Knowledge Transfer in the Irish Food Innovation System: Industry and Researcher Perspectives

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Abstract – **The EU's innovation strategy stresses the importance of improving knowledge transfer between public research institutions and third parties, including industry, and the requirement to reduce existing barriers in order to realise this objective. This requires both researchers and industry to change their cognitive and behavioural mindsets in relation to one another. This study aims to understand the current extent, purpose and nature of interaction between these public science providers and industry, from an Irish perspective, by examining levels of interaction and alternative viewpoints in relation to motivations and barriers for involvement in knowledge and technology transfer. The results reveal that if Ireland is to improve knowledge transfer and hence realise the economic benefits of public research certain changes must be made at a policy, institutional and industrial level.**

Keywords – **Knowledge transfer, technology transfer, Irish food sector**

INTRODUCTION:

In today's globalising economy, knowledge is the foremost strategic resource and learning is the most fundamental activity to achieving competitiveness and prosperity (Lundvall, 1992; OECD 1996). Research is therefore central to the success of 'knowledge economies'. Internationally, the public R&D system represents an imperative constituent of the framework conditions for carrying out innovation activities, which can create commercially applicable knowledge (Drejer and Jørgensen, 2004) and act as informative and strategic resources for companies, particularly to those developing new products (Tijssen, 2004). According to Rappert *et al* (1999), the current competitive environment places demands on firms to draw knowledge from external sources such as the public R&D system. However, in recent years there has been a growing perception that public research capacity and results have not been optimally utilised and thus, all of the potential economic benefits have failed to be realised (Rubenstein, 2003). This view is supported by Markman *et al* (1999), who suggest that research conducted in the public sector is not always efficiently or successfully transferred to industry. Therefore, at present there is a greater focus on commercialisation of public sector research than ever before (Wong *et al*, 2002) and it has become a necessity to understand and improve the means of technology transfer in order for society to reap the benefits of public science (Geuna and Nesta, 2003). This necessity is coupled with the current growing interest and pressure, among policymakers and academics, to ensure informed spending of taxpayers' money, conduct of useful and relevant research that represents good "value for money" and generation of wealth from publicly-funded research (Carr, 1992; Lyall *et al.*, 2004; Mustar *et al.*, 2006). To achieve this requires, amongst other things, the establishment of scientific and technical human capital which is the sum of researchers' professional network ties and their technical skills and resources (Bozeman and Coreley, 2004).

This paper examines the general interactions and knowledge transfer activities engaged in by researchers from Irish public science providers (public research centres (PRCs) and higher education institutions (HEIs, i.e. universities and institutes of technology) and from relevant food company personnel within the Irish food industry. In addition the similarities and differences in relation to each of their motivations for interaction and their perceptions of barriers that affect these interactions are also inspected.

In order to provide the background to this study, the current context of the Irish food innovation system is introduced. The paper then outlines the methodological approach taken to collect data from the public science and private industry domain. The results of two national surveys, directed towards both of these groups is then presented with particular focus on the extent and nature of interactions, the variety of knowledge transfer activities employed and the barriers to and motivations for researcher-industry and industry-researcher interactions and technology transfer. To conclude, the main findings of the research and some policy recommendations are presented.

THE PUBLIC R&D SYSTEM IN IRELAND:

According to Forfas (2006), the level of R&D conducted by the private food sector in Ireland was low, with 120 R&D performing companies in 2003, spending approximately €29 million. Thus, the suggestion is that public research can play a more important role in the development of the food industry's knowledge base in Ireland. Under the National Development Plan, 2000-2006, a total public fund of €105.39 million in food-related research, technology and innovation measures was made available. Of this, €69.84 million was allocated towards the institutional or public good programme, administered by the Department of Agriculture, Fisheries and Food through the Food Institutional Research Measure (FIRM). In addition to FIRM funded research, food related research is supported by the EU Framework programmes with some additional examples of biotechnology-related research funded by the Science Foundation Ireland. All of these programmes encourage researcher collaboration and industry interaction.

The science base in relation to food research in Ireland is mostly concentrated in public research centres (predominantly Teagasc) and the universities and to a certain extent in the institutes of technology, with some basic research undertaken in the private sector (ICSTI, 2002). The major food technology producers in Ireland are Teagasc, University College Cork and University College Dublin. These institutions differ from one another somewhat in their focus. Teagasc is specifically charged with supporting the Irish agri-food industry to attain the highest standards of safety, quality and innovation in food products and ingredients, with research as the focus and technology development services and training programmes seen as associated services. In contrast, the universities have a broader remit with a very strong focus on education. They view the development of high calibre graduates for the food industry as an important part of their contribution to the food sector. These different remits may lead to alternative motivations and/or perceptions of barriers in relation to knowledge transfer. Existing literature presents differences in motivations between different types of research institutions, with implications for technology transfer, (e.g. Joly and Mangematin, 1996; MacBeth, 2002) while Logar *et al* (2001) suggests that the overall culture of public science, relating to both universities and research institutes, poses a major barrier to building technology transfer conducive relationships with industry.

