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An Appraisal of the Optimal Conditions for Successful Technology Transfer to a Low Technology Industry: the Case of Publicly Funded Food Research in Ireland

Paul O'Reilly
Dublin Institute of Technology, paul.oreilly@dit.ie

Maeve Henchion
Teagasc, maeve.henchion@teagasc.ie

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Paul O'Reilly
Dublin Institute of Technology, paul.oreilly@dit.ie

Maeve Henchion
maeve.henchion@teagasc.ie

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PAUL O'REILLY

School of Management, Dublin Institute of Technology, Aungier Street, Dublin 2, Ireland
paul,oreilly@dit,ie

MAEVE HENCHION

Food Marketing Group, Ashtown Food Research Centre, Teagasc, Ashtown Dublin 15, Ireland
maeve.henchion@teagasc,ie

Abstract

Introduction

Technology transfer has been defined in many ways across various dimensions, but it can be simply synopsised as the movement of know-how, technical knowledge or technology from one organisation to another. In the context of this paper the focus is on the transfer of such know-how, technical knowledge or technology from public research centres in Irish higher education institutions and government laboratories to the Irish food industry. A review of the literature shows clearly that technology transfer is a highly complex process. Technology transfer can occur through many paths as it is not limited to the codified knowledge embedded in intellectual property rights, for example. It also includes the tacit knowledge that is embodied in the human resources of researchers. An evolution has occurred in how innovation is conceptualised, with a shift from a linear to a systems and network approach. Consequently definitions and models of technology transfer have also evolved. The study and understanding of the technology transfer process is paramount if the benefits of science are to be received and felt by society.

The research objective was to identify the success and failure factors in the achievement of technology transfer from publicly funded food research in Ireland. Twenty case studies documenting publicly funded research projects that both achieved technology transfer and had no/limited technology transfer were undertaken for the purpose of obtaining a greater understanding of the micro-level factors that currently affect and influence transfer of technology from the publicly funded arena to the commercial sector. By identifying and comparing cases where technology transfer was and wasn't achieved an opportunity was provided to develop and build instances of accomplishments and breakdowns and ultimately devise an effective toolbox to assist and maximise technology transfer within the Irish food sector.

This paper presents key insights from Irish researchers in terms of how they approach technology transfer. Among the key themes that emerged as a result of this research was the overarching importance of personal relationships between researchers and industry in terms of their influential impact on such things as communication approaches, type of interaction and technology transfer. The importance of having genuine industry buy-in and interest in projects outputs was also found to be necessary for ensuring higher potential for achieving technology transfer. The findings also recommend that researchers adopt a more focused approach by researchers in the management of their research. In particular researchers are encouraged to focus the potential application on the needs of a single or small number of specific enterprises rather than the needs of an industry or a sector as a whole. Overall the findings highlight the key role of the researcher and their personal motivations in relation to whether there will be successful technology transfer from the publicly funded research programme.

Keywords: technology transfer, publicly funded research, food industry

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Introduction

Research, as a key source of knowledge and new ideas is central to success in the new 'knowledge' economy. Operating in an environment characterised by significant economic, political and social change, this is particularly true in the Irish food industry. The current low level of R&D in the sector, and a growing recognition that companies need to look to knowledge sources outside as well as inside the firm to successfully innovate, brings the need for publicly funded food research into focus. The realisation of the significant social as well as economic benefits that may accrue as a result of publicly funded research however requires successful technology transfer and research commercialisation of the resulting output.

The public R&D system represents an important part of the framework conditions for carrying out innovation activities and creating commercially applicable knowledge (Drejer and Jørgensen, 2004). In part this is because publicly funded research is an important source of knowledge for firms, however publicly funded research can support innovation activities in other ways also and can contribute to a broader range of economic benefits. Martin *et al*. (1996, cited in Salter and Martin, 2001) identified a number of contributions that publicly funded research makes to economic growth such as increasing the stock of useful knowledge, training skilled graduates, creating new scientific instrumentation and methodologies; increasing the capacity for scientific and technological problem-solving; and creating new firms.

The transfer of scientific and technological know-how into valuable economic activity has become an important priority on many policy agendas, with links between industry and science being a crucial element of this policy direction (Debackere and Veugelers, 2005; Powers and McDougall, 2005; Fontana *et al.*, 2006). Indeed in many countries an optimisation of the interface between science and economy has become one of the most important guidelines of technology policy (Balthasar *et al*., 2000).

European Commission communications reinforce the emphasis on research and innovation. The report *More Research and Innovation: A Common Approach* (2005) noted that "the EU has no choice but to become a vibrant knowledge economy". In the Lisbon partnership for growth and jobs, the European Council singled out *knowledge and innovation for growth* as one of three main areas for action. The report highlights effective and efficient protection and management of IP is essential for research and innovation activities supporting the policy ambitions. However, it also notes that sub-optimal research collaboration and knowledge transfer between Public Research Organisations (PROs), particularly universities, and industry are one of the weaknesses of the European research and innovation system that must be overcome if there is to be development of a sustainable knowledge economy. This challenge has been recognised in Commission communications for a considerable time. The 1994 White Paper *Growth, Competitiveness, Employment. The Challenges and Ways Forward into the 21st Century* noted that the "greatest weakness in Europe's research and industrial base is the comparatively limited capacity to convert scientific breakthroughs and technological achievements into industrial and commercial successes". Apparent failure to close this gap represents a continuing challenge for the European Commission and highlights the complex issues involved.

