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Technological Innovation – A Route Towards Sustainability in the Irish Food Industry

Gráinne Kavanagh[1,3], Maeve Henchion[1], Mary McCarthy[2], Sinead McCarthy[1], and Gwilym Williams[3]

[1]*Teagasc Food Research Centre, Ashtown, Dublin 15, Ireland;*
[2]*University College Cork, Cork, Ireland;*
[3]*Dublin Institute of Technology, Kevin St., Dublin 2, Ireland*
grainne.kavanagh1@gmail.com ; maeve.henchion@teagasc.ie ; M.McCarthy@ucc.ie ; sinead.mccarthy@teagasc.ie ; gwilym.williams@dit.ie

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ABSTRACT

The sustainability of small and medium-sized enterprises (SMEs) is constantly challenged on today's dynamic operating environment. Evolving regulatory trends, difficult economic conditions, and diminishing natural resources, pose serious questions for all players across the food system. Technological innovation, as a means of ensuring future sustainability in the same in the face of such challenges, has been the focus of significant government investment in Ireland. This paper, aims to facilitate a greater understanding of the motivations and barriers influencing the decision by food SMEs to invest in technological innovation emanating from research conducted in publicly-funded research institutes.

Keywords: Food industry; Absorptive capacity; Innovation: Small and medium-sized enterprises (SMEs).

1 Introduction

Rapidly developing technologies, evolving consumer preferences, and ever-increasing competition, creates a challenging business environment for those operating in the food industry (Fortuin *et al.*, 2007). The established orthodoxy is that innovation is synonymous with competitive advantage, and in turn, long term survival of a company (Porter, 1985; Triall & Grunert, 1997). Innovation, as a result, affords a means of surviving and thriving in the dynamic agrifood industry (Fortuin *et al.*, 2007).

In Ireland, analogously to Europe, the majority of food companies can be classified as small or medium-sized enterprises (SMEs)[*] (Central Statistics Office [CSO], 2007). The majority of food SMEs are Irish-owned and are frequently located in rural communities (CSO, 2007; Avermaete *et al.*, 2004). As a result, they are believed to have a central role in the socio-economic fabric of peripheral regions of the country (Department of Agriculture, Fisheries and Food, 2010). However, a number of studies in the area have suggested that SMEs are at a disadvantage in terms of innovation due to low levels of human capital, lack of finances for innovation (Traill & Grunert, 1997), limited absorptive capacity (Menrad, 2004), and diseconomies of scale (Nooteboom, 1994). Furthermore, smaller firm size is thought to result in lower levels of dedicated research and development (R&D) resources, personnel and facilities in manufacturing firms (Supnithadnaporn & Jung, 2007; Shefer & Frenkel, 2005). External organisations, such as publicly-funded food research centres and third level institutes (TLIs), can have an influential role in addressing these failings by providing the knowledge and supports required to innovate (Batterick, 2009). This paper

[*] SMEs are enterprises that employ between 10 and 250 employees, have an annual turnover less than €50million, and/or an annual balance sheet under €43 million (European Commission, 2005)

aims to facilitate a greater understanding of the motivations and barriers influencing the decision by food SMEs to invest in technological innovation emanating from research conducted in publicly-funded research institutes.

2 Background to model and hypothesis

The subsequent section reviews the absorptive capacity literature in order to develop empirically testable hypotheses that are of relevance to the Irish food industry. Following this, the hypotheses are synthesised into a proposed framework, which characterises the factors influencing absorptive capacity in food companies.

Menrad (2004) suggested that the limited capacity of food SMEs to absorb and integrate external knowledge into current activities restricts the potential benefits of publicly-funded food research. The absorptive capacity of a firm refers to "the ability of the firm to recognise the value of new, external information, assimilate it and apply it to commercial ends" (Cohen & Levinthal, 1990:128). Drawing on previous work in the area, Cohen and Levinthal (1990) proposed that the ability to exploit new knowledge was a function of prior knowledge. Therefore, R&D has an important role in both generating innovation and facilitating learning. In the intervening twenty years since its definition, the concept of absorptive capacity has evolved from being a static, narrow, R&D focused process, to the recognition that it is a dynamic set of knowledge-based capabilities with many influencing factors (Zahra & George, 2002; Todorova & Durisin, 2007).

Many authors have equated the extent of a firm's absorptive capacity with its ability to successfully benefit from knowledge external to the firm (Cohen and Levinthal, 1990; Zahra & George, 2002; Todorova & Durisin, 2007; Schmidt, 2010). As a result, Schmidt (2010) inferred that the perceived value placed on external knowledge, and a firm's receptivity to engaging with sources of such knowledge would be reflective of their absorptive capacity. He suggests dividing external knowledge sources into two tiers depending on the level of complexity of knowledge arising from such sources, and accordingly, the extent of absorptive capacity required to exploit this knowledge. The first level incorporates the intra-industry knowledge of customers, suppliers and competitors. The second level refers to the knowledge from universities or other public research institutes (*ibid*.).While this approach is useful, it does not account for knowledge provided by consultants, which may be either scientific or non-scientific in nature. Additionally the competitive intelligence provided by state-funded, food industry support organisations cannot be as easily stratified in terms of complexity (e.g. Bord Bia - agency responsible for providing strategic market development, promotion and information services to the Irish food industry and Enterprise Ireland - agency responsible for the development and growth of Irish enterprises in world markets).

