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Abstract

This paper considers university-industry links from the perspective of industry rather than from the usual university-centred perspective. While the literature has shown that the characteristics of business firms influence the composition and intensity of university-industry links, little is known about whether university-industry links are similar or different across the technical activities of firms; for example between research and technological development activities (R&D) or during efforts at manufacturing improvement. The paper analyses the composition and intensity of university-industry links in a disaggregate fashion, to observe them across these various activities. While these links are often treated under the common heading of 'absorptive capacity', this paper argues that the composition and intensity of the university links varies substantially across these activities. Based on a comparative embedded case study design, it examines empirical evidence from a large company's (Unilever) technological activities related to two product groups (deodorants and margarine) in the United Kingdom (UK). We find that dramatic changes in the composition and intensity of university-industry links occur when the firm moves from research to technological development.

JEL Classification: O320, O390.

Key words: university-industry links, multinational corporations, R&D

1 Introduction

A vast literature has touched upon issues having to do with university-industry links. Quite often studies have focused on the bodies of knowledge (e.g. science and technology - Gibbons and Johnston, 1974; Narin and Olivastro, 1992; Narin et al., 1997; Hicks et al., 2000) and on the types of activities involved (e.g. academic or university research and industrial R&D - Tassey, 2005; Mansfield, 1991; 1992; 1995; 1998; Mansfield and Lee, 1996; Beise and Stahl, 1999).

It is noteworthy that studies about university-industry links are often dealing with specific types of activities. For instance, Mansfield (1991, 1995 and 1998); Mansfield and Lee (1996); David et al. (1994) and Beise and Sthal (1999) analyse the links between university research and industry innovation. Furthermore, studies on university- industry links are usually observing how frontier knowledge generated in universities is transmitted to industry (Mowery and Rosenberg, 1989; Rosenberg and Nelson, 1994; Meyer-Krahmer and Schmoch, 1998; Hicks, 1992; Monjon and Waelbroeck, 2003; Tassey, 2005; Furukawa and Goto, 2006). By narrowing their focus to these specific types of activities and knowledge, these studies are unable to bring evidence about how different types of technological activities in companies may draw upon both frontier and more established university-generated knowledge.

This paper departs from these approaches. It will consider not only frontier knowledge transmitted from universities to industry, but it will also look at how more established knowledge is transferred to industry. The paper is concerned with establishing how homogeneous is the composition and intensity of university-industry links across the various levels of R&D and manufacture activities undertaken by business firms.

The empirical evidence is based on 63 interviews carried out with Unilever personnel in two countries (the UK and Brazil) and the analysis of contracts between Unilever and universities and other external knowledge suppliers. The research used a comparative embedded case study design, covering two types of product groups: margarine and deodorants.

In section 2 the paper examines supply and demand side factors influencing university-industry links, formulates the research question and outlines the analytical framework used to tackle it. Section 3 explains the methodology. Section 4 presents the empirical evidence and section 5 the analysis. A conclusion is then provided.

2 An overview of demand side and supply side factors influencing university-industry links

Research on university-industry links has identified supply side (i.e. relating to universities) and demand side (i.e. relating to industry) factors influencing their occurrence. With respect to the supply side, universities have recently been more directly engaged in contributing to economic development; this has been termed the third mission of universities (Etzkowitz and Leydesdorff, 2000). Such mission is related to third stream activities, which are mainly concerned with the generation, use, application and exploitation of knowledge and other university capabilities outside academic environments (Molas-Gallart et al., 2002).

Third stream activities are usually measured in terms of the eventual intellectual property rights (IPR) and related licence revenues from patents, and the number of spin-off companies established, in addition to more mundane sources of revenue such as infra-structure letting (Molas-Gallart et al., 2002; OECD, 2003; Carlsson and Fridh, 2002). The literature on the supply side is quite vast, but the actual outcome of engagement in these activities is still open to debate.

If on the one hand there has been an increase in university patenting (Florida, 1999; Henderson et al., 1998; Sampat, 2006), on the other hand most of these patents are related to a few scientific areas such as biotechnology and electronics, and only a small proportion generate incomes from licences (Carlsson and Fridh, 2002; Geuna and Nesta, 2006). The focus of this paper is on the demand side. There is evidence that the following characteristics of firms influence university-industry links from such perspective: i) firm size and ii) the presence of research and technological development (R&D) activities.

Evidence from innovation surveys suggest that just certain types of firms draw directly from universities as a source of knowledge (Arundel et al., 1995; Cohen et al., 2003; Laursen and Salter, 2003; Hughes et al., 2006). Indeed, firms with different types of R&D activities and different sizes link differently with universities. With respect to the presence of R&D activities, a key contribution from Cohen and Levinthal (1990) argued that firms must perform R&D in order to be able to tap into external knowledge, including that from universities. Based on their greater resources, larger firms tend to be able to structure R&D activities and create absorptive capacities better than smaller firms. This is evident from two sets of studies.

First, historical studies focusing on the late 19th century such as Mowery and Rosenberg (1989) and Reich (1985) showed that when US firms increased their scale, they became able to formalize R&D activities in departments dedicated to R&D. Freeman and Soete (1997) argued that, as German chemical firms increased in scale, this was accompanied by a structuring of internal R&D. In both the US and German cases the formalization and presence of R&D activities was accompanied by stronger links with universities. A similar process unfolded in Japan in after the 1950s.[2]

Second, more recently several survey studies examined the relevance of firm size on university-industry links. Arundel et al. (1995); Arundel and Steinmueller (1998); Arundel and Geuna (2004); Tether (2002); Bayonna et al. (2002), Hoareau and Mohnen (2002), Veugelers and Cassiman (2003); Hughes et al. (2006); Charles and Conway (2001) all identified that firm size significantly and positively influences the probability of firms in engaging with universities.

It could be argued that the relationship between firms R&D capacity and their size depends in

[2] For an overview of the Japanese case see de Campos (2006).

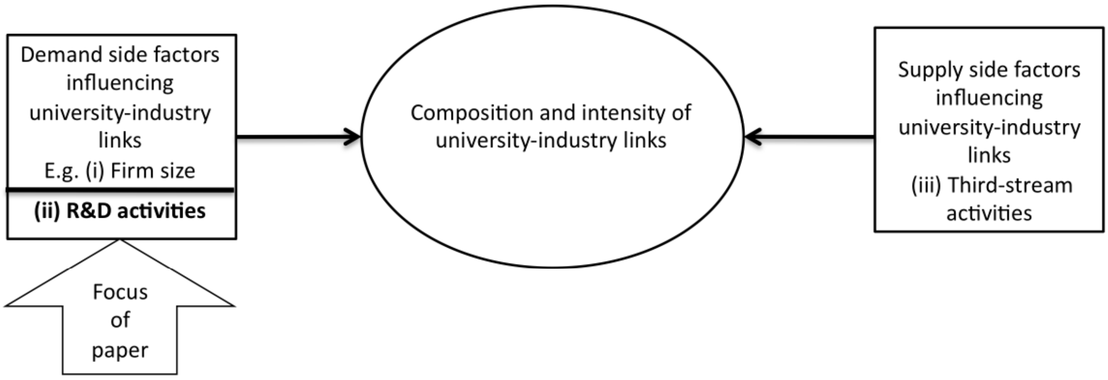
part on the organization of R&D, and its differentiation from manufacture. As firms have more resources and develop specializations, their knowledge demands move from being concerned only with the operation of technologies in manufacture, to innovation in R&D, which in turn may be related to an increase in the variety and intensity of the mechanisms involved in university-industry links. So far, studies about university-industry links tend to see the firm as a homogeneous entity, and in particular R&D is treated as a single entity. There is no differentiation in the composition and intensity of university-industry links across different R&D activities. In order to illuminate this problem, this paper will endeavour to differentiate the firm level R&D and manufacture activities and to examine how homogeneous are university-industry links across them.