Background to Study

This research has been undertaken as a component of a larger study of technology transfer from publicly funded food research. The TOOLBOX project, or to give its complete title description, "Development of a technology commercialisation toolbox for publicly funded food research", is funded under the Food Institutional Research Measure (FIRM) of the Department of Agriculture, Fisheries and Food and is conducted by a collaborative research team involving Teagasc, Ashtown Food Research Centre and Dublin Institute of Technology. The objectives of TOOLBOX are to provide a range of case illustrations, tools and management frameworks that will support researchers and research centres in their endeavours to transfer technologies, developed through publicly funded research, to industry. In addition, the project aims to contribute to policy development at national and research centre level and provide guidance for researchers to ensure greater uptake of their research findings by industry.

Research, development and innovation have a key role to play in the sustainable development and competitiveness of the food sector (Government of Ireland, 2006). The sector operates in an environment characterised by rapid change in the business, economic and regulatory climate. Reform of the CAP and the upcoming WTO agreement will require the sector to operate in a more open market driven economy. Increasing global competition and demanding and diverse retailer and consumer requirements all increase the competitive pressures placed on the sector. In order to realise competitiveness and maintain growth, there is a requirement for the industry to develop new products and processes (Jospin, 1998). Consequently, the Irish food industry is moving towards an economy that draws its competitive advantage from the skills and creativity of its people, and Irish food manufacturers are 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).

Critical to the success of this transition will be the national ability to innovate, to generate knowledge, ideas and technologies through high quality basic research and the commercial development of its findings, and to link effectively with knowledge generated elsewhere in the world. This requirement is reinforced in the Agri-Vision 2015 report (2006) which states that:

> "*The food industry must have the capacity and scientific knowledge to assist innovation and become more efficient and responsive to the market. The dependence of the competitiveness of the Irish agri-food industry on basic and applied R&D must be recognised. Its requirements are similar to other high tech industries and it must be supported in a similar fashion*."

The current level of R&D investment in the Irish food industry is low, with the sector spending 0.2 to 0.3% of sales on R&D (Government of Ireland, 2006). This low level is in part because the industry comprises a large number of Small and Medium Enterprises (SMEs), which do not have the capability or expertise to engage in R&D and which, in any event do not originate from such a background or culture. Whilst it could be argued that companies within the sector should undertake more research in their own self-interests, (indeed this is highly desirable and there are a number of government initiatives in place to support this), the current competitive environment places demands on firms to draw on

knowledge s sources outside of the firm according Rappert *et al* (1999). According to authors such as Zucker *et al.* (1998), companies are increasingly looking towards public science as one external knowledge source allowing rapid and privileged access to new knowledge. The discussion below will show that important benefits accrue to a nation where publicly funded research is conducted in addition to private funded research, i.e. where there is additionality rather than substitutability.

Literature Review

Definition of technology transfer

In simple terms, technology transfer involves the movement of an innovation, however, definitions of technology transfer differ widely in the literature, across disciplines (Reisman, 2005) and in the practical usage of the term. Reisman proposed that there are 182 independent technology transfer attributes, which are related to the actors involved, transaction characteristics, motivations, discipline, and perceived role of technology transfer, thus illustrating the complex nature of the process. Bozeman (2000) reported that technology transfer is described in numerous diverse ways, according to the research field and according to the purpose of the research. Bozeman defined the concept as "the movement of know-how, technical knowledge or technology from one organisation to another" (Bozeman, 2000, p.629).

Gibson and Rogers (1994) described technology transfer as the application of information (in the form of a technological innovation) into use. The process of technology transfer entails movement of a technological innovation from an R&D organisation to a receptor organisation (e.g. a private company). A technological innovation is fully transferred when it is commercialised into a product that is sold in the marketplace.

However, technology transfer involves more than movement of an innovation and may be considered a multi-disciplinary concept. Rogers *et al*. (2001) described technology transfer as a difficult type of communication process, spanning the stages from R&D to commercialisation, but with a particular focus on the interface between R&D and commercialisation. This definition highlights that technology transfer involves a communication aspect.

Technology transfer also involves a relationship dimension. Research and technology transfer activities comprise an extended series of "interactive relationships that connect the functional activities of basic (disciplinary) research, applied (problem-solving) research, development, diffusion, adaptation, and dissemination into an overall technology delivery system" (Feller *et al*., 1987).

Other definitions highlight that technology transfer does not happen by chance. Technology transfer refers to deliberate, goal-oriented relations between two or more persons, groups or organisations to exchange technological knowledge and/or objects and rights (Autio and Laamanen, 1995). Stock and Tatikonda (2000) further developed this idea of deliberate actions by describing the technology transfer process as consisting of inter-organisational activities employed to achieve both movement of technology across the organisational boundary from the source to the recipient and its utilisation by the recipient to achieve some particular objectives, with cost and time targets.

Levin (1993) added a social aspect to the definition. Technology transfer may be considered as a socio-technical learning and development process, where the technology is perceived as a social construction where human choice and values influence the result. Levin (1997) studied technology transfer from the viewpoint of the recipient company, viewing the process as movement of "*the physical objects, acquiring skills for operation and an understanding of the knowledge and cultural understanding built into machines*" (p. 298). Technological development is viewed as a social process whereby the resultant technology cannot be viewed as isolated from the actors involved in determining it (Levin, 1997). Implicit in this definition are the three faces of technology involved in the transfer process: *"Technology is the material artefacts, how to use the artefacts, and the knowledge of how to utilize it"* (p. 299).

Finally, there may be a commercial aspect to technology transfer. Power and McDougall (2005) defined technology transfer as the process by which technologies developed in universities are transformed into marketable products. Technology transfer was described in Decter *et al*. (in press) as the transfer of new knowledge, products and processes for business benefit and is influenced by the availability of skills to utilise the technology, exploitation skills, user education and the availability of transfer support.

