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From ivory tower to factory floor? How universities are changing to meet the needs of industry

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While policy recognises the need to facilitate university–industry technology transfer (UITT), international studies indicate that the setup and effectiveness of the associated instruments is highly context-specific. We examine the reorientation of Irish universities in the direction of facilitating UITT, with a substantive focus on the role of Ireland's technology transfer offices. This paper also questions how academic research is changing in line with policy rhetoric. We find that Irish university research and the management of its output are changing in a manner that is not incompatible with UITT, although with significant resource and skills constraints. These findings hold important lessons for national economic and innovation systems of comparable size, with a development trajectory shaped by foreign direct investment.

Policy makers in Ireland[1] have placed a marked emphasis on matters of innovation and view universities[2] as a key node in the Irish national innovation system (Forfás, 2004a). Yet with the exception of skill provision, the specific ways with which the capabilities of universities may be harnessed have entered the debate relatively recently (Forfás, 2007b).

We examine the changing face of Irish universities, placing particular attention on the recent evolution of technology transfer offices (TTOs). Although the present work is an exploratory analysis of selected university–industry technology transfer (UITT) issues, it attempts to fill an important gap in the literature complementing the generalised observations of Cunningham and Harney (2006) with empirical insights from individual universities.

Ireland, a small, open and rapidly growing economy, is a special case in that it possesses a technologically advanced economic system which, however, owes more to foreign direct investment than indigenous development. In that sense the broad innovation policy drive (and UITT) has an *ex post* 'afterthought' character, intended to sustain (rather than induce) the atypical Irish development model. Therefore, the insights provided here hold interest for the *ex nihilo* development of knowledge-transfer policies in similar environments, particularly in the new EU member states.

We find that both the scale and direction of research in Irish universities are changing in a manner that is not incompatible with UITT, although with significant resource and skills constraints.

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This paper is structured as follows: we begin by outlining the theoretical framework underpinning our conceptualisation of the processes and actors at play. We then introduce the Irish-specific environment for UITT before continuing with an analysis of UITT-related changes in Irish universities. The first part of our exploratory analysis presents an overview of this process of change as reflected in quantitative indicators of university-based research. The second part examines recent changes from the point of view of managers at Irish TTOs.

Theoretical rationale

Universities have historically played an important role in developed economic systems, not least as major providers of specialised skills. In addition (where the conditions permitted this to happen) universities have traditionally been instrumental in pushing further the boundaries of scientific knowledge. The role of universities in the translation of scientific knowledge into technology-relevant insights is much more ubiquitous than that suggested by the highly visible new-to-the-world innovations of a few leading institutions. Specifically, the capacity of universities to act as local agents and diffuse tacit knowledge to diverse geographic, sectoral and institutional contexts is of crucial importance (Florida and Cohen, 1999). Traditionally, universities have, for the most part, acted as passive repositories of scientific know-how, to be queried upon demand.

The recognition of the role of universities as engines of knowledge creation and diffusion has rationalised calls to expand their mission beyond traditional remits (Etzkowitz, 2003; Etzkowitz and Leydesdorff, 1997). Etzkowitz and Leydesdorff (1997) observe that the most effective innovation systems involve interactive communication and collaboration between a 'triple-helix' of institutional actors coming from government, industry and academia. The inherent advantage of triple helix arrangements lies with the fact that they make innovation systems more adaptive and better able to respond to successive technological revolutions. The triple helix is employed in this paper due to the heightened importance given to the university.

The 'triple helix' thesis specifically emphasises the three institutional spheres of university, industry and government and that the relational configuration of these three spheres forms the key to innovation (Etzkowitz and Leydesdorff, 1997). It is based on a spiral model of innovation, which allows all three institutional domains to interact with each other. The triple helix is, however, "more complex than the mutual interactions between the 'double helices' upon which it rests" (Leydesdorff, 2000) and is comprised of various linkages that take place at numerous parts of the innovation process. It can be characterised by this 'spiralling' of the three spheres, which are seen to be increasingly involved in each other's activities.

This analytical model has obvious prescriptive applications: organic university–industry–government arrangements that characterise leading innovation systems may be consciously encouraged elsewhere by replicating the conditions that gave rise to them in the first place. Universities in particular, are increasingly urged to become more 'entrepreneurial' (Etzkowitz, 2003), by collaborating more closely with industry (in research as well as training) and more broadly by adopting a corporate ethos. The 'new' economic role of academia has been documented in numerous studies (Etzkowitz and Leydesdorff, 1997; Bozeman, 2000; Siegel *et al*., 2003a; Santoro and Chakrabarti, 2002; Jones-Evans and Klofsten, 1999).

As a result of this 'new' role of academia many governments are beginning to rethink their science and technology (S&T) policies. The following section (on the Irish-specific environment for UITT) outlines the various initiatives and policies that the Irish government have pursued to increase the role of academia in the innovation process. In line with this reorientation with regard to the role of the university, the first theme that this paper seeks to examine is the extent to which the various facets of academic research are changing in a manner that agrees with the policy rhetoric.

The second main theme of the paper involves looking at the more nuanced changes that have taken place in TTOs in order to facilitate more effective UITT. In recent years 'tech transfer is growing in industry to accelerate product development, in academia to support research efforts, and in government to commercialize technologies' (Studt, 2004). It is increasinly seen as a new method to bridge the gap between the realm of academia and what is thought of as basic research and the sphere of industry and applied research. We understand the UITT process as: 'the transfer of the results of research from

universities to the commercial sector' (Carlsson and Fridh, 2002) and examine it from the point of view of the university. This paper builds on the work of Cunningham and Harney (2006) who emphasised that those nations with strong research systems and the capacity to leverage the commercial opportunities of their research will be best placed to prosper both economically and socially. These are observations that carry particular force in an Irish context where public policy has recently focused on enabling criteria to facilitate this development (Cunningham and Harney, 2006). Similar contextual studies have also attempted to shed light on how policy makers have attempted to stimulate technology transfer from university to industry e.g. Jasinski (2000) and Collins and Wakoh (2000) look at the cases of Poland and Japan, respectively.