In 2006 a Government of Ireland report stated that research, development and innovation have a key role to play in the sustainable development and competitiveness of the food sector (Annual Competitiveness Report 2006, Volume 1). In order to achieve this and to deal with continuous changes in the business, economic and regulatory climate, the Irish food industry must draw its competitive advantage from the skills and creativity of its people and its research base. Irish food manufacturers are thus required to move up their industry's value chain by increasing the knowledge content of their products (Department of Agriculture, Food and Rural Development, 2000) and become part of a national drive to improve their ability to innovate and to generate knowledge, ideas and technologies through high quality basic research and subsequently commercially develop their findings and link effectively with knowledge generated elsewhere in the world.

METHODOLOGY

Separate postal questionnaires were distributed to researchers involved in publicly funded food research and to food company representatives who were employed at Managing Director, General Manager, R&D/NPD Manager, Production or Quality Control Manager levels, depending on company size. The researcher list was compiled from various databases, from lists of attendees at launches of various EU and Irish funding calls, websites of relevant food research institutions, input from key informants and personal knowledge of the authors. This resulted in a database of 324 researchers, from junior to senior level, involved in publicly funded food research in Ireland. The industry list was developed using database information from RELAY (the national dissemination body, funded by the Department of Agriculture, Fisheries and Food, under the National Development Plan 2000-2006 with responsibility for communicating the results of publicly funded food research to the Irish food industry) , Bord Bia (the Irish Food Board), the Teagasc Food Training Database and in accordance with specific inclusion criteria in relation to company size (employs more than 10 people), and processing activities. In total, 267 industry questionnaires were distributed.

These postal questionnaires, which were professionally printed and accompanied by a pre-paid addressed envelope, were mailed to both groups. They were developed following a literature review and exploratory primary research using focus groups, consultation with public researchers and industry personnel, as well as a pilot phase. The pilots were conducted with researchers from a PRC and a HEI and with selected food industry representatives working in the area of new consumer foods. Topics addressed in the questionnaires included: the nature of interaction; importance and effectiveness of various technology transfer activities; perceived barriers and obstacles to technology transfer; and the role of public research, science providers and public researchers in the innovation system. A response rate of 46% was achieved for researchers and 26% for industry. Both required follow up telephone reminders, with the industry respondents requiring 3 follow-up rounds in order to retrieve adequate response numbers.

PROFILES OF RESEARCHER & INDUSTRY RESPONDENTS

Table 1: Profile of Researcher Respondents

	Category	n	%
Age group	21-30 yrs	29	19.5
	31-40 yrs	56	37.6
	41-50 yrs	35	23.5
	51-60 + yrs	29	19.5
Industry experience	Yes	36	24.5
	No	111	75.5
Org Type	PRC	69	46.3
	HEI	80	53.7
Research Type	Basic		18
	Applied		60
	Experimental		22

In the case of researchers, most were male (60%), in the 31-40 years category and without previous industry experience. In terms of job title, lecturing and research officer posts were the most popular forms of employment representing 32% and 30% respectively. Overall, the split between respondents employed in HEIs (54%) and PRCs (46%) was relatively even. The majority of respondents were actively engaged in food research (on average 78% of research time was food relevant) and had a strong focus on applied research (60% of time spent on applied research, 22% of experimental research and 18% on basic research).

In terms of the industry response profile, the employee numbers for all of the companies surveyed ranged from 10 to 1,500, with two thirds of companies employing less than 80 people. Turnover ranged from €350,000 to €230 million. The average turnover was €36 million but two thirds of companies had a turnover of less than €15 million. The average R&D spend as a percentage of turnover was recorded as 3.2% three years ago, 3% in the last 12 months and estimated to be 4.3% in three years time which indicates ambitious levels, given that EU's R&D intensity (R&D expenditure divided by GDP) stands at approximately 1.8% (OECD, MSTI, 2007). Regarding intellectual property the current figures, as outlined in Table 2 below, indicate that ownership of patents and/or licences is relatively low.

Table 2: Profile of Industry Respondents

	Category	n	%
Company classification	Innovator with formal R&D dept	23	34.3
	Innovator without formal R&D dept	32	47.8
	Non-innovator	12	17.9
Intellectual Property	Patents	22	32.8
	Licences	5	7.5
PSP experience	Yes	7	10.4
	No	60	89.6
Job title	Managing Director	27	40.3
	R&D / NPD Manager	7	10.4
	Production / Line Mgr.	5	7.5
	General Manager	10	14.9
	QA / QC	9	13.4
	Finance	2	3
	Other	7	10.5

In total, 82% of respondents work in companies classified by themselves as innovators, wherein R&D is conducted either through a formal function or by informal means. The majority of responses came from Managing Directors and General Managers (55%) which may indicate that no formal R&D function exists or that company size is small enough to allow directorial involvement in R&D. Additionally the results show that the majority of respondents have either a degree or masters qualification (37% and 31%

respectively), in either a business related or scientific discipline and have had minimal previous experience within the public science field (10%).

