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Open innovation strategies in the food and drink industry: determinants and impact on innovation performance

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Abstract: This paper considers open innovation strategies in the food and drink industry and seeks to examine the determinants of openness and the impact of open behaviours by companies on innovation performance. The study clusters food and drink companies in terms of their degree of openness measured across two dimensions, namely, collaboration breadth (broad to narrow collaboration ecosystem) and collaboration depth (deeper to surface collaboration). Findings show that food and drink companies can be clustered into three open innovation modes in terms of their search strategy for external knowledge ranging from limited collaboration with traditional partners to a broad and deep openness approach with a wide spectrum of external sources. Technology pressures emerge as a key driver for greater openness. Significantly, greater openness leads to enhanced innovation performance; however, it requires a dedicated architecture for collaboration to access and leverage external knowledge.

Keywords: open innovation; firm openness; collaborative innovation strategies; search strategies; open innovation performance, food and drink industry; cluster analysis.

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1 Introduction

The benefits of open innovation are increasingly recognised in the innovation management literature as the trend towards innovation collaboration across organisational boundaries intensifies [for reviews of the literature, refer to Dahlander and Gann (2010), Huizingh (2011) and Lichtenthaler (2011)]. Today's fast paced business environment

requires firms to explore the use of external sources of technology and ideas to augment in-house R&D (Wolpert, 2002; Chesbrough, 2006; Gassmann, 2006; Huston and Sakkab, 2006; Hagedoorn, 2002). Advances in information and communication technology have made companies more aware of externally generated scientific knowledge and they are starting to recognise that external R&D can create significant value (Gassmann and Enkel, 2004). As a result, the ratio of large firms' research to total research has shifted over the last 20 years (Slowinski et al., 2009). Start-up and small and medium-sized enterprises (SMEs) and even individuals now play a far more relevant role in knowledge and technology creation while large firms seek to collaborate with these smaller knowledge creators (Chesbrough, 2006).

Across studies, openness has been defined and empirically tested using different measures, underlining an organisational behaviour with multidimensional forms of expression. The most investigated perspective in the literature has been the direction of openness (i.e., outside-in, inside-out and decouple processes) (Gassmann and Enkel, 2004; Keupp and Gassmann, 2009; Lichtenthaler, 2008; Enkel et al., 2009), although research has also focused on firms' search strategies for external knowledge (Laursen and Salter, 2006), the governance modes for innovation networks (Pisano and Verganti, 2008) and the organisational structures chosen to define the links among partners (i.e., high vs. low integration level) (Chiesa and Manzini, 1998; van de Vrande et al., 2006). Together these studies bring a greater understanding of openness as an umbrella term for different organisational approaches which has meanings in different contexts.

Research to date however has been limited in explaining the choice of open innovation models followed by companies in respond to their innovation strategy and technology and the business environment in which they operate (Barge-Gil, 2010; Enkel et al., 2011). Search strategies are strongly influenced by the richness of technological opportunities available in the environment and the search activities of other firms (Nelson and Winter, 1982; Levinthal and March, 1993). This paucity in the literature comes from a biased theoretical and empirical view of open innovation as a binary, open vs. closed strategy (Chesbrough, 2003; Dahlander and Gann, 2010). However, there is a consensus that open innovation strategies reside on a continuum where firms invest in innovation activities exhibiting varying degrees of openness (Enkel et al., 2009) along the innovation funnel with different external partners (Lazzarotti and Manzini, 2009; Lazzarotti et al., 2011).

To address this research gap, this paper draws on the literature of organisational learning (Levinthal and March, 1993) to explain the choice of search strategy followed by companies. It attempts to answer two important research questions: what is the impact of firm context and its business environment on the search for external knowledge?; and how different open or interactive behaviours by companies in their search for innovation opportunities do influence their innovative performance?. We build on Laursen and Salter's (2006) model to develop and empirically test a two-dimensional openness framework to search for open innovation strategies in terms of the extent of collaborative ties (*collaboration breadth*) and the intensity of collaboration (*collaboration depth*). This two-dimensional approach aims to model firms' actual organisational behaviour where different innovation approaches (i.e., closed, semi-open, open) could be pursued by companies in respond to firms' innovation strategy moderated by the technological regime and the business environment in which they operate (Cohen and Levinthal, 1990; Klevorick et al., 1995; Schweitzer et al., 2011). In particular, this paper argues that a firm's collaborative innovation strategy is not solely a choice for a firm to make but

influenced by factors to some extent outside the firm which shape the firm's relationship with innovation partners (Christensen et al., 2005; Garriga et al., 2013).

In the present paper, we examine open innovation strategies in the food and drink (f&d) industry, Europe's largest manufacturing sector both in terms of turnover (€956 billion) and employment (generating 4.1 million jobs) (FoodDrinkEurope, 2012). Firms in this industry are viewed as operating in a mature and relatively low technology sector (Christensen et al., 1996; Grunert et al., 1997) characterised by lower private investment in R&D than other EU manufacturing industries (0.53% of sales in 2009) (FoodDrinkEurope, 2012). The knowledge-base in the f&d industry is highly distributed with significant technological transfers from other industrial sectors (Sarkar and Costa, 2008; Karantininis et al., 2010; Capitano et al., 2010; Traill and Meulenberg, 2002; Garcia Martinez and Burns, 1999). Advances from emerging scientific fields such as nanotechnology (Sanguansri and Augustin, 2006; Sastry et al., 2010) or biotechnology (Levidow and Bijman, 2002; Carew, 2005) present unique opportunities for application in the f&d industry, hence providing powerful incentives for f&d companies to engage in collaborative innovation with external partners.

Our study extends prior research in two important ways. First, we extend Laursen and Salter (2006) model by providing greater characterisation of openness with an additional dimension to capture innovation phase openness and taking firm context and its business environment into account. Constraints to effectively applying resources are important for open innovation (Garriga et al., 2013). Second, we observe the actions of an industry that operates outside of the commonly researched areas, hence contributing to our understanding of open innovation as a strategic business tool in mature and low technology industries.

The paper proceeds as follows. Following the introduction, Section 2 reviews the relevant literature on open innovation strategies and Section 3 presents our theoretical model. Section 4 describes the data and the methodology used in searching for open innovation modes. Section 5 presents the results of the empirical test. In Section 6, we discuss the findings, and conclude in Section 7 with practical implications of our findings and a future research agenda which takes into account the study's limitations.