Calls for closer industry–university interaction have resonated strongly with policy makers in Ireland (Forfás, 2004a, 2007a). The promotion of technology transfer activities at universities is but one manifestation of an on-going trend towards a greater participation of academia in the economy. However, the exact ways by which this is to be achieved in universities that have traditionally lacked formal linkages with industry are still unclear. International literature indicates that the UITT process is highly context-dependent, with the required policies and instruments differing by institution and also according to the size, structure, and absorptive capacity of the economic system it appeals to (Azagra-Caro *et al*., 2006; Lee and Win, 2004; Lee, 2000; Siegel *et al*., 2003a, b). Other international studies have shown that established traditions and informal procedures may jeopardise the effective introduction of formal UITT instruments such as TTOs (see Kneller (1999) for evidence from Japan). In considering technology transfer more broadly, the level of economic development and the specific intellectual property rights (IPR) regime are also crucial delineators (Correa, 1994; Kubielas and Yegorov, 2000). As in those cases, the specific institutional facilitators and bottlenecks prevalent in the Irish case can only be identified by way of detailed case study.

Ireland, due to its radical economic transformation in a relatively short period of time, makes for an interesting case study. This paper seeks to answer two important research questions: Are the various facets of academic research in Ireland changing in a manner that is in agreement with the policy rhetoric? What is the role of the TTOs in attempting to facilitate more effective UITT after a period of rapid change?

Irish-specific environment for UITT

Ireland's economy has undergone profound changes over the last couple of decades and is now frequently dubbed the 'Celtic Tiger'. This has drastically transformed some of the key players within the Irish national innovation system (Pontikakis *et al*., 2006).

Ireland, due to its radical economic transformation in a relatively short period of time, is an interesting case study on industry–university interaction and technology transfer

The government has reorganised its policy and funding priorities to coincide with the goal of becoming a 'knowledge economy' (Forfás, 2004b). With regard to funding, it launched the Programme for Research in the Third-Level Institutions (PRTLI) and Science Foundation Ireland (SFI) in 1998 to help build the innovative capacity and strengthen the performance of the higher education sector of the Irish economy. This involved a significant investment by the state to bolster the otherwise underdeveloped research capacity of the third-level sector. Especially important for encouraging university–industry linkages were the Centres for Science, Engineering and Technology (CSET), which have established seven world-class facilities for research throughout Ireland.[3]

The policy rhetoric has been consistent in its support for the promotion of innovation-intensive industry and linkages between industry and higher education. Several documents commissioned by the government have stressed the need for increased resources and the development of institutional structures in support of research, innovation and collaboration as conduits to global competitiveness. Examples of this change in national priorities have been expressed in numerous reports, such as *The National Development Plan* (1999), *Ahead of the Curve: Ireland's Place in the Global Economy* (Enterprise Strategy Group, 2004), *Building Ireland's Knowledge Economy – the Irish Action Plan for Promoting Investment in R&D to 2010* (Forfás, 2004a) and *Promoting Enterprise–Higher Education Relationships* (Forfás, 2007a). Mary Hanafin, TD, Minister for Education and Science expressed the sentiment concisely:

> Closer interaction between public knowledge institutions and enterprise is widely recognised as being increasingly important, as global competition forces companies to innovate more and strengthen core areas. Collaboration with knowledge institutions enables companies to gain access to new knowledge, specialist skills and the latest technologies. Higher education should, therefore, be underpinned by a coherent policy approach that includes the public and private sector. (Forfás, 2007a)

Irish industry is also beginning to change to reflect the increased openness of the Irish economy. During the period 1990–2000 the figure for inward direct investment from abroad for Ireland rose from 662.6 million to 25,783.3 million US dollars (OECD, 2004). This increased openness has forced companies operating in Ireland to become globally competitive and develop capabilities that allow for collaboration and cooperation between industry and cluster members (employing the Porterian (1990) definition which involves a geographic concentration of interconnected companies here). Companies are increasingly harnessing the technology and knowledge potential of the university to help cope with these global pressures (Geoghegan and Ryan, 2006).

Irish universities have for the most part embraced the new playing field that they operate in. The move to the entrepreneurial university and the enhanced third mission of the university (Etzkowitz *et al*., 2000) has provided a vision for many of Ireland's third-level institutions to redress the focus of their activities. In response, many have invested substantial amounts of money in enhancing services such as technology transfer through a wide array of commercialisation instruments. Contrasting this to the situation in 1998 the main role of industrial liaison officers then tended 'to be the promotion and marketing of university expertise, with little evidence of a proactive effort to work more closely with industry to widen the scope of the university's research results and to create new business and employment' (Jones-Evans, 1998).

Research methodology

This paper aims to examine the changing face of Irish universities, placing particular attention on the recent evolution of TTOs. A combination of primary and secondary research was carried out. The section on measures of realignment in Irish universities presents a number of quantitative indicators suggestive of how Irish universities have been transformed. Qualitative data, emanating mainly from personal interviews with TTO managers, is supplied to complement the general picture with insights from the day-to-day management of the UITT process.