A number of internal factors are thought to play a role in the development of absorptive capacity in a firm. Cohen and Levinthal (1990) attribute a component of the capacity to the level of human capital, or the stock of knowledge and training skills (Wagner *et al*., 2003) present within a company. Koc (2007) found that innovation capacity was positively affected by the depth and variety of employee skills and experience. Post-school qualifications are also hypothesised to contribute to technical, communication and social skills, and in turn, to contribute to improving innovation capability (Avermaete *et al.*, 2004). Additionally, the further development of staff through training has been found to translate into higher levels of innovation in firms (Freel, 2005; Avermaete *et al.*, 2004).

When looking at the structure of a firm, Lane *et al.* (2006) postulated that the company policies and processes which allow for adapting to change, can aid the transfer, sharing, integration and creation of knowledge. The existence of formal and informal knowledge transfer mechanisms within a company has been found to facilitate optimisation of knowledge integration (Fosfuri & Tribó, 2008; Zahra & George, 2002). Further to this, Lloyd (1998) in Daghfous, (2004), noted that a culture for innovation, fostered by empowerment of employees, improved levels of absorptive capacity in firms. Cooper *et al.,* (2004) proposed a number of key elements that contribute to a successful culture of innovation, including: a supportive environment for innovation, open communication, resources available for creative work and rewards for staff. The use of rewards to stimulate individuals and teams is enshrined in motivational theory and has been recognised as an effective way of aligning the interests of the employee with those of the organisation (Cormican & Sullivan, 2004). As discussed above, R&D facilities are thought to play an integral role in the development of absorptive capacity (Cohen & Levinthal, 1990). Due to the SME nature of the food industry, companies tend to focus on developmental rather than fundamental research (Freel, 2005; Santarelli & Sterlacchini, 1990), which may take place mainly in new product development (NPD) functions, as opposed to science intensive R&D facilities. Interestingly, the impact of involvement of senior management in NPD is not clear-cut within the context of the food industry. A number of studies have found direct involvement in NPD to be predictive of successful innovation (Kristiansen, 1998; Hoban,

1998). However, Stewart-Knox & Mitchell, (2003A, B) found this to be unrelated to product innovation success, a finding the authors attributed to the larger number of SME participants in their study. In SMEs, the manager may have a shorter term, tactical, as opposed to a longer-term, strategic role (Stewart-Knox & Mitchell, 2003B). The discussion above underpins our first hypothesis:

$H_{1:}$ The extent of a firm's absorptive capacity will be positively related to elevated levels of certain supportive internal factors: expenditure on training, educational qualification, communication linkages, undertaking NPD, formal strategy for innovation, culture for innovation, and managerial involvement in NPD.

Based on a comprehensive review of the absorptive capacity literature, Lane *et al.* (2006) proposed a broad model, which frames the concept within the realities of the business environment. By examining the concept in the wider context, more meaningful interpretation of results are possible (Fosfuri & Tribo 2006; Mowery *et al*., 1996; Szulanski, 1996). In doing so, "the role of the firm's environment in determining the incentives for investing in absorptive capacity" can be investigated (Lane *et al.*, 2006:857). In Porter's (1985) Five Competitive Forces model, he outlines how industry structure determines the degree to which factors such as suppliers, potential entrants, buyers, substitutes and industry competitors, impact on a firm's ability to be sustainable. If a firm perceives extensive pressure from these factors, it may be driven to innovate in order to increase its competitive advantage. Furthermore, mounting operating costs may necessitate innovation in order to reduce this outlay. However, the cost of innovating has been found to be prohibitive by the majority of firm's in two recent surveys of Irish companies (Forfás, 2008; Henchion *et al.,* 2008). In terms of the economic environment, the repercussions of limited credit availability are being felt across the manufacturing sector, and the food industry in no exception (Bord Bia, 2008). However, innovative product offerings and cost cutting measures have the potential to facilitate a price reduction and create sales. A complex relationship thus develops in which the business environment both constrains and drives innovation in firms. In terms of the regulatory environment, the restrictive nature of the European legislation, has often been blamed for the lesser development of functional foods, compared to in the US and Japan (Bech-Larsen & Scholderer, 2007). However, the need to comply with evolving legislation may also be inspiring and drive innovation in many companies.

Additionally, external to the company, the effects of the knowledge environment on innovation must be taken into consideration. Lane *et al*. (2006:857) defines the knowledge environment as "the knowledge produced by corporate and non-corporate sources". A number of studies suggest that information from commercial bodies (e.*g*. suppliers, clients or customers, and competitors) is of most importance for successful innovation (Avermaete *et al*., 2004; Rabson & Haigh, 2008). However, the acceleration effect of publicly-funded research in stimulating privately-funded research has also been demonstrated (Salter & Martin, 2001). Developing collaborations with research institutions is regarded as crucial for innovation particularly in small, low-tech firms, as the means to conduct research, and the necessary know-how, may be lacking (Avermaete *et al*., 2004). Larger, high-tech food companies can also benefit from this type of open innovation (Chesbrough, *et al.,* 2008). Stewart-Knox & Mitchell (2003B) found that communications with agencies (*e.g.* local or national research organisations) also enhanced innovation success. Taken together, these arguments lead to our second hypothesis:

