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Towards New Strategies for Improving the Transfer of Innovation Between University and the Food Industry

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Towards New Strategies for Improving the Transfer of Innovation Between University and the Food Industry

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Note: The authors' personal views are expressed in this article

Abstract

All commerce relies on effective strategies for completing a deal, but conducting the transaction at the university-industry interface with an intangible asset represented by research results remains a difficult proposition. Beyond differences of mission and culture, it is usually assumed that the established language of technology transfer can permit productive communication by a university across a wide diversity of industries. However, the experience of the authors indicates that an appreciation of aspects such as subtleties of language, conflicting goals, and market understanding must also be brought to bear in successfully completing a transaction. Information asymmetry remains a key challenge to overcome in this task, and the example of the food industry represents a special case. This article reviews key developments in technology transfer of food innovation across the university-industry interface in Ireland and suggests possible new directions for exploration in order to improve the effectiveness of this process.

Introduction

The successful commercialisation of technology emanating from the university sector remains a clarion call of governments around the world, and while the attraction is obvious, the task remains challenging (Wynn, 2020). There is a general consensus that innovation is synonymous with the competitive advantage necessary for the survival of a company (Porter, 1985), and this is no different for the agri-food industry (Fortuin *et al*, 2007). Ireland is a good case in point. Like many EU states, the importance of the food industry is woven into the fabric of the country, where issues of business and culture mingle to provide a unique socio-economic identity (Department of Agriculture, Fisheries and Food [DAFF], 2010).

A review of biotechnology development in Ireland at the turn of the twenty-first century acknowledged the importance of the brewing, dairy and food industries (Williams, 1998), but highlighted the high volume, low value nature of the sector. At that stage, the food industry was providing employment for almost 30% of those involved in Irish-owned manufacturing and accounted for about 20% of Irish exports (Uí Ghallachoir and Kavanagh, 1993). The agri-food industry in Ireland currently provides employment for 163,000 people (8.4% of total employment), with food and beverage manufacturing enterprises accounting for €26 billion of total turnover (Department of Agriculture, Food and the Marine [DAFM], 2015). The Food Wise 2025 government strategy identified over 400 recommendations for future sustainable growth in the sector.

In Ireland, analogously to many other states in Europe, the majority of food companies are small or medium-sized enterprises (SMEs) (CSO, 2007; Kavanagh *et al*, 2012). These are Irish owned and are often based in rural communities (Avermaete *et al*, 2004). A number of studies of this sector have suggested that SMEs are at a distinct disadvantage in terms of innovation, due to factors such as low levels of human capital, lack of finances for innovation (Traill & Grunert, 1997), limited absorptive capacity (Menrad, 2004), and diseconomies of scale (Nooteboom, 1994). Furthermore, smaller firm size generally correlates with lower levels of dedicated research and development (R&D) resources, personnel and facilities in manufacturing firms (Shefer & Frenkel, 2005; Supnithadnaporn & Jung, 2007).

Public research has the potential to play a fundamental role in the development of the food industry's knowledge base in Ireland (reviewed by Henchion *et al*, 2008). External research providers, such as publicly funded food centres (Teagasc or Science Foundation Ireland [SFI]) and third level institutions (TLIs), can have an influential role in addressing challenges by providing the knowledge and supports required to innovate (Batterick, 2009). In a survey published in 2008, about 20% of Irish public researchers reported interaction with the food industry (Henchion *et al*, 2008), spanning technology transfer, collaborative research, access to facilities, contract research and commercial services. Two significant barriers to technology transfer identified in this study related to the human capital of both the researcher and industry personnel in terms of networking, communication and technical skills, rather than structural problems with the system. The results of this study found that food technology was transferred, not through classical mechanisms of arms-length marketing between academic labs and private companies in a linear fashion, but rather *via* personal relationships among individuals in a non-linear model, and confirmed the findings of Harmon and colleagues (1997). This points to the need for an emphasis on the inter-dependency between technology, people management and information flows (Mitra and Formica, 1997).

An anticipated post-COVID 19 recession, exacerbated by Brexit, are further challenges facing Ireland, but there is also the continuing dichotomy of reconciling the supports needed for the indigenous agri-food economy with those required for firms set up under foreign direct investment (largely pharmaceutical, information technology and online services). Indeed, the atypical nature of the Irish technologically advanced economy, based on foreign direct investment in these areas rather than indigenous development, was highlighted by Geoghegan and Pontikakis (2008), and there is a strong argument for further investigation of the long-term effect of such a trajectory on future national economic progress.