The most common use of the term technology transfer relates to the transfer of inventions and associated know-how from research organisations to research users. From these definitions, it can be established that there are a number of aspects to technology transfer. Firstly, the process of technology transfer involves the movement of knowledge from a producer organisation to a receptor organisation. The second aspect of technology transfer is that a relationship or network of relationships develop or already exist between the transferring organisation and the recipient and inherent in this aspect is the need for communication. Finally, technology transfer does not occur by chance and has deliberate economic and social goals.

Technology transfer from public research centres

Recently, there has been an increased interest in technology transfer from a number of perspectives. Rubenstein (2003) proposed that there has been a perception that public research capacity and results were not being optimally used and thus the potential economic benefits were not entirely realised. This has resulted in growing pressure on policy makers to ensure informed spending of tax-payers money and that useful relevant research is conduct that represented good value for money (Carr, 1992; Lyall *et al*, 2004). The growing interest in generating wealth from publicly funded research amongst policy makers also arises amongst the academic community (Mustar *et al*., 2006). In the academic sector, the constraint of budget expenditure on research activities made licensing earnings, derived from technology transfer and research commercialisation activities, seem a potential solution to declining funds for research from traditional avenues (Rubenstein, 2003).

Furthermore, public research institutions are searching for new funds to compensate for the increasing budget inflexibility of public funding along with increasing costs structures associated with interdisciplinary research. A further reason for the growing interest in technology transfer relates to the appearance of new theories on growth and innovation, while a changing legal and regulatory environment also plays a role. At universities, changes in

research objectives and in the route of funding from public structural funds to more competitive channels has played a role in intensifying interest in technology transfer, which has manifested itself in the development of university-industry collaboration agreements (Geuna 2001, cited in Geuna and Nesta, 2003). Furthermore, there have been changes in the legal status of researchers in some areas, whereby researchers are encouraged and incentivised to supplement their research activities with technology transfer activities (Geuna and Nesta, 2003). For example, HEIs in Ireland have for the most part established policies relating to intellectual property and establishment of spin-off enterprises to incentivise researcher to move their research towards technology transfer.

Benefits accrue to companies that engage in industry-university/public research centre linkages. These include: networking and keeping up-to-date with university/public research centre research; access to expertise; general assistance and help with specific issues; goodwill to encourage future linkages and recruitment; assistance with experimentation; product testing and marketing; industry information; staff relations; social links; access to funding; increasing university/public research centre knowledge; independent credibility in testing; and, commercial credibility (Rappert *et al.*, 1999).

The technology transfer process

The process of technology transfer is a difficult type of communication, and demands trained and skilled personnel, adequate resources, and organisational and reward/incentive structures (Rogers *et al*., 2001). Rogers (2003) decomposed the procedure of deciding to adopt an innovation into five steps. The first step, the knowledge phase, involves individuals learning that a process exists and is relevant to an organisation's problems. Key stakeholders within the organisation are persuaded to engage the technology in the persuasion phase. During the decision phase, the stakeholders decide to use the innovation and the innovation is applied during the implementation phase. Whether the innovation has been successful is reviewed during the confirmation phase. In order to provide the reader with a comprehensive overview of the technology transfer process, a number of models of technology transfer are discussed in the following section.

Wang *et al*. (2003) defined the dominant objective of any technology process as the successful adoption by a significant majority of customers who can use the technology. Figure 1 presents an outline of the main steps in the technology transfer process as viewed by Wang *et al*. It should be noted that because every organisation pursues its own goals and culture, there is no single process that suits all organisations and instances (Wang *et al*., 2003).

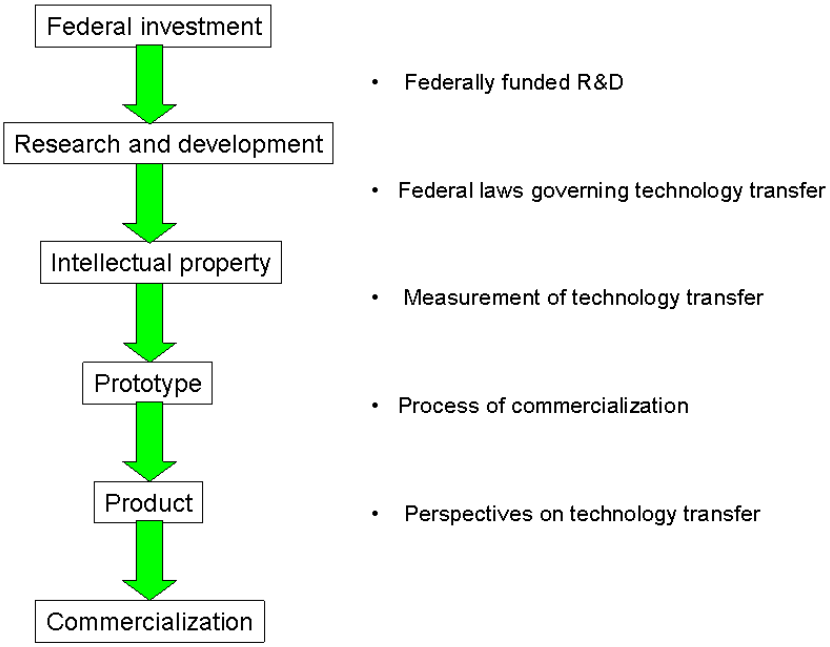

Figure 1: Overview of technology transfer process (Source: Wang, 2003)