$H_{2:}$ The extent of a firm's absorptive capacity will be positively related to the degree the firm perceives that the business environment has an impact on innovation activities (i.e. business environment encompasses the competitive, economic, operating, regulatory and knowledge environment)

The process of absorptive capacity is thought to be dynamic and involve constant feedback from the different stages and actors (Zahra & George, 2002; Todorova & Durisin, 2007). As a result, the priority placed on outcomes may also become a driver for investing in absorptive capacity. Lane *et al.* (2006) suggested examining both the commercial outputs (new products, patents and increased market share) and the knowledge outputs (scientific, technical and organisational outcomes). The knowledge outcome is thought to contribute to Cohen and Levinthal's (1990) 'bedrock of knowledge', and thus enhance the absorptive capacity of the firm. Additionally, the commercial benefit of investing in a new technology is a major driver of the decision to invest (Cohen & Leninthal, 1990). As a result, our third hypothesis is as follows:

$H_{3:}$ The extent of a firm's absorptive capacity will be positively related to the level of priority placed on both commercial and knowledge outputs.

The importance of the ability to innovate, in order to contend with the challenges facing the highly competitive, tight margin food industry, has been well recognised by academics, governments and leading international organisations (Porter, 1985; Traill & Grunert, 1997; Department of Agriculture, Fisheries and Food, 2010; Chesbrough *et al*, 2008; CIAA, 2007; EC, 2009). Although technological innovation (product,

process and packaging) has been the focus of most government support initiatives, for Irish food companies to maximise potential benefit from the State's investment, a minimal level of existing absorptive capacity is required in firms (Department of Agriculture, Fisheries and Food, 2010; Menrad, 2006). Technological innovation based on food R&D, has the potential to increase both the efficiency and productivity of the food sector through technological progress (EC, 2009). Advances in food science and technology are continually generating opportunities for potential value creation for food companies (Fryer & Versteeg, 2008). As a result, we can infer that companies that engage in technological innovation will have improved firm performance.

H_4: The extent of a firm's absorptive capacity will be positively related to engagement in technological innovation (and resultant firm performance).

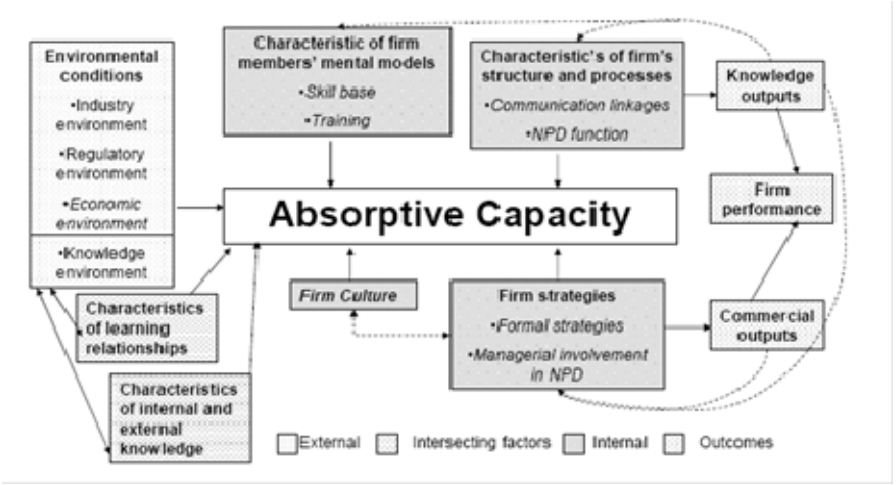

Figure 1. Proposed model of the factors influencing absorptive capacity in the Irish food industry. Source: Modified from Lane *et al.* (2006). Modified areas are highlighted in italics.

Figure 1 illustrates the conceptual framework used in this research. The framework builds primarily on the work of Lane *et al.* (2006), and was extended following a critical review of relevant literature, and a series of in-depth interviews with Irish food companies and government support agencies (*n*=7). A number of biases were found to exist in the literature, including a focus on high technology industries and large firms. Consequently, the interviews were conducted with a view to reconciling the literature within the context of the predominantly low-tech Irish food industry, in which 90% of companies are classified as SMEs (Teagasc, 2009). The results of the interviews are discussed in detail in Kavanagh *et al.* (2010). This paper aims to test the component parts of this modified model by investigating the hypotheses outlined previously.

3 Methodology

To investigate the proposed hypotheses, a survey was conducted among food companies operating in Ireland (*n*=445). A proprietary directory of food industry contacts was used to identify potential respondents. The directory originated from a previous project within the Teagasc Food Research Centre, Ashtown, and was updated and expanded using internet search verification. The questionnaire was piloted to proof for potential understanding problems relating to terminology and possible ambiguity. The final questionnaire was distributed by post between June and September 2010. A number of measures were implemented to maximise response rates, including those suggested in Dillman's (1978) *Total Design Method* (e.g. pre-approach, repeated postings, use of headed paper, hand-signing and personalising each letter). A number of companies declined participation (*n*=13) on the grounds of time pressures and a further 40 companies indicated they had ceased operations or amalgamated with other companies. This is reflective of the current dynamic economic environment (final cohort *n*=399). The final response rate achieved was 30% (n=127). Data were managed and analysed using PASW statistical software for Windows, SPSS® Base 18.0 (SPSS Inc., Chicago, IL, USA).