2 Literature review

Research has highlighted different approaches to open innovation in terms of the organisational form of acquisition or commercialisation of knowledge and technology and subsequent level of integration and time horizon (van de Vrande et al., 2006); the number and typologies of partners (Laursen and Salter, 2006; Pisano and Verganti, 2008); phases of the innovation process open to external collaboration (Gassmann and Enkel, 2004); direction of openness: inbound (i.e., technological acquisition) and/or outbound (i.e., technological commercialisation) (Lichtenthaler, 2008); and governance structures (Pisano and Verganti, 2008). All these contributions share the common understanding that innovation models are not exclusively open or closed but rather exhibit varying degrees of openness (Dahlander and Gann, 2010).

However, there is limited research explaining the choice of open innovation strategy followed by companies in respond to their innovation strategy and technology and the business environment in which they operate. As Chesbrough (2003) argues, the specific level and mode of open innovation is contingent on the particular business models chosen

by firms in a particular industry and the technological context. Incremental and breakthrough innovations go together (Kanter, 2010); in fact firms need both and collaborate with different external partners at different levels of interaction along the innovation funnel. In turn, some innovation stages tend to be more porous than others and open to partners at various degrees of intensity (Gassmann and Enkel, 2004).

Operating under an open innovation context depends on contributions from across a network of partners ranging from suppliers of raw materials, equipment, research institutes to consumers and customers that create value for the end consumer (West and Lakhani, 2008). Collaboration partnerships may serve different functions at different stages in the innovation process (Kessler et al., 2000; Roper et al., 2008). Consumers can play important roles in different innovation and value creation activities; for instance their involvement at the stage of product design assists firms to improve the 'fuzzy front-end' process of identifying consumers' needs and wants (Lusch and Vargo, 2006). By understanding what consumers' value and engaging in active dialogue and interaction, companies are able to develop superior value propositions relevant to their target consumer-base (Kemp, 2013). Engaging consumer in innovation has important implications for the f&d industry where true innovation is limited with the majority of introductions representing range extensions and new flavours rather than new brands or categories (Galizzi and Venturini, 1996; Grunert et al., 1997). This lack of meaningful differentiation results in approximately 60%–80% of new food products failing in the market place (Goldman, 2005). New product introductions are only the tip of the iceberg where many projects fail before the launch resulting in the loss of considerable time and expenditure (van der Valk and Wynstra, 2005). Co-creation with consumers hence offers f&d companies an opportunity to add value and extricate themselves from commodity sectors where the lowest cost provider holds sway (Garcia Martinez, In press).

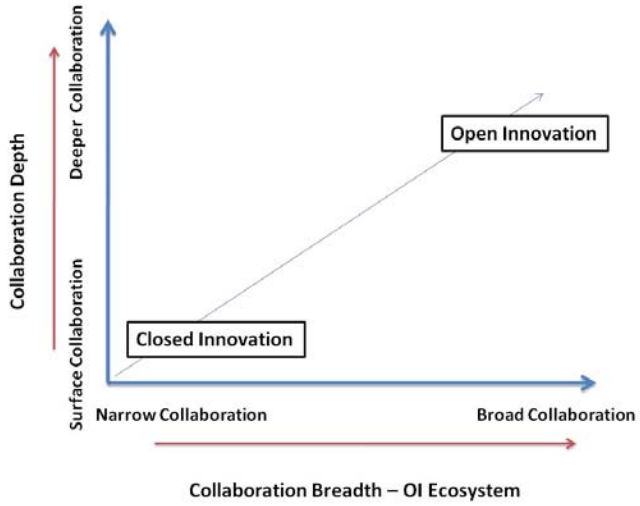
Cooperation with suppliers is found to enhance efficiency and complement the technological-base of the firm (Clark, 1989; Belderbos et al., 2004; Un et al., 2010). The f&d industry in particular shows a strong dependence on specialised suppliers of embodied technologies to execute innovation activities (Karantininis et al., 2010; Garcia Martinez and Burns, 1999). Collaboration with universities and research institutes on the other hand may allow access to tailor made, cutting edge technologies (Tether and Tajar, 2008; Tsai, 2009; Hung and Chiang, 2010); however it may also require the firm to collaborate with other actors in order to implement the technology (Berg-Jensen et al., 2007). Hence, collaboration linkages to different external technology and knowledge sources are found to co-exist (Roper et al., 2008) and this co-existence has been found to positively impact innovation performance (Grimpe and Kaiser, 2010; Leiponen and Helfat, 2010).

Firms should strive to diversify their open innovation ecosystems and avoid relying exclusively on a limited number of external partners. Collaboration through the same channel may result in a form of myopia which can blind the firm to other technological possibilities from other channels (Sofka and Grimpe, 2010). However, managing coordinated innovation by network partners requires substantial management attention (Ocasio, 1997). The role of R&D management changes completely and new capabilities and competencies are required (Witzeman et al., 2006). As noted by Christensen (2006, p.35), "open innovation can be considered an organisational innovation". It requires firms to implement core processes and develop knowledge management capacities (Lichtenthaler and Lichtenthaler, 2009) to apply the open innovation approach effectively (Gassmann and Enkel, 2004).

3 Theoretical framework

The objectives of this paper are to determine the impact of a firm's context and its business environment on the search for external knowledge and how different open or interactive behaviours by f&d companies in their search for innovation opportunities influence their innovative performance. Acknowledging that open innovation resides on a continuum, we build on Laursen and Salter's (2006) model to develop a two-dimensional openness framework in terms of the extent of collaborative ties and the intensity of collaboration (Figure 1). C*ollaboration breadth*, defined as the number of external sources of knowledge and technology that f&d companies collaborate with in innovation activities, aims to capture ecosystem diversity, ranging from narrow to broad collaboration as the number of external partners increases. The intensity of collaboration with each external partner is captured by *collaboration depth*, ranging from surface to deep collaboration as collaborative interactions intensify. Together these two dimensions represent the openness of individual firms' external collaboration strategy in innovation.

Figure 1 Openness of collaboration in innovation (see online version for colours)



Source: Own elaboration

3.1 Determinants of open innovation strategies

The literature on organisation learning based on the behavioural theory of the firm (Levinthal and March, 1993) argues that the contextual factors of the firm and its environment impact the search for external knowledge (Chen and Miller, 2007). Specifically, the context affects the availability of resources and constraints their application, as does the abundance of external knowledge that can be used for innovation. Garriga et al. (2013) find that fewer constraints enable a deeper search and increasing the number of constraints leads to a broader search for external knowledge.

