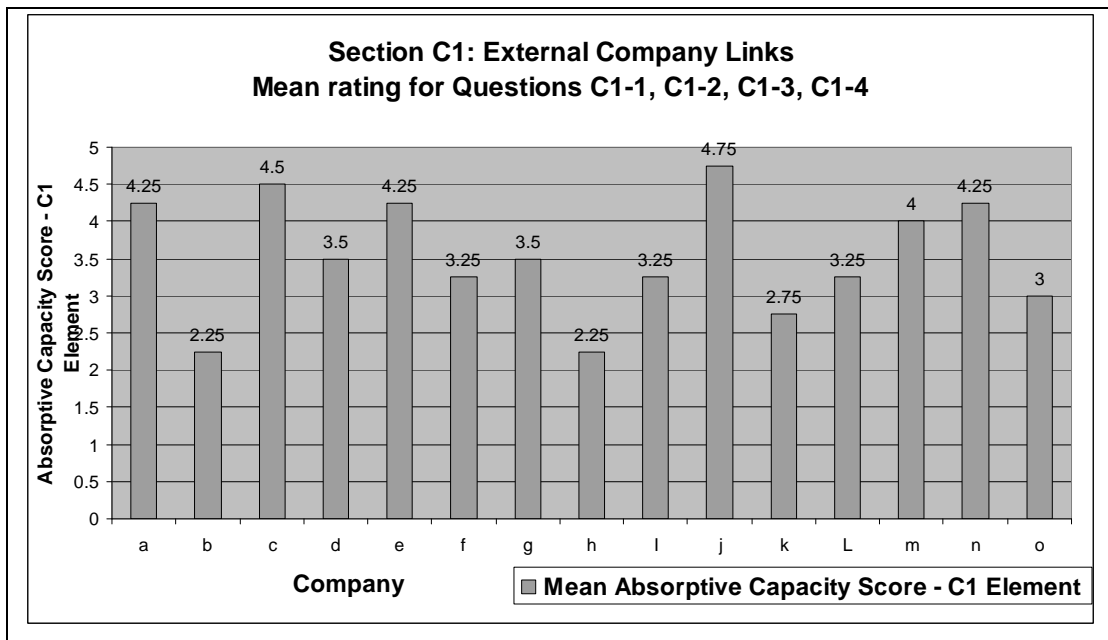


Figure 4.1: External Company Links ACAP indicator – Company Mean Ratings
(See Table 4.1 for company list)

4.1.3.2 Result from Section C2: Company Knowledge and Experience

Figure 4.2 shows the mean rating obtained for all companies on the 'Company Knowledge and Experience' ACAP indicator. The mean ratings from the four questions are presented below for each company. The four 'Company Knowledge and Experience' questions requested 'the level of agreement (on a scale of 1 to 5, where 1 = Totally Disagree, 5 = Totally Agree) with the following statements':

- Question C2-1:** Most of our staff are highly skilled and qualified
- Question C2-2:** We invest a great deal in training
- Question C2-3:** Most of the time we are ahead of our competitors in developing and launching new products
- Question C2-4:** We have capability to adapt others' technology

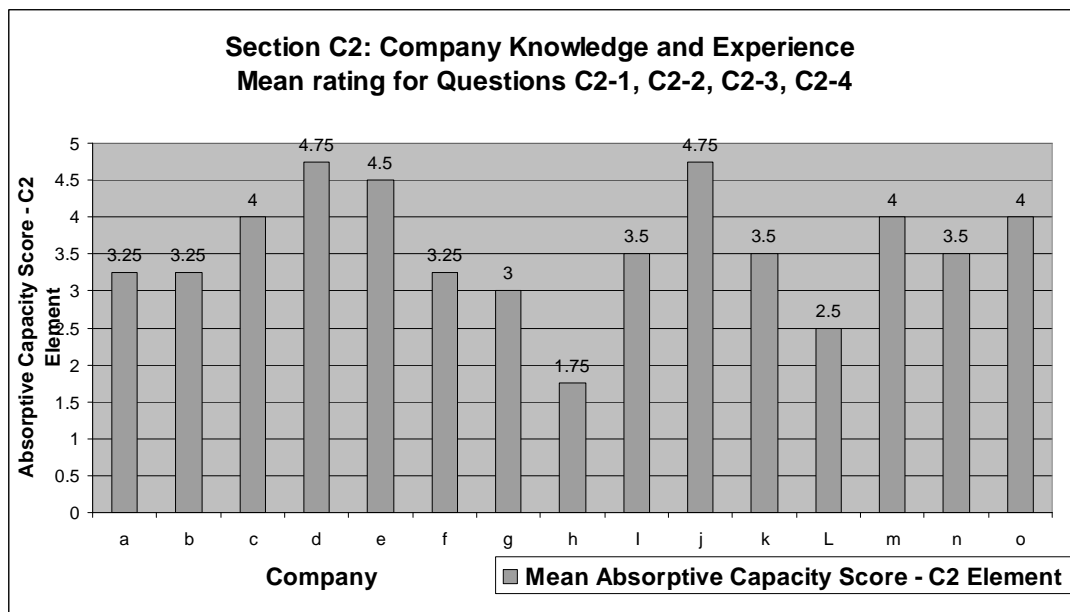


Figure 4.2: Company Knowledge and Experience ACAP indicator – Company Mean Ratings

4.1.3.3 Result from Section C3: Diversity of Company Knowledge

Figure 4.3 shows the mean rating obtained for all companies on the 'Diversity of Company Knowledge' ACAP indicator. The mean ratings from the four questions are presented below for each company. The four 'Diversity of Company Knowledge' questions requested 'the level of agreement (on a scale of 1 to 5, where 1 = Totally Disagree, 5 = Totally Agree) with the following statements':

- Question C3-1:** The company encourages and supports employees in knowledge acquisition from external sources
- Question C3-2:** The company has staff with a wide range of training and educational backgrounds
- Question C3-3:** The company specialises in a small number of technologies
- Question C3-4:** Development projects for new products are carried out by multi-discipline teams

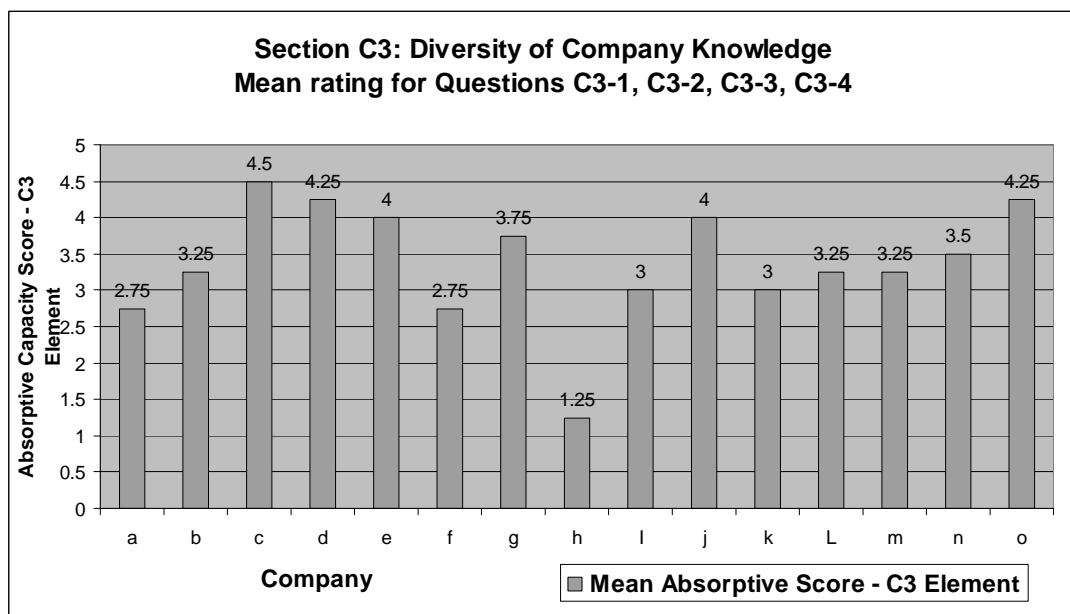


Figure 4.3: Diversity of Company Knowledge ACAP indicator – Company Mean Ratings

4.1.3.4 Result from Section C4: Company Strategic Posture

Figure 4.4 shows the mean rating obtained for all companies on the 'Company Strategic Posture' ACAP indicator. The mean ratings from the four questions are presented below for each company. The four 'Company Strategic Posture' questions requested 'the level of agreement (on a scale of 1 to 5, where 1 = Totally Disagree, 5 = Totally Agree) with the following statements':

- Question C4-1:** Achieving maximum product quality and superior products than our competitors
- Question C4-2:** Delivering superior products than our competitors
- Question C4-3:** Reducing our cost base
- Question C4-4:** Increasing market Share with existing products
- Question C4-5:** Being first to market with novel products

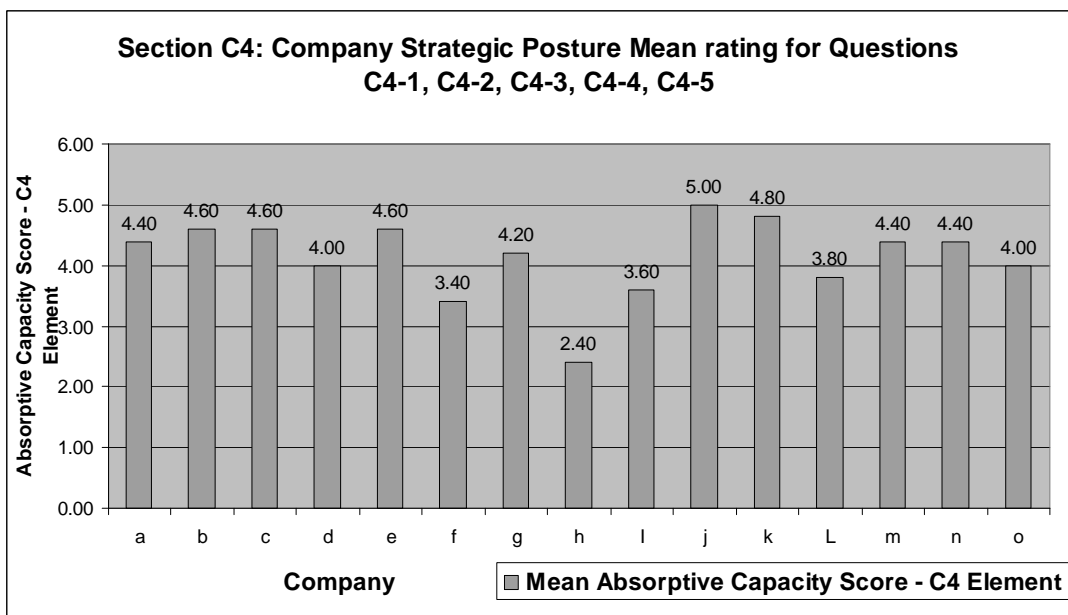


Figure 4.4: Company Strategic Posture ACAP indicator – Company Mean Ratings

4.1.3.5 Aggregate Scores for Section C: Absorptive Capacity Indicator

Figure 4.5 shows the mean rating obtained for all companies on all the ACAP indicator ratings C1 to C4.