Because technology transfer involves many different individuals and organisations and their diverse needs, it is difficult to define universally appropriate measures of transfer activity or effectiveness (Wang *et al*., 2003). The Interagency Committee of Federal Technology Transfer identified a number of mechanisms for successful transfer including: licensing, co-operative research and development agreements, technical assistance and consulting, reimbursable work for non-federal partners, use of facilities, exchange programmes and collegial interchange, publications and conferences. Other categories include graduates taking jobs in a particular technology sector, patents, manufacturing innovations, innovation networks, web hits to a science database, transfer mechanisms and knowledge spillovers (Wang *et al*., 2003). While Wang *et al's* model may be considered as a useful overview of the transfer of 'codified' knowledge, it does suffer from a number of limitations. The model is linear and ignores the relationship aspect of the systems of innovation approach. Furthermore, the model deals only with the transfer of codified knowledge, and ignores the transfer of tacit knowledge, which is an equally important element of technology transfer.

In an earlier review of technology transfer literature, Harmon *et al.* (1997) classified the literature into two groups. The studies of the first group assume a rational decision making point of view and regard technology transfer as a process that can, and should be, planned. These models have been described as arms-length, buy/sell transactions between university laboratories and private companies. In these models, inventors and future users of the technology function independently, without co-ordinating their efforts until initial negotiations regarding a specific technology when the two parties find one another through a formal search process that is normally mediated by a transfer agent. The majority of these studies focus on the processes of technology transfer from the research centre to industry, thus the major goal of these studies is to identify the most efficient methods of administering and facilitating the technology transfer processes and organisational forms that facilitate transfer. According to Cohen *et al.* (2002) this linear model of the innovation process is based on stages such as basic research, applied research, prototype development, market research, product development, marketing and selling similar to the model outline by Wang (2003).

Interventions are made at different and specific stages by strengthening public infrastructure, and providing incentives to the private sector, which is then expected to transform the technology, patents and systems into new products and processes. This group of studies encompasses several models.

The second major group of studies reviewed and categorised by Harmon *et al.* (1997) takes a different perspective on technology transfer, emphasising the relationship aspect of the process. This group of studies is primarily made up of non-linear models that emphasise multi-directional linkages, interdependency between "hard" technology and "softer" issues of people management and information flows, cumulative flows which involve individuals, organisations, regions and government, and the social, cultural, economic and institutional bases of innovative action (Mitra and Formica, 1997). In particular, these studies emphasise the importance of collaborative activities occurring within an established network of formal and informal relationships. A number of perspectives are found in this group of studies. In the communications perspective a successful transfer depends on the effectiveness of information flows between a set of individuals or organisations within a complex network of communication paths (Rothwell and Robertson, 1973). A co-operation perspective studies the process of co-operation between the parties involved that make the transfer easier. Among the facilitating processes identified in these studies are open communication, mutual interdependence, respect, trust and willingness to compromise (McDonald and Geiger, 1987). Research is moving away from examining the technology transfer process through stages of the research chain and is increasingly focusing on alliances among firms and public research centres and how these alliances pertain to the development and transfer of technology.

An example of a hybrid approach to the technology transfer process is that proposed by Callon *et al.* (1992), who proposed a 'techno-economic network' to examine the interactions between science, technology and the marketplace. A techno-economic network (Figure 2) is defined as *"a coordinated set of heterogeneous actors – public laboratories, technical research centers, industrial firms, financial organizations, users, and public authorities – which participate collectively in the development and diffusion of innovations, and which via numerous interactions organize relationships between scientific-technical research and the marketplace …a network is not just limited to the (heterogeneous) actors who make it up. A whole set of intermediaries circulates between them."*

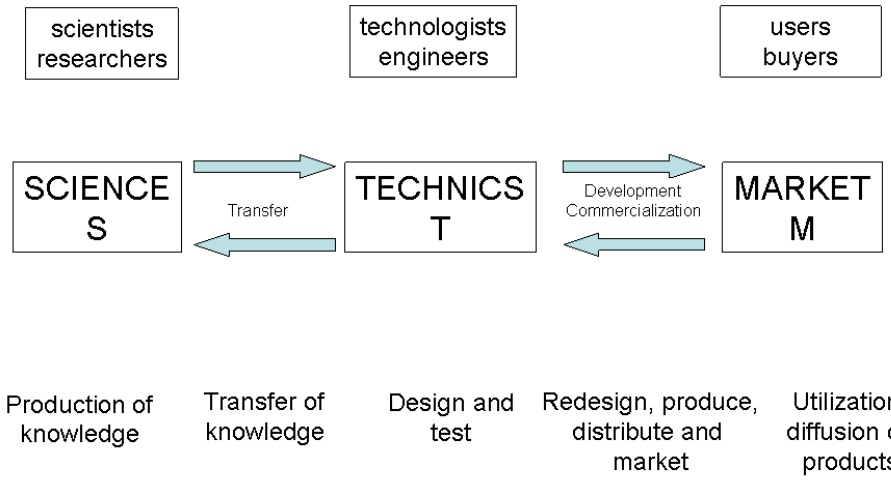

Figure 2: Techno economic model (Source: Callon et al, 1992)

The Callon *et al*. model recognises the interactions of actors in the transfer of technologies, as well as the movement of an innovation and indeed the model has accounted for the impact of the environment to a certain extent in the technology transfer processes by recognising the marketplace. In addition to technology transfer being important at an organisational level, it is also relevant at individual project level. Stock and Tatikonda (2000) developed a conceptual framework of effective technology transfer at project level. The framework captures the nature of the technology to be transferred, activities and interactions across organisation boundaries, and relationships between technology and organisation, all at the project level of analysis. The objective of this framework is to provide theoretical insight and practical guidelines into selection of the best management approaches for transferring a technology into an organisation and is called the inward technology transfer typology (Figure 3).