Secondary research informed the qualitative aspects of the paper, such as the design of the interview schedule. A multicase design[4] was used, due to the exploratory nature of our research. We endeavoured to avoid validity and reliability errors through several mechanisms. External validity was achieved through the interviewing of the majority (five[5] of the seven Irish university TTOs were interviewed) of the TTO managers of Irish universities, combined with an extensive literature search for methodologies applicable to the topic in question (Lee and Win, 2004; Santoro and Chakrabarti, 2002; Siegel *et al*., 2003a) to assure that reliability and formal case study procedures were observed. The interviews were held in the period January–April 2007. They provide insights as to what these TTO managers believe to be the most important areas of change, as well as on their views regarding existing facilitators and problems. One potential limitation of our study was that we could not directly observe what had happened, or was happening, in the TTOs.

During 1990–2000 the figure for inward direct investment from abroad for Ireland rose from 662.6 million $US to 25,783.3 million $US

Measures of realignment in Irish universities

The recent economic growth experience coincided with a time of dramatic change in Irish universities. The last two decades have seen an upsurge in the scale of higher education activities, with consistent increases in student numbers, the creation of three new universities[6] and the elevation of the status of the institutes of technology. The Irish higher education sector also stands out internationally in terms of its sharp skew towards the volume production of technical graduates (Wickham and Boucher, 2004), a change in focus that was instituted during the same period.

Part of the numerous changes occurring in the higher education sector, and of particular interest to our study, is the substantial increase in resources devoted to research and development (R&D). There was an almost eight-fold increase in higher education research and development expenditure (HERD) during the period 1990–2005 (from €70.5m in 1990 to €600.6m in 2006 (OECD, 2007). In qualitative terms, most of this growth is due to increased government funding, with the relative[7] contributions of industry diminishing over time (OECD, 2007). Expenditure growth has been further boosted post-2002, as a result of additional expenditure from the Higher Education Authority (HEA) PRTLI and SFI (Forfás, 2004c).

For much of the 1990s a large share of this expenditure was devoted to the upgrading of infrastructures (capital costs and other non-pay (non-payroll) costs), with the focus shifting to human resources after 2000 (Forfás, 2004c). However, over the same period, the proportion of higher education researchers relative to the national total has decreased, the increases overshadowed by the substantial growth in researchers working for industry.

Moreover, the resources committed to R&D focused more on some disciplines than others. Table 1 outlines HERD by field of science over the period

Table 1. HERD by field of science, by year

Field of science*	1992 (€m)	1994 (€m)	1996 (€m)	1998 (€m)	2000 (€m)	2002 (€m)	Period increase (times)
Natural sciences	39.1	52.8	55.9	74.2	85.5	115.9	×4.1
Social sciences	22.3	26.8	36.8	49.5	60.4	53.6	×2.4
Engineering	9.0	12.7	13.0	16.8	19.1	51.6	×5.7
Humanities	2.6	2.9	5.4	6.1	4.4	7.9	×3
Medical sciences	11.2	16.0	27.7	38.7	47.6	60.7	×5.4
Agricultural sciences	8.5	9.8	14.3	18.3	21.1	32.6	×3.8
Total	92.7	121.1	153.1	203.7	238.1	322.3	×3.5

Note: * Scientific discipline classification as per OECD (2002)
Source: Forfás (2004c)

1992–2002. Overall, engineering, medical sciences and natural sciences are the largest beneficiaries of such funding. The focus on S&T disciplines is also apparent in terms of the relative numbers of researchers (Table 2), with natural sciences researchers accounting for 38% of all researchers in 2002.

Furthermore, there can be little doubt that increases in R&D resource commitments have resulted in improvements in the capacity of Irish universities to deliver scientific and technological advances. However, establishing the exact magnitude of these improvements, and whether they have been on a par with increases in resources deployed is problematic. Measuring scientific and technological outputs is a notoriously difficult task as innovations do not always leave a measurable trail and their propensity to register on official statistics varies greatly.[8] In addition, the R&D search process takes time, which means that there is invariably a considerable lag before any appreciable outputs materialise. Therefore it should be noted that any conclusions drawn on the basis of the (partial and in some cases provisional) measures that follow are tentative.

In terms of observable scientific outputs, the overall picture is one of considerable growth. Custom counts of publications in peer-reviewed S&T journals (excluding humanities and the social sciences) revealed near consistent year-on-year increases (summary of the series in Table 3). Not all universities are as prolific, with institutions based in Dublin accounting for over 50% of the total number of papers published in 2006. The relative numbers appear to be consistent with the idea that scientific productivity depends on the historical accumulation of resources (including knowledge), with older and larger institutions generally doing better. The rate of growth varied considerably over time, topping 68% in the period 1994–1998.

Publication counts also allow us a glimpse into the relative scientific specialisation of different institutions. Thomson Scientific's *ISI Science Citation Index Expanded* database assigns each published paper to one or more subject categories on the basis of its research topic. Although these subject categories only loosely correspond to broad fields of science (e.g. such as those employed in the OECD, 2002 Frascati Manual), they afford a rich level of detail, which should on the whole, reveal trends on scientific specialisation.

We can get a feel for the overall specialisation of each university and for how this has evolved over time by looking at how tightly publications are concentrated within specific subject categories. Table 4 reports the estimated number of equally sized subject categories, on the basis of relative publication counts per subject category; this is a noisy measure of how 'focused', (or conversely 'spread out') the scientific efforts of universities are within subdisciplines. To get an idea as to how this measure works consider the following example: whereas in 1990 TCD publications were spread out across the equivalent of approximately 21 equally sized subject categories, at the same time the RCSI (a medical college) publications were more tightly concentrated, on the equivalent of approximately five equally sized subject categories.