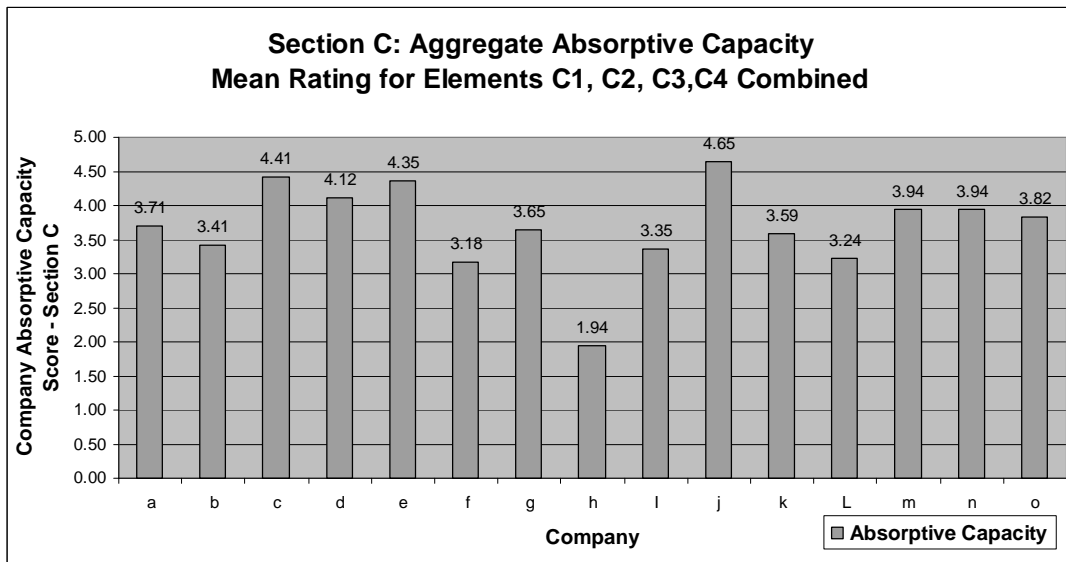


Figure 4.5: ACAP indicator – Company Mean Ratings for all Indicators

Figure 4.5 shows electronics company ‘j’ with the highest aggregate ACAP score of 4.65 out of a maximum of 5.00. Company ‘j’ scored the highest out of all the companies on the three ACAP indicators C1, C2 and C4. The lowest aggregate ACAP score of 1.94 was obtained by engineering company ‘h’. Company ‘h’ scored consistently low on all four ACAP indicators with the lowest score in C1, C2, C3 and C4. See Section 4.1.5 for further analysis of these company scores.

4.2 Analysis of Company Questionnaire Results

4.2.1 Comparison of variation in ACAP Elements for each company:

Table 4.3 below summarises the mean scores for all the companies on the four ACAP indicators. The sixth column on the table includes the standard deviation of these four scores for all companies. The purpose of this calculation is to identify the variation in the company scores between the four indicators of ACAP used in the study. For Example: Engineering company 'b' has the highest standard deviation between ACAP element scores at 0.96. For company 'b' the C1 'External Company Links' mean score is 2.25 compared to the 4.6 score for C4 'Company Strategic Posture'. The mean ACAP score for company 'b' is 3.41 from Figure 4.5 and their score of 2.25 in the C1 element is a good bit below this. This could possibly indicate an imbalance between the building of the four elements of ACAP for company 'b'. Further investigation would be needed. Software company 'L' have the second largest standard deviation at 0.91 on the table with their C1 score of 2.75 significantly below their mean ACAP score of 3.59. Stage two results will help to explain this result in section 4.3.4. as company 'k' were interviewed.

Company	C1 - Mean	C2 - Mean	C3 - Mean	C4 - Mean	Mean - Overall	STD Dev
a	4.25	3.25	2.75	4.4	3.66	0.79
b	2.25	3.25	3.25	4.6	3.34	0.96
c	4.5	4	4.5	4.6	4.40	0.27
d	3.5	4.75	4.25	4	4.13	0.52
e	4.25	4.5	4	4.6	4.34	0.27
f	3.25	3.25	2.75	3.4	3.16	0.28
g	3.5	3	3.75	4.2	3.61	0.5
h	2.25	1.75	1.25	2.4	1.91	0.52
i	3.25	3.5	3	3.6	3.34	0.27
j	4.75	4.75	4	5	4.63	0.43
k	2.75	3.5	3	4.8	3.51	0.91
L	3.25	2.5	3.25	3.8	3.20	0.53
m	4	4	3.25	4.4	3.91	0.48
n	4.25	3.5	3.5	4.4	3.91	0.48
o	3	4	4.25	4	3.81	0.55
Mean for Section	3.53	3.57	3.38	4.15		

Table 4.3: Comparison of variation in ACAP Elements for each company

4.2.2 Ranked Absorptive Capacity for Companies

The mean ratings for company absorptive capacity from Figure 4.6 are presented below for each company ranked from highest ACAP score to lowest ACAP score.

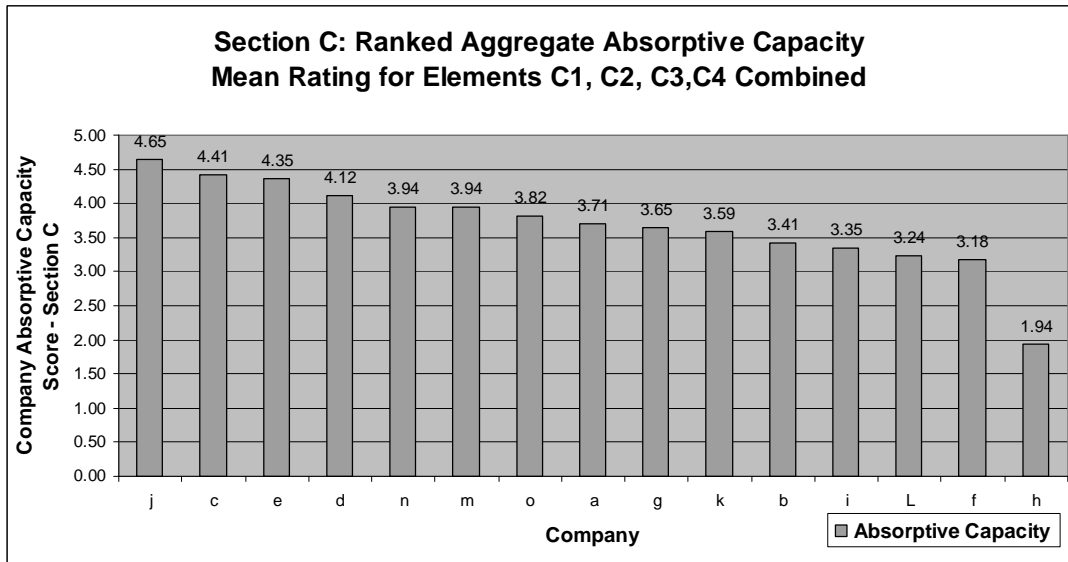


Figure 4.6: ACAP indicator – Ranked Company Mean Absorptive Capacity

The four highest ACAP scoring companies ‘j’, ‘c’, ‘e’ and ‘d’ operate in the electronics, engineering, renewable energy and avionics sectors respectively. The four lowest ACAP scoring companies ‘h’, ‘f’, ‘L’ and ‘i’ operate in engineering, medical technology, printing technology and marine engineering sectors respectively. The mean ACAP score is 3.91. These scores are converted into raw scores in section 4.2.5. The raw scores are used to test for correlation with other variables in sections 4.2.6 to 4.2.8.

4.2.3 Mean Ratings for ACAP Indicator Questions for All Companies

Figure 4.7 below includes the mean ratings for all companies across all the seventeen ACAP indicator questions in Section C. Section 4.2.4 presents this figured ranked for analysis.

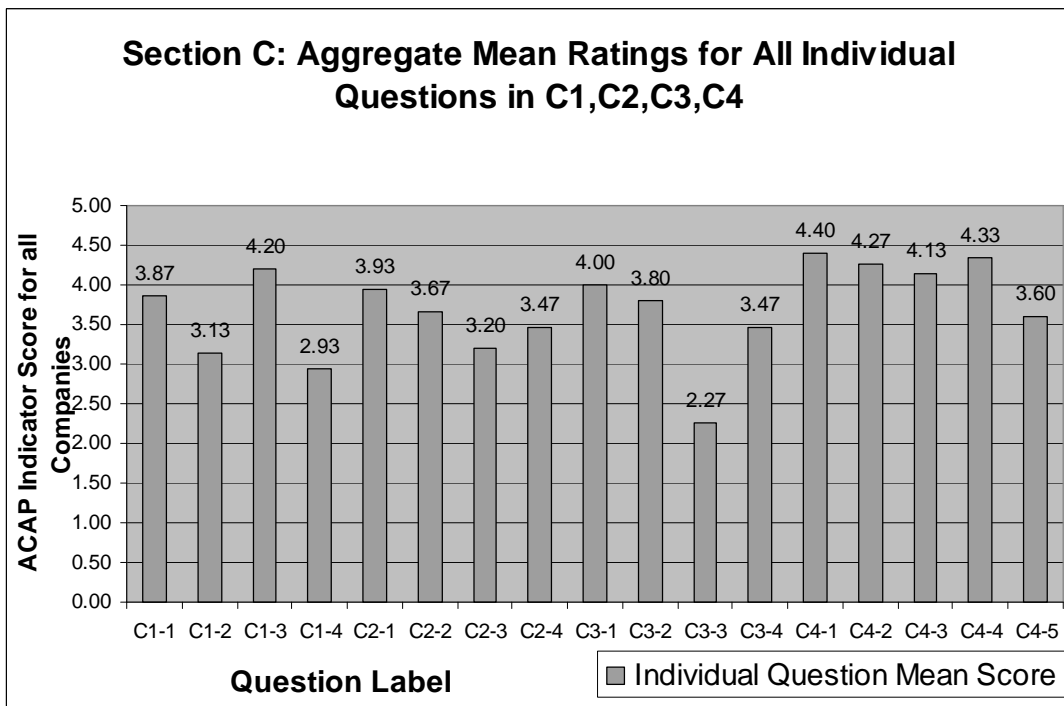


Figure 4.7: ACAP indicator – Aggregate Mean Ratings for All Individual Questions.
(See Section 4.1.2 for Questions)

4.2.4 Ranked Mean Ratings for ACAP Indicator Questions

Figure 4.8 below includes the mean ratings for all companies across all the seventeen ACAP indicator questions in Section C ranked from the highest to the lowest. The purpose of this analysis is to identify what elements companies are strong and weak across the group. All the companies are from the same region – North West Ireland. This has implications for the region and in particular for regional supports if absorptive capacity levels of companies are to be improved. The strongest and weakest ACAP indicators from the research data are presented below. The findings will be discussed in the discussion section.