3.1.1 Internal context

Open innovation research suggests that companies cooperate in innovation activities both to reduce costs and business risks and to extend skills, competences and creativity (Huang et al., 2009; Tether, 2002; Miotti and Sachwald, 2003; Belderbos et al., 2004). Firms also engage in collaboration to access specialised skill sets and better utilise internal creativity by exposing internal development staff to new knowledge, technology and organisational development processes (Calantone and Stanko, 2007; Chesbrough and Teece, 1996; Linder, 2004); although this strategy implies some drawbacks in terms of opening the market to new entrants and exposing core competencies to imitation and substitution. In the f&d industry, Bröring (2013) argues that open innovation helps f&d companies to fulfil two major tasks: closing (technological or market) competence gaps by outside-in open innovation, and bringing complementary resources together through coupled open innovation processes.

3.1.2 Architecture for collaboration

A central issue in open innovation is the development of optimal organisational structures that support joint efforts of innovation partners and ecosystems in resource investment, knowledge sharing and economic value creation (Agarwal et al., 2012). The transition towards open innovation confronts firms with considerable managerial challenges such as the transformation of business models (Chesbrough, 2007), implementing new types of R&D organisations and management structures (Gassmann and von Zedtwitz, 1999; Chesbrough, 2006, 2007; Chiaroni et al., 2010) and cultural change to accommodate a more externally oriented mindset than encourages employees to see the world as their technology-base (Huston and Sakkab, 2006). An open innovation approach takes significant time to implement as deeply engrained organisational mindsets need to be overcome and fears mitigated of losing control over proprietary technology (Chesbrough, 2003, 2006). Harnessing external knowledge then requires the development and implementation of suitable systems to look at this outside-in/inside-out view of the world (Slowinski and Sagal, 2010).

3.1.3 External context

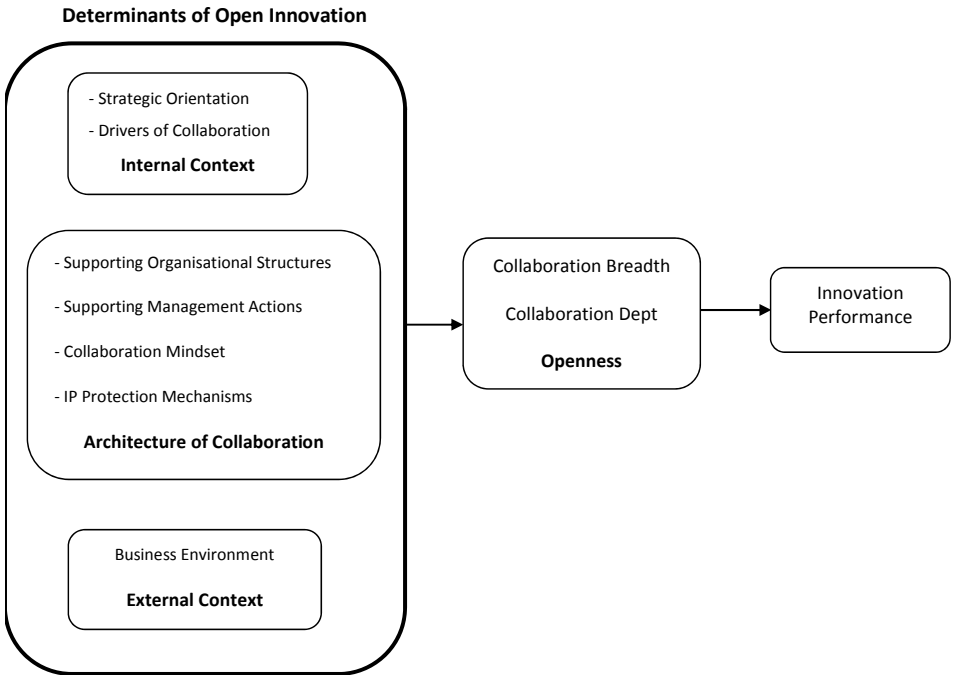
Prior research has looked at the impact of external context variables on the degree of openness, including type of industry (high tech vs. low tech) (Lichtenthaler, 2008; Gassmann and Enkel, 2004; Keupp and Gassmann, 2009); industry state of technology (in terms of intensity, turbulence and convergence) (Fortuin and Omta, 2008; Gassmann and Enkel, 2004; Ozman, 2008); globalisation trends, dynamics of product life cycle and customer/consumer preferences (Lagnevik, 2003; Sarkar and Costa, 2008; Bellairs, 2010). Innovation styles in the f&d industry are today dominantly oriented towards the market interface and customer-producer links. A central characteristic is the rapid changes in the competitive environment and in particular the adaptation to increasingly differentiated consumer demands and a strongly expressed need for reliable control systems to inform consumers about the quality, safety and origin of products (Garcia Martinez and Broffman, 2011; Traill and Meulenberg, 2002). Responding to external

pressures increasingly requires f&d companies to establish partnerships with external actors within and outside the food chain for the successful realisation of their innovative endeavours (Garcia Martinez, 2010).

3.2 Impact of openness on innovation performance

The question of how openness influences the capacity of firms to innovate and their ability to obtain higher economic returns is at the heart of open innovation research (Dahlander and Gann, 2010; Gassmann et al., 2010). Prior research suggests that firms can improve their innovative and financial performance by interacting with different partners. For instance, Un et al. (2010) find that collaboration with suppliers is beneficial to firms' innovation performance owing to the combination of complementary capabilities and the common goals between firms and their suppliers. Similarly, Laursen and Salter (2004; 2006) find that innovation performance increases with both the breadth and depth of external search. Besides impacting innovation performance, collaboration with external partners also tends to positively affect firms' financial performance (Belderbos et al., 2004, 2006; Aschhoff and Schmidt, 2008; Inauen and Schenker-Wicki, 2011). The present study focuses on the effects of openness on overall innovation performance as well as on individual facets of innovation performance. Our empirical model is depicted in Figure 2.