The calculations in Table 4 indicate a clear trend towards broadening out. Overall, Irish universities

Table 2. Researchers by scientific discipline in the higher education sector, 2002

	Natural sciences	Social sciences	Engineering	Humanities	Medical sciences	Agricultural sciences
Full-time equivalents	1076	618	488	354	217	44
%	38	22	17	13	8	2

Source: Forfás (2004c)

Table 3. S&T journal publications

Institution	1990	1994	1998	2002	2006
Trinity College Dublin (TCD)	251	359	415	529	795
University College Dublin	166	219	465	526	749
Dublin City University	43	80	132	123	243
University College Cork	118	117	363	472	693
National University of Ireland, Galway	116	172	231	253	378
National University of Ireland, Maynooth (NUIM)	46	47	75	73	141
University of Limerick	10	41	62	137	195
Royal College of Surgeons in Ireland (RCIS)	39	56	90	124	173
Total	**789**	**1091**	**1833**	**2237**	**3367**
Period growth		**38.3%**	**68%**	**22%**	**50.5%**

Source: Thomson Scientific, ISI Science Citation Index Expanded, custom queries performed by the authors (performed in April 2007 using search terms: article, letter, review)[9]

appear to be producing publications over a wider range of research areas now than they did a decade and a half ago. This indicates that, on the whole, Irish universities had a wider range of expertise available in 2006 than they did in 1990; a quality that may make them more attractive to industry, which is looking for specific types of university capabilities. NUIM and, to a lesser extent, TCD appear to be the exceptions to this trend, exhibiting only limited widening of scope during the period in question.

University patenting has been given priority in the strategic plans of Irish universities and could also cast some light on the presence (or otherwise) of a growing body of industrially relevant academic research. A non-exhaustive search of patent databases[10] performed by the present authors for the period 1990–2006 yielded only a handful of patents per institution per year (in most cases single-digit counts). Most patents were applied for or granted in the last four years. Our search also failed to trace any patents with inventors or proprietors affiliated with one of the recently established CSETs. However, we are unable to conclusively determine whether or not the number of university patents is growing on the basis of these counts, given the potential weaknesses of such narrowly defined searches.

An alternative indication of broader changes in the commercialisation activities of Irish universities (including patenting) is provided by an institutional survey carried out on behalf of InterTradeIreland (2006). While this survey also included academic institutions based in Northern Ireland, assuming that the differences in strategic focus and resources available in the two jurisdictions are not too great,[11] its overall findings may be indicative of the Irish situation. Table 5 presents the findings of the survey regarding technology transfer activities. The metrics reported by the institutions portray an increase in the scale of activities on all accounts for the period 2002/2003–2003/2004, with tentative increases also apparent in many measures in the following academic year (2004/2005).

Table 4. Number of equally sized subject categories

Institution*	1990	1994	1998	2002	2006
Trinity College Dublin	21.02	19.97	20.99	20.65	23.38
University College Dublin	17.08	19.66	22.94	26.84	25.96
Dublin City University	5.41	6.50	6.70	9.54	10.66
University College Cork	13.22	15.58	12.98	15.92	19.15
National University of Ireland, Galway	17.42	15.01	13.56	19.85	21.48
National University of Ireland, Maynooth	10.05	10.06	10.04	12.76	10.69
University of Limerick	2.73	4.61	8.84	11.86	15.30
Royal College of Surgeons in Ireland	5.31	10.00	10.27	10.61	11.94
Average	**11.53**	**12.67**	**13.29**	**16.00**	**17.32**

Notes: *'Equally sized subject categories' have been calculated as inverse values (10000/H*) of a normalised Herfindahl index'. If for a total of (N) three subject categories (a, b, c) denote the percentage of publications from each subject category, then the Herfindahl index is calculated as: $H = a^2 + b^2 + c^2$. The normalised Herfindahl index is then calculated as $H^* = (H - 1/N)/(1 - (1/N)$

Insights from Irish TTOs

Main themes

In this section we look at the key themes that emerged through our qualitative analysis of Irish

Table 5. Technology transfer activity in Irish universities

Activity reported	2002/2003	2003/2004	2004/2005 (incomplete)
No. of new license deals established	12	13	18
License income (€ thousands)	420	605	840
No. of spin-out companies formed using institutional IP	15	23	4
No. of patents applied for	88	110	126
No. of patents granted	12	24	16
No. of patents used in commercialisation deal (licensing/spin-out)	9	13	16
No. of new collaborative research contracts with industry	171	208	79
No. of new consultancy/knowledge transfer activities	307	344	14

Source: InterTradeIreland (2006: 13), institutional survey

universities and their role in technology transfer. Interviews performed with TTO managers constitute our main source of information. In the course of our research, a number of distinct themes have emerged that highlight how technology transfer and the method of delivery of such services has been transformed in some Irish institutes. The main areas under investigation here are:

- Policy and institutional support
- Motivations and rewards
- Barriers
- Capabilities that emerge through UITT

Policy and institutional support

University–industry collaboration has attracted considerable policy attention, with rhetoric recently centering on the significance of technology transfer for Ireland's 'knowledge-based economy' (Enterprise Strategy Group, 2004; Forfás, 2007b; Government, 1999). Universities have responded to the challenge by refocusing their industrial liaison activities and/or the establishment of TTOs.

However, there are indications that their efforts have been constrained by limited resources. Pandya and Cunningham (2000) singled out the lack of resources, in terms of both monetary and support structures as a major inhibitor of technology transfer and commercialisation in Ireland. While substantial progress has since been made, the insights provided by TTO managers in our interviews highlight that resource constraints remain a key concern.