At present, the literature does not provide an agreed measure for direct empirical testing of absorptive capacity (Schmidt, 2010; Lane *et al.*, 2006; Zahra & George, 2002). However, many authors have equated firm absorptive capacity with its ability to successfully benefit from knowledge external to the firm (Cohen and Levinthal, 1990; Zahra & George, 2002; Todorova & Durisin, 2007; Schmidt, 2010). Therefore, this study, building on the work of Schmidt (2010), clustered companies into three groups, based on the extent of their absorptive capacity, using two measures: (M1) level of receptivity to and, (M2) perceived value placed on external sources of innovation. These form the dependent variables. For each measure, internal reliability was tested using Cronbach alpha, with a score above 0.7 deemed acceptable as recommended by Nunnally (1978). For scales that did not reach 0.7, inter-item correlation means were computed. For this calculation, a score between 2.0 and 4.0 is preferable and was achieved for all such scales (Table 1 and 2) (Briggs & Cheek, 1986).

In order to determine the receptivity of a company to external sources of innovation (M1), respondents were asked to rank their level of agreement with five statements (relating to openness to academia, support bodies and publicly-funded research) on a five point Likert scale with 1=strongly disagree and 5=strongly agree. Principle Component Analysis (PCA), using direct oblimin rotation, was conducted to investigate how the statements loaded together (Table 1). A number of authors suggest the use of direct oblimin rotation as it accounts for the risks of correlation between variables, a distinct possibility in naturalistic data (Field, 2009; Costello & Osborne, 2005; Melton & Schuklenberg, 2009). As one of the statements loaded strongly on both components, this statement was removed and the analysis was rerun. A mean openness to external sources score was computed for each of the respondents, using the sum of the mean responses to three statements which loaded strongly together (factor loading >0.65). This was divided into tertiles (of low, medium and high) and used for further analysis.

Table 1.
Absorptive Capacity Measure 1 (M1) –factor loadings of questions assessing receptivity to external sources of innovation (with both 4 and 5 questions) and mean with standard deviation (SD) of the total respondent sample

	Loading with all five items	Loading with four items	Mean	SD
Component 1				
It is important for your company to develop a network of contacts in academia	0.81	0.80	3.51	0.82
Developing contacts in support agencies is relevant to your company	0.71	0.72	4.09	0.78
Ongoing publicly-funded research has significant potential application for your company	0.62	0.65	3.38	1.00
If your company was to collaborate with another company, both would benefit fairly	0.37		3.48	0.88
Cronbach alpha: 0.41 Inter-item correlation mean: 3.42				
Component 2				
The best sources of innovative ideas is from within your company (*reversed prior to analysis*)	0.71	0.92	3.31	0.99
If your company was to collaborate with another company, both would benefit fairly	0.51		3.38	1.00
Cronbach alpha: 0.54 Inter-item correlation mean: 3.66				

In order to ascertain the perceived value placed on different levels of external sources of innovation (M2), respondents were asked the extent to which they agreed that a number of different organisations were of use in company technological innovation activities (on a five point Likert scale with 1=*strongly disagree* and 5=*strongly agree*). Only companies who indicated they had engaged in technological innovation in the last three years were asked to complete this section (*n*=96). PCA using direct oblimin rotation was conducted and sources loaded onto two components (Table 2). The components were named *commercial* and *public sector.* As suggested by Schmidt (2010), the information available from public sector sources was taken to have a higher level of complexity, and those who found it useful were assumed to have a

higher level of absorptive capacity. Consultants and state-funded support agencies loaded strongly on the public sector component and were thus included in same.

Table 2.
Absorptive Capacity Measure 2 (M2) –factor loadings of commercial and public sector components and mean with standard deviation (SD) of the total respondent sample

	Factor Loading	Mean	SD
Component 1: Commercial			
Competitors	0.74	3.50	0.98
Customers/retailers	0.69	4.11	0.91
Suppliers	0.60	3.43	0.97
Cronbach alpha: 0.51 Inter-item correlation mean:3.68			
Component 2: Public sector			
Teagasc	0.80	2.97	1.14
Industry Support Groups e.g. ISME	0.79	2.68	1.13
Country Enterprise Ireland	0.76	2.55	1.01
Bord Bia	0.68	3.41	1.01
Enterprise Ireland	0.58	3.71	0.97
Consultants	0.55	2.23	0.92
Universities/3rd level institutes	0.51	3.10	1.05
Cronbach alpha: 0.81 Inter-item correlation mean: 2.93			

When three clusters were specified using K-means cluster analysis, the groups emerged as follows:

1) Companies that did not find external sources of information useful (M2: lowest level)
2) Companies that found commercial sources of information useful (M2: middle level)
3) Companies that found both commercial and public sector sources of information useful (M2: highest level).

Due to the removal of 'non-innovators' from M2, a slight skewing of results was seen when testing hypothesis 4. The inclusion of the 'non-innovators' in M1 provides a clearer picture of the relationship between absorptive capacity and firm performance.