Figure 2 Theoretical model



4 Research method

4.1 Data

The data for the study was gathered through a large online survey sent to senior R&D and innovation managers of f&d companies in the UK, Spain and Italy. The questionnaire administration and fieldwork took place in 2011. The questionnaire was pre-tested with senior R&D and innovation managers in seven f&d companies who completed the draft online questionnaire and provided feedback on the comprehensiveness and phrasing of questions. The survey was administered to a randomly selected sample of f&d companies from a commercial industry panel in the three studied countries. An e-mail explaining the aims of the study and containing a link to the online survey created using Qualtrics software was sent to selected companies. The survey included an initial filter question requesting respondents to indicate if they had collaborated[1] with external partners in innovation activities in the last five years. Depending on their response (yes/no), firms were directed to different sections in the survey. In this paper the analysis is confined to the sub-sample 'f&d companies engaged in external collaboration in innovation' which amounts to 71% of the respondents (284 firms). Valid responses per country were 108 for the UK, 92 for Spain and 84 for Italy. An analysis of non-response bias comparing early responses and late responses regarding research variables and demographic variables revealed no significant differences between the early and the late respondents. Sample statistics are shown in Table 1.

Table 1 Sample statistics

	Total sample (N = 398)		*Firms engaged in collaborative innovation (N = 284)*		
	N	*%*	*N*[1]	*%*	*% over total sample*
Country					
UK	198	50	108	38	27
Spain	98	25	92	32	23
Italy	102	25	84	30	21
Total	398	100	284	100	71
Firm size (employees)					
Micro and small	221	55	138	49	35
Medium	101	25	85	30	21
Large	76	20	61	21	15
Total	398	100	284	100	71

Note: [1]The total number of firms in the sub-sector classification ($N = 543$) exceed the number of firms in the sample ($N = 284$) as f&d firms might operate across different sub-sectors

Table 1 Sample statistics (continued)

	Total sample (N = 398)		*Firms engaged in collaborative innovation (N = 284)*		
	N	*%*	*N*[1]	*%*	*% over total sample*
Sub-sector					
Process meats and meat products	129	12	66	12	6
Fish and fish products	69	6	37	7	3
Processing and preserving of fruits and vegetables	86	7	60	11	5
Manufacture of vegetable and animal oils and fats	43	4	30	6	3
Dairy products	81	7	48	9	4
Manufacture of grain mill products, starches and starch products	32	2	20	4	2
Bread, cakes and biscuits	123	11	52	10	5
Confectionary	110	9	54	10	5
Pet food	48	4	24	4	2
Manufacture of other food products	128	11	52	10	5
Alcoholic drinks	178	16	66	12	6
Soft drinks and no-alcoholic drinks	78	7	34	6	3
Total	1105	100	543	100	49

Note: [1]The total number of firms in the sub-sector classification ($N = 543$) exceed the number of firms in the sample ($N = 284$) as f&d firms might operate across different sub-sectors

4.2 Procedure

The present analysis searches for open innovation strategies in the f&d industry using firm-level information. The degree of openness is defined in terms of external sources of knowledge and technology and measured by *collaboration breath* and *collaboration depth*. Similarly to Laursen and Salter (2006), in this paper we included eight external sources of knowledge and technology (universities and research centres, innovation intermediaries, government agencies, customers, suppliers, consumers, competitors, companies operating in other industries). In the first step, a cluster analysis is performed in order to group f&d firms into homogeneous categories in terms of the diversity (*breath*) and intensity (*depth*) of collaboration in innovation with each external partner.

Collaboration breath is constructed as the combination of eight external sources of knowledge and technology for innovation. Each source is coded as a binary variable in which zero represents the unused sources and one represents the used sources. Since the analysis is confined to the sub-sample 'f&d companies engaged in external collaboration in innovation', *collaboration breadth* ranges from one (when a firm only uses one external search channel) to eight (when a firm collaborates with all the channels listed in

the survey). To compute *collaboration depth*, firms were asked to indicate in a seven-point Likert scale the intensity of collaboration with each external source. We calculate the average collaboration partner intensity (i.e., sum of intensity scores for all partner types divided by the number of partners). Both measures were standardised before performing cluster analysis.

We perform a two-stage cluster analysis. First, we apply a hierarchical cluster analysis (Ward's method) of the two openness dimensions in order to group f&d firms into a number of categories which are with respect to the variables under investigation, as homogenous as possible (small within-cluster variance) and at the same time as different as possible (large between-cluster variance) (Lattin et al., 2003). The criterion for formation of homogeneous clusters was the relative increase of the merger coefficient: [(merger coefficient at stage k) – (merger coefficient at stage k – 1) – 1] (Milligan, 1981; Milligan and Cooper, 1985). In addition, we also examined the number of firms per cluster and whether the clusters identified could really be classified as different models of open innovation (Hollenstein, 2003). Results suggested a three cluster solution as the most appropriate representation of the data. A final three cluster solution using K-means cluster analysis was then developed using the initial seed points from the Ward's method.

In a second step, the analysis examined the impact of firm context and its business environment on the search for external knowledge. To this end, the clusters are characterised and interpreted in terms of;

a the openness dimensions used in cluster analysis itself (*collaboration breadth* and *collaboration depth*)

b internal factors such as innovation strategy and drivers of collaboration, as well as environmental factors driving the evolution from closed to open innovation models

c a set of variables capturing the development of optimal organisational architectures that support joint efforts of innovation partners and ecosystems in resource investment, knowledge sharing and economic value creation

d firms' structural characteristics (size, sub-sector affiliation, country).

Furthermore, to determine the effects of open innovation strategies on innovation performance, the analysis considered both the impact of openness on the overall innovation performance as well as on individual facets of innovation performance. The specific item indicators and questions for each measure are contained in Appendices 1 and 2.

5 Empirical results

5.1 Identifying open innovation strategies

The identification of open innovation models is based on *collaboration breadth* and *depth*. Table 2 lists all eight external sources of knowledge and technology included in the survey. Each firm was asked to indicate in a seven-point Likert scale the degree of collaboration with each source. Overall, the results indicate that the most important

source is suppliers of equipment and technology, followed closely by customers (i.e., retailers) and consumers. These findings underline the strong reliance of f&d companies on suppliers of scientific inputs and machinery (Garcia Martinez and Briz, 2000; Traill and Meulenberg, 2002). In Table 3, we examine the level of collaboration breadth and depth across countries and f&d sub-sectors. Overall we find that f&d firms cite seven sources of external knowledge (mean = 7.14). External collaboration depth is lower (mean = 4.34).