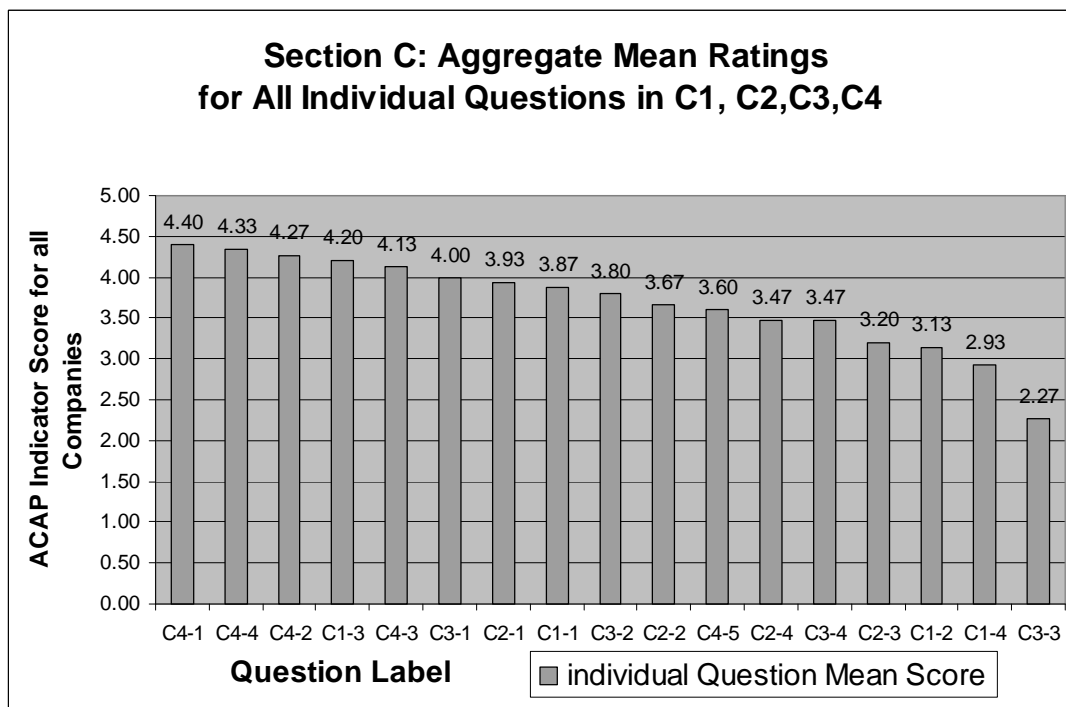


Figure 4.8: ACAP indicator – Ranked Aggregate Mean Ratings for All Individual Questions. (See Section 4.1.2 for Questions)

From Figure 4.8: Taking all the company ratings into account the three weakest ACAP indicators are for the following areas (starting with the lowest):

Indicator C3-3: The company specialises in a small number of technologies

Indicator C1-4: The company normally goes to other bodies (Universities, Institutes of Technology, Government Agencies etc.) to find out about fresh opportunities for introducing new products

Indicator C1-2: The company conducts frequent market research so as to be aware of customer needs

From Figure 4.8: Taking all the company ratings into account the three strongest ACAP indicators are for the following areas (starting with the highest):

Indicator C4-1: Achieving maximum product quality and superior products than our competitors

Indicator C4-4: Increasing market Share with existing products

Indicator C4-2: Delivering superior products than our competitors

4.2.5 Raw Scores for Company Absorptive Capacity

Figure 4.9 shows the accumulative or aggregate raw scores from the company questionnaire for the ACAP indicators for all 15 companies i.e. instead of using the mean, as presented previously, the raw ACAP indicator scores (1 to 5 scores) are added up for the seventeen ACAP indicators, for each company. They are effectively the same scores as Figure 4.7, but with a different scale. The reason for presenting the ACAP in this manner is to facilitate comparison with other variables. The aggregate ACAP for each company will be presented in this way for the rest of this research study report. Figure 4.10 presents the accumulative or aggregate raw scores. The ranked aggregate raw scores are used in section 4.2.6 to 4.2.8 to investigate if there is any correlation between the level of company ACAP and other organisational variables.

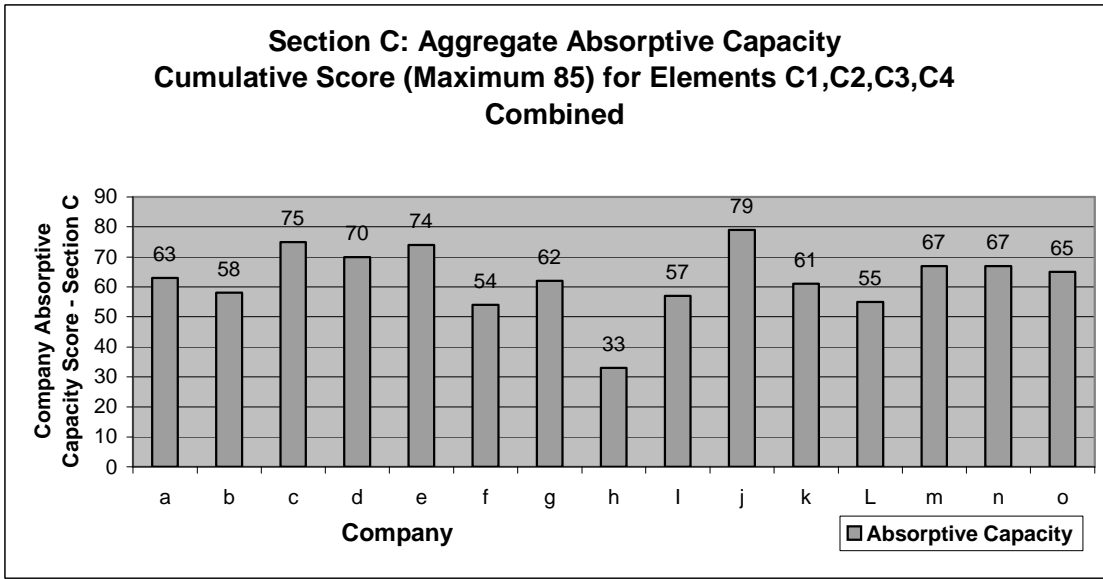


Table 4.9: *Company Absorptive Capacity - Accumulative Raw Scores*
(See Table 4.1 for Company List)

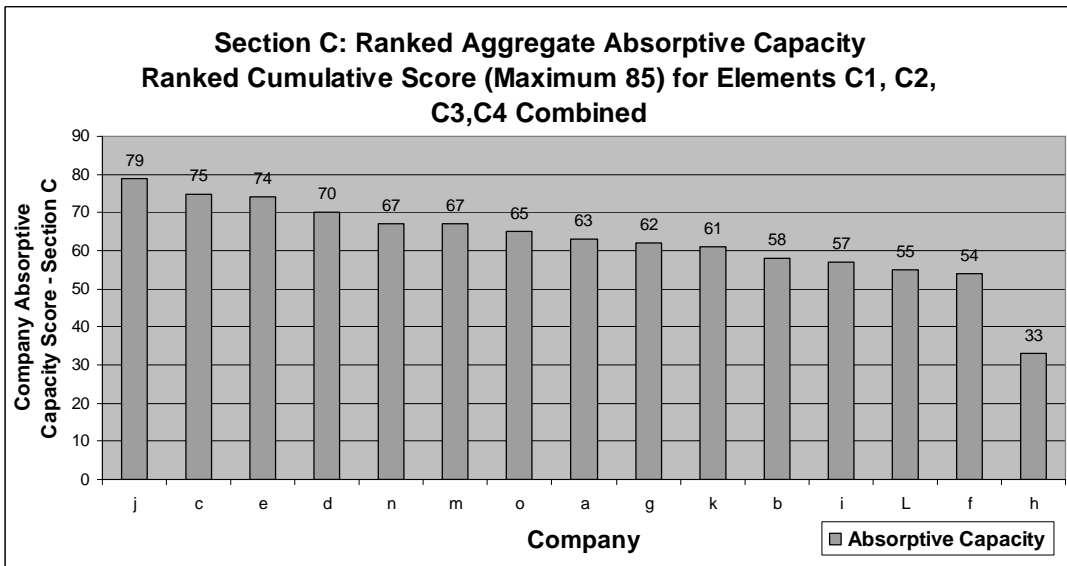


Figure 4.10: *Ranked Company Absorptive Capacity - Accumulative Raw Scores*
(See Table 4.1 for Company List)

4.2.6 Company Absorptive Capacity and R&D Spend

Figure 4.11 shows the aggregate company ACAP scores against the corresponding company level of R&D intensity. The R&D intensity is expressed as a percentage of company turnover. Company 'g' recorded the highest R&D intensity at 75%. This is a small new company in the medical technology sector with a small turnover so the high figure is understandable. Four companies are around the 20% level of R&D intensity:- company 'n' (25%), company 'e' (20%), company 'f' (16%) and company 'o' (15%)., with the rest of the companies 5% or lower. Company 'h' is the only company with 0% R&D intensity. The average R&D intensity is approximately 8% ignoring the 75% figure for company 'g' as an outlier.

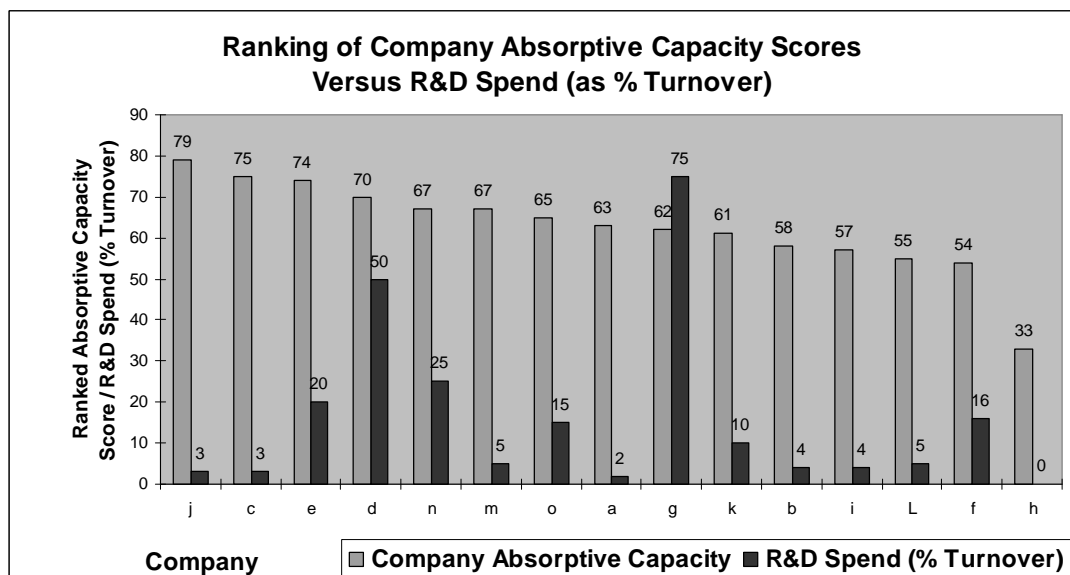


Figure 4.11: Ranked Company Absorptive Capacity Versus R&D Spend as (% Turnover) (See Table 4.1 for Company List)

Figure 4.12 shows the aggregate company ACAP scores against the corresponding company level of R&D intensity. The R&D intensity is expressed as a percentage of R&D Expenditure per Employee to normalise the effect of company size for comparison purposes.

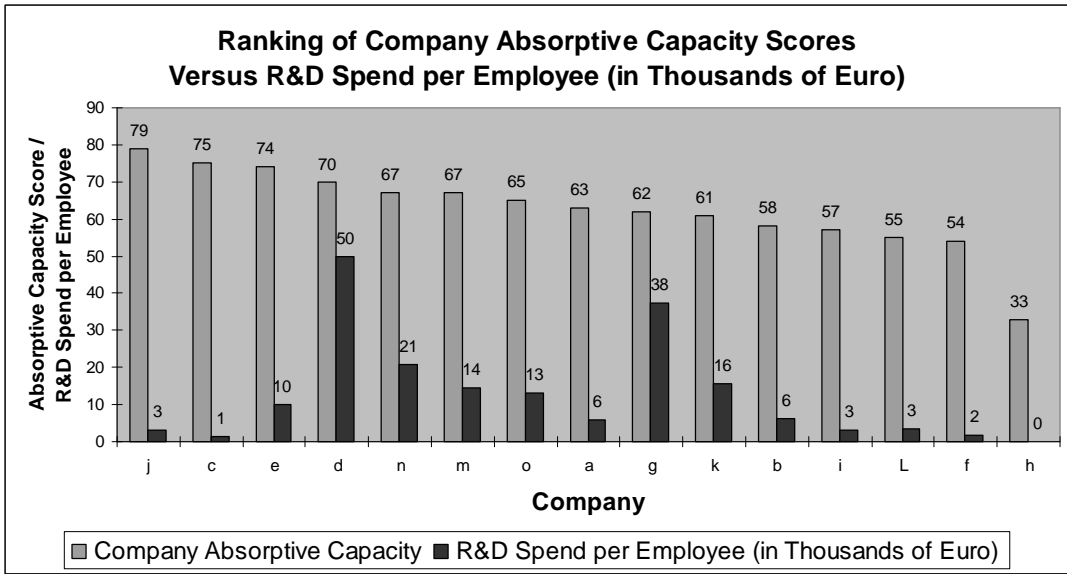


Figure 4.12: *Ranked Company Absorptive Capacity Versus R&D Spend per Employee* (See Table 4.1 for Company List)