In order to investigate the four hypotheses, measures for each independent variable were created based on the questionnaire. Details of the independent variables are provided in Appendix A. Due to the voluntary nature of the study access to exact measures of firm performance (*e.g*. sales, turnover, profit margin on innovative products) was not possible. Therefore, a proxy for firm performance was used based on the belief that firm performance was improved by engagement in technological innovation.

Four scales are included as follows; economic environment, operating environment, industry environment and innovation culture. For the first three scales, subjects were asked to indicate how strongly a selection of 13 external factors (e.g. retailers, wages bill, availability of credit, state of the economy) impacted on company innovation activities by rating the items on a five item scale (where 1=*None* and 5=*A lot*). The items were factor analysed, using PCA with direct oblimin rotation, and resulted in the identification of the three factors (loading score greater than > 0.6). For each company, a mean of responses to each of the three factors was computed and used for further analysis. In order to develop a measure for firm innovation culture, respondents were asked to endorse the statement "In the company I work for…" for

each of nine items (relating to implementation of change, empowerment of employees, allocation of resources for creative work, reward systems and the supportive nature of the environment for innovation) by choosing between five responses: *disagree strongly, disagree, neutral, agree, and strongly agree,* scored 1 to 5. Items that were phrased negatively were reversed prior to further analysis. A mean response for culture was computed and used for further analysis. Cronbach alpha showed an acceptable degree of internal consistency in the four scales, being in all cases above 0.7 as recommended by Nunnally, (1978). Chi squared distribution tests were used to validate the hypotheses involving categorical variables. Continuous data variables were subjected to Analysis of Variance (ANOVA) separately to identify the significant factors (Field, 2009).

4 Results and discussion

The descriptive statistics for the sample are presented in Table 3. The sample was reasonably representative of the sectors in the Irish food industry when compared to data provided by An Bord Bia (pers. comm. 10th December 2010); with some over representation of the meat sector and under representation of the marine sector. SMEs made up over three quarters of the cohort, compared to 90% in the general population of the Irish food industry (Teagasc, 2009). As is the case in most Irish food companies, the majority of the sample indicated they exported (78%).

Table 3.
Descriptive statistics of sample population

	n (%)
Sector	
Meat	27 (21.3)
Combination	23 (18.1)
Prepared consumer foods	21 (16.5)
Dairy	13 (10.2)
Seafood	10 (7.9)
Other e.g. confectionary	10 (7.9)
Fresh Produce	8 (6.3)
Beverages	7 (5.5)
Ingredients	3 (2.4)
Size – Employees number	
>10	12 (9.4)
10-49	50 (39.4)
50-99	25 (19.7)
100-249	21 (16.5)
250+	19 (15.0)
Export companies	97 (78.0)

Cross-tabulation between the two measures showed reasonable agreement, and verified the co-incidence of high levels of openness to external sources of innovation and high levels of perceived value of such sources. Chi-square statistics confirmed the relationship between the two measures ($\chi 2 = 13.15$, $p<0.05$).

About a third (34 %) of companies surveyed indicated a high level of receptivity to external sources of information (M1)(Table 4). Approximately half (45%) who specified they had recently engaged in a technological innovation perceived the knowledge within both commercial and public sectors as being of value to their business (M2). Only a quarter (25%) of 'innovators' did not attribute value to external information sources within this context, while about a third (29%) placed a higher value on knowledge emanating from the commercial arena than from the public sector.

Table 4.
Number and percentage of companies in the three levels of absorptive capacity for M1 and M2

	M1	M2
	Level of openness to external sources of innovation	Perceived value of different levels of external sources of innovation
	(*n*=123)	(*n*=95)*
	No. Companies (%)	No. Companies (%)
Level 1 (Lowest)	45 (36.6)	24 (25.3)
Level 2 (Middle)	36 (29.3)	28 (29.5)
Level 3 (Highest)	42 (34.1)	43 (45.3)

*As only companies which indicated they had engaged in a technological innovation were asked to complete the second measure, there are considerably less in this cohort.

The breakdown of means and proportions of the independent variables are presented in Table 5, along with chi-squared distribution tests of categorical variables and analysis of variance results for continuous variables. In support of hypothesis 1, the factors recognised as playing a role in the development of absorptive capacity were found to be more prevalent in the highest categories of both M1 and M2. When compared with the total population, higher levels of education generally corresponded with increased absorptive capacity (Lowest level, M1: 30% vs. total population 19%; M2: 22% vs. total population 20%; Highest level; M1: 53% vs. total population 45%). This is in line with findings by Koc (2007) and Avermaete et al. (2004), in which higher levels of educational qualifications were found to correlate with enhanced firm innovation capacity. In terms of training expenditure, for M1, companies in the middle group spent the most of the three levels (respectively in increasing order of absorptive capacity level, €26,619, €45,375, €29,650). In M2, which is specific to the 'innovators', this pattern was again evident. It is possible that this group have recognised the potential of investing in training in order to improve their level of absorptive capacity. Freel (2005) and Avermaete et al. (2004) found that the most innovative firms had trained more staff and invested more in staff training. However, in contrast to this, Romijn and Albaladejo (2002) asserted that training did not always translate into higher innovative capability; rather, such activities were often a vehicle for realising improved administrative efficiencies. The present study found that companies with higher levels of absorptive capacity were significantly more likely to have engaged in training aimed at increasing efficiency (e.g. lean manufacturing, change management and supply chain management ($p<0.05$)) and driving innovation (e.g. NPD ($p<0.01$)). These results indicate that such companies had an appreciation of both these beneficial aspects of training.