First is the issue of resources allocated directly to TTOs. TTOs perform both formal, administrative functions and, with technology transfer being a match-making exercise, less formal intermediation roles. Both are important roles that compete for the limited amount of human and financial resources vested in TTOs. It is worth considering that at any given time, TTOs are in the process of negotiating multiple deals which require an extensive skillset, ranging from a thorough scientific and technological understanding, to sound knowledge of IP legislation and best-practice procedures, to 'softer' people skills such as developed interpersonal communication abilities and negotiating prowess. Most of the TTOs we surveyed employ only a handful of individuals, who in some cases have to allocate part of their time to non-TTO duties.

During our interviews a general consensus emerged, that the ability of TTOs to fulfill their mission is constrained by the resources they have at their disposal. Most would want policy makers to back their rhetoric with more substantial resource commitments. All but one of the TTO managers interviewed, felt that they are under-funded and believe that a critical level of funding is missing, which would allow them to adequately exploit the opportunities presented for technology transfer. TTO manager 1 identifies the lack of staff as a 'huge problem', while TTO manager 4 underlines the inadequacy of funding by saying:

> Give us money to do our work properly… if you look at the way the resources are constructed in the UK and the US there is no comparison, so resourcing is the fundamental issue…

However, increasing resource commitments alone will not necessarily lead to positive outcomes. Of course, defining these positive outcomes and measuring the 'success' of a TTO is fraught with difficulties. A TTO's positive contribution cannot always be captured by the simple metrics of legal documents or direct monetary returns but must also consider its broader social impact. Nevertheless, international studies traditionally consider (rather narrow) metrics, which show significant variation in the efficiency of TTOs. Sometimes TTOs entrusted with considerable resources have very little to show for it (Walker and Ellis, 2000). Even in the USA where technology transfer activities have a long history of success, Studt (2004) found that only 8% of technology transfer participants believed that their efforts were 'very successful', though the overwhelming majority did report some measure of success. While the inherently uncertain nature of technological development may probably account for part of these differences, it is clear that, the productivity of resources directed at TTOs partly depends on local conditions.

Indeed, the efficient management of resources appears to feature high on the agenda of most TTO managers in Ireland. TTO managers appear to be well versed in the intricacies of collaborative arrangements and place high importance on the qualities of the technology transfer system. TTO managers 2 and 4 agree that increases in resource commitments must occur within an institutional framework that is conducive to their productive deployment.

In light of the relatively short history of sustained investment in university-based research in Ireland, it is perhaps too early to expect the presence of a critical mass of resources and organisational learning. Indeed, one may question whether such a critical mass will ever emerge within a small country such as Ireland. Given the multiple priorities assigned to universities, an appropriate level of resources for technology transfer is difficult to achieve even in much larger countries. Studt (2004) highlights that only a small portion of US universities allocate sufficient funding to generate a reasonable return on their technology transfer activities. For instance, despite its world-renowned success, MIT's commercialisation revenues are still only 3% of its research income (Lambert, 2003). The same report cites a 1998 NHS study, telling that an annual R&D expenditure of £20m is required for sustainable technology transfer i.e. to

cover the costs of a professional office. Lambert (2003) applied this data to the UK university sector, and noted less than 25% of universities would meet this threshold, even though 80% are now trying to run their own operations.

Motivations and rewards

Various studies have identified the range of discrete motivations for industry and universities to collaborate and transfer technology and knowledge (Bozeman, 2000; Graff *et al*., 2001; Lee, 2000; Thursby and Thursby, 2004). Our aim here is not to expand on that line of research, but rather to contribute our empirical insights from an Irish perspective.

Technology transfer is increasing at an unprecedented rate in Ireland (Cunningham and Harney, 2006) and one may question whether this is due to changing attitudes from either industry or from academic staff. This changing scene has brought about renewed pressure on academic staff to be commercially active. These changing attitudes and pressures encapsulate the changing emphasis in Irish universities and the more concerted push for the 'entrepreneurial university'.

Rewards for technology transfer are frequently linked to measures of performance. However, our interviews highlighted that 'research productivity' is difficult to measure and that commonly used performance metrics (such as patent counts) may only capture a small part of economically useful research results. There is the view that the focus on performance measurement may be misplaced, as it could lead to an inappropriate incentive structure. As stated by TTO manager 3:

> There is no focus on productivity, the focus is on – lets file as many patent applications as possible […]

Although there is certainly a need to ground performance on reliable metrics, it may be profitable to reconsider what these ought to be. It is clear that performance measurement should move away from narrow metrics and take into account the more nuanced outcomes of university research collaboration (e.g. industrial training opportunities for researchers, the creation of latent expert networks and the concurrent build-up of local capabilities) even if they do not translate into immediately tradable technology.

This issue relates to the degree of autonomy vested in universities. Local agents are more likely to have complete information on the state of research activity and thus better able to gauge productivity and align incentive structures.

When asked whether additional resources are required, TTO manager 5 agreed but suggested that resources alone may not suffice. In addition, TTO manager 5 suggested, policy makers should provide greater autonomy to universities:

> I think it would be a combination: additional resources yes and recognition that you need in terms of IP management or so forth, you need guidelines that can't be too restrictive in that you can't tie somebody to a straight jacket when it comes to licensing IP, I think what the policy makers need to recognise that at the end of the day IP is the property of the college and not the property of the funding agency, the college should be empowered to make it's own decisions in terms of how that particular IP should be licensed on a commercial basis.