Research funding in Ireland for food innovation

A detailed review of the evolution of government funded research in Ireland is beyond the scope of this current article, but most national governments have identified research priority areas and the perceived infrastructure necessary to achieve success in the field. For example, evolving through various incarnations over the past 30 years, the research prioritization initiative of the Irish government in 2012 (Department of Jobs, Enterprise and innovation [DJEI], 2018) originally identified 14 areas for investment (Table 1).

Table 1. Research priorities for Irish national development (DBEI, 2017)

Technology theme	National Priority Area
Information & Communication technology (ICT)	A. Future Networks and Communications
	B. Data Analytics, Management, Security and Privacy
	C. Digital Platforms, Content and Applications
	D. Connected Health and Independent Living
Health and Wellbeing	E. Medical Devices
	F. Diagnostics
	G. Therapeutics – Synthesis, Formulation, Processing and Drug Delivery
Food	H. Food for Health
	I. Sustainable Food Production and Processing
Energy Climate Action and Sustainability	J. Marine Renewable Energy
	K. Smart Grids and Smart Cities
Manufacturing and Materials	L. Manufacturing Competitiveness
	M. Processing Technologies and Novel Materials
Service and Business Processes	N. Innovation in Services and Business Processes

Within a specific food context, it is noteworthy that health and sustainability are identified as the priority areas for research, rather than new product development that builds on existing strengths of primary production and food processing.

Over the years, there have been signs of sub-optimal engagement of the food industry with academic research providers, implying a mismatch between government priorities and the needs of Irish food companies. For example, while an approximate eight-fold increase in higher education research and development expenditure was witnessed between 1990–2005 (from €70.5m in 1990 to €600.6m in 2006), most of this growth was due to increased government funding, with the relative contributions of industry diminishing over this time (OECD, 2012). National funding to support food research in these areas is disbursed by a variety of government support agencies, including Enterprise Ireland [EI], Department of Agriculture, Food and the Marine (DAFM) and Science Foundation Ireland, and this is complemented by researchers competing for European funding via Horizon 2020 and the

European Research Council. Many of these schemes require co-investment by industry actors. However, most Irish food and beverage companies spend less than 3% on research and development (R&D). Indeed, many spend less than 1% (Deloitte Ireland, 2021), and European Innovation Scoreboard data indicates that Ireland rates low in private co-funding of public R&D expenditure (KTI, 2019).

Science Foundation Ireland (SFI) is a national foundation for high level investment in oriented basic and applied research in the areas of science, technology, engineering, and mathematics (STEM) to assist the development and competitiveness of industry, enterprise, and employment in Ireland. SFI accounted for 23.4 percent (equivalent to €173.3m) of total government R&D spending in 2017 (Keogh and Hickey, 2019).

Within a national context, perhaps the apotheosis of government investment in third level technology has been the SFI Centres for Science Engineering and Technology (CSET) (Table 2), which largely mirror the national priority themes, and are dominated by non-food research.

Table 2. SFI Centres for Science Engineering and Technology

Name	**Research**	**Est.**	**Website**
ADAPT	Centre for Digital Content Technology	2014	https://www.adaptcentre.ie
AMBER	Advanced Materials and Bio-engineering Research	2013	http://www.ambercentre.ie
APC	Microbiome Institute	2013	http://apc.ucc.ie/
BEACON	Bioeconomy	2017	http://www.beaconcentre.ie//
CONFIRM	Smart Manufacturing	2017	https://confirm.ie/
CONNECT	Centre for Future Networks and Communications	2014	http://www.connectcentre.ie
CÚRAM	Centre for Research in Medical Devices	2014	http://www.curamdevices.ie
FutureNeuro	Neurological Diseases	2017	http://www.futureneurocentre.ie
iCRAG	Irish Centre for Research in Applied Geosciences	2014	http://www.icrag-centre.org
I-Form	Advanced Manufacturing	2017	http://www.i-form.ie/
INFANT	Irish Centre for Fetal and Neonatal Translational Research	2013	http://www.infantcentre.ie
Insight	Data Analytics	2013	http://www.insight-centre.org
IPIC	Irish Photonic Integration Centre	2013	http://www.ipic.ie
Lero	The Irish Software Research Centre	2014	http://www.lero.ie
MaREI	Marine and Renewable Energy Ireland	2013	http://www.marei.ie