RESEARCH RESULTS: RESEARCHER & INDUSTRY INTERACTIONS AND PERCEPTIONS

Extent and purpose of interaction

Much of the economic literature reveals that formal and informal, direct and indirect as well as deliberate and unplanned channels constitute the many circumstances of interaction between public research institutes and private organisations. In order to ascertain the extent and nature of interaction employed by researchers and industry within Ireland, and hence gain a basic understanding of their openness, both were asked to indicate the types of engagement that they employ. Researchers were asked to identify whether they engaged with a range of partner organisations for the purposes of technology transfer, collaborative research, access to facilities, contract R&D or commercial services (training & consultancy) over the past 3 years. Industry, on the other hand, was asked to indicate their sources of innovation and if they had collaborated with public science providers in order to fulfil their R&D objectives over the past three years.

Table 3 shows that Irish public researchers interact with a range of partner organisations, nationally and internationally, for a range of different activities. Irish HEI's are the most important partner, with food industry suppliers the least important partner. In terms of purpose, one can observe that interaction occurs mainly to conduct collaborative research. In addition it is evident that collaborations are more likely with Irish partners than with international partners (64% collaborative research with Irish HEIs and 39% with international HEI), reflecting the dominance of national funding over EU funding for public food research in Ireland.

Table 3: Researcher interaction with selected partner organisations by purpose:

Partner Organisation	Technology Transfer		Collab' research		Access facilities		Contract R&D		Commercial Services		At least 1	
	%	n	%	n	%	n	%	n	%	n	%	n
Irish HEI	11.4	17	64.4	96	16.1	24	12.1	18	6.7	10	74	111
Irish PRC	5.4	8	47	70	13	20	11.4	17	6.7	10	60	90
Int'al HEI	3.4	5	38.9	58	8.7	13	4	6	3.4	5	42	62
Int'al PRC	6	9	22.1	33	7.4	11	4.7	7	5.4	8	32	48
Food co	18.8	28	23.5	35	18.1	27	19.5	29	22.1	33	53	79
Food industry supplier	7.4	11	7.4	11	5.4	8	4.7	7	5.7	5	20	30

With regard to the levels of researcher interactions, it is observable that at least 20% of researchers engage with each partner for at least one defined purpose. However analysis of the levels of interaction with individual partners for a specific purpose indicates that levels are quite low with only one cell (collaborative research with Irish HEI) scoring above 50%. Given that most national and EU research funding programmes strongly encourage collaboration, as demonstrated by Ireland's current technology policy of developing a range of measures to expand collaborative links between industry and academic researchers, this result is surprising. However as data was not collected on the breadth of interaction within each category, it is possible that some researchers could have extensive linkages with a large number of organisations within one or more of the pre-defined categories and that this high level of interaction is masked within the available data. Nonetheless the level of collaboration with food companies is encouraging, at approximately 20% for each purpose, indicating that some attention is being paid to industry involvement in public science research projects.

Analysing interaction according to the type of research being undertaken, as outlined in Table 4, found that those researchers who conduct basic research, have significantly more interaction with international PRCs than those who do not. There is no significant difference however in the levels of interaction and non-interaction with Irish HEIs, Irish PRCs, international HEIs, food companies or food suppliers. In relation to those researchers conducting applied research, no significant difference was observed regarding interaction and non-interaction levels with any partner organisations. This suggests that researcher awareness and the presence of strong public-private relationships are lacking in terms of the critical commercial orientation needed for this type of research. Lastly, with regard to experimental research there seems to more likelihood to interact with food companies and food industry suppliers than not.

Fischer (1994) found that the previous industry experience of researchers impacted on technology transfer performance and interaction with industry. Other analysis conducted as part of this research demonstrated that researchers with previous industry experience, when compared to those without, displayed a higher tendency to interact with Irish PRCs, food companies and food suppliers but were less likely to interact with Irish HEIs, international PRCs and international HEIs. This may be a reflection of previously established personal relationships, the preservation of social capital and network ties (Lin and Bozeman, 2006) and possibly a higher recognition of the need for commercial awareness as part of their scientific research. The implication of these findings is an assumption that those researchers with a career spent in academia may have a lower propensity to engage in collaborative relationships with industrial partners.

Table 4: Researcher interaction with selected partners based on research type:

	Basic Research			**Applied Research**			**Experimental Research**		
Partner Org	Mean **No Interaction**	Mean **Interaction**	**P**	Mean **No Interaction**	Mean **Interaction**	**P**	Mean **No Interaction**	Mean **Interaction**	**P**
Irish HEI	17.46	17.34	ns	59.89	59.75	ns	22.05	22.06	ns
Irish PRC	17.11	17.55	ns	56.84	61.69	ns	24.12	20.73	ns
Int' HEI	14.73	20.9	0.03	57.93	62.27	ns	26	16.79	ns
Int' PRC	18.91	14.27	ns	58.65	62.08	ns	21.48	23.23	ns
Food co	20.42	15.01	ns	62.32	57.64	ns	15.58	27.32	ns
Food industry supplier	18.03	14.83	ns	61.69	52.5	ns	19.3	32.67	0.03

In order to get a more holistic interpretation of overall levels of interaction, the activities of industry were also analysed in terms of recent interaction with public science providers and the importance of external sources of innovation, as outlined in Table 5.