Cohen and Levinthal (1990) asserted that the existence of a dedicated R&D function was necessary to underpin strong absorptive capacity. In the present study, no significant difference was found in the prevalence of a NPD function across different levels of absorptive capacity. It is possible that the use of the term 'NPD function' as opposed to 'R&D function' was inadequate to differentiate sufficiently between the levels of R&D that were occurring. NPD in food companies varies immensely in terms of level of research involved (e.g. from recipe alteration in a 'kitchen' to large-scale pilot plants). By using a proxy for the level of R&D (i.e. respondents were asked if they had engaged with the Enterprise Ireland R&D support grant scheme, for details see Enterprise Ireland (2010)), significant differentiation was seen across groups for M1 (respectively in increasing order of absorptive capacity level, 28.2%, 55.9%, 61.5%, $p<0.01$).

In agreement with Lloyd (1998), significant improvement in the innovation culture was seen across increasing absorptive capacity groups (M1: respectively in increasing order of absorptive capacity level, 3.23, 3.31, 3.52, $p<0.05$). M2 also showed an increase across groups, but this was not significant. As M2 is specific to 'innovators', the extent of the variation between groups may be diminished and as a result, significance difference would be more difficult to discern. The level of internal communication linkages, the presence of a formalised innovation strategy and direct managerial involvement in NPD were not seen to differ significantly between groups. However, companies with lower absorptive capacity (as indicated by both measures) had reduced levels of all three variables compared to the overall sample. Communication linkages, particularly through cross-functional teams, are thought to instil a culture of trust and cooperation within the firm, thereby enhancing the exploitation of external knowledge (Fosfuri & Tribó, 2008, Cormican & Sullivan, 2004; Stewart-Knox & Mitchell, 2003B). However, the high proportion

of SMEs in the food sector, and thus lack of role definition amongst staff, may diminish the possibility of utilising this important aspect of an innovative environment. Managerial involvement in NPD was particularly insignificant across groups. This may indicate that managers in small firms concentrate on ensuring day-to-day operations run efficiently, as opposed to focusing on long term projects (e.g. product innovation). This is similar to findings by Stewart-Knox (2003A, B) that the role of the manager in SMEs centred on shorter-term, tactical decisions, as opposed to longer-term, strategic choices.

Hypothesis 2 aimed to investigate the link between the firm's perception of the business environment and extent of absorptive capacity. For most factors in the external environment, M1 gave better differentiation across groups than M2, and is selected here for further analysis (this may again be due to the exclusion of 'non-innovators' from M2). In terms of the impact of the competitive environment, the group with the lowest level of absorptive capacity perceived significantly less pressure from retailers, suppliers and customers than the medium and high levels (M1: respectively 2.67, 3.39 and 3.23, $p<0.001$). A similar trend was seen in the operating environment, as the perceived impact of operating costs on innovation activities was again less in the lowest group than the other two groups (M1:respectively, 2.44, 3.07 and 2.99, $p<0.05$). For both M1 and M2, economic environment did not show significance ($p>0.05$). The results suggest that firms that perceive pressure from the competitive and operating environment are more likely to be receptive to external sources of information.

The perception of the level of impact from regulation is also in line with the levels of absorptive capacity in firms. In comparison with the overall sample, the companies with the lowest levels of absorptive capacity are significantly less likely to indicate a high number of regulations impacted on their innovation activities (M1: 51.1% in comparison with 36.6% of the overall sample, $p<0.05$). While the importance of HACCP and ISO regulations were evident across all groups, companies with higher levels of absorptive capacity had an increased likelihood of indicating the importance of *nutritional information labelling*, *nutrition and health claim legislation* and *labelling requirements for allergens*. Additionally, recognition of the value of the knowledge environment was found to be aligned with the observed level of absorptive capacity in Irish food firms. Unsurprisingly, 83% of the firms classified as having a higher level of absorptive capacity, perceived the knowledge environment to be of use to their activities, in contrast to 11% of firms falling into the lower category.

Hypothesis 3, which examined the link between degree of absorptive capacity and priority placed on outcomes from investing in external knowledge, was not supported as presented in Table 3 (p-value >0.1). It is possible that the measures used to assess outcomes were too general in nature.

The final hypothesis looked at the relationship between extent of absorptive capacity and firm performance, based on the belief that firm performance is improved by engagement in technological innovation. In general, high levels of each type of technological innovation were reported across all groups, with product innovation most prevalent in this sample (77.8%), followed by packaging (57.1%) and process (53.2%). These levels are similar to those reported by Avermaete *et al.* (2004) in a survey of 177 food firms in 6 European countries (*i.e.* product innovators 77.9%, process innovators 62.1%, and packaging innovators not given). For both measures of absorptive capacity, product innovations were less common in the lower groups (M1: 68.2%, M2: 75.0%) than in the higher groups (M1: 85.7%, M2:86.0%). This difference is statistically significant for process innovators, with the higher groups (M1: 66.7% and 64.3%) far exceeding the levels of process innovation in the lower groups (M1:34.1%). A significant difference was not found across packaging innovators. As M2 is limited to 'innovators', an analysis of those not engaging in technological innovation was only possible with M1. The results indicate that 'non-innovators' were significantly more likely to have low absorptive capacity levels.