SSPC	Pharmaceuticals	2013	http://sspc.ie/
Vistamilk	Dairy Production Chain	2017	http://vistamilk.ie/

Notwithstanding this, in terms of quality of scientific research emanating from SFI-funded projects, Ireland reportedly ranks first in the world in animal and dairy, and second in agricultural sciences (Keogh and Hickey, 2019). However, it was also noted that the challenge for SFI is to establish 'data collection and analytical techniques to seek to establish a more direct link to the longer-term economic impact of their work'. The dominance of patent grants and applications is evident in this analysis, while mention of other instruments of IP protection, such as trademarks or design rights, is absent. As of 2017, the commercial outputs of SFI grants were below target (Table 3), which was partly attributed to 'data limitations' (Keogh and Hickey, 2019). Additionally, it is not possible to tell which proportion of these results relate to the food sector. SFI have committed to working with Enterprise Ireland (EI) to better track the progress of SFI funded intellectual property.

Table 3: Commercial outputs associated with SFI grants, 2013 – 2017
(adapted from Keogh and Hickey, 2019).

		2013	**2014**	**2015**	**2016**	**2017**	**Total**
Commercial Outputs	Licensed Technology	28	19	19	45	27	**138**
	Patents Awarded	12	20	29	9	23	**93**
	Patents Filed and Pending	57	43	47	67	53	**267**
	Spin-Out Companies	4	1	3	4	6	**18**

This overall trend was reflected in the DAFM report of 2015, which contextualized food innovation in terms of market-led criteria: 'At present, while Irish research institutes are rated well in terms of delivery of scientific research, the translation of this research to market solutions is not maximising commercial returns'. This report also highlighted the lack of scale in many Irish food concerns which prevents their ability to deliver in-house innovation, or to absorb the high-quality research developed by research institutes: 'A more collaborative approach between industry and science must be adopted both on agenda setting and delivery of outputs respecting both industry craft and academic know-how.'

The situation in Ireland contrasts somewhat with that in the UK. Research commissioned by the Food and Drink Federation (FDF) in 2018 (Stott, 2019) to identify both the opportunities available to manufacturers, and the barriers to growth, found that about 89% of food and drink manufacturers in the UK were involved in new product development, and that nearly half (46%) of respondents have an on-going collaboration with higher education or research initiatives.

Innovation: a question of definition?

In setting the research funding agenda, government policy documents are riven with the term 'innovation', and technology transfer will normally involve innovation to some degree (Wynn, 2020). However, there are subtle differences in the definitions of innovation (reviewed in Edison *et al*, 2014), and largely unacknowledged subjectivity is evident in this area.

Baragheh and colleagues (2009) defined innovation as "the multi-stage process whereby organizations transform ideas into new/improved products, service or processes, in order to advance, compete and differentiate themselves successfully in their marketplace". Similarly, Urabe (1988) defined it as "the generation of a new idea and its implementation into a new product, process or service", largely agreeing with that of Popadiuk and Choo (2006) ("innovation consists of new ideas that have been transformed or implemented as products, processes or services, generating value for the firm"). It must be noted that such definitions are laudably quite broad, but still fail to explicitly acknowledge aspects such as marketing or organizational innovation which are common in the food sector and integral to technology development. However, from many years of dealing with grant application schemes (both submission and evaluation) administered via the major research funders in Ireland, the authors note the pre-eminence of the patent as the desirable stated end-goal of research outputs (usually side-lining other protection mechanisms). Indeed, over the past twenty years, Ireland has been successful in heightening the awareness of academic staff to the merits of patenting, but there is less of an appreciation of the role of instruments such as trademarks or design rights, which are more widely used by the food industry (in addition to marketing and manufacturing innovation to enable rapid penetration of a target market).