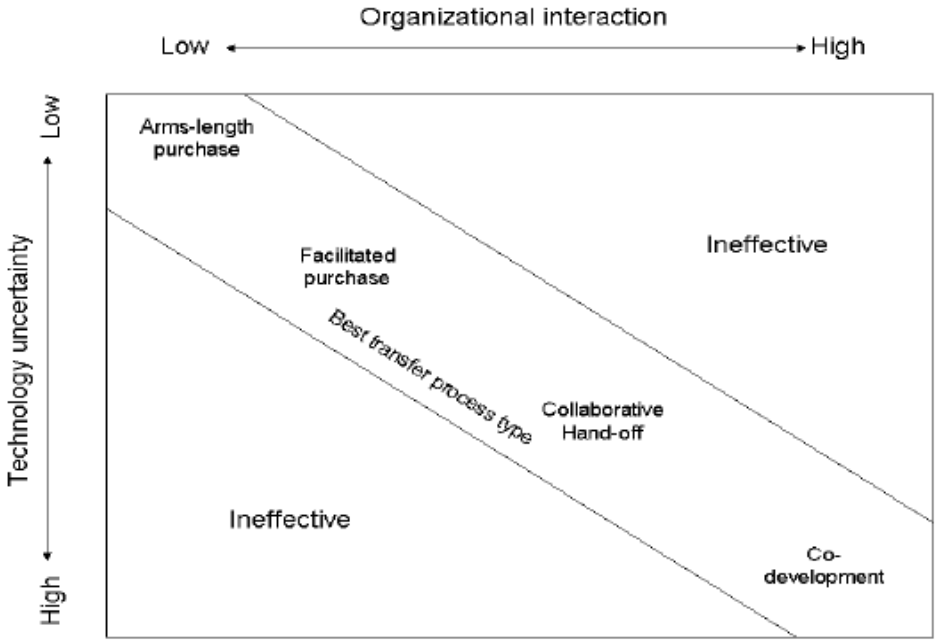

Figure 3: Inward technology transfer typology (source: Stock and Tatikonda, 2000)

The ITT typology identifies along the diagonal the best choice of technology transfer process type by matching the intrinsic technology uncertainty of the technology to be transferred and the organisational interaction between the technology source and recipient. There are four transfer process types: arms-length purchase, facilitated purchase, collaborative hand-off, and co-development. Each transfer type represents the best match, or fit, between technology uncertainty and organisational interaction (Stock and Tatikonda, 2000).

Goldfarb and Henrekson (2003) conducted a comparison of two alternative commercialisation models – bottom-up and top-down. The bottom-up approach focuses on creating (economic) incentives for universities to commercialise their research output and allowing them to experiment to find the best means to do that. The top-down approach represents an attempt to directly create mechanisms that facilitate commercialisation. Goldfarb and Henrekson (2003) proposed that by correcting incentive structures,

commercialisation performance could be improved. Commercialisation of university ideas generally requires the continuing involvement of academic inventors (Jensen and Thursby, 2001). The academic reward structure encourages the production of knowledge that is a useful input into other academics' research. Researchers wish to have their papers cited because this is a signal that they have established a reputation within the academic community. There is much evidence that the production of such knowledge is a central objective of academic researchers, as citation measures are associated with higher income and prestige. This presents a potential difficulty in the commercialisation of university ideas. There is little reason to believe that the goal of producing useful inputs into the research of other academics is congruent with the goal of producing commercially valuable knowledge. Goldfarb (2001) provided statistical evidence that the pursuit of practical goals is unlikely to be congruent with the pursuit of academic goals. Because of this, research sponsors with applied goals in mind have difficulty building relationships with high profile academics. The creation of incentives and the weakening of disincentives for the academic to direct effort towards commercialisation activities are generally necessary for technology transfer. Mechanisms that are commonly used to elicit involvement in a project of commercial value are sponsored research, consulting and starting a new firm. Compensation means include salary, royalties and equity.

In terms of technology transfer models for the food industry little has been developed and put forward in the literature. Donnelly (2000) presented a model for innovation management in public research. This model focuses on extending the task of generating information to its application. Research is viewed in the context that research information represents the instigation of a process that persists until the value and usefulness of the information is established. This includes application trials and pilot scale validation. The model illustrates the move from pre-commercial development to where commercial funding takes over. While industry/researcher interaction not specifically included in the figure, operationalisation of the model assumes that the researcher will play a key role in the entire process and facilitate industry-researcher interaction at all stages. The model does highlight the issue of what is useful information and the need to achieve balance between the public good aspect of research undertaken and the needs of businesses for information protection.

Morrissey and Almonacid (2005) proposed a 'dynamic' model for technology transfer in the context of seafood processing. The model incorporated a number of elements including: engagement with SMEs and entrepreneurs at an early stage in the project, flexibility in the research plan, and access to capital for technology transfer. These authors believe that the current market-driven economy requires a dynamic research and technology strategy that can speedily respond to market changes, where innovation and adaptation are essential elements in successful ventures. External and internal factors should be considered throughout the project and the model should allow decisions by participants to change the experimental design or terminate the effort if considered non-viable. Internal and external impacts relate to new demands, new regulations, new trades, new information and new technologies.