It was found that the level of industry engagement with public science providers for the purposes of achieving their R&D objectives is very low. While the level of engagement is higher with Irish providers than foreign providers, the highest percentage interaction, attributed to both quality improvements and the development of new products stands at only 18%. The table demonstrates public science providers, in the main, provide little impact in terms of the objectives listed. These results contrasts with Konttinen *et al's* (2006) observations that in the past two decades firms have increasingly viewed universities and government laboratories as key external sources of technology and product development along with suppliers and competitors.

Table 5: Industry interaction with Public Science Providers for defined purposes

R&D aims & objectives	**Irish PSP**		**Foreign PSP**	
	n	%	n	%
Quality Improvements	12	17.9	8	11.9
Cost reductions	2	3	2	3
Development of new products	12	17.9	9	13.4
Safety	4	6	2	3
Ensure compliance to regulations	6	9	5	7.5
Customer request	1	1.5	2	3
Environmental impact improvement	4	6	1	1.5

The findings also indicate that utilising public science providers for the purposes of helping industry respond to changing customer requests was rated at only 1.5%. This may be indicative of the fast moving nature of consumer markets, the ability of industry themselves to modify current product offerings that require low-scientific input and the fact that researchers work within longer timeframes which often conflict with industry's shorter timelines.

Santoro and Chakrabarti (2002) note that firms can acquire knowledge and technology from many external sources including competing firms, research organisations, government laboratories, industry research associations, and higher education institutions such as universities. In terms of assessing the sources of innovation that Irish industry utilise, it can be observed that public research institutes (including Teagasc) and HEIs are ranked as the least important source, where 5 = most important and 1 = not important. Therefore, from Table 6 below, it is clear that industry relies more on its own internal R&D and places more importance on engagement with other industrial counterparts than public science providers as sources of innovation. Thus, while public research is important in the absolute sense, its direct impact is often much less than other sources of knowledge, whose position within the supply chain lend themselves to making more direct and instant contributions (Cohen *et al*, 2002; Klevorick *et al*, 1995). The importance of these sources could also reflect the nature of R&D undertaken by the food industry, which emphasises development over research.

Those sources rated by industry as most important were internal R&D, customers, raw material suppliers and equipment suppliers, indicating that companies rely on innovation sources that are in close proximity and with whom they frequently interact. The contribution of suppliers, as acknowledged by this research, in terms of technical developments and industry innovations has been outlined by other empirical research which states that in most cases these interactions occur in the context of a well developed network of inter-industry alliances and relationships (Marengo and Sterlacchini, 1990; Klevorick *et al*, 1995; Martinez and Briz, 2000).

Kruskal-Wallis tests demonstrated that for companies classified as non-innovators, the role of Teagasc was of significantly greater importance than for innovators, while internal R&D was a significantly more important source for companies classified as innovators. Furthermore, the importance of trade shows was scored higher by innovators than non-innovators. All other categories showed no significant difference in ranking between innovators and non-innovators. All of these industry findings are important as, from a food innovation systems perspective (Lundvall 1992; Nelson, 1993), innovative capabilities of a firm depend on its ability to communicate and interact with a variety of different external sources who can act as knowledge providers (Menrad, 2002). The suggestion therefore is that Irish firms may need to take a more innovative outlook in order to improve their levels of interaction with external knowledge and innovation sources.

However, the researcher findings also indicate room for improvement in relation to interaction levels. The results indicate that both parties must take action in terms of developing a relationship approach that allows multi-directional linkages, cumulative informational flows and adjust social, cultural, economic and institutional bases of innovative action (Mitra and Formica, 1997).

Table 6: Importance of innovation sources for industry

Innovation sources	**Mean**
Internal R&D	4.2
Customers	3.9
Raw materials suppliers	3.4
Equipment suppliers	3.3
Competitors	3.2
Consultants & private labs	2.7
Teagasc	2.6
Other research institutes	2.4
Universities	2.2
Institutes of technology	2.1

Knowledge Transfer Activities

Channels of information flow between public research institutes and industry are of critical importance to ensuring that knowledge is transferred effectively. The specific range of activities and channels that researchers and industry utilise to transfer and obtain knowledge was therefore examined under the heading of knowledge transfer activities. Respondents were asked about the frequency and effectiveness of these activities where 1 = not at all and 5 =very often/very effective. In the main, the responses from both PRCs and HEIs were similar to each other. The results demonstrate that there is a gap between the activities most frequently used by researchers and industry thus suggesting that dissemination channels may lack focus and effectiveness. Additionally, both sets of respondents possess some alternative viewpoints in relation to what constitutes the most effective mechanisms for knowledge transfer. These findings are revealed in Table 7 below.