Our research also indicates that basic extrinsic rewards for university staff have changed little over the years. These at present include monetary rewards and the prospect of promotion. The latter though seems to have been more rhetoric than reality in the past, as technology transfer activity is only now beginning to be recognised as a criterion for career advancement. TTO manager 2 while agreeing that it had changed significantly recently still believed that more could be done:

> I think what's not there… but I would like to see would be rewards counting towards promotion within the academic environment, in other words and I'm being simplistic here probably far too simplistic – 'is one patent worth three papers?' I don't know – when you're counting these kind of areas, technology transfer activities in their promotionally academic field, I think it gets very very weak.

Within an Irish context several of the TTO managers highlighted aspects such as the visibility of the researcher and, related to that, the need for achievement by the researcher (somewhat similar to that of trait theory within the entrepreneurship and leadership fields). TTO manager 3 highlighted that:

> I think these larger funded agreements are seen as quite prestigious so to be involved in an SFI CSET is certainly seen to be prestigious.

TTO manager 5 furthered this intrinsic motivational aspect:

> the other reward is I suppose the satisfaction of seeing your idea move into industry, move into a product offering, that's a personal reward for people.

TTO manager 4 focused on the futility of extrinsic rewards by saying:

> They don't care about the money so... it's publication and recognition.

There are also indications that a lot of the time there

is a disparity between the initial expectations and the outcomes for both parties. The two cultures were depicted as very different with a university's focus on research and knowledge creation and industry focusing on the drive to commercialisation. TTO manager 2 emphasised that:

> I think there's a lot of work needed up front to make sure that mismatch doesn't occur. Academics very often would think that they can get the money and do their own thing – all of a sudden they find that now industry – if they've contributed – certainly will want a little bit more authority if that's the right word, or input, changing the direction more than they would have expected.

It was emphasised that the extent of this mismatch in expectations relied heavily upon a number of factors such as: the level of sophistication of the collaboration, prior experience in collaborations of a similar nature, and the personal relationships of the key individuals involved in the project.

Barriers

International evidence suggests that many TTOs see little or no success despite huge amounts of capital being spent on technology transfer.

Given the degree of policy emphasis (and resources) devoted to UITT in Ireland, it is important to identify barriers that may jeopardise the success of the process.

Various authors have attempted to identify the barriers that preclude the successful transfer of technology from universities to firms (Graff *et al*., 2001; Siegel *et al*., 2003b; Studt, 2004; Walker and Ellis, 2000). Consensus among academics on the range of barriers that impede technology transfer is rare, as these appear to differ in various contexts. For example Cunningham and Harney (2006) identified three types of barriers to commercialisation of research, namely institutional barriers, operational barriers and cultural barriers. Siegel *et al*. (2003a) identified the main barriers to technology transfer in a study of US colleges as: culture clashes, bureaucratic inflexibility, poorly designed reward systems, and ineffective management of university TTOs. Walker and Ellis (2000) identified largely similar barriers in a British context.

Our research employed the Siegel *et al*. (2003a) list of barriers to investigate if the same set of factors is seen as relevant in an Irish context and whether or not these barriers had changed significantly over the last ten years. We found that TTO managers in Ireland had differing views with regard to the barriers highlighted by Siegel *et al*. (2003a). However, we found some points of agreement. The first overlapping issue was that of culture clashes: Irish TTO managers highlighted this as a major potential barrier. Other academics have focused on the culture clash as one of the main hindrances, e.g. Graff *et al*. (2002) argue that 'university technology transfer is overly complex, cumbersome, and bureaucratic, or that OTT [Office of Technology Transfer] staff seem inexperienced and unprofessional, failing to treat them as valued customers'.

TTO manager 2 highlighted the time frame as symptomatic of this clash with regard to the different approaches:

> Industry tends to work off time frames that are fairly short as you would expect, that was one of my biggest frustrations, when I was in industry with — not so much the time frame involved in the research because you expect that would be medium to long term but more in terms of the examples of getting deals done, closing things out and whatever else.

TTO manager 5 followed on this point:

> I suppose the barrier that because you are an academic institution you're doing pie in the sky stuff and you live in an ivory tower — you can't work your industry needs or industry norms or industry time lines — these are the types of barriers — I think it's changed in the last five years.

Another generic aspect that causes problems with Irish technology transfer activities is that of IPR. Chapple *et al*. (2005) underline the importance of IP generation and exploitation as a central issue for institutions of higher learning in line with the views of most of the Irish TTOs interviewed. In an Irish context the TTO managers agreed that this process of IPR and the successful negotiation of agreements has lead to many problems with the transfer of technology. Some highlighted the lack of expertise and resources in the area of IP management, while others focused on the disproportionate values attributed by either party. TTO manager 5 identified IPR as the main barrier:

> I suppose the main barrier with any type of collaboration with industry is the whole issue: if you develop new intellectual property, who owns it? How can you exploit it commercially? And what should the return to the academic party be?

Following on from this many of the officers also identified the 'publish or patent' dichotomy in stopping potential technology transfer. Owen-Smith and Powell (2001) explored the reasons why academics choose to patent and suggested that institutional success at patenting is dependent upon three main factors: the perceived benefits by faculty of patenting, the quality of the TTO and finally the university as a collective enterprise. They go on to say that a TTO's crucial first step is to convince faculty of the benefits

of collaboration and patenting. TTO manager 5 seemed to agree with this view, stressing the importance of this decision:

> When it comes down to it — you won't win every battle, you'll win most of them hopefully — you'll have to [see] publish or patent as one of the biggest challenges we face on a day-to-day basis.