From this review the following research question can be posed:

How homogeneous is the composition and intensity of university-industry links from the perspective of manufacturing, technological development and research activities?

In order to answer this question, the following analytical framework is proposed.

Figure 1 – Analytical framework



Source: Own elaboration based on review of the literature.

The review of the literature identified that both demand and supply side factors influence the occurrence of university-industry links. While much attention has been paid to the supply side, factors such as firm size and the types of R&D activities have also been covered on the demand side. In this study, we will focus on a specific set of demand side factors, namely R&D activities (including manufacture). The application of this analytical framework is explained in the next section.

3 Research method

In order to answer the research question posed above it was deemed that a case study methodology would be adequate. There were two reasons underpinning this choice. First, case studies are suitable to test assumptions that have not yet been tackled in the existing body of knowledge about a particular topic (Yin, 2009). It was considered that this was the case for the analysis of how homogeneous university-industry links are across different types of R&D and manufacture activities. Second, case study is an adequate methodology to generate detailed evidence, and this was deemed as suitable for the analysis of R&D activities at the level of the firm as proposed in this paper. These two factors counterbalanced the limitation of case studies in terms of creating evidence that is barely prone to wide generalizations.

Two key concepts were operationalized in the research. These are: i) the R&D and manufacturing activities, which were labelled the technological activities at the firm and ii) the composition and intensity of university-industry links.

With respect to the former, it was deemed that an initial distinction between manufacturing and R&D activities should be made (table 1). This approach drew upon a widely tested and applied framework to classify technological activities and capabilities (e.g Lall,1992; Bell and Pavitt, 1995; Ariffin, 2000 and Figueiredo, 1999). The various levels of technological activities are summarized in table 1.

Table 1- Suggested levels of technological activity in the firm

Activity	*Sub-level of activity*	*Main Task*
Routine Production	(1) Manufacturing	Operation of given process to generate a specified product
Research & Development	(2) Minor Technological Development	Adaptation of products and processes for specific markets
	(3) Intermediate Technological Development	Improvement of products and processes done autonomously
	(4) Advanced Technological Development	Design of products and processes
	(5) Applied Research	Tactical, short-term research
	(6) Disciplinary Research	Research underpinning levels (5) and (7)
	(7) Exploratory Research	Fundamental, long-term research

Source: Own elaboration based on review of the literature.

It becomes evident from table 1 that technological development is an activity that is quite distinct from research. Technological development is concerned with product and process adaptation, improvement and design (levels 2 to 4). Research is concerned with scientific activities that generate knowledge. Such knowledge can be useful in at least two ways. In the case of applied research (level 5) it can serve for direct practical product and process application. In the case of disciplinary research (level 6) the knowledge underpins such application. Furthermore, research can be concerned with knowledge created from long-term curiosity-driven problems that may have no immediate application (exploratory research in level 7).

University-industry links can occur at each of these levels. The categories conceived are summarized in table 2.

Table 2 – Categories of university-industry links

University Activity	*Links with Industry*	*Types of Links - Elaborated*
Education	*Human Resources Development and Hiring*	1) BScs and MScs
		2) PhDs and Post-docs
Research	*Information and Knowledge Based*	3) Social networks and informal contacts
		4) Short-term contractual arrangements
		5) Long-term contractual arrangements
		6) Very long-term contractual arrangements

Source: Own elaboration based on review of the literature.

These categories reflect the following two aspects. Firstly, this paper is concerned with the transmission of established and frontier knowledge from universities to industry. This is done by means of training undergraduates, masters, doctors and post-doctoral researchers (OECD, 1990; Mowery and Rosenberg, 1989; Salter and Martin, 2001). This is reflected in human resources development and hiring in links 1) and 2) in table 2. Secondly, we acknowledge that knowledge exchange happens both by informal and formal means. The latter has to do with contractual arrangements of various lengths (e.g. consultancy - Charles and Conway, 2001; joint-research - Mowery and Rosenberg, 1989 and campus based laboratories - Etzkowitz and Webster, 1998; Hatakenaka, 2003;). The former has to do with the exchange of knowledge by means of social networks (Gibbons and Johnston, 1974 and Faulkner et al., 1995). This is reflected in information and knowledge-based links (links 3) to 6) in table 2).

The main element of the design of the research was to cover each of the technological activities mentioned above, checking the occurrence of university-industry links at each of these levels. In addition, a measure of intensity was attached to the categories. The different types of links that occur at various levels of technological activity could vary in their intensity.

As such, intensity was described as: (i) absent, (ii) ad-hoc (referring to links that occur a few times in any period, but which are not part of the firm’s policy), (iii) frequent (referring to links that occur several times in any period, but which are not part of the firm’s policy) and (iv) programmatic (referring to links that are a part of the firm’s policy irrespective of the amount of time that they occur in any period).

In choosing this research design, there was some consideration about using patent and scientific publication data. Specifically, it might be that joint-patenting and joint-publication data reflecting the collaboration between university and industry personnel might be useful. A key limitation of these types of data is that they reflect a subset of technological activities in companies. In terms of joint-patents, they reflect just the more formalized end of such activities. In terms of joint-publications, they reflect the more knowledge intensive end of the research activities. An excessive focus on these indicators would miss the overarching approach envisaged to firm activities in this research, covering the whole array of R&D and manufacturing activities undertaken in business firms.[3]

The case study firm where the research was undertaken was Unilever. The company was selected because it enabled the exploration of the variability of university-industry links in terms of the array of technological activities discussed. In addition, Unilever trades a variety of product groups. Hence a comparative embedded case study was designed partly reflecting the broad divisions of the company: foods (covered by margarine) and home and personal care (covered by deodorants). A total of 40 interviews were implemented across two research laboratories, two innovation centres, two factories and a corporate centre in the UK (table 3).

Table 3 – Interviews implemented during the research

Country/Product group-organization	*Unilever Margarine*	*Unilever Deodorants*	*Unilever Cross-product*	*Universities*	*Total*
UK	12	14	8	6	40
Brazil	8	10	2	3	23
Total	20	24	10	9	63

Source: Own elaboration.

The comparative embedded case study approach enabled the triangulation of evidence between the two product groups following standard good practice in this type of research (Yin, 2009). A small number of interviews was carried out with relevant university staff and staff cutting across deodorants and margarine to explore trends and confirm specific cases and data aspects. Furthermore, the data consistency was checked across the firm technological activities, and with respect to data collected in two innovation centres, two factories and a corporate centre in Brazil by means of 23 interviews in a separate part of this study (de Campos, 2006). Unilever also granted access to contractual data, which were used to explore trends within research activities. Finally, public documents (e.g. Annual Reports and press releases) were collected and used to further test the evidence gathered. Dossiers were compiled for the two product groups in Brazil and in the UK, and this formed the basis for the analytical work.

Unilever kindly agreed to participate in the research and offered full support in terms of complete and access and freeing time from its staff to participate in meetings, interviews and discussions, as well as in helping with access to databases, archives and site visits. This agreement was granted provided that the following two conditions were respected: first, all evidence emerging from fieldwork interviews and direct observation should be recorded in the form of notes so that no voice recording device was to be used. Second, four confidentiality disclosure agreements lasting a total of seven years starting from 2002 (when initial contacts were undertaken) were to be signed with both divisions in the UK and the Brazilian subsidiary. All agreements expired in 2009 and the research results are discussed in the next section.