Table 2 External sources of knowledge and technology in the f&d industry

Knowledge source	*% companies using this source*[1]	*Mean value*[2]
Universities and research centres	75	3.79
Innovation intermediaries	78	3.80
Government agencies	80	3.83
Customers (i.e., retailers)	93	5.17
Suppliers	93	5.13
Consumers	90	5.01
Competitors	76	3.99
Companies operating in other industries	80	4.00

Notes: [1]Frequencies of companies who answered from two to seven,
[2]1–7 Likert scale: 1 = not at all; 7 = to great extent

Table 3 Collaboration breadth and depth in the f&d industry

	N. of firms[1]	*Breadth mean*	*Depth mean*
Country			
UK	108	7.05	4.36
Spain	92	7.47	4.39
Italy	84	6.92	4.24
Total	284	7.14	4.34
Sub-sector			
Process meats and meat products	66	7.64	4.82
Fish and fish products	37	7.68	4.98
Processing and preserving of fruits and vegetables	60	7.72	5.08
Manufacture of vegetable and animal oils and fats	30	7.90	5.14
Dairy products	48	7.33	4.57
Manufacture of grain mill products, starches and starch products	20	7.95	5.58
Bread, cakes and biscuits	52	7.23	4.50

Notes: [1]The total number of firms in the sub-sector classification ($N = 543$) exceed the number of firms in the sample ($N = 284$) as f&d firms might operate across different sub-sectors

Table 3 Collaboration breadth and depth in the f&d industry (continued)

	N. of firms[1]	*Breadth mean*	*Depth mean*
Sub-sector			
Confectionary	54	6.98	4.63
Pet food	24	7.90	4.83
Manufacture of other food products	52	7.27	4.51
Alcoholic drinks	66	7.33	4.64
Soft drinks and no-alcoholic drinks	34	7.18	4.50
Total	543	7.14	4.34

Notes: [1]The total number of firms in the sub-sector classification ($N = 543$) exceed the number of firms in the sample ($N = 284$) as f&d firms might operate across different sub-sectors

Hierarchical cluster analysis and the stopping rule based on the relative increase of the merger coefficient (Milligan, 1981; Milligan and Cooper, 1985) produced a three-cluster solution. This solution was accepted on three grounds (Hollenstein, 2003):

1 the statistical properties in terms of the relationship between within-cluster and between-cluster variance

2 the number of firms per cluster (the solution with four clusters was dropped since one cluster contained very few observations)

3 the plausibility of the open innovation strategies identified.

A final three cluster solution using K-means cluster analysis was then developed using the initial seed points from the Ward's method (Table 4). This second step technically improved the solution by moving some cases from one cluster to another but it did not change its substantive meaning. Both openness variables exhibit significantly different patterns at the 1% significance level. In addition, a MANOVA test confirmed that the clusters had a significantly different profile.

Table 4 Open innovation models

Openness dimension	*CL1*	*CL2*	*CL3*	*F ratio*	*Significance*
Breadth	7.93	7.52	3.63	608.848	.000
Depth	5.58	3.55	2.64	305.228	.000
N of cases	128	115	41		
% of firms	45	40	14		

5.2 Determinants of open innovation strategies

As previously discussed, the specific level and mode of open innovation is contingent on the particular business models chosen by firms in a particular industry, the technological context and the business environment in which they operate (Chesbrough, 2003). In the present study, we include a set of variables representing the firm context and external environment to determine their impact on the level of openness (Table 5) (Appendices 1

and 2). To provide greater characterisation of open innovation models, we compute the partner depth for each external source of knowledge and technology (Table 6). Additionally, we develop a new openness dimension (*phase depth*) to capture the number of phases of the innovation process (from idea generation to commercialisation) open to collaboration (wide to localised collaboration). Finally, we include several structural characteristics of f&d firms such as size (employees), sub-sector and country (Table 7).

Table 5 Determinants of open innovation models

Determinants	*Cluster*[a]		
	*1***	*2*	*3*
Internal context			
Strategic orientation	5.78	4.46	3.74
Driver of collaboration	5.83	4.79	4.03
External context			
Business environment	5.67	4.57	4.35
Architecture of collaboration			
Supporting management actions	5.79	4.79	4.11
Supporting organisational structures – units			
(% of firms within the cluster which have a dedicated unit)	88	66	51
(% of the total firms declaring to have a dedicated unit)	54	36	10
Supporting organisational structures – roles			
(% of firms within the cluster which have dedicated roles)	81	70	58
(% of the total firms declaring to have dedicated roles)	50	39	11
Collaboration mindset	5.79	4.67	4.41
IP protection mechanisms	5.79	4.70	5.83

Notes: [a]Cluster means, **p < 0.05

Table 6 Partner depth and phase depth by open innovation model

Openness dimensions	*Cluster*[a]		
	*1***	*2*	*3*
Partner depth			
Universities and research centres	5.16	2.95	1.88
Innovation intermediaries	5.29	2.72	2.17
Government agencies	5.27	3.03	1.56
Customers (i.e., retailers)	6.01	4.55	4.29
Suppliers	6.04	4.54	3.98
Consumers	6.07	4.29	3.76
Competitors	5.38	3.27	1.66
Companies operating in other industries	5.49	3.11	1.83

Notes: [a]Cluster means, **p < 0.05

Table 6 Partner depth and phase depth by open innovation model (continued)

Openness dimensions	*Cluster*[a]		
	*1***	*2*	*3*
Phase depth			
Idea generation	5.48	3.58	3.20
Experimentation	5.51	3.93	3.34
Engineering	5.57	3.77	3.07
Manufacturing	5.78	4.25	3.32
Commercialisation	5.84	4.48	3.46

Notes: [a]Cluster means, **p < 0.05

Table 7 Structural characteristics of f&d firms by open innovation model

Structural variables	*Cluster*[a]			*Total*
	1	*2*	*3*	
Size (number of employees) (%)				
Micro	9	21	42	19
Small	25	36	30	30
Medium	42	23	12	30
Large	24	20	16	21
Sub-sector (%)				
Process meats and meat products	30	22	4	23
Fish and fish products	19	9	5	13
Processing and preserving of fruits and vegetables	33	14	2	21
Manufacture of vegetable and animal oils and fats	16	8	-	11
Dairy products	21	14	12	17
Manufacture of grain mill products, starches and starch products	13	2	-	7
Bread, cakes and biscuits	20	16	17	18
Confectionary	22	13	24	19
Pet food	12	7	-	8
Manufacture of other food products	22	15	14	18
Alcoholic drinks	26	20	19	23
Soft drinks and no-alcoholic drinks	14	9	12	12
R&D intensity (%)				
< 0.5 m	4	7	25	8
0.5–1 m	10	14	12	12
1–2 m	10	22	27	18
2–3 m	27	30	19	26
3–4 m	30	13	5	20