Technology transfer between universities and industry: an insight into the challenge

Here we define 'technology transfer as the series of measures necessary to progress technology through the exploitation chain with a view to generating wealth. While this all-encompassing definition includes intra- and inter-organization cooperation, in this article we refer specifically to the transfer of innovation from third level institutions to companies, and exclude knowledge transfer unless it generates income for the university. Consensus models for technology transfer identify the main actors in the process as the university (as an emitter), the industry (as a receiver), and the transferred technology as the message (for example, Mayer and Blass, 2002), with the university Technology Transfer Office (TTO) often cast in the role of translator of the message between academia and industry (Arenas and Gonzalez, 2018). Largely achieved through technology licensing and contract research, this is generally agreed to be a challenging process, influenced by such inter-related factors as the availability of commercially relevant research, scientific and technical human capital (and behaviour), availability of funding for research and development, organization motivation-mission and socio-political factors. The challenges in the transfer of the results of publicly funded research to industry have been well documented (Markman *et al*, 1999; Geuna and Nesta, 2003; Rubenstein, 2003).

Even in a capitalist, free-market economy, the process of technology transfer is challenging (Geoghegan and Pontikakis, 2008. In the US, the reported average time from invention disclosure to licence is 4 years (Steven, 2017) with even the highest performing technology transfer programmes licensing only 20-25% of the disclosures they receive. At the same time, US universities will typically try to patent 60% of received disclosures (Steven, 2017). About 12% of university patents are transferred to the private sector by licensing to start-up companies (Di Gregorio and Scott, 2003). Out of all inventions generated at the University of California, 20% were linked to at least one licence, and nearly 25% were eventually patented (Wright *et al*, 2014). Of relevance to the prospective commercial partner, only an estimated 3% of disclosures finally result in marketed products (Steven, 2017), representing an interesting benchmark for EU states and cash-strapped universities.

Such statistics must be contextualized against the investment in research and associated activities. Studt (2004) highlighted that only a small portion of US universities allocate sufficient funding to generate a reasonable return on their technology transfer activities. The Association of University Technology Managers (2014) reported that universities in the US spent $65.1 billion on research and development (R&D) in 2013 (an increase of 2.3% on the previous year). During this time the innovations created yielded a total of 43,295 licenses and options, but only 7% of the US universities' R&D budgets originated from sponsored research.

In the absence of comparative data for the 'united states of Europe', it is difficult to assess the success of European counterparts in the technology transfer challenge. The Expert Group of the European Commission has begun the process of compiling a European-wide set of harmonized indicators for knowledge transfer (Campbell *et al*, 2020). In reviewing the data from the 2019 European Association of Knowledge Transfer Professionals (ASTP) survey, the Expert group noted a number of limitations, including inconsistency of definitions and data collected, combined with incomplete data (Campbell *et al*, 2020).

Until relatively recently, comprehensive statistics on the efficacy of technology transfer in Ireland between third level institutions and industry were unavailable. This has changed radically with the formation of Knowledge Transfer Ireland (KTI) which was established in 2013 as a partnership between Enterprise Ireland and the Irish University Association (KTI, 2021). The overall remit of this organization is to establish best practice for technology transfer at the intersection of the university and industry. The KTI Annual Knowledge Transfer

Survey offers an invaluable insight into this process, providing indicators of overall performance. For example, in 2019 alone there were 137 new patent applications, 26 spin-out companies, and 14% of the research provider organization budget was dependent on industry collaboration (KTI, 2019). However, these surveys have thus far not provided a breakdown of deals specifically involving the food industry.

One may safely conjecture a few assumptions through which the effectiveness of technology transfer between TLIs and industry can be viewed. Firstly, one must be prepared not only to invest heavily in university research, but also in the resources available to catalyse technology transfer from universities to industry. Secondly, there is a high attrition rate in moving technology across the university-industry interface, and this points to the need for the continual identification of new measures to track and aid success in this regard. Finally, related to the measures to aid in technology transfer, questions must be asked about the factors influencing the receptivity of companies to university research, and whether a sector-specific approach is needed in this task

Current consensus model for technology transfer

The range of available technology transfer models has been reviewed by Arenas and Gonzalez (2018). The main actors in the technology transfer equation are academic researchers, university administrators (technology transfer offices, but also other functions of the university spanning finance and legal services) and industry personnel (Siegel and Phan, 2005). Among the nuances of each technology transfer model, which can be complex (Bozeman, 2000), lies the challenge of reconciling the commercial role of the technology transfer office with the needs of the academic researcher (Sætre *et al*, 2009). There is an inherent mismatch between the research orientations of firms and universities, with an excessive focus on fast commercial results in firms, and on basic research in universities. (Howells *et al*, 1998; OECD, 2012).