[3] Other aspects considered against these types of data were that joint-publications are concerned with knowledge that is sometimes applied across various product groups in a single company, and it would not be possible to distinguish entirely between deodorants and margarine product groups. Furthermore, patents have limited application at the level of a single company. In spite of these limitations, exploratory studies with patents and joint-publications were undertaken and these are presented in the appendixes.

4 Empirical evidence

4.1 Deodorants product category

Operations related to the product group of deodorants were by and large carried out in two sites in the UK: Leeds and Port Sunlight. Leeds housed the manufacturing site and the Global Technology Centre for Deodorants in the UK, dealing with development for two kinds of applicators: aerosols and roll-ons.

Most of the research based in the UK on deodorants was carried out in the Research Laboratory at Port Sunlight. There, the research on product issues was carried out by the Deodorants Research group and research on processes was carried out by the Process Sciences group. This latter group also did work on other product categories within the Home and Personal Care Division. Both research groups received support from groups specialized in underlying disciplines (e.g Measurement Sciences).[4]

4.1.1 Deodorants: manufacturing and minor technological development

The Leeds site was responsible for Unilever's deodorants manufacturing in the UK. Minor process changes were also carried out here. It had a workforce of about 650 operators and was organized around seven technical functions including: 1) manufacture (including loss control), 2) maintenance, 3) dispatch, 4) safety, 5) quality, 6) innovation and projects and 7) engineering. Manufacturing activities were largely divided between aerosols, and other forms of applicators (sticks, roll-ons) and formulations (creams and liquids). This also involved other personal care products.

The factory in this site was the largest producer of aerosols in the world, manufacturing 300 million of such flasks per year in addition to 100 million sticks and roll-on applicators. It processed about 30 brands, with some 400 variants and sizes. The bulk of its output (55%) was directed to large retailing chains in the UK and Europe.

Two main inter-related trends can be identified in the 1990s. First, the factory adopted Total Production Maintenance (TPM) for its manufacturing practices. Second, it began greater integration with R&D activities as this facilitated intra-corporate interactions.

TPM in the production of deodorants was adopted as part of Unilever's global strategy in the 1990s. The TPM programme focused on minor process improvements and relied substantially on shop-floor autonomy. In 2002, the factory received TPM Excellence certification from the Japan Institute of Plant Maintenance.

In the early 1990s the factory had tended to operate in a non-integrated fashion in relation to R&D. Adaptations to processes were implemented by the Process Sciences group at the Port Sunlight Laboratory. The bulk of the product adaptation work was done by the Development Department at the Leeds site which, at this stage, was mainly responsible for the UK market. The factory's manufacturing operation had been responsible mainly for implementation of product and process specifications.

In the 1990s the factory began greater integration with R&D activities as this facilitated intra-corporate interactions. As part of Unilever's strategy for the international location of its technological activities, the Development Department was upgraded to Global Technology Centre status. Global Technology Centres lead technological development projects across subsidiaries globally. As a result the manufacturing operations on the site began to interact directly with Global Technology Centre for Deodorants, and Deodorants Research and Process Sciences at the Port Sunlight Laboratory. There were also more interactions with

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[4] For an overview of the UK deodorant's operations, please, refer to appendix three.

external suppliers. Intra-corporate interactions with the Global Technology Centre for Deodorants were both formal and informal.

Intra-corporate interactions were less frequent with Process Sciences than with Global Technology Centre for Deodorants. The plant was part of a team led by Process Sciences that benchmarked performance in the manufacture of roll-on applicators globally. Other types of intra-corporate interactions included collaboration with Unilever manufacturing sites overseas.

4.1.2 Deodorants: intermediate and advanced technological development

In the 1990s, intermediate and advanced technological development activities were shared between the Research Laboratory at Port Sunlight and the Development Department in Leeds. The bulk of these activities were carried out at the Research Laboratory. It performed mainly more elaborate manufacturing improvements and advanced technological development related to formulation and packaging.

Thus, when it was formed in the mid-1990s, the Deodorants Research group at that time comprised about ten professionals and focused on applied research. Throughout the 1990s it became increasingly involved in product improvements, troubleshooting and support to marketing.

The Development Department in Leeds was mainly involved in implementing improvements on the basis of product guidelines produced by Deodorants Research. It was responsible for the UK market and worked independently of the teams in the Research Laboratory at Port Sunlight. Intra-corporate interactions between the Department and the Research Laboratory were aimed at obtaining specific knowledge for developments. The Department had much less extra-corporate interactions, e.g., with suppliers.

In 2001 the Development Department assumed Global Technology Centre status, was given global and regional mandates, and became known as the Global Technology Centre for Deodorants. The nature of the newly formed centre's activities was scaled up, from implementing minor and intermediate technological development activities towards carrying out more elaborate intermediate and advanced technological developments.

These changes enabled its members to extend their knowledge to include non-technological related matters, and achieve a better understanding of the underlying scientific background to various issues. This change in the nature of the activities of the Global Technology Centre for Deodorants was reflected in the longer scales of projects. This came at the expense of some of the activities of Deodorants Research.

Global Technology Centre for Deodorants was organized around: 1) marketing, 2) market research, 3) formulations, 4) sensorial analysis and 5) packaging. The centre took on responsibility for the development of improved and novel formulations, and packaging and became more involved in the development of processes for aerosols and roll-ons over time, an area that it increasingly shared with Process Sciences. It was responsible for analytical work in quality control and product characteristic evaluation.

It was striking that, following its upgrade to Global Technology Centre for Deodorants the department developed closer intra-corporate interactions with the Deodorants Research, Process Sciences and disciplinary research groups in Port Sunlight, which ranged in frequency. The Centre was also generating frequent applied research questions, and research groups were involved in a third of Global Technology Centre for Deodorants major technological projects. These might be related to the optimization of new formulations or studying the effects of changes in applicators on the functional claims of products.

Global Technology Centre for Deodorants increased its extra-corporate interactions, and contacts with suppliers became more frequent, both in terms of direct knowledge and exchange of technical information and papers, particularly for formulations. These interactions occurred both in development work for long-term projects and for short-term troubleshooting.

Other sources of external knowledge with which Global Technology Centre for Deodorants interacted included consultants who could be involved in design and engineering. In the course of its operations, the Development Department exchanged product and process specifications with other departments in Unilever. From 2001 onwards, the Global Technology Centre for Deodorants played a crucial role in transferring technologies for Regional Innovation Centres involved adapting key technologies to regional circumstances and transferring them to manufacturing sites. The Global Technology Centre for Deodorants also interacted closely with the manufacturing activities on the Leeds site. The intensity of these interactions increased on the run up to product launch. These interactions often took the form of shop floor level studies.

4.1.3 Deodorants: applied and disciplinary research

Over time, Unilever increased the research intensity of its developmental work. This realization came in parallel with greater integration of R&D activities. Deodorants Research had grown to around 100 employees, and was becoming more involved in research intensive areas such as generation of new ingredients.

In 1998 Deodorants Research was downsized to 50 members and finally to 15 in 2003. After the Global Technology Centre for Deodorants was established, Deodorants Research focused on greater specialization, concentrating on applied work supporting product claims and market tests. In practice, this meant that Deodorants Research kept its research core, while more developmental related work was transferred to the Global Technology Centre for Deodorants. The Global Technology Centres increased their advanced development activities, and assumed initial leadership of projects. Deodorants Research led projects when they were in the most research intensive stages and it interacted very little with the Leeds manufacturing site. The bulk of its intra-corporate interactions were with Global Technology Centre for Deodorants and with other research groups in Research Laboratory at Port Sunlight.