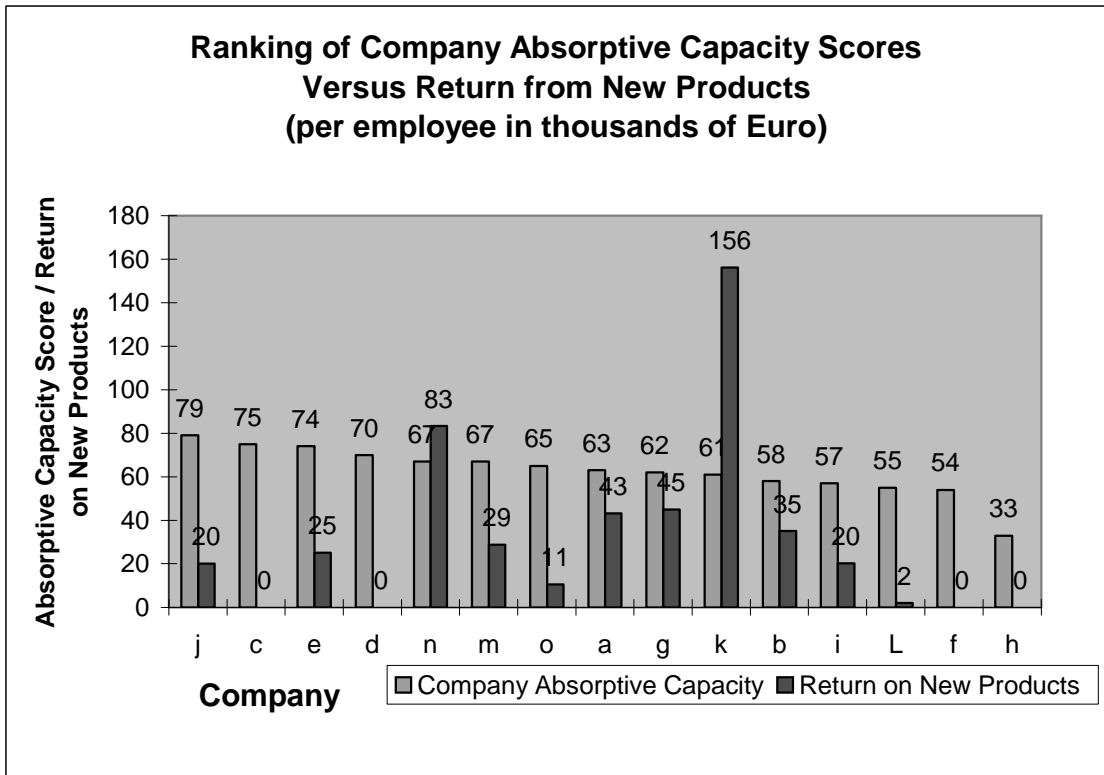


Figure 4.13: *Ranked Company Absorptive Capacity Versus R&D Spend per Employee*

4.2.7 Company Absorptive Capacity and Company Age

Figure 4.13 presents the ranked company ACAP scores plotted with the age of the companies surveyed. On inspection of the data there does appear to be an inverse relationship between ACAP and company age. The companies with the highest ACAP scores, on the left of the figure, are relatively new companies. The companies with the lowest ACAP scores, on the right of the figure, are more mature companies.

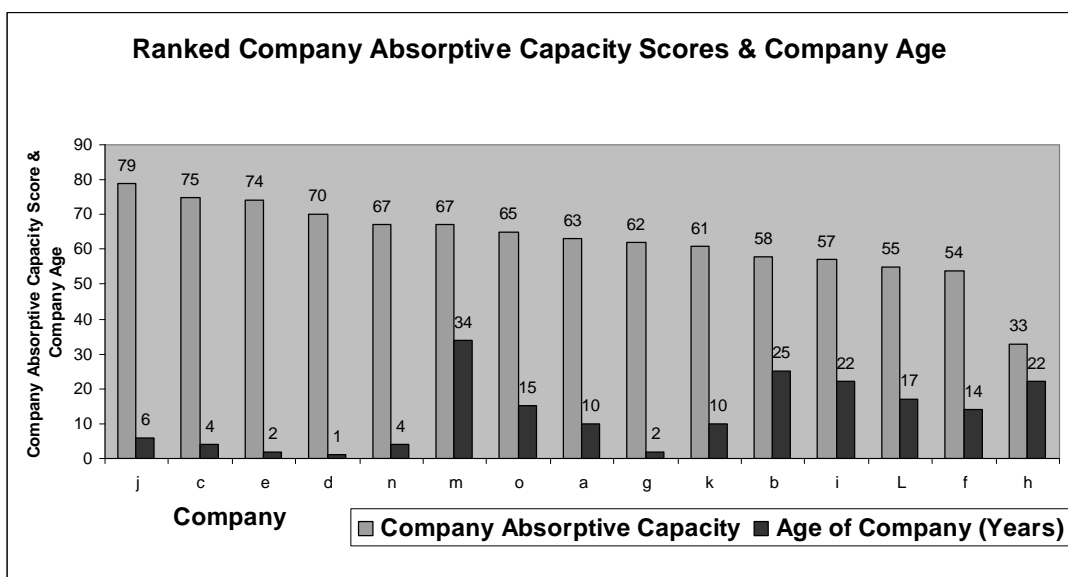


Figure 4.14: *Company Absorptive Capacity Scores & Company Age*
(See Table 4.1 for Company List)

To analyse this a further the companies are divide into three groups based on company ACAP score. The top five ACAP scoring companies are placed in one group, the middle five ACAP scoring companies are placed in the next group and the lowest ACAP scoring companies are placed in the third group. Three groups of five companies, with each group associated with a relative level of company ACAP – top, middle and bottom. Figure 4.14 presents the grouped data for the three company groups.

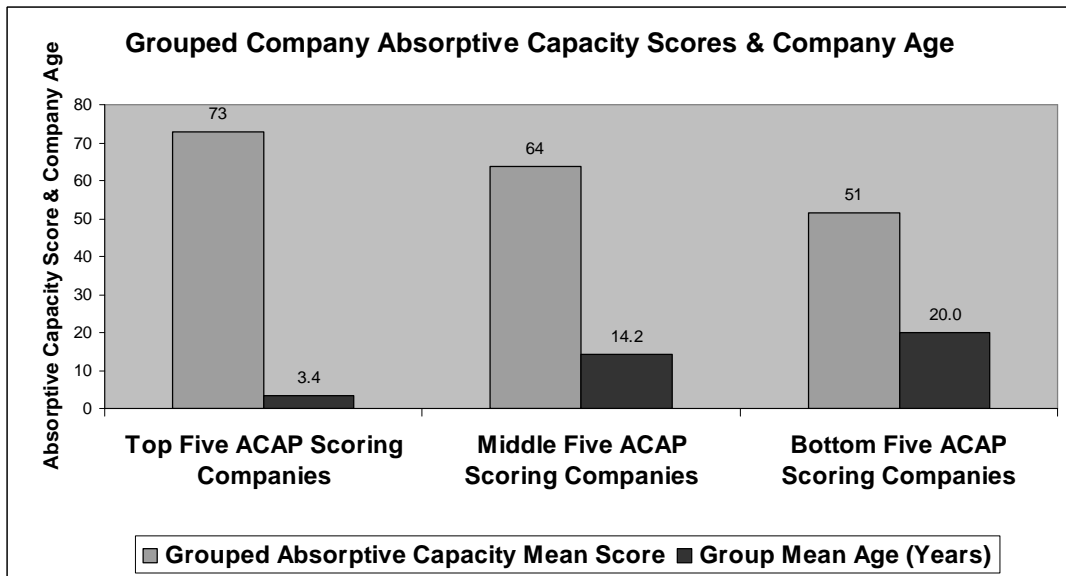


Figure 4.15: Grouped Company Absorptive Capacity Scores & Company Age (See Figure 4.12 for Group Companies)

4.3 Results from Stage Two: Structured Company Interviews

4.3.1 Company ‘e’

Company ‘e’ is a very small company in the renewable energy sector. The company are two years old and are primary involved in the design of new products and consultancy in the renewable energy sector. The company obtained an ACAP score of 74 in the company questionnaire which is the third highest score out of the fifteen companies. The Managing Director rated the competitiveness level of their market as 4 on the competitiveness scale. The motivation for the companies R&D work is to aim to be first to market with novel products. The latest product launched is a hand-held mobile device for calculating the carbon footprint of buildings. R&D is a proactive and a continuous company activity. The company rely heavily on a network of collaboration partners to provide input into the development of its products. The collaboration partners for the company include academic institutions both north and south of the border, government

agencies and technology centres. The company is continuously looking for partners to collaborate with through formal or informal channels. For example: A French company were approached on learning of specific capabilities they possessed. This knowledge had been received from InvestNI industry information services. Following the initial approach skilled personnel based in Ireland with links with the French company came on board in partnering development work with the company. This open attitude to innovation that company 'e' has is explained by the Managing Director:

“We seek specific expertise and skills from a number of sources in universities. We’re also looking for networking opportunities. I look for what I call ‘shared leadership’ in projects. Any input from college sources is great, even just to be told that I’m not talking rubbish, it’s great for my confidence, or for finding another way around a problem.”

- MD Firm 'e'

Information sources regarded as very relevant for innovation are customers, InvestNI business information services including patent searches and trade international exhibitions. The MD of the company commented that he used to be a teacher and he developed certain habits in the way he processes information from external sources:

“I read material from all sources and always summarise it. I’m a great user of mind-maps. I put down concept maps when I’m trying to find a technical solution. I can then bring it along to someone else and it helps me explain what I’m trying to do or point to the gaps in the knowledge that I’m trying to fill”

- MD Firm 'e'.

4.3.2 Company 'd'

Company 'd' are a very small start-up company with currently one product being developed for the avionics sector. The company obtained an ACAP score of 70 in the company questionnaire which is the fourth highest score out of the fifteen companies. The Managing Director rated the competitiveness level of their market as 3 on the competitiveness scale. The motivation for the companies R&D work is the availability of

emerging technologies to make the development of their particular product possible. The Managing Director of the company is a pilot and had spotted an opportunity to develop an electronic records storage device for flight data in the avionics sector. Product development work is carried out in collaboration with a technology centre located at Letterkenny Institute of Technology (EPICENTRE) and experts in other disciplines (product design) from Letterkenny Institute of Technology. The product relies on a number of technology suppliers i.e. software platforms etc. and a lot of the R&D is in the integration of these various components. The Managing Director has developed his business through the CEIM project run by WESTBIC. He has also received assistance through the Enterprise Ireland Mentor Scheme, the Enterprise Ireland Innovation Voucher Scheme and the BMW Research Voucher schemes. The most important sources of information for innovation at company 'd' are the internet, government agencies, trade shows, suppliers of technology and competitors. The Managing Director outlined what he referred to as the 'path of learning' he went through in the development of his product;

"I was very product focused to start off with. The idea was to do the content and the hardware. When I looked at it from a business point of view on the CEIM programme it made more sense to get the content from others to start off and get it out on the market. It took some time for the business strategy to evolve as it changes a few times"

-MD Company 'd'

4.3.3 Company 'a'

Company 'a' are a relatively small company with 52 staff providing machinery to the construction sector for the last ten years. The company obtained an ACAP score of 63 in the company questionnaire which is the eight highest score out of fifteen companies i.e. about midway in the ACAP rankings. The General Manager rated the competitiveness level of their market as 5 on the competitiveness scale, commenting that it was:

"dog eat dog" - General Manager Company 'a'

The motivation for the companies R&D is to maintain a:

“competitive edge , continuous improvement edge”

-General Manager Company ‘a’

One way the company innovate is by improving existing designs of their machinery. They take an older model of their product and aim for an end-of-life boost for this model on the market. They use their supply chain contacts and use feedback from suppliers and customers to provide input. They organise multi-discipline project management meetings and come up with suggestions for improvement:

“we came up with thirty six product improvements and implemented twenty four of them within six months. The idea is to deliver a bundle of new improvements, including retrofit upgrades of machinery features to offer value”

‘a’

– General Manager Company

The company carries out most of its R&D work internally. They have been involved in the Intertradeireland FUSION technology transfer programme in partnership with Ulster University. A mechanical engineering graduate was recruited for new product development at the company funded by the FUSION programme. The general manager commented:-

“They needed support and we had no-one to mentor them (the graduate engineer). We don’t have enough engineering competence. It’s the one area of the company we have this problem - we cannot attract them to our way of life – retaining engineers is a problem for us. We have a huge need for FEA (Finite Element Analysis) people, we’ve just spent thousands of euro on Solidworks and Cosmosworks software” -General Manager Company ‘a’

The most important sources of information for innovation are customers with competitors a close second. Trade exhibitions are also rated as very relevant sources of information.