Note: [a]Cluster means

Table 7 Structural characteristics of f&d firms by open innovation model (continued)

Structural variables	*Cluster*[a]			*Total*
	1	*2*	*3*	
R&D intensity (%)				
4–5 m	10	3	7	7
> 5 m	9	11	5	9
Country (%)				
UK	38	36	44	38
Italy	26	30	41	30
Spain	36	34	15	32

Note: [a]Cluster means

5.3 Cluster 1: the true open innovator

This cluster consists of 128 firms with a broad (partner breadth = 7.93) and deep (partner depth = 5.58) search strategy (Table 4). Significantly, when examining single partner depth and single phase depth (Table 6), the intensity of collaboration is high for each typology of partner and across all innovation phases. Cluster 1 shows a prevalence of large companies, which are medium-high investors in R&D (Table 7). They mostly operate in the 'processing and preserving of fruits and vegetables' and 'process meats and meat products' sectors where the technological variable is key to sustained growth as a result of the biotechnology revolution and the need to maintain better process controls, exploit economies of scale and guarantee food safety, origin and quality (Traill and Meulenberg, 2002).

As a result, the business environment is perceived as challenging with greater market pressure to respond to increasingly differentiated consumers demands. Companies react by adopting an aggressive innovation strategy (strategic orientation factor), with a focus on technological leadership and an emphasis on radical innovation (Bröring, 2013). The driver of collaboration factor is high and, above all, the goals of 'expanding the company's competence-base' and 'accessing advance technologies' characterise Cluster 1. A structured approach to openness, presumably built over time, is applied with several supporting management actions at work and supporting organisational structures (units and roles) specifically designed to interact with external partners. Moreover, a favourable attitude towards innovation and collaboration is strongly encouraged. In Cluster 1 a broad set of IP protection mechanisms is used, suggesting the existence of a protection policy of innovation outcomes, considered in the literature as crucial for innovation collaboration (Alexy et al., 2009).

5.4 Cluster 2: the selective collaborator

This cluster includes 115 firms, for which partner breadth is significantly high (7.52) suggesting a strong engagement in innovation collaboration with a wide range of external partners (Table 4). In contrast, Cluster 2 exhibits both a lower partner depth (3.55) and lower single partner depth and single phase depth suggesting a more selective approach towards collaboration compared to Cluster 1 (Table 6). The intensity of ties is

significantly high for certain partners, in particular suppliers, customers and consumers, considered as the traditional partners in the f&d industry, especially during the development phase. Thus, Cluster 2 is less technology-oriented but responsive to market dynamics. Ties with universities and research centres are particularly low suggesting that Cluster 2 companies do not rely on input from external sources generating pre-competitive, future-oriented knowledge and cutting edge technologies (Tether and Tajar, 2008).

Cooperation with suppliers is strong and likely aimed to enhance efficiency (Clark, 1989; Belderbos et al., 2004), as the prevailing driver of 'reducing time to market' seems to confirm. However, the driver of collaboration factor is lower than for Cluster 1 (Table 5). Small and even micro firms characterise this cluster, also including a higher percentage of f&d firms with low R&D intensity (Table 7). A less aggressive strategic orientation suggests a focus on incremental innovation. The business environment is perceived as less challenging compared to Cluster 1, where technological pressure is higher. No particular sub-sectors are emerging as prevalent or particular countries. However, the presence of sub-sectors in which the influence of the final consumer is particularly intense (e.g., dairy products, cake and biscuits, confectionary, alcoholic drinks) seems to confirm that innovation is mainly incremental, representing range extensions and new flavours (Galizzi and Venturini, 1996; Grunert et al., 1997). In this context, modes of collaboration such as co-creation with consumers would allow f&d companies to develop superior value propositions relevant to their target market (Garcia Martinez, In press). Organisational structures and roles designed to support collaboration are rare in Cluster 2 possibly due to the smaller firm size. Both supporting management actions and collaboration mindset show a lower mean value. IP protection mechanisms are less used than in Cluster 1, reinforcing the lower level of managerial practices adopted in Cluster 2.

5.5 Cluster 3: the incipient collaborator

This cluster of 41 firms is the smallest (14% of firms) but clearly distinct from the other two clusters with a significantly lower collaboration breadth (3.63) and depth (2.64) (Table 3). Very few are therefore the types of search partners and the activated ties (again with suppliers and customers) show a weak intensity. Regarding determinants of openness, Cluster 3 is very similar to Cluster 2 in terms of size, sub-sectors, country, R&D intensity and organisational structures. However, lower mean values are exhibited for all factor variables.

5.6 Open innovation strategies and innovation performance

A key contribution of this paper is the effects of open innovation on innovation performance. In the literature, innovation performance is approximated by several indicators such as R&D inputs, patents counts, patents citations or counts of new product announcements. Following this stream of literature, we operationalise the innovation performance variable by including six items to capture the impact of openness on a wide range of areas (Table 8). The aim is to determine if greater openness leads to an enhanced innovation performance. It is worth pointing out that we are only considering the incremental impact on innovation performance from open innovation strategies as opposed to the overall innovation performance derived from internal and/or open

innovation activities. Therefore, we would expect Cluster 1 which exhibits a high level of openness to show a higher impact on innovation performance against all six objectives; conversely Cluster 3 with a lower degree of openness is expected to show a lower impact on innovation performance against the set measures. However, this does not imply that Cluster 3 companies should be classed as non-innovators since they could innovate thanks to internal R&D activities.

First, we analysed the impact of openness on innovation performance as a first order factor (α = 0.91) (Table 8). As hypothesised Cluster 1 shows the highest impact on innovation performance and there are significant difference among the three clusters (F-value = 19.582; p = 0.000). These findings suggest that Cluster 1's broad and deep openness approach allows f&d companies to gain additional value (Chesbrough, 2003; West and Lakhani, 2008; Kessler et al., 2000; Roper et al., 2008). In contrast, Cluster 2 and Cluster 3 exhibit a lower impact on innovation measures due to their lower degree of openness.