The research activities of Deodorants Research were complemented by those of Process Sciences. The latter was formed in 1982, and ten years later had a staff of 200. In 1995, its long-term research on processes was assimilated by Corporate Research, with Process Sciences becoming more involved in applied research. Process Sciences serviced both deodorants and the manufacturing activities of the Home and Personal Care division in general. It provided the research base for manufacturing and supply chain improvements by working on synthesising the microstructure of ingredients. It also dealt with macro-structure controllers. Process Sciences contributed via changes in manufacture. These activities were multidisciplinary. The research agenda was largely dictated by the commercial needs of Unilever. Process Sciences was involved in similar intra-corporate interactions although they were more targeted to the manufacturing sites, and interacted with external equipment suppliers.

Deodorants Research and Process Sciences provided applied research in deodorant products and processes for Global Technology Centre for Deodorants drawing on specific groups to provide the knowledge required for their projects. These included specific disciplines such as Statistics and Physical Sciences, and also multidisciplinary ones. Deodorants Research and

Process Sciences's applied research also drew upon specific capabilities.

Measurement Sciences supported not only Deodorants Research, but also those research groups involved with other products, in the development of new product and process technologies. It drew on physics, chemistry, materials, modelling and chemical sciences and had 40 PhDs in its 100 strong workforce which incorporated both scientific and managerial skills.

The picture that emerges from the above discussion is one of an intricate network of intra-corporate interactions between the various technological activities related to deodorants. With R&D activities in Unilever becoming more integrated over time, intra-corporate interactions intensified across the whole array of technological activities, from manufacturing (level 1) to R&D (levels 2 to 6). This occurred following the upgrading of the Development Department to a Global Technology Centre for Deodorants, and the increased knowledge demands made to Deodorants Research. The transfer of responsibilities towards the Global Technology Centre for Deodorants did not result in a substantial increase in extra-corporate interactions as most of its knowledge sources were internal. Some extra-corporate interactions (e.g with suppliers) increased, although they were of secondary importance compared to internal sources of knowledge.

4.1.4 Deodorants: university links to manufacturing and minor technological development

The Leeds factory's links with universities included *Human Resources Development and Hiring*. This involved the hiring of bachelors students, via the summer placement programme, and graduates for managerial positions. In addition, the factory sent some of its operators to study engineering in the University of Leeds. The University of Manchester Institute of Science and Technology offered two-year study diplomas in manufacturing systems engineering and manufacturing management. There were similar arrangements with the Open University, which often involved operators.

Information and Knowledge Based links were developed as operators pursuing higher education became mediating contacts with academics that were sometimes hired by the factory on ad-hoc short-term contractual arrangements. These hirings could be for issues such as continuous improvement and cost improvement maintenance and engineering. The knowledge obtained was used to tackle product and process problems that were beyond the scope of Global Technology Centre for Deodorants and Process Sciences. Academics were also involved in the projects of students in the summer placement programme, on such issues as reduction of stocks and costs and quality.

4.1.5 Deodorants: university links to intermediate and advanced technological development

The transfer of more elaborate technological development activities from Research Laboratory at Port Sunlight to Global Technology Centre for Deodorants meant that the latter had to increase its basic knowledge. However, this did not result in a substantial increase in university links.

In terms of *Human Resources Development and Hiring*, the Development Department hired bachelor graduates with expertise in chemistry. This was done on a programmatic basis. With the creation of Global Technology Centre for Deodorants, greater expertise was needed in emulsions and particles and mould design and metals. Thus, the Centre hired PhD graduates and this was done on an ad-hoc basis. In 2003 a professor of chemistry from the University of Hull visited Global Technology Centre for Deodorants as part of his sabbatical to learn about personal care compounds.

The Centre exploited its social networks and informal contacts for information and knowledge required for regulatory issues. These interactions often occurred on an ad-hoc basis in meetings, e.g. with government bodies and trade associations. Sometimes they involved exchanges of ideas via telephone calls or e-mail.

The type of *Information and Knowledge Based* links that intensified with the creation of the Centre included short-term contractual arrangements. However, these were ad- hoc and related to development of formulations. These contracts involved consultancy for troubleshooting in areas where Unilever lacked expertise. These short-term arrangements were usually mediated by consultancy companies contracted by the Centre, for example, a spin-off company from the University of Southampton. A few short-term contracts were made directly with universities, e.g. the Centre carried out a project with The University of Manchester Institute of Science and Technology on spray issues. Use of these links was limited because of the difficulties involved in negotiating IPR with universities. Also, the Centre needed rapid results and academics frequently needed several months to familiarize themselves with the problems.

The Centre had a contract with the University of Leeds to advise on environmental issues, e.g. pollution reactors, air quality and safety. These were joint-projects implemented with other partnering companies, aimed at assuring regulatory bodies that the evaluations were impartial and scientific.

Finally, Global Technology Centre for Deodorants could access knowledge via the very long-term contractual arrangement between Unilever and the Department of Chemistry at Cambridge University (campus based laboratory – appendix five). The Centre began to absorb simulation techniques in formulations developed in Cambridge, however these were not direct links. The knowledge created in Cambridge was tailored by Deodorants Research at the Research Laboratory at Port Sunlight before being transferred to Leeds.

4.1.6 Deodorants: university links to applied and disciplinary research

This section provides information on the types of university links that existed with the three research groups dealing with deodorants: Deodorants Research, Process Sciences and Measurement Sciences.

In terms of *Human Resources Development and Hiring*, all three groups employed PhDs on a programmatic basis. In Deodorants Research this happened as the size of its staff fluctuated between ten and around 100 members. In addition, in 1997 to 2002 Deodorants Research was providing funding for six doctoral or post-doctoral researchers. This was seen as a way to access and absorb external knowledge. However, after 2003 it was decided that this was not a very effective way of achieving this.

Process Sciences also hired PhDs and it varied from 200 members in the early-1990s to less than 100 after its long-term research was transferred to Corporate Research. Between 1997 and 2002, the Group was fully or partly funding three doctoral and post-doctoral researchers.

Measurement Sciences employed about 40 PhDs in 2003 and its department head held an honorary position in the University of Liverpool.

The intensity of the social networks and informal contacts varied across the three groups. In Deodorants Research these *Information and Knowledge Based* links occurred on an ad-hoc basis. They served mainly to signal academic relevance and mostly consisted of membership in professional societies. Some members of Deodorants Research acted as editors of academic journals.

Process Sciences drew on its social networks and informal contacts very frequently. These links provided means to learn about potential partners. Process Sciences did not resort to confidentiality agreements until these initial interactions had taken place. It had a flexible attitude to publication by academics once the patent had been approved. Measurement Sciences used its links quite extensively by providing lectures, PhD supervision and participation in conferences. These links were used to learn about new areas and to establish networks.

The intensity of short-term contractual arrangements also varied across the three research groups. In Deodorants Research an examination of contract data for the period 1997 to 2002 reveals that there were programmatic links (table 4). During this period contracts involving short-term research were increased *in lieu* of consultancy. These contracts involved delivering tangible outputs, as e.g. the synthesis of a compound, but the personal interaction they promoted provided Deodorants Research with substantial underlying knowledge.

Process Sciences also established links with relevant departments. Contract data for 1997 to 2002 shows that it was involved in contract research and that this was done in parallel with consultancy. In addition to providing Process Sciences with specific knowledge, these contracts were the basis for longstanding informal relationships. Hence, they reinforced informal exchanges of information with universities.

The Measurement Sciences group used these links on an ad-hoc and infrequent basis and represented the only type of contractual arrangements entered into by the Group. Measurement Sciences needed to be a team-member rather than a team leader in projects supplying specific knowledge.

Only Deodorants Research and Process Sciences engaged in long-term contractual arrangements, the bulk of which for the former involved British universities between 1997 and 2003. Most of these contracts involved research, although occasionally academics were hired as consultants. At the time of the field-work in 2003, the average length of a Deodorants Research project was between three and 12 months.