When asked about collaboration with third level institutions:

“Our door is always open. We would love to build a lasting relationship with them. We know how to build the machines but you guys would really know the way they work” - General manager Company ‘a’

4.3.4 Company ‘k’

Company ‘k’ are a small company with 10 staff operating in the software sector for the last ten years. The company obtained an ACAP score of 61 in the company questionnaire which is the sixth lowest score out of the fifteen companies. The Marketing Manager rated the competitiveness level of their market as 3 on the competitiveness scale. The company produce computer applications for management and in particular project management functions. The marketing manager interviewed described their R&D activity as mainly proactive:

“Our development cycle is two years – we look two years ahead. We can usually see what’s coming – It’s a relatively stable environment”

-Marketing Manager company ‘k’

The key strengths in terms of innovation and the way the company can ‘usually see what’s coming’ is because their software architects are members of key industry software developer councils. These councils are a key source of information input into company ‘k’ and a source of advice for development work. The most relevant sources of information for innovation are employees, the internet and suppliers – in particular *Microsoft*.

When asked about collaboration with third level institutions:

“It doesn’t really come-up. We employ graduates but there aren’t a lot of opportunities to work with them. They’re only interested in open-source (software) and don’t really have an idea about the business realities of business software”

-Marketing Manager company ‘k’

When asked about how they innovate:

“We’re a small company with a flat structure. We’ve got our ear to the ground and can change tack quite quickly to take advantages of opportunities that arise.”

-Marketing Manager company ‘k’

The respondent was prompted for an example of ‘taking advantage of opportunities that arise’:

“For contact and interaction at the developer councils an internal Microsoft group were interested in one of our software application products. We produced a flavoured version of the software for them. We were able to build this into our development cycle.”

-Marketing Manager company ‘k’

4.3.5 Company ‘i’

Company ‘i’ are a relatively small company with 31 staff operating in the marine sector for the last twenty two years. Their particular area of expertise is in the field of marine hydraulic equipment. The company obtained an ACAP score of 57 in the company questionnaire which is the fourth lowest score out of the fifteen companies. The company rated the competitiveness of their sector as 4.

The company occasionally do R&D work which is mainly reactive in nature. When asked about their trigger or motivation to innovate:

“It’s basically to develop our products, to broaden our customer base. We don’t want to have our eggs in one basket so we’re looking to develop our products for other sectors like the oil and gas sector when the sector we’re in isn’t developing.”

-Director company ‘i’

When asked about how they carry out who they collaborate with:

“We did an RTI project with a University to scale up our products. It was a very slow process”

-Director company ‘i’

The company are going to get ISO accredited because it is a necessary requirement to enable them to be able to sell their products in the oil and gas sector.

4.3.6 Company ‘L’

Company ‘L’ are a relatively small company with 37 staff producing printing technology products for the last seventeen years. The company obtained an ACAP score of 55 in the company questionnaire which is the third lowest score out of the fifteen companies. The company rated the competitiveness of their sector as 4. The Senior R&D Engineer explained that the reason they carry out R&D continuously:

“We do R&D to survive. It used to be carried out by our parent company in Germany but we now do our own local R&D. The technology we’re dealing with isn’t rocket science – we’re competing with companies all over the world”

- Senior R&D Engineer company ‘L’

The company used to be presented with products designed elsewhere and they manufactured the product. How this changed:-

“It was four years ago we began to carry out our own local R&D. Initially it was reactive due to competitive pressures, now it would be more proactive”

- Senior R&D Engineer company 'L'

The company identified government agencies and third level institutions as their most relevant sources of information for triggering or supporting innovation. They rated the employees of the company as not relevant in this regard. The company look outside the organisation to collaborate on new product development. They currently have an IntertradeIreland funded FUSION technology transfer project in partnership with University of Ulster involving the use of Radio Frequency Identification (RFID) tags in their industry.

When asked about how they use external information to improve their business:

“When we hear about one of our competitors who has managed to achieve something in the manufacturing process we make an attempt to at least mimic the process improvement in our own facility”

- Senior R&D Engineer company 'L'

4.3.7 Company Characteristics & ACAP Scores

In reviewing the findings from these interviews it is possible to identify some common themes, which appear to differentiate between firms with high ACAP scores and firms with low ACAP scores in this study. These findings are highlighted here and discussed in the next section.

4.3.7.1 Generic Characteristics of high ACAP companies

Company 'e' and company 'd' are the two highest scoring companies on ACAP of the companies interviewed at stage two and the third and fourth highest ACAP scoring companies overall, respectively. Both companies collaborate extensively and the nature of their innovation is open. They are both less than two year old and operate in cutting

edge technology fields. Both companies have extensively used supports available from government agencies and third level institutions and they actively pursue innovation partners. The two companies are proactive in their innovation behaviour and their products rely on emerging technologies and their strategy is focused on bringing novel products to market first.

4.3.7.2 Generic Characteristics of low ACAP companies

Company 'i' and company 'L' are the two lowest scoring companies on ACAP of the companies interviewed at stage two and the sixth and fourth lowest ACAP scoring companies overall, respectively. Both companies are approximately twenty years old. Both companies have had applied research projects in association with third level institutions. Company 'i' has a reactive innovation profile while company 'L' innovates to keep their market share rather than to lead.

4.4 Hypothesis Testing

There were two hypothesis presented in Section 2.6.3.

Hypothesis 1: Companies with higher levels of R&D intensity have greater absorptive capacity.

Figures 4.11 and 4.12 presented in Section 4.2.6 contain the data obtained from the company questionnaire that is relevant for this hypothesis. The two figures are reproduced below. Figure 4.12 contains the ranked company ACAP scores versus the R&D intensity (R&D Expenditure as % of Turnover). Based on the inspection of the results presented in this figure there is no positive association between R&D intensity and company ACAP. If there was a positive relationship between the R&D intensity and company ACAP then the R&D spend would be highest for the companies towards the left of the graph and lowest for the companies towards the right of the graph. Company 'h' has the lowest R&D expenditure (0%) and the lowest ACAP score, however in the main the trend is not observed to confirm a positive relationship between the two variables.

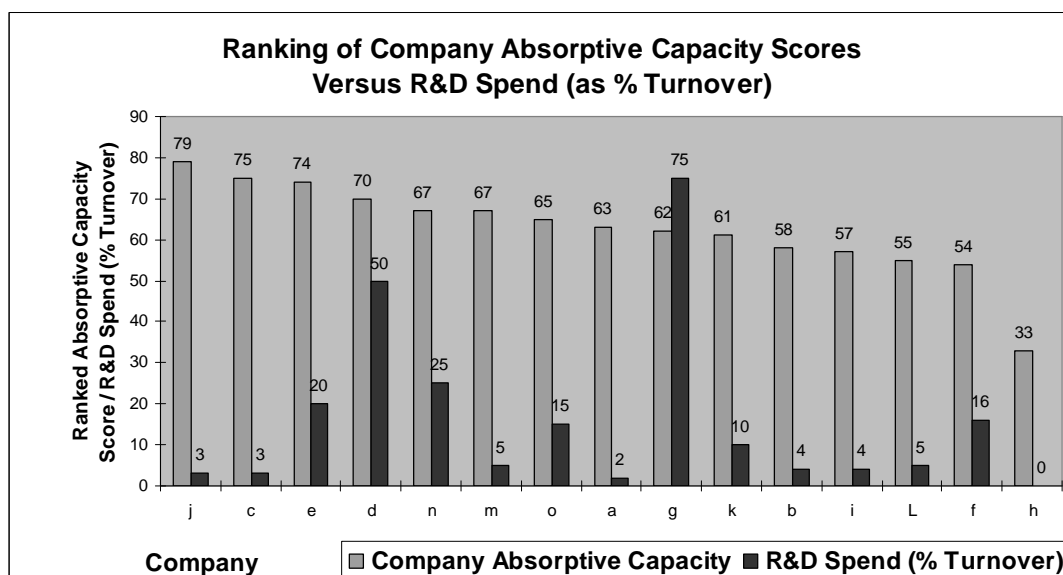


Figure 4.12: *Ranked Company Absorptive Capacity Versus R&D Spend as (% Turnover)* (See Table 4.1 for Company List)

Figure 4.11 contains the ranked company ACAP scores versus the R&D intensity (R&D Expenditure per Employee). Based on the inspection of the results presented in this figure there is no positive association between R&D intensity and Company ACAP across the range of fifteen companies.

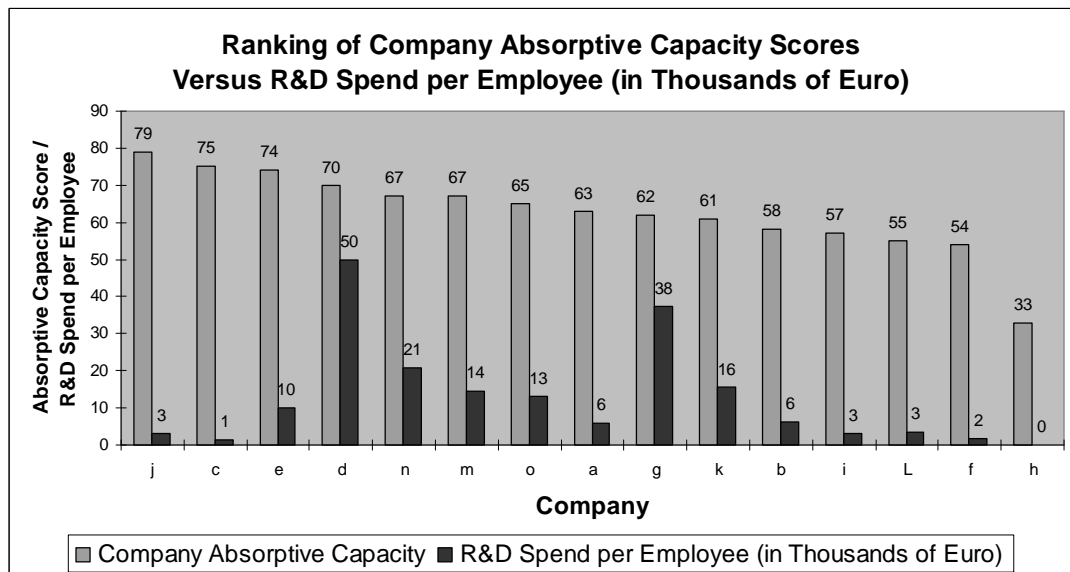


Figure 4.11: Ranked Company Absorptive Capacity Versus R&D Spend per Employee (See Table 4.1 for Company List)

The results from both these results demonstrate that the hypothesis is not proven in this research study.

Hypothesis 2: Companies with higher levels of absorptive capacity tend to be proactive and open in their innovation while companies that have a modest absorptive capacity tend to be reactive and closed in their innovation.