Regarding individual performance measures, Cluster 1 again shows the highest mean values for each item ($p < 0.05$) while Clusters 2 and 3 are quite similar. Cluster 3 companies are slightly open to external ideas and technologies and coherently draw out little value from collaborations. Cluster 2 companies are more open although the intensity of collaboration is quite low and exhibit a similar impact on innovation performance. Considering that Cluster 2 shows a lower level of collaboration architecture tools, these findings suggest that setting up collaborations with external partners is not a sufficient condition to enhance innovation performance. Openness must be managed in order to effectively provide value (Gassmann and von Zedtwitz, 1999; Chesbrough, 2006, 2007; Chiaroni et al., 2010). In other words, the creation over time of a dedicated architecture for collaborations to access and leverage external knowledge appears as a key condition for improved innovation performance.

Table 8 Impact on innovation performance by cluster

Innovation performance mean values	*Cluster*[a]		
	*1***	*2*	*3*
Overall impact on innovation performance	5.79	4.97	4.59
Individual measures			
Stimulate creativity and idea generation capability	5.69	4.10	4.20
Reduce innovation risks	5.61	4.10	4.02
Reduce new product/process development cost	5.73	4.08	4.24
Reduce time to market	5.59	4.14	3.88
Introduce new or significantly improved products or services	5.59	4.42	4.95
Introduce new or significantly improved process of producing our products or services	5.95	4.31	4.93

Notes: [a]Cluster means, **p < 0.05

6 Discussion

In this paper we search for open innovation strategies in the f&d industry where research in growth policy and innovation studies remains limited (Bigliardi and Galati, 2012). By

applying cluster analysis to a two-dimensional openness concept measuring the extent and intensity of collaboration, we identified three clusters representing different search strategies ranging from limited collaboration with traditional partners to a broad and deep openness approach with a wide spectrum of external sources.

Technology pressure emerges as a key driver for greater openness. The open innovation literature suggests that technology intensity requires organisations to cooperate as corporate R&D performance can no longer be achieved by a company on its own (Fortuin and Omta, 2008, Gassmann and Enkel, 2004). Technological turbulence seems to exert a similar impact (Ozman, 2008) positively impacting the acquisition of technology. Rapidly changing technological conditions will increase the motivation of f&d firms to engage in a high number of interactions to access and leverage new knowledge residing outside the firms' boundaries. In this context, radical or breakthrough innovations, using new technologies and creating new markets, are likely to emerge. Lastly, technological convergence will reshape the competitive arena and the borders of the different industries, forcing firms to collaborate (Fortuin and Omta, 2008). Real breakthroughs in the marketplace require a wider knowledge-base resulting in f&d companies often needing to search widely and deeply to gain access to critical external knowledge assets for the successful realisation of their innovative endeavours (Garcia Martinez, 2013). The importance of supply chain collaboration for improved innovation performance has been stressed in the literature (Sahay, 2003; Cantista and Tylecote, 2008; Soosay et al., 2008). However, downstream companies are sometimes structured and managed in a manner that does not promote collaboration among their internal supply chain partners (West and Lafferty, 2007). Research by Dunne (2008) on the Australian food industry further demonstrates that building closer relationships even with important supply chain partners is difficult and resource intensive.

Technological intensity, turbulence and convergence are normally associated with biotechnology and nanotechnology industries. Their increasing importance in the preservation and processing sub-sectors characterising Cluster 1 may contribute to explain its higher openness propensity. Cluster 1 companies emerge as pursuing radical innovation and aspiring to assume leadership roles. They are mainly large companies identified in literature as the pioneers of open innovation (Lichtenthaler and Ernst, 2009a). Moreover, R&D investment in Cluster 1 is higher, an additional variable considered in the literature as a pre-requisite to successfully learn from collaboration and technology acquisition [i.e., absorptive capacity concept developed by Cohen and Levinthal (1990)].

F&d companies have been forced to rethink their business models to adapt to the economic imperative and global competitive landscape (Lagnevik, 2003; Sarkar and Costa, 2008; Bellairs, 2010). Cluster 1 faces a strong need to adapt to increasing consumers' requirements for food quality, variety and safety. Responding to external pressures increasingly requires f&d companies to establish partnerships with external actors within and outside the food chain. Cluster 1 also shows the highest level of managerial actions supporting collaboration as well as an internal firm environment (collaboration mindset) strongly directed towards innovativeness and interaction. This suggests that the opening of innovation processes is not an extemporary phenomenon but rather deeply embedded in internal processes, well managed and coordinated (Bigliardi et al., 2010).

As suggested by Bigliardi and Galati (2012), there are intermediate (less open) models of collaboration. In that sense, Cluster 2 could be interpreted as a model in

transition towards greater openness as suggested by the high partner breadth which seems to reveal a strong curiosity towards different types of potential external partners or on the other hand, a reasoned choice, consistent with the context and available resources of the firms (mainly smaller firms) composing Cluster 2. Supporting this hypothesis is the fact that Cluster 2's perceived impact of openness on innovative performance is not too low but lower than for Cluster 1. The inclusion of financial performance measures in future studies could help to shed some light on organisational behaviours. Lastly, it is worth pointing out that f&d firms in Cluster 3 declare some level of collaboration suggesting a progressing trend towards openness in the f&d industry. Future case studies would help identifying the key issues surrounding the implementation of collaborative processes with external partners to assist f&d companies in the development of an optimal architecture for collaboration that supports joint efforts of innovation partners and ecosystems in resource investment, knowledge sharing and economic value creation.

The role of IP mechanisms is difficult to interpret given the conflicting views in the literate regarding its role as a facilitator or rather as an obstacle to collaboration and open innovation approaches (Alexy et al., 2009). Our findings suggest an enabling role given the positive relationship between their intensity of use and the degree of openness.

The investigation of the impact of openness on innovation performance shows that open innovators (Cluster 1) set up successful collaboration and draw out value from openness. The consistent interplay between external factors, internal factors and collaboration architecture contributes to this purpose. Less open approaches (Cluster 3) miss out on synergies and complementarities while companies in Cluster 2 seek a more selective collaborative approach although without great success possibly due to the lack of an enabling architecture for collaboration.

These findings have important managerial implications as they provide a guide towards greater openness. However, the richness of possible choices is broad and totally contingent on internal and external contextual variables. The framework presented in this paper assists f&d managers to consider the opportunity for opening up their innovation processes in different ways according to the different level of each variable. The number of variables involved suggests that the implementation of open approaches is always challenging and requires the orchestration of different aspects, which could generate issues with no easy solutions; for instance, how can firms encourage people to collaborate and to share knowledge? How can firms monitor the progress of the collaborations, particularly if several partners are involved? How can firms avoid conflict when sharing innovation outcomes? These are just some of the challenges managers would face in the transition towards open innovation.