In Process Sciences these links chiefly were in the form of consultancy projects with both academics and other institutions. Process Sciences was involved in only a few research contracts, the average time-length of its projects being 18 months.

Deodorants Research was the only group interviewed that implemented very long- term contractual arrangements and these were with Cambridge University. Since 2001 the Group had been developing links with the campus-based laboratory. As mentioned above this involved tailored simulation methods developed in Cambridge, and transferred to Global Technology Centre for Deodorants. Deodorants Research was also the only group using university spin-off companies on an ad-hoc basis related to a few contracts between 1997 and 2003.

One final point related to applied and disciplinary research: table 4 shows the frequency of contractual arrangements related to all the formal links analysed above for both Process Sciences and Deodorants Research. The contracts are classified by country of origin, and distinguish between contracts with universities and contracts with other institutions.

Table 4 – Deodorants Research and Process Sciences: contractual arrangements biannual average, 1997 to 2002

Institution/Years	**1997/1998[1]**	**1999/2000**	**2001/2002**
UK Universities	8 (66%)	24 (55%)	16 (31%)
Non-UK Universities	2 (17%)	4 (9%)	2 (4%)
Sub Total (Universities)	10 (83%)	28 (64%)	18 (35%)
Other Institutions[2]	2 (17%)	16 (36%)	34 (65%)
Total (Universities and Other Institutions)	12 (100%)	44 (100%)	52 (100%)

Notes: 1. Data for 1997 and 1998 were incomplete at the time the database was being implemented.
Source: Own elaboration based on Unilever Research database of contracts.

It shows that Deodorants Research and Process Sciences contracts were mostly with British universities. Both groups showed an increasing trend in the number of contracts with other institutions. It follows, therefore, that in the final period, universities were not the main external source of knowledge even for research activities. Knowledge sources included some foreign non-university institutions. Hence the demand for knowledge was not country-specific, and the company looked for centres of excellence, regardless of nationality.

Table 5 summarizes the findings on Unilever's links with universities in connection with its deodorants and margarine businesses and with respect to deodorants it suggests three main points.

Table 5 - Margarine, Deodorants and Corporate Research: Summary of University-Industry Links, Late 1990s to Early 2000

Technological Activities/ Product	Deodorants	Margarine
Routine Production/ Technological Development		
(1) Manufacture/ (2) Minor Development		
Human Resources Development and Hiring		
BScs and MScs	Programmatic	Programmatic
PhDs and Post-docs	Absent	Absent
Information and Knowledge Based		
Social networks and informal contacts	Absent	Programmatic
Short-term contractual arrangements	Ad-hoc	Ad-hoc
Long-term contractual arrangements	Absent	Ad-hoc
Very long-term contractual arrangements	Absent	Absent
Technological Development		
(3) Intermediate/ (4) Advanced		
Human Resources Development and Hiring		
BScs and MScs	Programmatic	Programmatic
PhDs and Post-docs	Ad-hoc	Absent
Information and Knowledge Based		
Social networks and informal contacts	Ad-hoc	Ad-hoc
Short-term contractual arrangements	Ad-hoc	Ad-hoc
Long-term contractual arrangements	Absent	Absent
Very long-term contractual arrangements	Absent	Absent
Research		
(5) Applied/ (6) Disciplinary		
Human Resources Development and Hiring		
BScs and MScs	Programmatic	Programmatic
PhDs and Post-docs	Programmatic	Programmatic
Information and Knowledge Based		
Social networks and informal contacts	Ad-hoc to Programmatic	Programmatic
Short-term contractual arrangements	Ad-hoc to Programmatic	Programmatic
Long-term contractual arrangements	Programmatic	Programmatic
Very long-term contractual arrangements	Programmatic	Absent
(7) Exploratory	Programmatic at all types of links	

Source: Own elaboration based on fieldwork.

First, *Human Resources Development and Hiring* links involving bachelor students/graduates were programmatic at all levels of activity from manufacturing to disciplinary research (levels 1 to 6). The most important involved various kinds of training, chiefly for existing employees, but also for university students and potential employees. Applied and disciplinary research (levels 5 and 6) were associated with these kinds of training, and occurred in a programmatic fashion in connection with doctoral and post-doctoral research. Also, the human resources-centred links with universities sometimes provided the context for consultancy projects.

Second, with the exception of these *Human Resources Development and Hiring* links and a few *Information and Knowledge Based* links, there were few links associated with the whole spectrum of technological development activities in the company, from minor to advanced (levels 2 to 4). These kinds of activities usually involved a dense network of intra-corporate knowledge-centred interactions within the company. In terms of extra-corporate sources, technology development activities were sometimes involved in links with suppliers, and only very occasionally with universities. The demands for knowledge generated in this whole complex of technological activities almost never drew directly on university sources. These contacts were sometimes mediated via the Port Sunlight Research Laboratory or consultancy companies, so that this level of activity was able to draw upon university knowledge.

Third, almost all of the *Information and Knowledge Based* links with universities were with applied and disciplinary research in Unilever (levels 5 and 6). Many of these links used contractual arrangements (particularly long-term ones). The knowledge derived from these links contributed to the company's technological development, but for the most part indirectly via the company's own research activities. It was these levels of activity and capability in Unilever that generated almost all of its demand for research-based knowledge from universities. This involved many university activities although generally those more directly related to research. They included direct research outputs (e.g. resolving a problem), or more indirect ones such as the pool of knowledge resulting from university research (accessed via consultancy). Unilever often wanted the results of specific investigations generating material deliverables, and the associated knowledge. There were several links with centres of excellence, e.g., the Unilever laboratory at Cambridge University's Chemistry Department.

4.2 Margarine product category

Operations related to the product group of margarine were carried out at Purfleet and Colworth in the UK. Purfleet housed the manufacturing site controlled by the affiliate Unilever Bestfoods and the European Regional Innovation Centre for Spreads and Health Products, which was involved in technological development related to margarine.

Most of the UK based research on margarine was carried out in the Food Research Centre (FoodRC) at the Research Laboratory at Colworth. This encompassed the Safety and Environmental Assurance Centre (SEAC), responsible for safety analysis of formulations. The research at Research Laboratory at Colworth into product issues was carried out in close proximity with the Global Technology Centre for Margarine, based at the Research Laboratory at Vlaardingen in the Netherlands.[5]

4.2.1 Margarine: manufacturing and minor technological development

In 2003, the Purfleet site was responsible for Unilever's margarine manufacture in the UK. It contributed to projects dealing with the implementation and review of product and process

[5] For an overview of the UK deodorant's operations, please, refer to appendix four.

adaptations and improvements.

The Purfleet site was organized around: 1) production, 2) engineering, 3) finance, 4) human resources, 5) supply chain and 6) technical functions. The production, supply chain and engineering functions were responsible for manufacturing, and included planning, sourcing (procurement and import of raw materials), processing, quality control and delivery of final goods. In 2003, the some 310 personnel were employed on the site, 180 in manufacture, including about 60 technicians qualified in engineering, 40 technical engineers and 80 apprentice engineers. They processed 15 different formulations and 300 different packages, corresponding to a total output of about 260,000 tons/year.

Product and process adaptation and improvement projects in which the factory was involved drew upon specifications transferred via intra-corporate interactions with European Regional Innovation Centre for Spreads and Health Products. The time scales of projects were up to 18 months. Longer term projects generally involved cost reductions or process improvements. The factory was basically involved in running trials.

Since the mid-1990s, the Purfleet site underwent two major changes. First, the factory became involved in Unilever’s effort to adopt TPM (a similar process was described for deodorants above). Second, its technological development activities moved from being local to regional.