Section 4.3.7.1 presented the findings from the stage two structured telephone interviews including the generic characteristics of high ACAP companies. High ACAP companies refer to the companies who obtained high Absorptive Capacity scores in this study. The

companies with high ACAP scores that were interviewed in stage two displayed proactive innovation profiles and also a propensity for open innovation. This is described in more detail in Section 4.3.7.1.

Section 4.3.7.2 presented the findings from the stage two structured telephone interviews including the generic characteristics of low ACAP companies. Low ACAP companies refer to the companies who obtained low Absorptive Capacity scores in this study. The companies with low ACAP scores that were interviewed in stage two displayed predominantly reactive innovation profiles and also a propensity for following and imitating competitors. The low ACAP companies did not display tendencies for exclusively closed innovation having carried out FUSION technology transfer projects in partnership with academic institutions.

The element of the hypothesis concerning the tendency for companies to be proactive/reactive in their innovation depending on their level of ACAP was proven based on the findings in this research study. Company 'e' and company 'd' are the two highest scoring companies on ACAP of the companies interviewed at stage two and the third and fourth highest ACAP scoring companies overall, respectively. Both companies collaborate extensively and the nature of their innovation is open. They are both less than two year old and operate in cutting edge technology fields. Both companies have extensively used supports available from government agencies and third level institutions and they actively pursue innovation partners. The two companies are proactive in their innovation behaviour and their products rely on emerging technologies and their strategy is focused on bringing novel products to market first.

The element of the hypothesis concerning the tendency for companies to be open/closed in their innovation is not proven in this research study.

5 Discussion

5.1 Introduction to Discussion

The results from this research study are presented in Section 4. Commentary on these results is also contained in section 4. Section 4.4 includes hypothesis testing. The discussion section provides further commentary on results and hypothesis outcomes. The results and findings from this research study are considered in the context of the existing body of knowledge and similarities and differences in findings with previous literature are highlighted. Some new findings are also presented. It would be advised to read Section 4 before this section.

5.2 Hypothesis Findings

The results relevant to hypothesis 1 are presented in Section 4.4. There was found to be no definite positive relationship between firm R&D intensity and higher levels firm absorptive capacity when examined using two metrics of R&D intensity; - R&D Expenditure as a percentage of company turnover and R&D Expenditure per Employee.

If the result of company absorptive capacity is viewed through a different lens something else is revealed. The five companies with the highest absorptive capacity were examined with the knowledge intensity of the sectors they operate considered. The top five companies operate in knowledge intensive sectors: Electronics, Avionics, Software and Renewable Energy. At the other end of the scale the results show that none of the bottom five companies operate in particularly knowledge intensive sectors. The results show that high absorptive capacity is associated with companies operating in knowledge intensive sectors. This is not a surprising result and is to be expected.

The metric used to measure R&D activity in this study is R&D intensity. This is a commonly used metric for R&D activity in the literature. A number of firms in this study are based in business development centers on the sites of third level institutions. These firms have a bundle of supports available and indeed R&D facilities and staff for their innovative activities. The R&D metric used in this study does not capture this element of

their R&D activity. This underestimation would affect the results used in hypothesis 1 analysis. Section 2.3.2 outlined the discussion in the literature concerning the appropriateness of using certain metrics for measuring R&D activity. Section 5.3 examines the research outcomes and the R&D metrics used in this study in more detail.

The results relevant to hypothesis 2 are presented in Section 4.4. The hypothesis focused on the link between firm absorptive capacity and firm tendency to be proactive/reactive in innovation, as proposed by Cohen and Levinthal (1990). The element of the hypothesis concerning the tendency for companies to be proactive/reactive in their innovation depending on their level of ACAP was proven based on the findings in this research study. The high ACAP companies collaborate extensively and the nature of their innovation is open. It was found that the high ACAP companies are proactive in their innovation behaviour and their products rely on emerging technologies and their strategy is focused on bringing novel products to market first. It was found that the low ACAP firms' have a reactive innovation profile and focus on keeping their market share rather than leading in the market.

5.3 R&D and firm Absorptive Capacity

This study did not see a positive link between R&D intensity and firm ACAP. The literature suggests other metrics are possibly more suitable for measuring R&D activity. R&D engagement is found to be relevant to ACAP (Schmidt, 2005). The presence of a larger share of R&D employees is positively associated with innovation, particularly for manufactured goods (Abrue, 2006) concluding that: 'it is the number of employees rather than the expenditure on R&D that has the greatest effect on innovation' (2006:16). A lot of research focuses on research intensity as measures of R&D activity and determinants in empirical studies of ACAP. Moreover, a lot of government agencies supporting innovation use the metric of R&D intensity for targeted funding of programmes to support innovation at firm level. It was expected in this study that hypothesis 1 would be proved. The rejection of hypothesis 1 in this study focuses attention on the how R&D activity was measured. The two findings by Schmidt (2005) and Abreau et al. (2006)

suggest other relevant metrics for R&D activity such as frequency and continuity of R&D activity and the proportion of staff involved in R&D. These suggestions should be taken on board for any future research.

5.4 Threshold Absorptive Capacity

In an Irish context the study by Ledwith (2003) concludes that the successful exploitation of partnerships in the context of NPD depends on the absorptive capacity of the firm. It was suggested in Section 2 that the literature suggests that a threshold level of absorptive capacity exists. Firms must reach the threshold level before they can have positive outcomes from partnerships, particularly when the partnerships are with third level institutions. The quantitative data captured the effect of the threshold level of firm ACAP occurring company 'a'. Company 'a' carries out most of its R&D work internally. They were ranked midway in the firm ACAP rankings. They have been involved in the Intertradeireland FUSION technology transfer programme in partnership a university. The project was not as successful as expected and one of the reasons cited by the company for the lack of success in the partnership was the lack of appropriate competence in-house to mentor the graduate who was recruited. The company lacked the appropriate level of absorptive capacity, particularly in the ACAP determinant of company knowledge and experience. It can be argued that this is a competence deficiency rather than a weakness in company absorptive capacity. This is true, with company competencies closely linked to a company's absorptive capacity. In general, company competencies are determinants of company absorptive capacity.

5.5 Stimulation of Innovation Activity

The literature findings have shown that the existence of ACAP is not only determined by R&D activities, but also by the organisation and stimulation of knowledge transfer within the firm as well as the employment of qualified personnel. In particular, the stimulation of innovation activities and knowledge transfer is found to be an important building block of exploitive absorptive capacity (Schmidt, 2005). Findings from stage two of this

research study show that firm ACAP is positively associated with the stimulation of innovation activities. This is particularly evident with the interviewed firms with high ACAP scores. These companies are both less than two year old and operate in cutting edge technology fields. What was noticeable from these companies was the strategic orientation of their company NPD activities towards 'finding a solution'. These companies were based in business development centres located in third level institutions. Both companies have extensively used supports available from government agencies and third level institutions and they actively pursue innovation partners. The location of the companies within the business development centres places them in an environment where innovation of innovation and knowledge transfer is encouraged, supported and indeed one of the primary functions of the centres. Companies located outside technology and business development centres do not have the practical business and technology supports and also are exposed to an environment which is innovation focused. These findings suggest that firms absorptive capacity can be enhanced by locating in environments that stimulate and encourage innovation.

5.6 Innovation Versus Continuous Improvement

Cohen and Levinthal (1990) distinguish between a firm 'learning-by-doing' and a firm acquiring outside knowledge and using it to do something quite different. They propose that firms with absorptive capacity can do the latter. The former activity of 'learning-by-doing' could be described as continuous improvement and the activity facilitated by absorptive capacity described as innovation in an industrial context. This study has found that there is a lot of confusion in industry concerning the distinction between continuous improvement and innovation. Moreover, there are widely differences in what firms regard as R&D. This is not just confusion about terminology, it is an important distinction when trying to study the innovation outputs of firms and their R&D activity. More importantly, for the firms it is important for them to be able to distinguish between innovation and continuous improvement for their business performance. This study did not attempt to define innovation and R&D activity too rigidly, particularly in the stage one company questionnaire as it was not desirable or feasible to go to that level of

granularity. Perhaps because of that, the stage two company interviews revealed different interpretations or confusion about what the different activities entail.

For example when discussing R&D with company 'i' the Company Director commented about work which was clearly research and development work "we never called it that". On the opposite end of the scale when talking to company 'a' the General Manager classified company activities that were clearly continuous improvement activity as 'pro-active innovation'.

In the literature there are examples of this confusion of terminology and the nature of activities. The study by McAdam (2004) of barriers to innovation at SMEs in Northern Ireland, very close to the area of study in this research, found that confusion between continuous improvement and fundamental innovation within the companies studied was underlined by local government agencies, which failed to distinguish adequately between these issues leading to a lack of targeted funding for innovative practices. Hoffman (1998) questions the vagueness of how 'major innovations' achieved in firms are quantified in the research literature of innovation at firm level. In this study innovation outputs were determined from new or improved products or services. This was a satisfactory measure for this study.

5.7 Weakest Absorptive Capacity Elements

The three weakest scores for the indicator questions that measured firm absorptive capacity presented in section 4.2.4. of the results section were (starting with the lowest):

Indicator C3-3: The company specialises in a small number of technologies

Indicator C1-4: The company normally goes to other bodies (Universities, Institutes of Technology, Government Agencies etc.) to find out about fresh opportunities for introducing new products

Indicator C1-2: The company conducts frequent market research so as to be aware of customer needs

These are the areas that the companies, taken as a whole, are weakest. All the companies are from the same region – North West Ireland. Although this research focuses on absorptive capacity at firm this finding has implications for absorptive capacity at regional level. The three areas are discussed in Sections 5.7.1 to 5.7.3 below.

5.7.1 Diversity of Knowledge

The lowest scoring indicator; company diversity of knowledge (**Indicator C3-3**) is not surprising for the companies surveyed due to their small size. Small companies, by their nature, tend to focus on a small number of technologies. The companies in this study were either engineering companies with standard technologies, predominantly manufacturing based or high technology companies with focused products in niche areas. It is of benefit to companies if they have exposure to a diverse range of technologies to facilitate the identification of opportunities and linkages across the technology areas. There are no negative implications for the region implied by this low score. Similar companies in other regions would be expected to have low scores in this area also.

5.7.2 Collaboration with Knowledge Centres

The second lowest indicator; collaboration with knowledge centres (**Indicator C1-4**) is significant. The low scoring of companies for this activity is a bit confusing because the telephone interviews confirmed high levels of engagement for high scoring ACAP firms. Indeed, low scoring ACAP firms had engaged in FUSION technology transfer programmes. They did, however, tend to be ‘one-offs’. An examining of the question which was asked to the companies might help to explain the low scoring on this indicator of these companies:

‘The company normally goes to other bodies (Universities, Institutes of Technology, Government Agencies etc.) to find out about fresh opportunities for introducing new products’

The inclusion of the word ‘normally’ in the question excluded companies who had ‘one-off’ technology partnerships with knowledge centres from responding positively to this question. This is a correct approach assuming that ‘one-off’ interaction with knowledge does not build firm absorptive capacity and/or unsuccessful interactions do not build firm absorptive capacity. This raises the notion of the nature of improvements to firms absorptive capacity in general – whether improvements to firm absorptive capacity by any interactions or interventions are permanent or transient improvements.

The low scoring on this indicator, leaving aside the partial explanation presented above has implications for the region. Section B results showed that 80% of companies collaborate in their innovation activities and 67% of R&D activity occurs all the time. So who are the companies collaborating with and why are there low levels of collaboration with knowledge centres? Section 2.4 of the literature review highlighted the key position of academic institutions in a knowledge based economy. Knowledge Centres are only one source of collaboration, but one which is becoming increasingly important for SMEs if they want to target niche or global markets (Marques, 2006). Hoffman (1998) proposed that there is an inherent mis-match between the interests of the HEIs and the needs of the

SMEs. The qualitative data in stage two of this research provided some evidence of a mis-match between Knowledge Centres interests and firms requirements. Companies commented on partnerships with Knowledge Centres: they took too long to set-up and too long to deliver results, that they don't really have an idea about the realities of developing business software or that opportunities to interact with Knowledge Centres did not arise.