Determinants of technology transfer success

A particularly useful framework for framing the determinants of technology transfer is the Contingent Effectiveness Model of Technology Transfer developed by Bozeman (2000). The model draws its name from assumption that technology transfer parties have multiple goals and effectiveness criteria. The model says that impacts of technology transfer can be

understood in terms of who is doing the transfer, how they are doing it, what is being transferred and to whom. The model includes the five broad dimensions determining effectiveness: (1) characteristics of the transfer agent – the institution or organisation seeking to transfer the technology; (2) characteristics of the transfer media – the vehicle, formal or informal, by; which the technology is transferred; (3) characteristics of the transfer object – the content and form of what is transferred; (4) the demand environment – the factors pertaining to the need for the transferred technology; and (5) characteristics of the transfer recipient – the organisation or institution receiving the technology. These dimensions are thought to be broad enough to include most of the variables examined in studies of university and government technology transfer activities (see Figure 4).

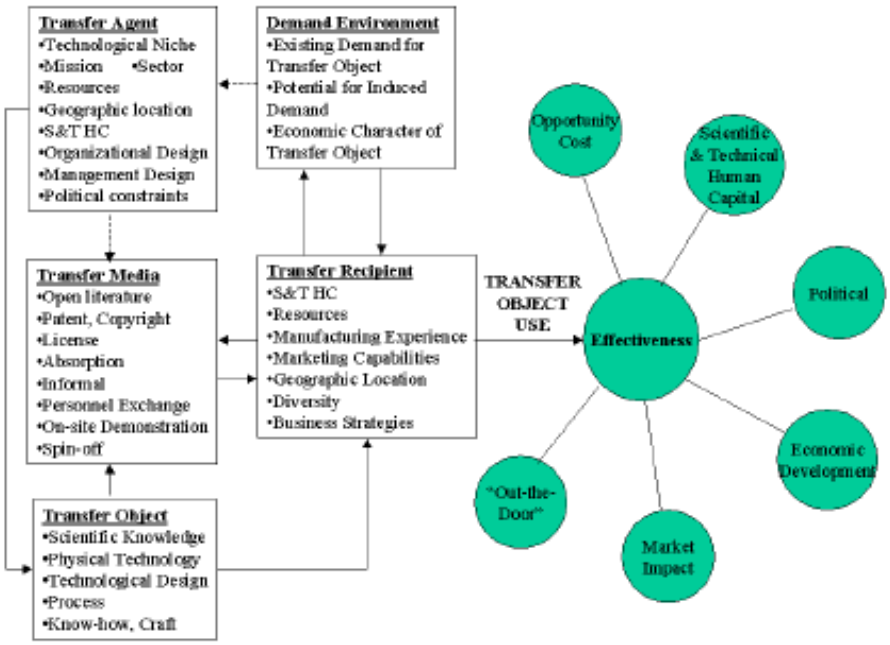

Figure 4: Contingent Effectiveness Model of Technology Transfer (Bozeman, 2000)

A review of the literature shows clearly that technology transfer is a highly complex process. Technology transfer can occur through many paths as it is not limited to the codified knowledge embedded in intellectual property rights, for example. It also includes the tacit knowledge that is embodied in the human resources of researchers. An evolution has occurred in how innovation is conceptualised, with a shift from a linear to a systems and network approach. Consequently definitions and models of technology transfer have also evolved. The study and understanding of the technology transfer process is paramount if the benefits of science are to be received and felt by society.

Methodology

Research approach

The research objective was to identify the success and failure factors in the achievement of technology transfer from publicly funded food research in Ireland. Twenty case studies documenting publicly funded research projects that both achieved technology transfer and had no/limited technology transfer were undertaken for the purpose of obtaining a greater

understanding of the micro-level factors that currently affect and influence transfer of technology from the publicly funded arena to the commercial sector. By identifying and comparing cases where technology transfer was and wasn't achieved an opportunity was provided to develop and build instances of accomplishments and breakdowns and ultimately devise an effective toolbox to assist and maximise technology transfer within the Irish food sector.

All cases were approached with significant flexibility and conducted on the basis of exploratory style interviews. The primary methodology direction was taken from approaches validated and discussed by Eisenhardt (1989). A semi-structured guide was used to facilitate basic questioning within specific thematic areas and allowed for probing beyond immediate direct answers. The guide served to assist comparability of projects that achieved or had no technology transfer.

All interviews were recorded and transcribed. Thematic analysis of the data was subsequently undertaken with the aid of NVivo, a software tool specifically designed to aid systematic analysis of qualitative data. This analysis enabled the researchers to explore key themes emerging from depth interviews and provided the opportunity to compare and contrast opinions and attitudes from researchers who had achieved technology transfer and those who had not.

Case study profiles

The research methodology involved twenty case studies of completed publicly funded food research projects. In all cases the research was deemed complete in the context that the technology objectives has been achieved or the technology transfer objectives were no longer being pursued. The scientific objectives of each of the projects had been achieved and this was validated by a minimum of three peer reviewed academic journal papers. Data collection for the case studies was primarily through semi-structured interviews with the lead researcher or primary investigator on each of the projects. The interviews were supplemented by publicly available information on the projects and reports made available from the research funding agency, in this case the Irish Government Department of Agriculture, Fisheries and Food. Of the 20 cases 12 were identified as having achieved their technology transfer objectives while 8 were deemed to have achieved little or no technology transfer. In as much as was possible, given access requirements, the case study institutions mirrored the distribution of public research funding. The cases were evenly distributed between product and process oriented research.

Findings

In analysing the differences between cases that achieved technology transfer and those that did not, notable distinctions in behaviours, attitudes, motivations and awareness levels of researchers were apparent. Further insights were also achieved in terms of understanding approaches to dissemination and communication practices used by researchers, the nature of relationships between researchers and industry, and the perceived barriers that exist in achieving technology transfer, from a researcher perspective. The main findings arising from this analysis in the following sections.