In all analyses of the sector, teaching as the primary raison d'être of a university must be recognised (Hughes and Kitson, 2012). Additionally, it should also be noted that researchers do not necessarily need to use technology transfer offices to engage in technology transfer. In some cases, they have direct contact with industry (Nilsson *et al*, 2010), while conversely, such links may extend to the development of technology which may not be patentable (Perez *et al*, 2011). The general role in promoting co-operation, supporting agents with recruitment that allows a correct technology transfer process, carrying out monitoring and cultural activities, and seeking the good of society with the development of technologies, are all additional activities for TTOs (Perez *et al*, 2011).

Studying activities between institutions to arrive at a best practice model for technology transfer is difficult, and arguably too few studies have acknowledged the inter-disciplinary nature of the activity. Challenges include the difficulty of comparing universities due to lack of detailed information (Rybnicek and Konigsgruber, 2019), small data sets (Wright *et al*, 2014) and lack of access to contracts which are confidential (Chais *et al*, 2018).

In the experience of the authors, technology transfer personnel often learn their craft organically, and frequently move to the university technology transfer office with 'chalk face' experience gained from industry. There then follows a period of re-equilibration as staff become familiar with the policies of the host university, and in turn, they may influence future formulation of these policies. While notable exceptions exist, the general dearth of commercial management skills among many academics has been noted (Arenas and Gonzalez, 2018), and TTO staff are often called upon to supplement any deficiencies in this regard. Increasingly, TTO staff with a scientific background are adding to their qualifications via business degrees.

A generalized linear model for technology transfer described by Tahvanainen and Hermans (2008) is illustrative of the general approach. The main steps involve catalysing an initial interaction with a target company, followed by negotiation (Table 4). It should be acknowledged that this model needs to be modified according to specific situations.

Table 4. Steps involved in technology transfer between university and company

Marketing of innovation to pool of potential collaborating companies

- Preparation of non-confidential summary & ancillary marketing literature
  - Establish understanding of market worth of technology
- Marketing of innovation via personal contacts, active (mail-shot, conferences) and passive (website) methods
  - Refine value offering based on initial feedback

Initial contact with potential collaborating company

- Send non-confidential summary to company and mutual non-disclosure agreement for signature (one-way or two-way to be decided based on specific situation)
- Meeting and presentation to potential collaborator: conduct mutual needs assessment and refine technology value proposition based on discussion
- Decision on future interaction: technology evaluation, option-license, collaboration (along with consideration of available grant funding) or terminate discussion (establish timeline for decision point)
  - Evaluation of technology component under materials Transfer Agreement, if required

Negotiation of agreement type governing interaction

Ireland's framework for research commercialisation is encapsulated in the National IP Protocol, established in 2019 (DBEI, 2019). It suggests best practice guidance on the expected norms for research-related engagements between industry and Ireland's research performing organisations (RPOs), including formation of spin-out companies from such research. Researchers are not obligated to disclose their inventions to the university, but there are incentives to commercialisation as indicated in the university IP policy (TU Dublin, 2020). For example, there is a defined process for agreeing to patent an innovation, which requires the completion of an invention disclosure form, along with the assignment of the IP to the university. If the technology has an inventive step and is novel, and also possesses industrial application, then it is sent to a patent attorney for review.

While the role of mass media in assisting technology diffusion is irrefutable (Bray and Lee, 2000; Rogers *et al*, 2001), diffusion theory also highlights the importance of enlisting influential thought leaders to this task. The difference between these mechanisms is that media can disseminate ideas to a greater number of people in a short time, whereas leaders facilitate an understanding of the innovation, and can build confidence through persuasive arguments.

International studies indicate that the success of technology transfer is highly context-dependent: policies and instruments differ among institutions and also vary according to size, structure, and absorptive capacity of the economic system (reviewed by Geoghegan and Pontikakis, 2008). Some have warned against processes focused on short-term revenue maximisation which can clash with secondary system elements, with concomitant adverse impacts on technology commercialisation outcomes (Hallam *et al*, 2014). Others have criticized the 'traditional' linear model of technology transfer which places too much emphasis on patents and licensing revenue, while disregarding the impact of technology transfer reputation (Bradley *et al*, 2013), contrasting with a bi-directional information exchange model.