Table 7: Frequency and effectiveness of Knowledge Transfer Activities

	Frequency			Effectiveness		
	PSP Mean	Industry Mean	Sig ** = 95% *** = 99%	PSP Mean	Industry Mean	Sig ** = 95% *** = 99%
Resource sharing (use of PSP facilities by industry	2.3	1.7	ns	2.9	2.4	* *Res
Staff mobility (researchers to industry / vice versa)	2.3	1.9	ns	3.3	2.2	*** Res
Patents / licenses	1.6	1.9	ns	2.5	2.2	ns
Scientific publications	3.7	2.3	*** Res	3	2.3	*** Res
Trade publications	1.9	2.6	*** Ind	2.8	2.7	ns
RELAY submissions / bulletins	2.9	2.3	*** Res	3	2.2	*** Res
Scientific conferences	3.7	2.3	*** Res	3	2.5	** Res
Training courses	2.5	2.9	** Ind	3.3	3.2	ns
Informal contacts	3.2	3	ns	3.4	3	ns
Best practice guides	1.9	2.7	*** Ind	2.7	2.7	ns
Technical brochures & reports	2.5	2.9	** Ind	3	2.6	ns
Internet	2.6	2.9	ns	3	2.7	ns

Not surprisingly, given current reward and grading schemes, scientific publications and scientific conferences were the most frequently utilised knowledge transfer mechanisms for researchers. However, when asked about the effectiveness of same for transferring knowledge to industry, researchers rated them as less effective than the frequency at which they are used, suggesting that they realise their limitations as an industry dissemination device. In relation to these activities, industry responses showed different results and they rated these activities as not important, with mean scores of 2.3 for frequency of scientific publications and conferences and 2.3 and 2.5 respectively for effectiveness. Other significant differences regarding frequency responses were found for the use of trade publications and best practice guides, which were both rated much higher by industry than researchers and for utilisation of RELAY bulletins which was rated much higher by researchers than industry. Examining effectiveness it can be observed that researchers gave significantly higher effectiveness ratings for staff mobility, scientific publications and RELAY bulletins, than industry.

The most frequently exploited knowledge transfer activity, from an industry perspective, was the use of informal contacts, while they deemed externally provided training courses to be the most effective activity. Overall the mean scores for industry in terms of frequency and effectives were relatively low with mean scores ranging from 1.7 (frequency of resource sharing; i.e. the use of PSP facilities) to 3.2 (effectiveness of externally provided training courses). The range for researchers ranged from 1.6 (frequency of patents and licences) to 3.7 (frequency of scientific publications). It is interesting to note that both researchers and industry rated patents and licences as low in terms of both frequency and effectiveness with no significant difference[1] between the two groups. These results correlate strongly with Cohen *et al*'s (2002) assertion that in most industries, including food, patents and licences are not nearly as important as other channels, such as publications, public meetings, conferences, consulting and informal exchange for conveying public research results to industry.

The findings presented herein suggest that the informal arena, as opposed to formal institutional settings, is recognised as important for both sets of respondents for the exchange of knowledge. In relation to published literature, (i.e. publications,

[1] Mann-Whitney tests were used to test for difference.

direct exchange that facilitates supplementary information, between public and private partners is also seen as a necessary complement (Walsh & Bayma, 1996). However within this research it must be noted that there is quite a considerable difference between scientific publications and trade publications in terms of use and perceptions of effectiveness between the two groups.

Barriers to interaction & technology transfer

According to Jones-Evans *et al* (1999), a major problem in increasing the collaboration between academia and industry, in all countries, is the difference in the organisational and institutional cultures of universities and industrial firms. In many cases, this is due to a lack of appreciation of each others' differences. For example, universities may not appreciate the differences in the development of academic research as opposed to industrial research, especially in terms of time conception, priorities and bureaucracy. Brown (1994) also points to the cultural divide as an obstacle, stating that those within the public science field cannot remove their industry interaction related deficiencies without compromising their ability to carry out their primary missions of teaching and research. The issue of culture however is only one of many barriers. Many other authors have identified a number of barriers to achieving effective research impact and technology transfer from both the researcher and end user standpoints (Drejer and Jørgensen, 2004; Caputo *et al*, 2002; Logar *et al*, 2001).

The research findings outlined herein illustrate that researchers and industry have contrasting opinions about what barriers impede the realisation of technology transfer and restrict engagement between the two entities. This suggests therefore that a large gap exists between the knowledge level in industry and the public research community, which has the affect of reducing the possibility of knowledge transfer from the one domain to the other (Drejer and Jørgensen, 2004).

Both researchers and industry respondents were asked to rate the importance of a particular list of barriers. This list was representative of the numerous and frequently quoted barriers found in the relevant literature. The largest barriers all recorded a score greater than 2.5 on a 5 point scale where 1= not important and 5 = very important.