In the 1990s the Purfleet site’s Development Department’s mandate was restricted to the UK. With the creation of the European Regional Innovation Centre for Spreads and Health Products in the late 1990s, the Centre's reach increased from local to regional and it was able to support product launches in other manufacturing sites in Europe.

The bulk of the manufacturing site’s intra-corporate interactions was with the European Regional Innovation Centre for Spreads and Health Products and were both formal and informal. On the formal side, the factory personnel participated in reviewing product and process innovation projects. This involved weekly meetings of multi-function project teams. The Centre defined line trials and suggested process specifications. These were then tested in the factory for manufacturing robustness. At the same time, the Centre ran consumer tests and trials. The plant provided feedback on these tests and if a product launch was recommended, it took part in both the planning and implementation of changes before product roll-out in the marketplace. In addition both parties had daily informal conversations about projects, which had clearer milestones than in the past. These milestones acted as ‘deadlines’, and also defined whether or not a project should continue.

Extra-corporate interactions occurred with suppliers and retail chains. They have become more frequent in recent years, involving short-term and longer-term interactions.

4.2.2 Margarine: intermediate and advanced technological development

The bulk of the UK-based intermediate and advanced technological development activities for margarine were carried out in the European Regional Innovation Centre for Spreads and Health Products. The Centre was also partly responsible for more elaborate product innovations relating to brands such as ‘Flora’ and for getting regulatory approval for these products at European level.

The Centre was involved in creating and improving novel formulations. Given the functional nature of its products, it often needed information about the nutritional value of ingredients. To obtain this information, the Centre drew on the knowledge bases of the Research Laboratories at Colworth and Vlaardingen. Indeed, a substantial part of the advanced technological development activities was done outside the UK, by the Global Technology

Centre for Margarine in the Netherlands, which was responsible for developments in edible oils. The more research intensive parts of projects were conducted at FoodRC at Colworth.

The European Regional Innovation Centre for Spreads and Health Products matched consumer feedback with scientific knowledge on ingredients. The Centre identified consumer needs through market research and interacted with the research laboratories, which provided the underlying scientific evidence. FoodRC and the Global Technology Centre for Margarine were responsible for framing general questions, tackling them, perhaps refining the questions and continuing research. Eventually, new ingredients were defined between European Regional Innovation Centre for Spreads and Health Products and the research laboratories.

Hence, in terms of intra-corporate interactions, the European Regional Innovation Centre for Spreads and Health Products liaised with FoodRC and the Global Technology Centre for Margarine as a member in a combined project. The Centre also interacted frequently with the Marketing Department and with the factory at Purfleet.

In terms of extra-corporate interactions, the European Regional Innovation Centre for Spreads and Health Products interacted with suppliers, to define the commissioning of ingredients.

4.2.3 Margarine: applied and disciplinary research

A substantial part of the applied research in margarine was carried out by the Dutch Global Technology Centre for Margarine, which had intense intra-corporate interactions with FoodRC. The latter was involved in the more disciplinary research content, which involved studies in product microstructure. Both the British and the Dutch centres collaborated on projects, which also involved European Regional Innovation Centre for Spreads and Health Products, which created a continuum between them.

The FoodRC at Colworth researched in nutrition and health, consumer sensation, perception and behaviour, flavour and active delivery systems, and physics and physical chemistry of food and food manufacture. These were supported by multidisciplinary groups. FoodRC research programme in margarine dealt with biopolymer and fat structures. This involved skills in molecular modelling. The resulting knowledge was transferred to Global Technology Centre for Margarine.

In Colworth, the launch of novel formulations and processes was assisted by SEAC, which provided expertise in toxicology. SEAC granted approval for new formulations in terms of environment, life cycle and safety.

The discussion above illustrates the network of intra-corporate interactions between the various R&D activities related to margarine. This network was the most relevant source of knowledge for the various technological development activities. These activities were integrated into projects involving research and advanced technological development. The output of such projects was transferred to European Regional Innovation Centre for Spreads and Health Products, which interacted with the factories at Purfleet and elsewhere in Europe to implement intermediate and minor development projects related to manufacturing.

4.2.4 Margarine: university links to manufacturing and minor technological development

The Purfleet site had links with universities for *Human Resources Development and Hiring.* Like its peer in Leeds, the site trained undergraduate students via summer placements. This was done on a programmatic basis.

The site also hired graduates with Engineering bachelors degrees through Unilever’s annual recruitment programme. The factory manager usually participated in the recruitment process and was a member of the selection panels. Our interviews revealed that it was becoming increasingly difficulty to recruit engineers suitable for manufacturing activities. After 2000 the number of candidates for jobs in Unilever has been increasing in line with the increase in the number of engineering courses in British universities. However, most of the graduates recruited came from only a few universities (generally Loughborough, Cambridge, Strathclyde and - particularly graduates in Chemical Engineering - Imperial College London).

Members of the staff could apply to register for a part time Master in Business Administration (MBA) degree at the London Business School, which they fitted around their daily working duties. This was done frequently. The company initially paid the course fees, which employees repaid over an extended period. The Purfleet site had also autonomy to support a one year postgraduate Advanced Course in Design, Manufacture and Management in the Institute of Manufacturing at Cambridge University.

The factory staff developed *Information and Knowledge Based* links on a programmatic basis involving social networks and informal contacts. The staff helped Unilever to hire graduates for manufacturing and post-graduates for other areas of the company by participating in campus presentations and meetings, visiting between five and 10 campuses a year. In addition, there were ad-hoc informal contacts with academics at business conferences and every six months, there were student visits to the site.

The factory used both short-term and long-term contractual arrangements occasionally. Short-term contracts generally involved annual consultancies with university staff. In the mid-1990s a long-term arrangement was forged which involved a representative from Purfleet liaising with universities to take part in research and lectures.[6] This arrangement continued for five years.

4.2.5 Margarine: university links to intermediate and advanced technological development

In 2003, most of these types of activities were carried out by the European Regional Innovation Centre for Spreads and Health Products. The Centre reported that it had very few direct links with universities. In terms of *Human Resources Development and Hiring,* although it hired several bachelors graduates on a programmatic basis between 1998 and 2003 there were no masters or doctoral graduates on the staff.

The Centre exploited social networks and informal contacts links on an ad-hoc basis. Between 1998 and 2003 these involved occasional interactions with academic government advisors, at professional meetings, or exchanges through telephone calls or e-mails. However, these kinds of contacts were mostly related to particular regulatory issues, and were not contacts that might result in future work together. Members of the European Regional Innovation Centre for Spreads and Health Products also visited universities, to help Unilever's recruitment programme.

The Centre used ad-hoc short-term contractual arrangements for small consultancies perhaps near to product launch if there was a need to investigate a customer related issue.

4.2.6 Margarine: university links to applied and disciplinary research

The bulk of the applied and disciplinary research work carried out in the UK for margarine was performed by FoodRC at Colworth, and integrated with the activities of Global Technology Centre for Margarine in the Netherlands. During 1997 and 2003 the former was particularly interested in research into Product Microstructure, which, although usually

[6] This also involved occasional funding for universities.

related to several product categories, was of particular significance for the work of the Research Laboratory at Colworth.