Non-linear models of technology transfer are receiving increased interest as a means of bridging the university-industry divide, and within the context of this article, a major focus involves the identification of strategies to more productively engage with food firms. Reflecting on limited published data, and from the previous chalk-face experience of the authors, a relatively high number of Irish-based food SMEs do not engage in technical R&D. Among those that do, a significant proportion are unsuccessful in this pursuit. In an economic climate of constrained resources and development timeframe pressures, replacing or adding further products and services to a company portfolio is a significant challenge. Increasing the level of support interaction between the university and an SME, outside of the traditional, short timescale, arms-length approach, may provide a means of encouraging companies to engage. A primary way of doing this is to extend the excellent information acquisition capabilities of the university to the company, addressing information asymmetry via joint technology and market assessment, and deploying a stage-gated approach based on reciprocity to assess progress. University technology transfer offices, such as TU Dublin Hothouse, have a high degree of proficiency with online database searching (especially patents and market data). This shared knowledge model would have great value in relationship building. Confidence generation through such measures may also permit the team to pursue technology development by building on ideas already in the market place, thereby creating a faster and cheaper route to the market with something already proven elsewhere (Fegan, 2016).

Reconciling industry and university TTO perspectives on the technology transfer process

Unlike universities, industry has the key objective of profitability, and therefore seeks new technologies with the potential to deliver on this goal (Brennan and Turnbull, 2002). In this way, industry will always look for technologies that add tangible value, and tend to view the university–industry collaboration exclusively within this context (Fialho and Alberton de Lima, 2001).

Information asymmetry and differences in institutional motivation are critical challenges to be analysed and reconciled. In terms of specific outputs, firms are usually interested in how quickly new patents or new products can be obtained, and understandably want to delay academic research publications in order to avoid disclosing information. University researchers, in contrast, are typically motivated to publish research results quickly. Industry is concerned about secrecy and misalignment of expectations with regard to IP rights, being guided exclusively by the need to derive a profit from their investment. Thus, agreements need to be established in a commercially timely manner that ensures the ability to commercialise with appropriate returns.

Within this context, it is useful to consider the contrasting perspectives underpinning the interaction of food companies and third level institutions. It is important to discriminate between types of companies in this question, essentially based on scale of operation (SME and multi-national) and consequent available resources. Technology transfer staff are often initially placed in the role of matchmaker, being the initial point for contact with a company that not only wishes to access specific expertise within a university, but is also seeking a recommendation for a researcher with sensitivity to the commercial perspective. TTO staff can be compromised in this role unless objective protocols are in place. A clash of cultures is evident in many cases, with the divide between basic and applied research approaches in the university vying with the need for appreciation of rapid timelines and tangible milestones of the food company, which are often at odds with the academic environment (Rahmany *et al*. 2013). Across the spectrum of research collaborators, resource-strapped food companies can be a demanding partner.

In the experience of the authors, a decision of a food company to proceed with a university collaboration will be prefaced by a consideration of the market feasibility of the early-stage innovation, with a cost-benefit analysis and IP ownership rights to the fore. Regarding the latter, a commonly seen desire is for the company to have full ownership of the technology. The ‘time-to-market’ of the technology is another poorly appreciated concept, as is the integration of the technology which emanates from the collaboration into the business strategy of the company. The challenge in overcoming such information asymmetry is formidable, but one mechanism of risk limitation and confidence building is provided by grant support for small scale pilot projects, such as an Enterprise Ireland Technical Feasibility project grant, which funds the project at no cost to industry to allow the researcher to journey-plan the project.

Building a relationship between TTO staff and a potential commercial collaborator is an aspect which has received relatively little attention in the literature. Licensing a university technology to a commercial partner is a common occurrence that encapsulates many of the typical challenges in this process. The efficacy of technology transfer is influenced by market pull/push, development of a sustainable personal relationship between licensor and licensee to facilitate tacit knowledge transfer, the capacity to successfully assimilate and exploit technology (absorptive capacity), and geographical proximity (Lee, 2012). Following license, the need for structures to transfer know-how and tacit information between university and licensee has been acknowledged (Alavi, 2016).

Relationship capital in the technology transfer equation includes all external links with customers, suppliers, and the organization's collaboration networks (Edvinsson and Malone 1997; Sveiby 1997; Stewart 1998). In the context of a TTO, this translates into potential licensees (industry and start-ups), faculty inventors, and collaboration with other parties important to the process of technology transfer.