A lack of resources and the inefficient deployment of resources were regarded as key hindrances in the successful exploitation of UITT. Some TTOs in Ireland receive more funding than others and this is seen to account for some of the disparity in the exploitation of commercialisation and UITT. Highlighting the new role that technology transfer is being set, Enterprise Ireland has decided to add additional funding to TTO in the form of a €30m fund. This will help with what TTO manager 3 believes is missing from the Irish TT process: 'expertise, the ability to negotiate, personnel within the university to draft agreements'.

Capabilities

The strategic management literature points to two main ways for firms to achieve a competitive advantage: the outside in and inside out perspectives of strategy formulation, also known as the positioning-based and resource-based viewpoints (Mintzberg *et al*., 1998). De Wit and Meyer (2004) label this 'the paradox of markets and resources' and it is through the lens of 'resources' and the inside out view that we questioned the TTO managers to gain an insight into the capabilities that firms offer universities and, in turn, what capabilities universities offer to firms.

Several authors have stressed that knowledge creation that involves external linkages brings more successful results for the firms concerned (Eisenhardt and Martin, 2000; Henderson and Cockburn, 1994; Powell *et al*., 1996), with universities in particular being a promising source of commercially exploitable knowledge (Etzkowitz, 1994). Within the Irish context, Forfás[12] and the Advisory Science Council (2007a) have outlined that two key constraints for the enhancement and deepening of university–industry research collaboration were first, the low absorptive capacity of firms in Ireland, and interestingly:

> A gap in the availability of applied research capability that enterprises can readily access. At the same time that substantial resources have been invested in building up the research capabilities in the higher education sector it has become apparent that a significant gap exists in the applied research area of most relevance to enterprise. (Forfás, 2007a)

Collaboration for collaboration's sake will not suffice in the modern, dynamic, competitive environment. Lee (2000) in his empirical investigation into the sustainability of university–industry research collaboration cites some commonly extolled reasons as to why a firm may want to collaborate with a university.[13] These reasons were employed in an Irish context to examine what TTO managers viewed as the main rationale for firms to enter collaborative agreements with universities. Our research highlighted that TTO managers believe that it is dependent on a number of factors (e.g. size of firm, industrial sector they operate in, location etc.) and so it is problematic to generalise.

It can be quite difficult to measure what benefit an industrial partner may obtain from collaborating with a university or research centre. Lee (2000) found that assigning a dollar amount can be quite problematic, as most of the companies that he surveyed did not evaluate the collaboration monetarily, citing that it can be quite difficult to assign a value to information and that even new product development, improved yields and saving personnel costs in pursuing false R&D leads may not be possible to replicate on a balance sheet. Our investigation suggests that companies purposely searched for a university that had certain capabilities presumably expecting that this in turn would engender capabilities within their own company. When questioned on the topic, all of the TTO managers agreed that firms come to their universities specifically for the capabilities they offer. When asked specifically with regard to the CSET, TTO manager 5 pointed out that:

> Absolutely, they look at the expertise on the different technologies, different scientific disciplines, different techniques, different research programmes, an understanding, an appreciation, the human insight into systems or whatever it might be on biology side or ICT side.

Day (1994) segmented capabilities into: product development, marketing, product and process design, value chain and finally operations. This served as our segmentation of capabilities with regard to the questions that were posed. It turns out that the majority of the TTO managers viewed product development, and product and process design as the most important capabilities that firms sought and entered into university–industry collaboration to achieve. One that was not mentioned in Day's list but came up quite frequently, was the technical excellence that the university can offer firms.

When one looks at the capabilities which a firm can offer to universities several elements emerged in our interviews, including: access to new technology, technical excellence and a view into what cutting edge innovations are taking place which otherwise would not be at the disposal of the university researcher. This was exemplified by TTO manager 3:

> So access to technology is quite a big issue and that allows them to publish in better journals because they have access to equipment and so forth, so they have a better chance of improving the impact of the journal that they publish in.

Therefore, access to such resources emerged as an important motivation for university–industry collaboration. Other perspectives that were given signalled the perspective that industry offers academics with regard to what TTO manager 4 labelled 'market view' and a commercial outlook to the research that academics are performing.

Conclusions

The paper examined the case of Ireland to answer two important theoretical questions. First, the extent to which the various facets of academic research are changing in a manner that agrees with the policy rhetoric on UITT. Secondly, what is the role of the TTOs in facilitating more effective UITT after a period of rapid economic change. This paper has employed both qualitative and quantitative research to illuminate these answers. Our study serves primarily as an illustration of one country's efforts in this regard. The generalisability of this research to other countries will depend on the context in question. Insights are likely to be of relevance to small, internationally connected nations, eager to accelerate the transition to a knowledge-based economy.

It is clear that Irish policy makers have shown consistent support and have for the most part backed their rhetoric with significant resources. This paper questions the actual impact of the policy rhetoric. The paper shows that the establishment (and in some cases, the substantial empowerment) of TTOs signals that individual institutions (with the support of the relevant funding authorities) have also been eager to respond to the policy rhetoric. The process of change though has not been confined to 'bridge building' but also appears to be impacting on the type of knowledge produced at universities as outlined in the section on the measures of realignment in the Irish university sector.

With regards to the 'big picture', the range of quantitative indicators explored here shows a broad realignment of university research that is compatible with the objectives of UITT. Not only has the scale of resources afforded to universities for research increased many times over, but the qualities of this research have also changed. The increase in science and engineering related research serves to illustrate change in prioritisation of research in universities, which can be directed apportioned to policy initiatives. Partial measures of research output (scientific publications and self-reported university-owned patents) indicate that the capabilities of universities have been upgraded. In terms of the thematic specialisation of this output, the overall trend over time is one of broadening out, with scientific publications appearing in a progressively greater range of research areas. Metrics of technology transfer activities (licensing, patenting, spin offs, collaborative research and consulting) also portray increases in recent years. Collectively, these findings show that, in the context of a rapidly growing economy, at least on the surface, a realignment of university research activities can happen rather swiftly.