Table 5.
Means and proportions of independent variables with Chi square analysis of categorical variables and one-way ANOVA between continuous means

	Total		Low		Medium		High			
	Measure 1	**Measure 2**	**Measure 1**	**Measure 2**	**Measure 1**	**Measure 2**	**Measure 1**	**Measure 2**	**Measure 1 χ^2or F value**	**Measure 2 χ^2or F value**
Hypothesis 1 – Internal factors										
Qualification Level 1	18.8%	20.0%	30.0%	22.2%	10.0%	16.0%	16.7%	21.6%	5.58	0.55
Qualification Level 2	36.5%	36.3%	33.3%	33.3%	46.7%	36.0%	30.6%	37.8%		
Qualification Level 3	44.8%	43.8%	36.7%	44.4%	43.3%	48.0%	52.8%	40.5%		
Training spend (Euro)	32,181	38,722	26,619	42,597	45,375	48,650	28,265	29,650	1.64	1.12
Communication linkages	62.6%	68.4%	51.1%	70.8%	69.4%	78.6%	69.0%	60.5%	4.00	2.66
Firm Culture	3.36	3.38	3.23	3.18	3.31	3.40	3.52	3.48	3.49*	2.63
Innovation strategy	13.8%	15.8%	6.7%	16.7%	13.9%	10.7%	13.8%	15.8%	3.98	0.81
Mgt. involvement in NPD	90.2%	91.6%	88.9%	87.5%	94.4%	92.9%	88.1%	93.0%	1.04	0.69
NPD function	62.0%	70.2%	48.9%	62.5%	69.4%	81.5%	70.0%	67.4%	5.21	2.48
R&D grant	48.2%	55.8%	28.2%	38.9%	55.9%	53.8%	61.5%	64.3%	9.82**	3.35
Hypothesis 2 – External factors										
Operational environment	2.81	2.83	2.44	2.74	3.07	2.80	2.97	2.89	3.99**	0.15
Competitive environment	3.09	3.18	2.68	2.83	3.39	3.20	3.23	3.35	8.55***	2.95
Economic environment	2.88	2.9247	2.5427	2.6364	2.9500	2.7143	3.14	3.21	2.97	2.59
Regulatory environment – Level1	36.6%	31.6%	51.1%	50.0%	27.8%	17.9%	28.6	30.2%	14.08**	9.13
Level 2	30.9%	30.5%	33.3%	29.2%	38.9%	42.9%	21.4%	23.3%		
Level 3	15.6%	37.9%	33.3%	20.8%	50.0%	39.3%	32.5%	46.5%		
Knowledge environment	44.7%	43.0%	11.1%	40.9%	41.7%	21.4%	83.3%	58.1%	46.03***	9.38**
Hypothesis 3 – Outputs										
Knowledge outputs	3.3%	4.2%	2.2%	4.2%	2.8%	3.6%	4.8%	4.7%	0.48	0.05
Commercial outputs – NPD	37.4%	46.3%	40.0%	33.3%	33.3%	53.6%	38.1%	48.8%	0.39	2.33
Commercial outputs – market share	30.9%	41.1%	24.4%	25.0%	36.1%	46.4%	33.3%	46.5%	1.45	3.42
Commercial outputs – patent	72.4%	74.7%	66.7%	62.5%	69.4%	78.6%	81.0%	79.1%	2.43	2.55
Hypothesis 4 – Firm performance										
Product innovation	79.5%	85.1%	68.2%	75.0%	86.1%	92.6%	85.7%	86.0%	5.42	3.16
Process innovation	54.1%	60.6%	34.1%	54.2%	66.7%	55.6%	64.3%	67.4%	11.14*	1.55
Packaging innovation	57.4%	63.8%	55.3%	58.3%	66.7%	66.7%	54.8%	65.1%	1.86	0.44
Not engaged in technological innovation	10.6%		22.2%		5.6%		2.4%		10.402**	

***Significant at 0.1%, **significant at 1%, *significant at 5%

5 Conclusions

In this paper we aimed to facilitate a greater understanding of the motivations and barriers influencing the decision by food SMEs to invest in technological innovation emanating from research conducted in publicly-funded research institutes. Low absorptive capacity has been found to impede progress in this area by a number of studies of the food industry (Menrad, 2004; Batternick, 2009; Schmidt, 2010). Given the importance of the food industry to the Irish economy and its recovery (Department of Agriculture, Fisheries and Foods, 2010), we undertook an investigation of the factors affecting absorptive capacity in Irish food companies.

Our first hypothesis was partially supported as the factors recognised as playing a role in the development of absorptive capacity were found to be generally more prevalent in firms with higher levels of absorptive capacity. Companies in the medium and high groups indicated they were spending more on training and had invested in staff with higher qualification levels than the lowest group. In particular, a culture of innovation has been highlighted as an important building block in firm absorptive capacity. Such findings are in line with Lloyd (1998) who linked increasing levels of absorptive capacity with positive firm culture. This observation was also made in previous work by the same authors, in which quantitative interviews with representatives from the food industry found culture to be a vital component of firm receptivity to external information. As a result of such findings, the addition of culture in the modified version of the Lane *et al*. (2006) model is justified.