Barriers to technology transfer

Two major barriers were identified by researchers in the context of achieving technology Transfer – incompatible researcher performance measurement systems and industry demands for short term solutions.

Discontent regarding current performance measures related specifically to the fact that priority and emphasis is given to academic publications and funding, while industry contributions in the form of technology transfer and commercialisation of results is not measured or weighted in terms of guaranteeing or contributing to researcher career progression. This became a barrier in terms of researchers prioritising their time towards concentrating on academic publishing rather than activities that involved bringing their research closer to industry take-up.

Industry demands for short term solutions rather than longer term research objectives that are normally involved in engagements with public research providers referred specifically to industry's focus on "trouble-shooting" and a relative "short-sightedness" in relation to innovation agendas. Researchers who had achieved technology transfer displayed similar opinions to those who did not, regarding industry's short-sighted focus. The pace of industry, as well as high expectations, was also cited as strong, industry specific, barriers by researchers in both achievement categories. Researchers who did not achieve technology transfer believed industry's high expectations to be a major problem in achieving technology transfer, while those who did achieve it, did not believe this to be an issue in terms of a barrier.

Interestingly these barriers were identified by those researchers who had achieved technology transfer and those that did not. The recognition of industry challenges by those who had achieved technology transfer suggests these challenges may be overcome within the existing food innovation system. However, the concern about performance measurement for this group also raises concerns about the sustainability of the current levels of technology transfer. Indeed the issue of incompatible performance measurement systems was more frequently cited by researchers that had achieved technology transfer. There is therefore a concern that, while these researchers are currently working to overcome industry challenges, they may become less satisfied about how their performance assessment reflects their efforts in this area.

Relationship between researchers and industry

Researchers were asked to describe the nature of their relationship with industry. The most frequently mentioned descriptions of their relationships were 'good overall', 'established' and/or 'mutually beneficial'. However, while these descriptions were representative of many of the researchers who achieved technology transfer, the same cannot be said for those researchers who had limited/no technology transfer. In fact this group of researchers were quite varied in their descriptions of industry based relationships, with some admitting to 'weak', 'formal' or non-existent relationships.

The research findings herein suggest that, in general terms, those researchers, achieving technology transfer are more likely to have better relationships with industry than those researchers who have not achieved technology transfer. Those who achieved technology transfer also seem to see the establishment and management of relationships as an ongoing process, with some researchers involved in forming new relationships currently.

Criteria for establishing and maintaining good relationships with industry were also discussed. Overall, researchers with successful technology transfer were much more forthcoming with their opinions concerning the conditions necessary for good relationships. The main finding was that 'casual personal relationships' was seen as the most important criterion, by a substantial margin, for good relationships with industry. Having high levels of interaction, which is intrinsically linked to the presence of casual personal relationships, was also seen to be important. Getting industry's involvement with research projects as well as researchers' having prior experience in dealing with specific companies was also cited as supportive. The most popular response in terms of criteria for good relationships emerging from those researchers who did not achieve technology transfer efforts was 'formal relationships', which contradicts the logic of the highest rated criteria as mentioned by researchers with successful technology transfer.

Overall these findings indicate that technology transfer will not be achieved with a quick-fix solution but will require, among other things, on-going investment of time and effort in building and maintaining relationships.

Mode of researcher-industry interaction

In the main, when asked about the purpose for interacting with industry within the context of the specific research project being discussed, researchers indicated that obtaining general information and feedback relating to overall research objectives, specific research tasks or broader information about issues affecting the industry itself were key objectives. These findings illustrate the necessity to engage with industry to ensure that research being undertaken is relevant and that research tasks are being approached in the most efficient and industrially relevant manner. Encouragingly, it also shows that those with limited/no technology transfer are aware of the potential role and contribution of industry interaction in their research projects.

Dissemination of research results was also investigated. It was found that workshops were the most popular form of dissemination for all researchers. However, it must be noted that for most projects, this was a stipulated and compulsory requirement upon completion of the project. Important to note also is that limitations of the workshop format, in terms of its capacity to engage with industry were more frequently recognised by researchers who had achieved technology transfer. Other important mechanisms mentioned, related to the concept of 'general interaction', which reiterates the importance of casual interaction with industry and 'industry documentation', which illustrates an awareness to utilise industry relevant and accessible communication media in order to inform industry of research outputs. The absence of real differences in the use of dissemination mechanisms between researchers who achieved technology and those who had limited/no technology transfer suggests that poor dissemination is not a barrier. However, this is not to say that dissemination is not an important consideration for achieving technology transfer. Rather it seen by all as researchers as a necessary element of their work.

Commercial awareness levels among researchers

Due to the varied nature of research projects both in terms of industry sector and research outputs, the initial impetus for the research project was explored, which elucidated whether the researcher was driven and influenced by particular industry needs or by personally bound and academic interests. The most popular response in describing the origins of individual research projects was the fact that the research reflected researchers' own experience and interest, with both groups of researchers placing equal importance on this basis. An 'extension of previous research' was the second most cited project foundation, with the successful technology transfer researchers citing this more often. This suggests that these researchers are aware of the "project pipeline" and do not see the delivery of scientific objectives as a final or sufficient end point of each project necessarily.

The biggest difference in responses between both research groups was in relation to research projects arising from a market opportunity validated by industry. In this regard, those researchers who achieved successful technology transfer were much more likely to derive their research projects from such foundations, indicating their relevance and accuracy in terms of dealing with genuine industry needs.