7 Conclusions

Although open innovation is a business model that has attracted a lot of attention in the academic world since Chesbrough first started writing about it in the early 2000's, there are still large gaps in our understanding of how it is used strategically in a business context. While there is increasing evidence that open innovation and associated strategies also prevail in more traditional and mature industries (Huston and Sakkab, 2006), further research should consider barriers to its wider implantation due to the maturity in the application (Enkel et al., 2011) and firms' absorptive capacity (Cohen and Levinthal, 1990; Acosta et al., 2011; Alarcón and Sánchez, 2013).

An important limitation of our work is the use of self-reported performance measures regarding the achievement of performance objectives through open innovation. While a similar approach has been followed in prior innovation studies [e.g., Chiang and Hung (2010)], objective measures (i.e., number of new products or economic-financial data) are arguably more adequate (Lichtenthaler, 2009). However, a study by Dess and Robinson (1984) finds that there is a strong correlation between objective and subjective performance measures. Additionally, the present study only considered the incremental impact on innovation performance from open innovation strategies as opposed to the overall innovation performance derived from all types of innovation activities (internal and external). This approach allows determining the creation of value by open innovation but it limits drawing between-clusters comparisons in terms of innovation performance in general.

In addition, future studies could consider including performance measures to capture the impact of open innovation on social innovation objectives such as sustainability, climate change, obesity, etc. (Spiertz and Kropff, 2011; Leach et al., 2012; Lybbert and Sumner, 2012).

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Notes

1 Siding with Bogers (2011) and Enkel et al. (2009) we define collaboration in innovation activities as any relationship involving sharing of work between a firm and different external partners along the innovation process. Accordingly, collaboration can refer to joint activities leading to minor changes to existing products, processes or services as well as genuine innovations and products, processes or services that are new to the company.

Appendix 1

Determinants of open innovation models

Factor	*Measurement*	*Cronbachs's alpha*	*Source*
Strategic orientation	1 We aspire to be the technological leader	0.923	Lichtenthaler and Ernst (2009b), Lichtenthaler (2008) and Milles and Snow (1978)
	2 We focus on radical rather than incremental innovation		
	3 We try to hire the best scientists and experts in the market		
	4 R&D and marketing are our core competencies		
	5 We normally use innovative, flexible and non-routine technologies		
	6 We have a broad product/market portfolio		
	7 We have a broad technology portfolio		
Driver of collaboration	1 Expand the company's competence-base	0.876	Huang et al. (2009), Calantone and Stanko (2007), Chiaroni et al. (2009), Chesbrough and Teece (1996), Linder (2004), Lynch (2004), Gassmann and Enkel (2004) and Lazzarotti et al. (2011)
	2 Access to advance technologies		
	3 Stimulate creativity and idea generation capacity		
	4 Reduce/share the risks of innovation		
	5 Reduce/share innovation costs		
	6 Reduce time to market		
Business environment	1 Increasing technology development cost	0.831	Chesbrough (2006)
	2 Shorter product life cycles		
	3 Economies of scale in R&D have been reduced		
	4 Rapidly changing customer/consumer needs and preferences		
	5 Customer/consumer product demands and preferences are highly uncertain		
	6 It is difficult to predict changes in customer/consumer needs and preferences		

Determinants of open innovation models (continued)

Factor	*Measurement*	*Cronbachs's alpha*	*Source*
IP protection mechanisms	1 Patents	0.927	Cassiman and Veugelers (2002), Arundel (2001), de Faria and Sofka (2010), Amara et al. (2008), Gallini (2002), Alexy et al. (2009), Pisano (2006), Hertzfeld et al. (2006), West (2006) and Henkel (2006)
	2 Designs		
	3 Trademarks		
	4 Non-disclosure agreements and other contractual agreements (e.g., joint development agreements)		
	5 Copyrights		
	6 Trade secrets		
	7 Product complexity		
	8 Lead time		
Supporting management actions	1 Top management is fully committed to maximising collaborative results	0.904	The Mine Survey (2000)
	2 Each collaborative project has a 'champion' to ensure collaboration success		
	3 We formally assess the trade-offs between internal development and external acquisition		
	4 We increasingly rely upon internal search capabilities to scan and assess external knowledge		
	5 We use project management techniques to manage the collaborations		
	6 We formally asses the performance and results of collaborative projects		
	7 We have a reward and incentive system to recognise the benefits of collaborative innovation		
	8 We use internet-based systems to facilitate the search of potential partners		
	There are organisational roles within the company to facilitate cultural change by developing the understanding, knowledge, processes and skills required in technological collaborations with external partners		

Determinants of open innovation models (continued)

Factor	*Measurement*	*Cronbachs's alpha*	*Source*
Collaboration mindset	1 We give our staff time and resources to generate new ideas 2 Our staff easily adapt to new situations 3 We set our staff creative and challenging objectives 4 We allocate resources for our staff for continuous professional development 5 There is a high level of collaboration within functional areas to identify and resolve emerging issues in innovation activities 6 There is a high level of interaction across different functional areas in innovation activities	0.933	Subramaniam and Youndt (2005), Kang and Snell (2009), Kang et al. (2007), Radaelli et al. (forthcoming) and Jiménez-Barrionuevo et al. (2011)
Supporting organisational structures	There is a formal organisational unit within the company to coordinate and support technological collaborations with external partners There are organisational roles within the company to facilitate cultural change by developing the understanding, knowledge, processes and skills required in technological collaborations with external partners	0 If not existing 1 If existing	The Mine Survey (2000)

Appendix 2

Categorical variables used to characterised open innovation models

Variables	*Description*	*Categories*	*References*
Size (employees)	Employees number (full-time and part-time)	1 Micro, if the number of workers is < 9	European Commission (2003)
		2 Small 10–49	
		3 Medium 50–250	
		4 Large > 250	
R&D intensity	Expenditure on R&D as a % of sales over the last two years	< 0.5 m	Lichtenthaler (2008), percentages considered relevant in the food and drink industry
		0.5–1 m	
		1–2 m	
		2–3 m	
		3–4 m	
		4–5 m	
		> 5 m	
Country	UK, Spain, Italy	For each country	
		0 If not belonging	
		1 If belonging	
Sub-sector	See Table 1	For each sub-sector	
		0 If not belonging	
		1 If belonging	