In terms of *Human Resources Development and Hiring* links, FoodRC had about 500 employees when the fieldwork was implemented. Of these, 45 were PhD graduates employed on Product Microstructure. The Centre hired PhD's on a programmatic basis, and these served as a source of expertise. A similar trend was identified at Colworth at least since the 1970s. The head of research in Product Microstructure held visiting appointments in the Universities of Birmingham and York (in Chemical Engineering and Chemistry respectively).[7]

In terms of *Information and Knowledge Based* links, contracts since 1997 dealing specifically with Spreads and Culinary Category which encompass margarine, involved four scholarships (including PhD students and post-doctoral researchers) which were fully or partly funded by Unilever. This was seen as a way for the company to access external networks of knowledge and was a recent trend. In previous decades, the company's approach was to internalize as much research expertise as possible. In the 1990s and early 2000s, the belief was that Unilever should obtain knowledge through access to external networks. For instance, three of the researchers in a short-term contract on spreads and culinary products were from Dutch universities. FoodRC also took Marie Curie students from time to time, although these did not appear in the Database of Contracts analysed.

The social networks and informal contacts were used by the Centre on a programmatic basis and was seen to be an integral part of their links with universities. In the 1970s Unilever UK was more interested in local knowledge networks. However, over time, the company had participated in international networks, at first via the laboratory's chief scientist and subsequently via new recruits and participation in conferences and meetings. Doctoral graduates hired by the company could be sources of informal contacts with external networks.

Short-term contractual arrangements between 1997 and 2003 related specifically to Spreads and Culinary Category was treated in a programmatic fashion. These contracts mostly involved clinical trials, where Unilever paid all of the research costs and retained the IPR. This enabled the company to ascertain that specific product claims were scientifically valid.

There were only five long-term contractual arrangements between 1997 and 2003. This included some projects with universities on Product Microstructure. These covered rheology, kinetics and biopolymers. The research on the Contracts Database showed that they lasted for three years on average. These can be considered programmatic because it is crucial for Unilever to monitor the latest scientific developments in these areas. Consultants were used in several years to work on the Spreads and Culinary Category; however there were no data about whether or not they were from universities.

The data in table 6 refer to the research projects that were led by the FoodRC, particularly on Spreads and Culinary Category products, which include margarine. The data shows an increase in completed projects over the five years. Because Unilever has strong expertise in margarine, having been involved with this product from its inception, the company was more interested in forging links with foreign institutions to take part in international networks of research excellence than with absorbing specific pieces of knowledge. Hence, only a minority of projects involved the Centre in Colworth and UK universities; most were with foreign universities in Europe – and especially the Netherlands, but also in France, Greece, Germany

[7] Source: http://www.eng.bham.ac.uk/business/visit.htm (last accessed 27/04/2003).

and Ireland, and in Japan and the US. The company looked for expertise worldwide to exchange ideas with academics in centres of excellence.

Table 6 – Spreads and culinary: contractual arrangements biannual average, 1997 to 2002

Institution/Years	**1997/1998[1]**	**1999/2000**	**2001/2002**
UK Universities	2 (19%)	1 (4%)	2 (6%)
Non-UK Universities	5 (45%)	14 (50%)	14 (44%)
Sub Total (Universities)	7 (64%)	15 (54%)	16 (50%)
Other Institutions[2]	4 (36%)	13 (46%)	16 (50%)
Total (Universities and Other Institutions)	11 (100%)	28 (100%)	32 (100%)

Notes: 1. Data for 1997 and 1998 were incomplete at the time the database was being implemented.
Source: Own elaboration based on Unilever Research database of contracts.

The data also reflects the fact that research on spreads and culinary products involved other types of research organizations including UK and non-UK hospitals and public research laboratories. Arguably, this would have provided Unilever with support for carrying out clinical tests studying the functional claims of part of its margarine line. Other less specific studies could have been performed by companies offering research related services.

Table 5 (section 4.1.6) summarizes Unilever's links with universities in connection with its margarine business.

In manufacturing and minor technological development activities (levels 1 and 2) both *Human Resources Development and Hiring* and a particular aspect of *Information and Knowledge Based* links were programmatic. The former involved hiring bachelors and MScs and the latter involved the creation of social networks and informal contacts.

However, both were used mainly for training and recruitment purposes and not for strengthening relations with universities and potential contracts. These types of links were either direct through hiring students or indirect by supporting internal placements and university courses. Visits to universities did not result in strengthening relations with universities although they contributed to the company's recruitment and training activities. Contractual arrangements were on an ad-hoc basis, and the knowledge needs at this level were mostly obtained internally via intra-corporate interactions between the manufacturing site and the European Regional Innovation Centre for Spreads and Health Products.

At intermediate and advanced technological development activities (levels 3 and 4), there were slightly fewer links with universities than at the lower level of activities. This evidence challenges the notion that university-industry links increase and become stronger the more elaborate the technological activities. Although this is sometimes the case, this finding contradicts this view. The only programmatic links here were for *Human Resources Development and Hiring*; *Information and Knowledge* based links were all ad-hoc.

This was because most of the knowledge demands at this level were supplied internally. The European Regional Innovation Centre for Spreads and Health Products had internal links that expanded 'up-stream' to the FoodRC at Colworth and the Global Technology Centre for

Margarine in the Netherlands, and 'down-stream' to the Purfleet site and elsewhere in Europe. These intra-corporate interactions were accompanied by an almost complete absence of external links with universities at this technological development level. External contributions to Unilever 'technology' in margarine, were more likely to come from suppliers and consumer market-research.

Most *Information and Knowledge Based* links with universities were associated with applied and disciplinary research activities in the company (levels 5 and 6). At these levels, the company drew upon *Human Resources Development and Hiring* links, particularly related to doctoral and post-doctoral researchers, as a gateway to external networks of academics. To access these, the company saw social networks and informal contacts as very important. Links with universities occurred through short-term and long-term contractual arrangements. At this level of activity, the margarine business in the company generated almost all of its direct demand for research-based knowledge from universities. Unlike the case of deodorants, British universities were outnumbered by foreign universities. Universities were as relevant as other sorts of institutions such as hospitals. Longer-term links were few in number, but they were also considered to be a programmatic element of the company's research agenda.

4.3 Exploratory research

4.3.1 Corporate Research: overview of activities

Exploratory research (level 7) in Unilever was carried out by Corporate Research. It was established in the 1970s, when Unilever devoted a specific share of its R&D investments to longer-term 'blues skies' research. Until the late 1980s, the agenda of Corporate Research was generally not dictated by business imperatives, instead it was expected to generate knowledge to challenge business assumptions or new techniques, which would potentially be useful throughout the company. Hence, projects tended not to have a specific business objective. For instance, such research helped Unilever to develop measurement instruments in-house and generated fundamental knowledge on colloids. It was expected that this fundamental knowledge would generate technologies applicable in the business. However, Corporate Research was not directly concerned with the company's business imperatives.

In the 1990s Corporate Research was funded by the Central Research and Engineering Fund, and represented about 10% of Unilever's expenditure on research. It was expected that this investment would generate new business opportunities. It was also designed to fund the creation of a knowledge base with synergies across product categories. In some cases, the investment proved extremely worthwhile, for example by producing pregnancy testing kits, a product category that was eventually divested.

Gradually, Corporate Research was forced to respond to more immediate business imperatives as a result of re-structuring of Unilever's strategy in the 1990s. This resulted in its problems becoming more aligned with those of business product categories. For instance, instead of creating fundamental knowledge or instruments, this area began to tackle business-oriented fundamental questions such as the use of sensory perceptions of food in creating 'salty tasting' foods that did not have implications for health. Also, Corporate Research was used by the company to monitor the latest developments in science. New developments were evaluated in terms of their potential to be included in new technologies for Unilever. The time horizon of these projects was between five and 10 years. Unilever considered Genomics, Informatics, Nanotechnology and Neuroscience to be four areas that would have a major impact on its business. Before 2003, some of this research was performed at Port Sunlight and some at Colworth, but after that time it was mostly transferred to Colworth.