Human capital is defined as an individual's knowledge, experience, capabilities, skills, creativity and innovativeness (Edvinsson and Malone 1997); these aspects are all connected and contribute to success at work. Investment in TTO staff is crucial (Sveiby and Lloyd, 1987), but a common attribute of TTO offices is the ubiquity of short term contracts among the staff, resulting in discontinuity of relationships with commercial partners and potential damage to relationship capital. The performance of TTO staff may also suffer, with ramifications for "employee confidence" (Sveiby, 1997) and consequently adverse impact on performance in the role (Albert and Bradley, 1997).

Resource deficits regarding in-house capabilities of technology transfer offices may be supplemented as required by consultant services. Many consultants are connected to a multi-disciplinary team of associate consultants with broad technical, industrial, management and marketing expertise (Table 5). However, it is important to note that such interactions cannot substitute for a strong in-house and integrated capacity in this aspect.

Table 5. Consultant services that may be beneficial for TTOs

Advice on sourcing research funding: especially relevant to EU programmes such as Horizon 2020
Facilitation, networking and brokerage
Identifying prospective licensees/development partners and securing partnerships
Accessing a wide network of technology and commercialisation experts
Conducting technology valuation and market analysis
Elucidation of product development pathways
Conducting state-of-the-art reviews of technology
Delegation and advice on project management

Collaborative R&D programmes with universities and SMEs

Developing product development roadmaps

Conducting IP Audits of pre- and post-patent portfolios.

Towards possible solutions for more efficient food technology transfer from TLIs to industry

According to Moshonsky and colleagues (2014), "academic knowledge is only relevant to industry if it motivates practitioners to take action inspired by its content", and this is very relevant to the business model of food SMEs and perceptions of university intellectual property.

A major jobs provider for economies all over the world, the food industry is characterized by relatively low entry level criteria for business start-ups, a receptive marketplace for consumer-orientated products, and a light regulatory touch (relative to sectors such as the pharmaceutical industry). Countering this, competition is intense, margins can be low and marketing campaigns must be responsive to fast changing consumer trends.

However, it is in the area of new product development and government support where the food sector is arguably at a significant disadvantage. Paucity of financial resources and limitations in technological capability represent barriers to any SME in adopting new technologies (Guzzini and Iacobucci, 2017).

Previous studies have identified skills gaps in the technology transfer process among researchers (Henchion *et al*, 2008), and called for education in this area via graduate training, and also the strategic training of personnel in companies and technology transfer offices (Siegel and Phan, 2005). Other issues relate to reward systems in universities that are inconsistent with greater entrepreneurial activity.

At the moment, protection of intellectual property in TTOs inevitably dwells on patents (Bradley *et al*, 2013), and this viewpoint is also present in research support agencies. This conflicts with new product development based on incremental innovation strategies, which is characteristic of many food SMEs. Indeed, the pre-eminence of patents as a tool for protecting IP is still common in the literature. For example, Arenas and Gonzalez (2018) in a wide ranging review of the instruments of technology transfer focused on aspects such as patents, publications and presentations, but did not mention trademarks or design rights. Indeed, others have written that the latter merely represented a fall-back position to reclaim some value in the situation where a patent was unobtainable (Chais *et al*, 2018). The relevance of trademarks and design rights to the food sector needs to be acknowledged by development agencies and suitable support instruments enacted to address this deficit. For the food sector, technological and marketing innovation are inseparable, and this integrated view represents an advantage in the marketplace. This observation implies that invention disclosures, not patents as such, are the critical input in university technology transfer when it comes to food innovation. Additionally, although patents on university technologies nominally disclose those inventions, a significant amount of knowledge related to practicing and commercializing these technologies remains tacit or uncodified, residing in the mind of the faculty inventor (Lee, 2019)

In Ireland, the disparity in the suitability of different IP tools is exacerbated by the presence of a strong pharmaceutical and medical device manufacturing sector, which deals in radical technologies that are eminently suitable for patenting. A lack of recognition of other 'creative' IP protection mechanisms (trademarks, design rights, domain names), combined with varying definitions of the term, 'innovation', represents a significant hurdle facing the food industry in dealing with grant agencies. Here, the discrimination between radical and incremental innovation is important. While the former suggests a major technological development that can only be developed over time, the latter refers the application of a new technology to deliver organisational benefits over a shorter time scale (delivered within a 6-24 month period) (Wynn, 2020).