In Table 8, it can be noted that the highest score, from the point of view of researchers, was insufficient time with the lowest score given to 'lack of interest in commercialisation'. Research from Jones-Evans *et al* (1999) found that on an individual level, researchers have increasingly less time to both establish and undertake collaborative projects with industry in addition to their teaching and administrative duties, particularly in the context of continued emphasis on traditional outputs for academic work, such as publications, and low levels of value attributed to collaborative industrial R&D, except as a source of income.

Interestingly, researchers stated that some of the other important barriers to knowledge transfer were 'lack of information about companies' research activities', 'difficulty finding appropriate companies for technology transfer', 'lack of interest from industry' and the 'low R&D budgets of potential industry partners'. Friedmans' tests found no significant differences between 'not enough time', 'lack of information' and 'low R&D budgets', however it found significant difference between 'low R&D budgets' and 'lack of interest from industry' indicating that the top three identified barriers all carry the same weight in terms of their impact as a barrier. It is important to recognise that the majority of these barriers are all industry related which may indicate one of two things. Firstly, that in the main, researchers' lack of open and informal relationships with industry actually create these negative industry related viewpoints to act as barriers and secondly that researchers believe that it is a human capital element that poses a barrier to technology transfer as opposed to any overarching structural issues.

'Hindrance to academic publications' was also cited as an important barrier, albeit not the highest. This assertion links to Logar *et al's* (2001) research, which states, that researchers find it difficult to adjust to the private sector's culture of aggressive market entry in the context of their merit system which does not place weight on success in relation to commercialisation projects.

Analysis of differences in perceived barriers by PRCs versus HEI researchers found that there were no significant differences with the exception of the 'lack of specialist technical transfer support'. In this instance, researchers from PRCs were more likely to see it as an obstacle than researchers from HEIs.

Table 8: Researcher perceptions of barriers and obstacles

Barriers and obstacles	Total Mean	PRC Mean	HEI Mean	P value
Lack of information re: company research activities	3.5	3.6	3.5	ns
Difficulty finding appropriate companies for tech transfer	3.3	3.3	3.4	ns
Not enough time	3.8	3.7	3.9	ns
Scientific independence impaired	3.1	3	3.1	ns
Hindrance to academic publication activities	3.4	3.3	3.5	ns
Neglect of basic activities	3	3.2	2.8	ns
Lack of technical facilities	2.9	3	2.7	ns
Lack of interest from industry re: scientific research	3.4	3.6	3.3	ns
Lack of qualified personnel in industry	3.1	3.2	2.9	ns
Lack of specialist tech transfer support	3.1	3.6	2.8	0.0
Nature of research offers limited tech transfer opportunities	3.1	3.1	3	ns
Lack of interest re: involvement in commercialisation	2.7	2.9	2.6	ns
Insufficient administrative support	3.1	3.2	3.1	ns
Lack of organisational support for commercial application	2.7	2.8	2.6	ns
Research staff lack commercial awareness	3.2	3.3	3.1	ns
Lack of goal alignment re: costs	3.1	3.2	3.1	ns
Lack of goal alignment re: delivery schedules	3.1	3.2	3	ns
Low R&D budgets within industry	3.5	3.4	3.6	ns
Lack of confidence in research results	2.9	3	2.8	ns
Lack of funding to support researchers to engage in tech transfer	3.4	3.5	3.4	ns

From an industry perspective it is interesting to observe that the largest barrier, as illustrated in Table 9, was associated with industry's belief that high budgets are required for technology transfer and collaboration with the public sector. In addition to this barrier, industry perceived that public research is limited in its ability to be commercially applied and that researchers lack commercial awareness. These results correspond to Caputo *et al*'s (2002) research which suggested that high costs and modest information in relation to public or private incentives to innovate act as obstacles to innovation diffusion within firms. The importance of these industry related barriers also mirrors researcher responses in relation to the importance of industry related barriers.

These viewpoints, coupled with high rankings for such obstacles as 'lack of contact with public science providers', and 'lack of goal alignment with public science timeframes' suggest that the human capital element, of both research and industry personnel, in terms of networking, communication, culture and technical skills, is a significant barrier. Cultural differences received an average ranking, with eight other categories deemed to be larger barriers. This challenges Logar *et al*'s (2001) research which stated that from the private sector viewpoint, university culture, void of a strategy directed at commercialisation and dominated by rules and regulations, was one of the largest obstacles to developing relationships with the private sector. However elements of 'culture' may in fact be embedded in other barriers which received higher rankings. Another element to consider in relation to cultural disparities is the concept of partner trust. By minimising perceptions of cultural barriers the possibility of building trusting partnerships that ensure legitimate and continued knowledge access which subsequently leads to successful knowledge transfer is made easier (Sherwood and Covin, 2008).

In relation to the barriers that were perceived to display the weakest form of obstacle it can be observed that industry is not concerned with the quality of research or with confidentiality issues.