How can the interaction between firms and Knowledge Centres be improved? This is indeed a whole research area in itself. Examining this scenario from an absorptive capacity perspective i.e. the focus of this study is appropriate. The absorptive capacity at firm level could be introduced as a factor in the establishment of partnerships between firms and Knowledge Centres. Most partnerships are funded by government agencies such as Science Foundation Ireland, Enterprise Ireland, IntertradeIreland etc Firms absorptive capacity could be assessed and this could be introduced as one of the criteria for funding. Firms with an appropriate level of absorptive capacity and firms satisfying the other required criteria could proceed with the partnership. Firms not reaching the appropriate level of absorptive capacity could have targeted intervention, where feasible to enhance their absorptive capacity and to perhaps form a partnership afterwards. The key here is that the absorptive capacity concept be introduced into the application process; not solely as a barrier to enter such partnerships but as an instrument to identify where resources or supports should be targeted. The absorptive capacity evaluation, if introduced to the process should reduce the number of partnerships that do not produce positive outputs and encourage more partnerships due to the positive association. This process would require an instrument to measure the absorptive capacity at firm level. This research can contribute to the development of this instrument.

5.7.3 Market Research

The third weakest indicator concerns the level of market research carried out by firms. (**Indicator C1-2**). This is a common weakness in engineering and technology firms that has often been identified in the innovation and NPD literature. This is an area where support agencies can and do offer support to firms at regional level.

5.8 Company Age and Firm Absorptive Capacity

Section 4.2.7 presents the results of a comparison of the company absorptive capacity scores with the age of the companies. On inspection of the data there does appear to be an inverse relationship between ACAP and company age. The companies with the highest ACAP scores are relatively new companies. The companies with the lowest ACAP scores are more mature companies. The table below contains the details.

	ACAP Mean Score (STD Dev)	Mean Age (years) Mean Age (STD DEV)
Top Five Companies	73 (5)	3.4 (1.9)
Middle Five Companies	64 (2)	13 (12)
Bottom Five Companies	51 (10)	20.0 (4.4)

Table 5.1 Company Absorptive Capacity and Company Age

The mean age of the top five companies at 3.4 years the mean age of the bottom five companies at 20.0 years. Both of these age scores have acceptably small standard deviations to be representative of the groups of companies. The middle five company mean age is not as representative of the group with such a large standard deviation relative to the mean age.

What can be implied from this finding? The literature suggests that absorptive capacity is accumulative and path dependent. Therefore should we not expect older companies with longer histories to have higher levels of absorptive capacity? Company 'e' and company 'd' are two of the companies in the top five grouping. These companies were interviewed in stage two. Company 'i' and company 'L' are two of the companies in the bottom five grouping. These companies were interviewed in stage two also. If we take these companies as representative of the two company groupings the following profiles emerge:

The **newer companies** collaborate extensively and the nature of their innovation is open and proactive and they actively pursue innovation partners. They are both less than two year old and operate in cutting edge technology fields. Both companies have extensively used supports available from government agencies and third level institutions The two companies products rely on emerging technologies and their strategy is focused on bringing novel products to market first.

The **older companies** have a reactive innovation profile. They occasionally use government agencies to support their innovation. Their strategic aim is to keep market share rather than lead the market with superior products. Their attitude to innovation is often in the short term rather than a more strategic view. They have carried out innovation partnerships with third level institutions with mixed results. Often the motivation to get involved in these programmes is the provision of funding for equipment and the payment of salaries for project personnel.

The possible reasons for these different profiles are many, such as culture, leadership etc. McAdam et al. (2004) identified weaknesses for SMEs in Northern Ireland were predominantly culturally based that required substantial time and effort to overcome. It is outside the scope of this study to identify the reasons in this study. What can be identified from the findings in this study is that the newer companies are tightly tied into the 'soft' infrastructure referred to in the innovation framework model. The older companies are more isolated and removed from the 'soft' infrastructure. A lot of support from

Knowledge Centres and Government Agencies is targeted at business start-ups and for good reason. However, it appears from the findings of this study that there is a secondary benefit to receiving assistance from Knowledge Centres and Government Agencies apart from the direct support receives. This secondary benefit is that contact with these bodies stimulates innovation, promotes and provides networking opportunities and knowledge sharing; - all key elements of building absorptive capacity. Like the 'two faces of R&D' this effect is the 'two faces of interaction with Knowledge Centres'.

It could be concluded from the findings in this study that it is not surprising that the new companies which have been born into the globalised knowledge economy, which has emerged over the last ten years, will always have a different culture and outlook towards change, collaboration etc than more established companies. This firm culture and outlook is manifesting itself in the level of a firms' absorptive capacity.

6 Conclusions

6.1 Introduction

This section includes a summary of the findings from this research study and the implications of these findings for the innovative capacity of firms. There are also some findings for innovation at regional level – in particular related to the ‘soft’ infrastructure of the region of study. Section 6.2 lists the aims of the research study and how they have been achieved. Section 6.3 presents the main findings and conclusions from this research study. Section 6.4 examines the main research questions. Section 6.5 includes recommendations for future research.

6.2 Summary of Research Aims Achieved

The key aims this research study were:

Aim 1: To collect (qualitative and quantitative) data on the innovative capacity traits and innovation performance of engineering technology firms in the North West of Ireland.

This was achieved for fifteen engineering and technology firms in the region. Restricting the study group to engineering and technology firms in the one region removed differences in absorptive capacity due to sectoral differences between firms and ensures the same ‘soft’ infrastructure is available to the firms’ studied.

Aim 2: To obtain a quantitative measure of the absorptive capacity of engineering and technology firms in the North West of Ireland.

A methodology for measuring absorptive capacity at firm level was developed and used to obtain a measure of the firms’ absorptive capacity. The methodology developed for measuring absorptive capacity was developed based on determinants of absorptive capacity from previous literature. A previously used methodology was adopted customised for the study group.

Aim 3: To identify any relationships between the company innovative capacity traits and innovation performance and their relative levels of absorptive capacity.

The research reveals an innovation profile of firms with high levels of absorptive capacity. This is described in the main findings below below.

6.3 Main Findings and Conclusions

- ❖ There was found to be **no definite positive relationship between firm R&D intensity and higher levels firm absorptive capacity** when examined using two metrics of R&D intensity across the fifteen firms. A number of firms in this study are based in business development centres on the sites of third level institutions. These firms have a bundle of supports available and indeed R&D facilities and staff for their innovative activities. The R&D metric used in this study does not capture this element of their R&D activity.
- ❖ The **metrics used to measure R&D activity** is particularly sensitive in research and innovation. The rejection of the first hypothesis in this research focuses attention on the choice of metrics used. Other relevant metrics for R&D activity exist such as frequency and continuity of R&D activity and the proportion of staff involved in R&D. A lot of research focuses on research intensity as the measure of R&D activity. Moreover, a lot of government agencies supporting innovation use the metric of R&D intensity for targeted funding of programmes to support innovation at firm level. This study has shown that R&D activity levels could be captured more accurately using a selection of metrics, such as frequency and continuity of R&D activity and the proportion of staff involved in R&D. This finding has implications for research and for institutions supporting innovation.

- ❖ High absorptive capacity is associated with companies operating in **knowledge intensive**. The companies with the highest absorptive capacities in this study group operate in the Electronics, Avionics, Software and Renewable Energy sectors. None of the low scoring absorptive capacity companies operate in knowledge intensive industries.
- ❖ Findings from stage two of this research study show that firm ACAP is positively associated with the **stimulation of innovation** activities. This is particularly evident with the interviewed firms with high ACAP scores. A number of these companies were based in business development centres located in third level institutions where innovation and knowledge transfer is encouraged, supported and indeed one of the primary functions of the centres.. These findings suggest that firms absorptive capacity can be enhanced by locating in environments that stimulate and encourage innovation.
- ❖ This study has found that there is a lot of **confusion in industry concerning the distinction between continuous improvement and innovation**. Moreover, there are widely differences in what firms regard as R&D. This finding is similar findings in the the literature in a geographical region close to the area of study McAdam (2004) who found that confusion between continuous improvement and fundamental innovation within the companies studied was underlined by local government agencies, which failed to distinguish adequately between these issues leading to a lack of targeted funding for innovative practices. This issue is of fundamental importance to companies, researchers and supporting agencies whose remit is to stimulate innovation.
- ❖ The results reveal an **innovation profile of firms with high levels of absorptive capacity**. The companies are less than 5 years old and operate in knowledge intensive sectors. This profile includes tendencies to extensively use supports available from government agencies and third level institutions. They actively pursue innovation partners. The nature of their innovation is open and proactive.

- ❖ At **regional level** the weakest elements identified were company diversity of knowledge and market research. There are no negative implications for the region implied by this low score. However it would be beneficial if a similar analysis was carried out on a similar cohort of companies in a different region. A comparison between the regional scores on the different elements of absorptive capacity could have implications for the infrastructure at regional level. This could focus funding on areas of regional innovative capacity needing improvement – most likely in the ‘soft’ infrastructure which is closely linked to firm absorptive capacity.

- ❖ The other low scoring indicator of firm absorptive capacity was **firm collaboration with knowledge centres** (Third level institutions etc). The qualitative data in stage two of this research provided some evidence of a mismatch between Knowledge Centres interests and firms requirements. How can the interaction between firms and Knowledge Centres be improved? One possible action suggested is that the absorptive capacity concept be introduced into the funding application process for innovation partnerships. The absorptive capacity evaluation, if introduced to the process should reduce the number of partnerships that do not produce positive outputs and encourage more partnerships due to the positive association. This process would require an instrument to measure the absorptive capacity at firm level. This research can contribute to the development of this instrument.

- ❖ On inspection of the data there does appear to be an **inverse relationship between ACAP and company age**. The companies with the highest ACAP scores are relatively new companies. The companies with the lowest ACAP scores are more mature companies. What can be implied from this finding? The literature suggests that absorptive capacity is accumulative and path dependent. Therefore should we not expect older companies with longer histories to have higher levels of absorptive capacity? What can be identified from the findings in

this study is that the newer companies are tightly tied into the 'soft' infrastructure referred to in the innovation framework model. The older companies are more isolated and removed from the 'soft' infrastructure. A lot of support from Knowledge Centres and Government Agencies is targeted at business start-ups and for good reason. However, it appears from the findings of this study that there is a secondary benefit to receiving assistance from Knowledge Centres and Government Agencies apart from the direct support receives. This secondary benefit is that contact with these bodies stimulates innovation, promotes and provides networking opportunities and knowledge sharing; - all key elements of building absorptive capacity. Like the 'two faces of R&D' this effect is the 'two faces of interaction with Knowledge Centres'. The lesson to be learned is that support agencies need to have a portfolio of supports which attract mature as well as newer companies to benefit.

6.4 Key Research Questions

The key research questions of this research are:

1. Is firm absorptive capacity significant for innovation at firm level?

The literature suggests (Zahra and George, 2002) that it is crucial for firms operating in knowledge-based competitive sectors of industry. This research study found that companies with the highest absorptive capacity operate in knowledge intensive sectors of industry. The companies with the highest absorptive capacity demonstrate best practice in innovation activities in terms of collaboration, networking and strategic orientation. This suggests a close relationship between absorptive capacity level at firm level and positive innovative characteristics. Based on the findings from this research absorptive capacity at firm level is indeed significant as firms with high levels of absorptive capacity have been shown to have a number of the key ingredients to innovate successfully.