The second hypothesis set out to explore the relationship between levels of absorptive capacity and perception of the environment. The highly competitive nature of the food industry, in conjunction with mounting operating costs and numerous regulatory requirements, may be inspiring companies to invest in developing absorptive capacity in order to facilitate innovating. However, companies with lower levels of absorptive capacity appear to perceive less of an impact from the business environment. If such companies do not appreciate the environmental pressures necessitating innovation, they may be unaware of the need to change (*i.e*. 'pre-contemplative' as seen in Prochaska *et al., 1995*). This raises policy implications, as companies with low absorptive capacity may need specifically targeted interventions that bridge the gap between actions and consequences (*i.e.* the potential of innovation for addressing environmental pressures). Such interventions would need to precede recommendations on ways to increase absorptive capacity for such companies.

In terms of priority placed on outcomes from investing in external knowledge, the measures applied in this survey were not significant and as a result the third hypothesis is rejected. In future work, more direct measures of prioritised outcomes may yield more informative results (*e.g.* expected return on investment, hurdle rates or required increase in market share). Qualitative research with those operating on the ground in the food industry may be a useful approach to elucidating such measures.

With regards to the final hypothesis, more direct measures of firm performance, possible in surveys enforced by legislation, may demonstrate more definite benefits to investing in absorptive capacity development. However, the data did show that lower levels of absorptive capacity were linked with lower levels of technological innovation, particularly process innovation. A significant difference was not found across packaging innovators and it is possible that publicly-funded support agencies are not thought to be of value in terms of assisting packaging innovation. The input of commercial sources (*e.g.* retailers and suppliers) may be particularly influential here. The higher proportion of packaging innovators in the group which favour the input of commercial sources (*i.e.* M2 group 2) gives extra credence to this assertion.

Overall, the model presented in Figure 1 provides a good overview of the internal and external factors that impact on absorptive capacity in the Irish food industry. When testing the hypotheses, M1 generally identified clearer differences between groups than the M2. When applying the second measure, the distinguishing characteristics of each level of absorptive capacity may have been more difficult to discern due to the sole focus on 'innovators' (and the resultant reduction of variation between groups). Further exploration of the subtle differences between groups is thus warranted. In addition, further work is needed to identify the required outcomes of technological innovation, which are of most relevance to Irish food firms. This paper did not address the intersecting factors which underpin the relationships between industry and publicly-funded research agencies. An investigation of these factors was conducted previously and the results are discussed in Henchion *et al.,* (2008).

In line with visions for the food industry outlined in the European (CIAA, 2008) and national (Department of Agriculture, Fisheries and Food, 2010) strategy documents, this paper focuses on leveraging innovation in food SMEs. In addition, by investigating the factors impacting on optimising knowledge transfer from research into food companies, this paper contributes to identifying 'best practice' experiences in

knowledge exchange in regional food chains (CIAA, 2007). As a result of developing the understanding of the barriers and drivers to industry uptake of publicly-funded food research, targeted supports can be constructed to facilitate technological innovation within food SMEs, and in doing so, maximise return from the State's investment in food-orientated research and development.

Table A1.
Determinants of absorptive capacity level in Irish food companies

Variable	Definition
Hypothesis 1 – Firm Performance	
Product innovation	Dummy: 1, engaged in product innovation in last three years; 0, otherwise
Process innovation	Dummy: 1, engaged in process innovation in last three years; 0, otherwise
Packaging innovation	Dummy: 1, engaged in packaging innovation in last three years; 0, otherwise
Hypothesis 2 – External factors	
Operational environment	Mean score for impact on innovation activities of operational environment measures (energy costs, wages bill, waste charges)
Competitive environment	Mean score for impact on innovation activities of competitive environment measures (consumer trends, retailer, competitor, supplier)
Economic environment	Mean score for impact on innovation activities of economic environment measures (state grants, tax incentives, availability of credit, state of the economy)
Regulatory environment	Responses were grouped into tertiles as follows: 1) 0-3 ticked, 2) 4-5 ticked, 3) 6-8
Knowledge environment	Dummy: 1, knowledge environment impacts on innovation activities; 0, otherwise
Hypothesis 3 – Internal factors	
Qualification level	1 = Secondary School, 2= 3rd Level Cert/Diploma or Degree, 3= Masters or PhD
Training spend	Average expenditure on training activities over last three years
Communication linkages	Dummy: 1, high level of communication linkages in firm; 0, otherwise
Firm culture	Mean score on culture of innovation measure
Innovation strategy	Dummy: 1, formal innovation strategy in place within firm, 0; otherwise
Hypothesis 4 – Outputs	
Knowledge outputs	Dummy: 1, *developing the understanding of the area within the company* was one of the three most important factors when deciding to invest in a technological innovation; 0, otherwise
Commercial outputs (CO) – NPD	Dummy; 1, *would result in new product/s for the company* was one of the three most important factors when deciding to invest in a technological innovation; 0, otherwise
CO – market share	Dummy; 1, *increased market share* was one of the three most important factors when deciding to invest in a technological innovation; 0, otherwise
CO – patent	Dummy: 1, Patent a company process/product was a priority; 0, otherwise

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