Also important to investigate in terms of researcher focus on potential commercial outputs was whether the researcher considered potential beneficiaries at the project outset and whether this consideration was broad in scope or alternatively, focused on individual or targeted groups of companies. It was found that those researchers whose projects aimed at a specific end user were more likely than not to have achieved technology transfer while those projects that were broad in focus were equally likely to achieve/not achieve technology transfer.

In order to ascertain levels of awareness concerning the protection of research outputs, researchers were asked about their overall approach to intellectual property, in the context of the project. The majority of researchers stated that their research was non-patentable research, with equal representation from those with and without technology transfer, while others (all with successful technology transfer) stated that they thought about IPR at some level and were aware about patent potential from the initial stages of the project. Within the middle range of responses, researchers admitted that they did not think about patents while others said that they were aware of intellectual property rights at the time but did not pursue them as a project objective.

In analysing the link between levels of IPR awareness and successful technology transfer, it was noted that all researchers deemed to have exceptional levels of IPR awareness were successful in their bid to achieve technology transfer. However, there was no direct positive relationship between researchers with high to mid levels of IPR awareness and achievements in technology transfer. These researchers were equally likely to achieve or have limited achievements in technology transfer. Of those with low levels of IPR awareness, the majority of researchers at this level did not achieve technology transfer. Finally, of those who had no IP awareness, at the time of their research project, all were successful in achieving technology transfer. However, it is important to recognise that the technologies involved in these research projects produced non-patentable outputs so having IPR awareness was not relevant to their technology transfer approaches.

Motivations and personal benefits for involvement in technology transfer:

In terms of personal motivations, it was observed that 'personal satisfaction' and seeing an 'end commercial product' were primary motivators for those who had achieved technology transfer. Additionally, they were motivated by building 'links with industry' and believed the work to be 'interesting' while also feeling a 'sense of commitment' to the research itself. On the other hand, researchers who had not achieved technology transfer demonstrated two things. Firstly, as a group they were far less unified by a common motivator and secondly, they did not place emphasis on industry oriented motivators. The identification of personal benefits of technology transfer identified by both groups of researchers also varied considerably. Gaining industry recognition and impact was seen as the main benefit by those with successful technology transfer while improving their commercial acumen was also cited. Industry recognition was not identified as a benefit by any of the researchers that did not achieve technology transfer, while only one respondent mentioned improved commercial acumen as a benefit.

Researcher perceptions on technology transfer success and failure factors

Researchers were asked specific questions in relation to the reasons why technology transfer was or was not achieved. The reasons cited for success were categorised under external, personal and project specific reasons in order to help clarify the grounds for success and failure in more detail. For projects that achieved technology transfer, external conditions, specifically in relation to obtaining 'genuine industry interest' and the 'accessibility of a scale up plant' were the most important reasons for success. This highlights the importance of physical infrastructure to support pilot scale validation.

From a personal perspective, the researcher's relationship with industry was also deemed to be critical. Project specific factors did not rate as highly. Projects that did not achieve technology transfer were mainly as a result of no real market demand, according to researchers. This is deemed as an external factor in terms of analysis but in real terms this is also a project specific issue. Issues with dissemination and high development costs were cited as other external problems while on a personal level, researchers admitted that 'time' was a main cause of failure to achieve commercial impact. The absence of market demand and high development costs are two factors that could or should have been identified at project proposal stage. This suggests that stricter stage-gates at the project proposal stage within research groups and more stringent evaluation would improve technology transfer rates.

Discussion and Conclusions

This paper presents key insights from Irish researchers in terms of how they approach technology transfer. Among the key themes that emerged as a result of this research was the overarching importance of personal relationships between researchers and industry in terms of their influential impact on such things as communication approaches, type of interaction and technology transfer.

The importance of having genuine industry buy-in and interest in projects outputs was also found to be necessary for ensuring higher potential for achieving technology transfer. This has important implications for the design of technology transfer processes whereby industry interaction is required at the much earlier stage of developing the research idea and proposal. In this context key inputs are required regarding the demand environment and the required technology object as described by Bozeman (2000). Related to this, a particularly important finding of the research is the need for a more focused approach by researchers in the management of their research. In particular researchers are encouraged to focus the potential application on the needs of a single or small number of specific enterprises rather than the needs of an industry or a sector as a whole. This enhanced focus represented an important success factor in the cases examined as it allowed the researchers to more accurately identify the technology object requirements and seek feedback on these requirements. The focus also facilitates researchers to manage their communication channels to a smaller number of target transfer recipients and allow for the informal flow of communications that is also identified as a success factor.

In general terms the research highlighted that Irish researchers have growing levels of awareness in the areas of technology transfer and IPR, which is encouraged by structural and culture changes within their specific organisations. However, for a significant number of researchers technology transfer is still approached in a relatively ad hoc manner without serious commitment. The findings highlight the key role of the researcher and their personal motivations in relation to whether there will be successful technology transfer from the publicly funded research programme. The individual researcher must interact directly with industry, not just at the technology transfer stage, but ideally throughout the project. Intrinsic rewards appear to have a greater level of importance with the researchers studied. At the same time, there is clear support for the need for the top-down approach with a correction of incentive structures at public research centres to encourage participation in the commercialisation process as suggested by Goldfarb and Henrekson (2003). Indeed in the context of the Irish public research environment this will be critical if researchers currently succeeding in technology transfer endeavours are to continue their efforts. This is particularly necessary given the apparent lack of R&D sophistication in the food industry, as this places additional responsibility on the public researcher to develop their research further down the research chain. This requirement should be included in any technology transfer process model for the food industry.

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