Table 9: Industry perceptions of barriers and obstacles

Barriers and obstacles	Total Mean
High level R&D budgets req'd for engaging in TT and collaborative activities	3.7
Public research outputs offer limited opportunities for commercial application	3.4
Research staff in PSPs lack commercial awareness	3.3
Excessive admin & project management requirements when collaborating with PSPs	3.2
Difficulties with public research funding application processes	3.2
Difficulty finding expertise in PSPs	3.2
Lack of contact with PSPs	3.1
Lack of goal alignment with PSPs re: time frames	3.1
Cultural differences between company and PSP	3.0
Lack of sufficient tech expertise to exploit public research outputs within companies	3.0
Lack of technical facilities to exploit research outputs within company	3.0
Lack of incentives & motivations on part of public researchers to get involved with TT to industry	3.0
Lack of support for engaging in TT within company	2.9
Difficulties agreeing TT arrangements with PSP (e.g. IP)	2.8
Confidentiality issues impinge involvement with PSP	2.7
Concerns re: quality of research	2.7
Previous experience working with PSPs did not yield significant returns	2.1

Motivations behind involvement in technology transfer:

Feldman (2006) states that at the heart of technology transfer is the individual who is motivated by a set of personal and institutional incentives. In this regard, understanding the reasons why certain individuals and/or organisations engage themselves with technology transfer is essential to developing future policies and incentives to improve current levels of research commercialisation.

The main motivation behind researcher involvement in technology transfer, as illustrated by Table 10, was to 'secure funds for research', with 'gaining insight into scientific research', 'promoting diffusion of research findings', 'testing application of research' and 'achieving research community recognition' close behind. While the majority of motivations are denoted as important (mean values above 3), none of the top five embrace a motivation that links directly to industry in terms achieving recognition therein or supporting their business objectives. While diffusion of research findings is mentioned, this may in fact be in relation to dissemination within the research community, given previous findings relating to frequency of knowledge transfer activities via scientific publications and conferences. Therefore these motivations are quite insular in their focus and imply that researchers interact with industry to obtain a personal or institutional benefit as opposed to a mutual one.

'Accessing patents and licences' and 'achieving personal financial gain' were not regarded as important, (all obtained a mean score below 2) and therefore are not sufficient motivators for involvement in technology transfer. In relation to patents and licences within Ireland, emphasis on these issues, while in its embryonic phase, has gained momentum in recent years with establishment of technology transfer offices and the employment of Intellectual Property Rights Officers within PRCs (Teagasc).

Friedman tests found no significant difference between securing funds, gaining insight into scientific research and promoting diffusion of research findings but found significant difference between securing funds and testing the application of research. This thus identified the three most important barriers, and shows that targeting any of these three should result in similar outcomes. Unlike the analysis of differences in perceived barriers by public research centre versus HEI researchers, analysis of differences in motivations found significant differences related to four motivations, as outlined by P-values in Table 10. In all cases, except for access to patents and licences, the motivations were stronger for researchers from HEIs than from PRCs.

Table 10: Researcher motivations

Motivations	Total Mean	PRC Mean	HEI Mean	P
Secure funds for research	3.9	3.7	4.1	0.018
Gain insight into scientific research	3.8	3.8	3.9	ns
Promote diffusion of research findings	3.8	3.9	3.7	ns
Test Application of Research	3.7	3.7	3.6	ns
Achieve research community recognition	3.7	3.7	3.7	ns
Achieve recognition from my organisation	3.6	3.7	3.5	ns
Gain practical experience	3.5	3.4	3.5	ns
Assist RO / HEI Mission	3.4	3.3	3.6	ns
Provide real world experiences	3.3	3.0	3.7	0.000
Access complementary company expertise	3.3	3.3	3.2	ns
Achieve industry recognition	3.2	3.3	3.1	ns
Create student jobs & internships	3.1	2.7	3.4	0.000
Support business objectives of industry partners	3.0	3.2	2.8	ns
Access company resources	2.8	2.9	2.8	ns
Achieve personal financial gain	2.0	1.9	2.0	ns
Access patents and licenses	1.9	2.1	1.7	0.035

Table 11, indicates that the main reasons industry engage with public science providers is to access new ideas, reduce time to market with new technologies, access government funding and develop their own staff. Overall, all motivational categories, with the exception of one ('prevent competitors from acquiring new technologies') obtained a mean score above three, indicating the relative importance of all categories. These motivations illustrate an acknowledgement by industry that accessing technological knowledge cannot be solely accumulated through internal learning processes (Sherwood and Covin, 2008) and that to maintain competitiveness in terms of reducing time to market industry can avail of the valuable commodity that is public sector research (Wong *et al*, 2002). While gaining access to public science provider expertise, facilities and intellectual capital are all classified as important; the goal in the future will be to increase the relative importance of these as key motivations for involvement with public sector institutions