The aspect of varying perceptions of the word, 'innovation', may also extend to the perception of the activities of a technology transfer office (TTO) among potential company partners. Re-branding of the TTO office to an 'office for technology commercialization' or 'industry engagement' might make the outreach message more explicit for the food sector, while also implying a two-way dialogue between prospective partners. This process which has already begun in some US universities (Bradley *et al*, 2013).

Poor margins on many food products, compared to the pharmaceutical sector, may result in universities cherry-picking which life science innovation is progressed to market. Such 'homerun' technologies (Litan *et al*, 2007), which promise high returns within a short amount of time, are usually licensed or sold to high technology industries (Lerner, 2005). However, the prospect of 'selling' in the shorter term, combined with more ready market access, means that food innovation can be a much better bet for a university technology portfolio. To prevent the possibility of any such preferential treatment of technologies, there needs to be a discrimination between academic engagement (knowledge-based collaboration by academic researchers with non-academic organisations – consultancy, contract research, networking) and licensing. Some companies have been reported to consider it significantly more valuable than licensing university patents (Cohen *et al*, 2002), while university income from academic engagement can be significantly greater than the income derived from intellectual property (Perkmann *et al*, 2011). A broader-based approach in compiling metrics for European 'knowledge transfer' is evident in the latest Expert Report from the European Commission (Campbell *et al*, 2020).

The food industry is characterized by fast evolving advertising strategies, with a keen awareness of end-user preferences (product attributes, price), seasonality and fashion trends. Tried-and-tested approaches include re-branding (including glamorisation) of products to appeal to new customers; examples include seacuterie, superfoods (*e.g.*, cannabidiol), veganism, flexitarianism, snacks-on–the-run, sugar-free products (and sugar substitutes), hard hydration and reduction of food waste (extending to imperfect produce).

However, marketing innovation, underpinned by peer-reviewed scientific fact, is a potent discriminator in advertising food innovation. Probiotic dairy products and cholesterol-reducing spreads are two examples of this approach, but the integration of basic food science with evolving medical and environmental advantages is best illustrated by the approach taken by Marlow Foods to market the meat replacement product, Quorn. A sixties child born out of a projected need to address a forecast of protein shortages in the seventies (which never came to pass), Quorn is the only single cell protein approved for human consumption and is comprised of the fungus, *Fusarium venenatum* (Wiebe, 2004). While formatted to have a similar mouthfeel to meat, Quorn's eventual market launch in the 1980's coincided with a wave of interest in vegetarianism, and so was well placed for market re-positioning to take advantage of this trend. The nineties heralded yet another opportunity for market penetration in the form of prion disease of cows; a link was discovered between bovine spongiform encephalopathy and a variant of the fatal Creutzfeldt-Jakob disease, which badly damaged the meat market. As the twenty first century dawned, a greater level of health awareness and recognition of the role of animal fats in heart disease led Marlow Foods to use the low cholesterol-high fibre nature of Quorn to marketing advantage (with high profile endorsees). Currently, in response to climate change awareness, the Quorn production process is justifiably marketed for its low environmental footprint relative to beef production.

Conclusion

The focus of technology transfer professionals understandably remains the identification of 'the right way to do it', but usually involves a one-size-fits-all approach in the quest to unlock the secret of rapid technology uptake by industry (Hallam *et al*, 2014; Arenas and Gonzalez, 2018). However, in this article we have called for a re-assessment of such an approach, and proposed specific mechanisms to improve the success of transferring technology from third level institutions to the food industry. At the policy level, such an approach will require measures such as a widening of the definition of innovation, a recognition of the utility of a wider variety of IP protection mechanisms, a specific consideration of marketing and organizational innovation, and the development of education programmes to support actors in addressing information asymmetry. Research grant-aid must be tailored to support such needs. Within TTO offices, human resources must be expanded to include discipline specialists who possess a keen awareness of the capabilities of food-based SMEs, and are capable of developing sustainable relationships. This may also involve a re-branding of such offices to market the relevance to all potential commercial partners. Policies need to be developed to ensure fair allocation of commercialization resources across the span of university research strengths. The latter will require a re-design of output metrics for TTOs, complementing short-term revenue generation strategies with a more sustainable longer-term approach that permits non-linear technology transfer routines. TLIs must rise to the challenge of supporting food companies in their quest for scale, sustainability and international competitiveness.

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