2. If absorptive capacity is significant for innovation at firm level – how can it be enhanced?

A measurement tool was developed from previous literature and employed on this research study to measure absorptive capacity at firm level. The four pillars of absorptive capacity are included in this measurement tool : - External company Links, Company Knowledge and Experience, Diversity of Company knowledge and Company Strategic Posture. Any measure or intervention that can improve a firms’ performance or capability in any of these pillars of absorptive capacity will enhance a firms’ absorptive capacity. The literature suggests that all four pillars are relevant and none of the pillars can be neglected. These four pillars involve multiple aspects of a firms capability, resources, outlook etc. The findings from this research study are such that it is possible to comment on the proposed methods to be deployed by government agencies to improve the absorptive capacity of firms in Ireland. An extract from the Interdepartmental Committee on Science, Technology and Innovation report (July 2004) report is presented below. This is followed by a commentary on the appropriateness of this strategy using the findings from this research

This report provides a vision that:

“Ireland by 2010 will be internationally renowned for the excellence of its research and be at the forefront in generating and using knowledge for economic and social progress, within an innovation driven culture”. It also states that: “a key priority will be the improvement of the absorptive capacity of firms in Ireland so that they are equipped to identify, access and leverage other knowledge sources, as well as making the most of their own”.

This Requires: Improved management capability, skilled R&D personnel, better R&D facilities and equipment. Underpinning these lies the business strategy and within that a strong and forward-looking technology strategy”

Interdepartmental Committee on Science, Technology and Innovation report (July 2004)

The strategy puts a lot of focus into promoting and improving R&D capability for Irish firms which is part of the 'Company Knowledge and Experience' pillar of absorptive capacity. The strategy also includes a reference to the strategic posture pillar of absorptive capacity. There is no reference to the two other pillars of absorptive capacity i.e. 'External company Links', and 'Diversity of Company knowledge'. As a strategy it is appropriate.

The strategy suggests investment in R&D infrastructure at firm level. The two pillars of absorptive capacity not referred to in the strategy could be addressed through focused programmes from government agencies such as Enterprise Ireland. These focused programmes would focus on the stimulation of external company links through networking opportunities etc. This is in fact already happening with the Innovation Voucher scheme that encourages firms to apply for project funding on projects with multiple company partnerships.

Appropriate 'Business strategy' and 'innovation strategy' referred to in the extract are indeed fundamental to the enhancement of absorptive capacity at firm level. Offering incentives for firms to invest in R&D infra-structure is relatively straightforward. The results from this research suggest that trying to re-orient firms to focus on innovation at business strategy level and technology strategy level is much more elusive. Based on the evidence from this research the most success in this endeavour will be with start-up companies operating in knowledge intensive industries rather than established companies in stable sectors.

6.5 Recommendations for Future Research

There are three further research areas linked to this research that would be of interest:

1. The first suggestion for further research would be a detailed study into the process of building absorptive capacity at firm level. This research would be most appropriate applying a longitudinal approach where a set of firms are tracked and monitored for an extended period of time rather than a ‘snap-shot’ approach. With the time dimension built in it would be possible to start to see the causes and effects of the underlying determinants and drivers for successful building of absorptive capacity. In particular the effect of interventions such as access to higher education institutes, technology transfer programmes, technical training, management training, mentoring etc on the level of firm absorptive capacity could be tracked and monitored. Moreover, the cumulative effect of building ACAP could be studied.

2. The second suggestion for future research would be to apply the methodology employed in this study to a similar cohort of firms in a different region of Ireland or even abroad. This would provide data to compare across regions. The results would provide data on regional innovation infrastructure and possibly inform ‘soft’ infra structure investments decisions in the region.

3. The third suggestion for future research would be to carry out research into the understanding of firms, government agencies and knowledge centres of their understanding of the concepts of innovation, continuous improvement and research and development. Ideally, a benchmark type classification system could emerge to avoid the current confusion and non-standard understanding of these terms.

References

- Abreu, M., Grinevich, V., Kitson, M., and Savons, (2006) 'Latest Research on Regional Variations and Absorptive Capacity in the UK', Practice , SPRU 40th Anniversary Conference.
- Becker, W., and Peters J. (2000) 'Technological Opportunities, Absorptive Capacities, and Innovation', Volkswirtschaftliche Diskussionsreihe No. 255, Augsburg
- Bower, G. H. and Hilard, E. R., (1981) Theories of Learning. Englewood Cliffs, NJ: Prentice Hall.
- Cockburn, I., Henderson, R., (1998) 'Absorptive capacity, co-authoring behaviour, and the organisation of research in drug discovery'. *The journal of Industrial Economics* 46(12), 157-181.
- Cohen, W.M. and Levinthal D.A. (1989) 'Innovation and learning: the two faces of R&D'. *The Economic Journal*, 99, 569-96.
- Cohen, W.M. and Levinthal D.A. (1990) 'Absorptive capacity: a new perspective on learning and innovation'. *Administrative Science Quarterly*; 35(1):128-52
- Daghfous, A., (2004) 'Absorptive Capacity and the Implementation of Knowledge-Intensive Best Practices', *SAM Advanced Management Journal* (1984) 69 (2), 21-27
- Decter, M and Bennett D. (2007) 'University to business technology transfer – UK and USA comparisons'. *Technovation*, 27, 145-155.
- Fiol, C.M., Lyles, M.A., (1985), 'Organisational Learning'. *Academy of Management Review*. 10(4), 803-813.
- Freel M. S. (2000) 'Barriers to Product Innovations in small manufacturing firms'. *International Small Business journal*, 18:2, 60-80.
- Freel, M.S. (2005) 'Patterns of innovation and skills in small firms'. *Technovation*, 25, 123-134.
- Hoffman, K. and Parejo M. (1998) 'Small firms, R&D, technology and innovation in the UK: a literature review'. *Technovation*, 18(1), 39-55.
- Kaufmann, A. and Todtling, F. (2002) 'How effective is Innovation Support for SMEs? An Analysis of the Region of Upper Austria'. *Technovation*, 22, 147-59.

- Kim, L., (1997a) 'The dynamics of Samsung's technological learning in semiconductors'. *California Management Review*, 39(3): 86-100
- Kim, L., (1997b) *From imitation to innovation: The dynamics of Korea's technological learning*. Cambridge, MA: Harvard Business School Press
- Lane, P. J., and Lubatkin, M. (1998) 'Relative absorptive capacity and inter-organisational learning'. *Strategic Management Journal*, 19; 461-477.
- Lofstrom, S. M. (2000). 'Absorptive capacity in strategic alliances: Investigating the effects of individuals' social and human capital on inter-firm learning. Paper presented at the Organisation Science Winter Conference, Keystone, CO.
- Ledwith, A. and Coughlan P. (2005) 'Splendid Isolation: Does networking really increase new product success?' *Creativity and Innovation Management*, 14:4, 366-373.
- Mahnke, V. , Pedersen L. and Venzin, M. (2005) 'The impact of knowledge management on MNC subsidiary performance: the role of absorptive capacity', *Journal of International Business*.
- Marques, J.P.C. and Caraca, J.M.G. (2006) 'How can university –industry-government interactions change the innovation scenario in Portugal?- the case of the University of Coimbra.' *Technovation*, 26, 534-542.
- Mangematin, V., and Nesta L. (1999), 'What kind of knowledge can a firm absorb?', *International Journal of Technology Management* 18(3/4), 149-172
- Mowery, D.C., and Oxley, J.E. (1995) 'Inward technology transfer and competitiveness: The role of national innovation systems.' *Cambridge Journal of Economics*, 19: 16-93.
- McAdam,R. and McConvery T. (2004) 'Barriers to innovation within small firms in peripheral location.' *International Journal of Entrepreneurial Behaviour and Research*, 10:3, 206-221.
- Nahapiet, J., and Ghoshal, S. (1998) 'Social capital, intellectual capital, and the organizational advantage.' *Academy of Management Review* 23: 242-266
- Neely, A. and Hii J. (1998) 'Innovation and business performance: A literature review' – Report commissioned by the Government Office- Eastern Region from the Centre for Business performance, Judge Institute of management Studies, University of Cambridge.
- Neely, A. and Hii J. (1999), 'The innovative capacity of firms' - Report commissioned by the Government Office- Eastern Region from the Centre for Business performance, Judge Institute of management Studies, University of Cambridge.

- Nelson, R.R. and E.N. Wolff (1997), 'Factors behind cross-industry differences in technological progress, *Structural Change and Economic Dynamics* 8, 205-220.
- Nicholls-Nixon C.(1993). 'Absorptive capacity and technological sourcing: implications for the responsiveness of established firms. PhD. Unpublished, Purdue University.
- Nieto, M. and Quevedo, P. (2005). 'Absorptive capacity, technological opportunity, knowledge spillovers, and innovative effort.' *Technovation*, 25, 1142-1157.
- Rothwell, R. and Dodgson, M. (1991) 'Technology strategies in small firms'. *Journal of General Management*, 17:1, 45-55.
- Rothwell, R. and M. Dodgson (1991), 'External linkages and innovation in small and medium-sized enterprises', *R&D Management* 21, 125-137.
- Schilling, M. (1998) 'Technological lockout: An integrative model of the economic and strategic factors driving technology success and failure.' *Academy of Management Review*, 23: 267-284
- Schmidt, T. (2005), 'What Determines Absorptive Capacity', Paper presented at the DRUID Tenth Anniversary Summer Conference on 'Dynamics of Industry and Innovation: Organisations, Networks and Systems'.
- Simonetti, R. (1994), 'The dynamics of market shares: a dis-equilibrium model', Paper for the Eunetic Conference in Strasbourg.
- Stock, G. N., Greis, N.P., Fischer, W.A., (2001). 'Absorptive capacity and new product development'. *The Journal of High Technology Management Research* 12, 77-91.
- Storey, D. (1992) United Kingdom: Case study. In *Small and Medium Sized Enterprises, Technology and Competitiveness*, ed. OECD. Paris.
- Interdepartmental Committee on Science, Technology and Innovation (July 2004) 'Building Ireland's Knowledge Economy: the Irish action plan for Promoting Investment in R&D by 2010', Interdepartmental Committee on Science, Technology and Innovation.
- Tang, N., Peng, I., Agnew, A. and Jones, O. (1995) 'Technological alliances between HEIs and SMFs: Examining the current evidence.' *Proceedings of the European Conference on Management of Technology. Technological Innovation and Global Challenges*, ed. D. Bennett and F. Steward, 147-154.
- Teece, D, Pisano, G. (1994) 'The dynamic capabilities of firms: an introduction'. *Industrial and Corporate Change* 3(3): 537-56
- Teece, D. J., Shuen, A. (1997) 'Dynamic capabilities and strategic management.' *Strategic Management Journal*, 18: 509-33

Tilton, J.H. (1971) 'International Diffusion of Technology: The Case of Semiconductors. Washington, D.C.: Brookings Institution.

Van Den Bosch, F.A.J., R. Van Wijk and H.W. Volberda (2003), 'Absorptive Capacity: Antecedents, Models and Outcomes.', *Blackwell Handbook of Organisational Learning & Knowledge Management*, 278-301

Van Den Bosch, f.A.J., H.W. Volberda and M. De Boer (1999), coevolution of Foirm Absorptive Capacity and Knowledge Environment: Organisational Forms and Combinative Capabilities., *Organisational Science: A Journal of the Institute of Management Sciences* 10 (5), 551-568.

Veugelers, R. (1997) Internal R&D expenditures and external technology sourcing. *Research Policy*, 26, 303-15.

Warner, M., 1996. Innovation and training, in; Dodgson, M., Rothwell, R. (Eds.), *The Handbook of Industrial Innovation*. Edward Elgar, Cheltenham.

Zahra, S. A., George, G. (2002) 'Absorptive capacity: a review, re-conceptualisation, and extension.' *Academy of Management Review*; 27:185-203