Table 11: Industry motivations

Motivations	Mean
Access new ideas	3.6
Reduce time to market with new technologies	3.5
Access government funding for company R&D activities	3.5
Technical development of own staff	3.5
Reduce company R&D costs	3.3
Access public science provider facilities	3.3
Access public science provider expertise	3.3
Recruit and retain staff	3
Access public science provider intellectual property	3
Provides technical endorsement for your company (i.e. tested at …)	3
Prevent competitors from acquiring technologies	2.8

Conclusion:

The research findings provide a number of important insights into science, technology and innovation policy development in Ireland generally, particularly in relation to technology transfer. From these findings one can identify the areas that require improvement in terms of building levels of interaction and the contrasting viewpoints of public science providers and industry which need to be addressed in order to enhance relationships, and hence knowledge and technology transfer, between the two in the long term.

In relation to levels of interaction and engagement, while some interaction is present for a range of different purposes, levels need to be improved upon if Ireland is to maintain and develop standards of diversity and novelty within the food sector. Interactive relationships, as discussed by such authors as Gibbons and Johnston (1974), Kline and Rosenberg (1986), Nelson (1990) and von Hippel (1988) are vital to the innovation process. In this vein, recognition of the complexity of public-private partnerships (Rothwell, 1994) as well as the need for a multi-directional approach (Mitra and Formica, 1997) must also be considered and therefore, taking current interaction levels into account, Irish researchers and industry must both actively pursue multiple forms of engagement for diverse purposes in order to maximise the value obtained from engagement.

The level of interaction with the food industry, whilst somewhat encouraging, suggests that current Irish policies which focus on a range of measures to develop collaborative links between industry and academic researchers have yet to bear fruit. The necessity to develop a programme that marries the private sector's need for new products and technologies with the public sector's ability to develop research projects that address those needs in the context of open and informal communication and dissemination links is therefore apparent. The creation of effective links however is not a straightforward task regardless of a clearly formulated policy. Issues relating to firms' absorptive capacity (Cohen and Levinthal, 1990) and levels of researcher skills pose as significant issues in developing these links. To date, no programme has been targeted at developing skills of existing researchers which is of considerable importance given the store of tacit as well as codifiable knowledge that exists within this group. Additionally, a programme which acts to educate industry on the types of funding available for research, the potential for collaborative public-private agendas and partnerships and the availability of research findings may also be a necessary policy consideration.

The differences in the value placed on mechanisms for knowledge transfer also demonstrate a gap that restricts levels of successful engagement. In terms of frequently utilised transfer activities, while researchers rely on scientific publications and scientific conferences, industry depends on informal contacts, trade publications and external training courses. What is encouraging however is the joint recognition from both parties that informal contacts and training courses are some of the most effective mechanisms for improving rates of knowledge transfer. This suggests therefore that improving levels of effectiveness within the public and private domain can be done by addressing these activities and will have a mutually beneficial effect on both parties. Addressing all of the issues surrounding levels and methods of interaction brings an acknowledgement for the inter-relatedness between heterogeneous actors and knowledge fields (Lundvall, 1992).

The barriers, identified by Irish based researchers, specifically the high importance given by researchers to the 'lack of information about companies' research activities' and the assertion by Irish industry that researchers lack commercial awareness, emphasises the importance of bi-directional exchange of knowledge as acknowledged by Meyer-Krahmer and Schmoch (1998). Both researchers and industry had perceptions about the deficiencies of the other party which they felt constituted the main barriers to achieving successful technology transfer. Addressing and changing these perceptions is an essential task and will encourage an environment wherein both parties can consider the other as a potential partner. However, in relation to reducing barriers, Kaufmann and Tödtling (2001) issue a word of warning. They caution against reducing barriers between researchers and industry in a way that minimizes diversity, claiming that "*adjusting the science system's mode of interpretation, decision rules, objectives and specific communicative standards to those of the business sector eliminates exactly the factor which stimulates innovation: diversity*". Instead the authors advocate the concept of '*bridging'* which focuses on '*making one system's operation understandable and thus, its output usable for another system – is required*" (Kaufmann and Tödtling, 2001, p802).

Motivations of researcher and industry respondents illustrate that the different cultural backgrounds of the public and private respondents impact upon their general motivations for involvement in knowledge and technology transfer. For both sides, personal motivations act as the main catalysts for involvement in knowledge and technology transfer processes. Creating an environment wherein both parties are motivated by reasons that attribute benefits to both parties is therefore essential. This may only arise if relationships between the two strengthen however.

In conclusion, the findings prove that, based on current levels of interaction and the disparities that are present in relation to barriers and motivations for public science researchers and industry, a lot has to be done if Ireland is to effectively establish and maintain networks and collaborations in order to improve knowledge and technology transfer within the food sector. Changes must happen at the policy institutional and industrial level which is a complex task. At a basic level however, industry must begin to believe that public research is a strategic resource while researchers, in parallel, must play a more active role in their relationship with industry in order to maximise the impact of their research results.

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