To answer the second main focus of the paper i.e. the role of the TTOs in facilitating more effective UITT, insights from technology transfer managers give us a taste of the more nuanced changes (and issues that might accompany them), that follow a policy-driven realignment of university missions.

These hold important lessons for an international audience. With regards to policy and institutional support, the Irish case highlights that the scale of resources allocated to TTOs must be proportional to the expectations attached to their new missions. While the budgetary limits of TTOs are set with national concerns in mind, technology transfer and patenting is an international activity, requiring resources that can compete at that level. Changes in institutional rules proved much more difficult to put in place, with extrinsic rewards for technology transfer among university staff changing little over recent years. The 'culture clash' between industry and academia (the 'publish or patent' dichotomy), though not exclusively an Irish phenomenon, is probably amplified by a lack of institutionalised rewards that recognise both basic and applied outcomes of research.

Insights from the problems associated with the UITT process in Ireland are in line with the findings of previous studies in other national settings (Graff *et al*., 2001; Siegel *et al*., 2003b; Studt, 2004; Walker and Ellis, 2000). An overarching conclusion emerging from our study is that, while the presence of university capabilities is a necessary condition for fruitful technology transfer, it is not a sufficient one. The intricacies of the technology transfer process and the need to nullify information asymmetries mean that its success rests to a great extent with the context-specific attributes of the local TTO, including the experience of local staff and its institutional autonomy.

Our findings lead us to conclude that, in the context of a small country such as Ireland, UITT is not easily amenable to benchmarking; the danger is that university research becomes aligned towards servicing a narrow set of indicators (e.g. patent applications) to the detriment of other useful activities. Importantly, given the indivisibilities associated with knowledge production, it is not at all clear that the traditional performance metrics used in countries such as the USA and the UK, are also relevant in the context of a small open economy such as Ireland. More generally there appears to be a fundamental contradiction between the 'benchmarking' and 'return on investment' culture that permeates policy at present and

the inherent uncertainty surrounding research. It is unclear how this contradiction might be resolved, other than perhaps with some yet to be discovered institutional innovation.

Notes

1. Ireland in this paper refers solely to the Republic of Ireland and excludes any reference to Northern Ireland.
2. Our study focuses on universities in Ireland and, in the interest of international comparability, excludes the Institutes of Technology (ITs), whose research activities differ substantially both qualitatively and quantitatively. Originally labeled Regional Technical Colleges (RTCs), they have recently been re-branded as Institutes of Technology. O'Connor (2001) tells us that the aim of these institutes is to have a regional-based tertiary institute that lessens the need for students to travel. The majority of the ITs are perceived to place a greater emphasis on technical graduates and applied research that is closely linked to vocational skills development.
3. These 'world-class facilities for research' are exemplified by the size of the grants on offer, as the CSET 'have established some of the largest grants offered anywhere in the world for research that brings together academic and industrial partners' (Harris, 2007) which range from one to five million euro. Science Foundation Ireland also state that 'Few agencies in the world have made such a commitment to supporting outstanding research partnerships between industry and higher education' (Harris, 2007).
4. As per Yin (1989), case study research generally answers one or more questions which begin with 'how' or 'why'.
5. As the interviews were given on the condition of confidentiality we are unable to disclose the names of participating institutions.
6. The University of Limerick (1989), Dublin City University (1989) and the National University of Ireland, Maynooth (1997).
7. There are also indications that after 1998 the contributions of industry have also decreased in absolute terms (Forfás, 2004c: 6–7). However, it is unclear whether this is indicative of a persistent trend.
8. Specifically, there are indications that this propensity tends to vary according to the scale of the resources employed (which may potentially distort the picture for Ireland), across countries and across time (Kane, 2001; Tijssen and van Leeuwen, 2003).
9. By way of a disclaimer, these counts should be seen as indicative. They may be biased with regards to double counting (e.g. in papers with more than one author in different institutions), under-counting (e.g. affiliation misspellings) and the specific journal coverage of the ISI database.
10. The authors performed searches for patents with at least one inventor or assignee (proprietor) based at an Irish university (alternative spellings of institution names were attempted) on the databases of the European Patents Office, the United States Patents and Trademarks Office and the commercial database, Derwent World Patents Index. We also attempted to consult the Irish Patents Office database but were unable to obtain any useful information due to the limited functionality of the present query system. In any case, this search cannot be considered exhaustive and should only be seen as indicative, as patents with inventors/assignees with multiple affiliations may be underrepresented or double-counted. Our counts may also fail to provide an accurate depiction of patenting activity given the various administrative lags and the varying propensity of some institutions to apply for protection at different jurisdictions. Misspellings and the coding conventions adhered to in different databases may have also biased our counts.
11. An assumption that is broadly supported by the findings of the same report (InterTradeIreland, 2006: 8–9).
12. Forfás acts as the advisory board for national policy regarding enterprise, trade, science, technology and innovation. 'Forfás' is an Irish language word meaning growth or prosperity.
13. These include the desires to: solve specific technical or design problems; develop new products and processes; conduct research leading to new patents; improve product quality; reorient R&D agenda; have access to new research (via seminars and workshops); maintain an ongoing relationship and network with the university; conduct 'blue sky' research in search of new technology; conduct fundamental research with no specific applications in mind; and recruit university graduates.

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