4.3.2 Corporate Research: university links

Corporate Research included all types of links because its research had a much longer time horizon. This time scale accommodated all forms of human resources (e.g. doctoral and post-doctoral research), social networks, and contractual arrangements of any time length.[8]

Human Resources Development and Hiring links involved grants for doctoral and post-doctoral researchers. They were used for the purpose of possibly hiring these researchers, and to cement relations with academics. In the early 1990s the company provided finance to support lectureships in universities.

Information and Knowledge Based links were programmatic, for example in the social networks and informal contacts (see appendix five, for the participation of Corporate Research in the formation of Unilever campus-based laboratory in Cambridge).

These included feedback from academics into the company's research programmes, and Unilever's Corporate Research scientists sitting on academic steering committees. In terms of contractual arrangements, the company provided universities with grants for research on programmatic short-term, and long-term bases. Other institutions, such as government technological institutes, could be involved.

In the early 1990s there were no major IPR issues, however, IPR has become more relevant in recent years. Corporate Research has began to accommodate consultancy contracts (although in the interviews their time length was not specified). This may indicate a move towards a more formalized relationship with universities and a reduction in social networks and informal contacts. However, further investigation would be needed to confirm this.

Very long-term contractual arrangements links with the campus-based laboratory in the Cambridge University Chemistry Department are programmatic (see appendix five). These involve pre-competitive research in docking techniques (study of the interactions between molecules with different characteristics, such as between proteins) and in the generation of a database of simulations of new molecules. The toxicological analysis done by SEAC at Colworth is also connected to the simulation of toxicological analysis (to filter out compounds that are likely to be toxicologically suspect) to avoid clinical tests.

From the data on contracts (table 7), in the period from 1999 there has been a twofold increase in the total number of exploratory research projects performed by Corporate Research. Up to 2002 British universities were the most important source of knowledge at this level. This indicates that the home knowledge-base in more fundamental research, largely produced by universities, tends to be more relevant to local companies than that generated elsewhere.[9]

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[8] The reverse is true, i.e. it is more difficult to accommodate longer-term research in short-term activities. For instance, a Development Laboratory concentrating on short-term issues is virtually unable to investigate research questions over a long period of time.

[9] This point was often emphasised by Keith Pavitt before the fieldwork.

Table 7 – Corporate Research: contractual arrangements biannual average, 1997 to 2002

Institution/Years	**1997/1998[1]**	**1999/2000**	**2001/2002**
UK Universities	18 (58%)	34 (48%)	57 (38%)
Non-UK Universities	4 (13%)	14 (19%)	33 (22%)
Sub Total (Universities)	22 (71%)	48 (67%)	90 (60%)
Other Institutions[2]	9 (29%)	24 (33%)	60 (40%)
Total (Universities and Other Institutions)	31 (100%)	72 (100%)	150 (100%)

Notes: 1. Data for 1997 and 1998 were incomplete at the time the database was being implemented.
2. Other institutions included both public and private research laboratories and other companies providing specialist services.

Source: Own elaboration based on Unilever Research database of contracts.

However, in 2001/2002 the growth in contracts with British universities has been overtaken by growth in the number of contracts with other institutions and with non-UK universities: the number of contracts with other institutions (e.g. public and private research laboratories) and non-UK universities has more than doubled, while contracts with British universities have increased by about 68% in the period. From the fieldwork, it emerged that dealings with British universities are becoming increasingly difficult for Unilever, which may be reflected in this trend.

Table 8 summarizes the university-industry links with Corporate Research (this table is collapsed in table 5 – level 7). Unilever's links are programmatic. Interactions with universities at this level for both *Human Resources Development and Hiring* and *Informal and Knowledge Based* links served to provide Unilever with recruits and specialized knowledge for its research programme.

Table 8 – Corporate Research: summary of university-industry links

Technological Activities/ Period	Late 1990's Early 2000's
Research	
(7) Exploratory	
Human Resources Development and Hiring	
BScs and MScs	Programmatic
PhDs and Post-docs	Programmatic
Information and Knowledge Based	
Social networks and informal contacts	Programmatic
Short-term contractual arrangements	Programmatic
Long-term contractual arrangements	Programmatic
Very long-term contractual arrangements	Programmatic

Source: Own elaboration based on fieldwork.

The company used contracts of varying time lengths in a programmatic fashion with a variety of institutions. The company also has links with specialized research centres, such as the Chemistry Department in Cambridge, for more specific types of knowledge.

5 Analysis

Table 5 (section 4.1.6) summarizes the information of the empirical section of the paper. The following three key issues emerge.

First, in manufacturing and minor technological development activities (levels 1 and 2) links with universities are almost entirely related to *Human Resources Development and Hiring*. Consequently there is relatively little involvement between these activities and university research. The bulk of their knowledge demands are met by intra-corporate sources (chiefly Regional Innovation Centres and Global Technology Centres). This applies to both deodorants and margarine products.

Second, and again for both product categories, there are few links with universities at the level of intermediate and advanced technological development activities (levels 3 and 4). Most of these are related to *Human Resources Development and Hiring* and (to a lesser extent) to *Information and Knowledge Based* links in terms of short-term contractual arrangements and social networks and informal contacts. As in manufacturing and minor technological development activities, most of the knowledge demands from intermediate and advanced development activities are met internally. Interactions are mostly with manufacturing sites, related to feedback on product developments. However, this also involves interactions with applied and disciplinary research activities. Hence a substantial part of the knowledge is supplied by the Research Laboratories.

Third, as can be seen from table 5, most programmatic links with universities happened with research activities (levels 5 to 7). This illustrates the contrast between research, and technological development and manufacturing activities. Research activities were responsible for the bulk of the knowledge demands made on universities. Applied, disciplinary and exploratory research activities all had programmatic links with universities beyond *Human Resources Hiring and Development*. This was particularly the case for social networks and informal contacts and (short and long-term) contractual arrangements.

A closer look at the data on contractual arrangements (Table 9) reveals a tendency for these to be more frequent at the exploratory research (level 7), rather than at the applied and disciplinary research levels (levels 5 and 6). In the two periods between 1999 and 2002 there was a growth in the proportion of university contracts for exploratory research and a decrease in either applied or disciplinary research for deodorants and margarine. This increase in fundamental research contracts is consistent with the increase in joint-publications between Unilever and universities. Arguably this increase in exploratory research occurred in parallel with the disclosure of results, reflected in an increase in publications from an annual average of 48 papers between 1995-1996 to 68 between 1999-2000 (Appendix 1).

Table 9 - University contracts: research levels 5 to 7 biannual average, 1997 to 2002

Research Level/ Period	1997/1998[1]	1999/2000 (a)	2001/2002 (b)	(b/a)
Applied - Disciplinary (levels 5-6)	17 (43%)	43 (47%)	34 (28%)	0.79
Exploratory (level 7)	22 (57%)	48 (53%)	90 (72%)	1.88
Total (level 5 to 7)	39 (100%)	91 (100%)	124 (100%)	1.36

Note: 1. Data for 1997 and 1998 were incomplete when database was being implemented.
Source: Own elaboration based on Unilever Research database of contracts.

Although there was an increasing concentration of demand for knowledge at the level of exploratory research, Unilever drew upon a variety of sources at all research levels. This is evident from two aspects of the data analysed. First, in the case of margarine (table 6) and Corporate Research (table 7) Unilever frequently consulted non-UK universities through international networks of scientific research. Second, Table 10 shows that Unilever also increasingly drew upon other institutions at both levels of research and particularly in the last two periods. For applied and disciplinary research, contracts grew by 73% and for exploratory research they more than doubled. In fact, during the course of the fieldwork it was reported that the company sought out centres of excellence in the different knowledge areas, regardless of their location or institutional affiliation. The company considered the capacity of knowledge suppliers to meet its needs in a competent and timely manner and under mutually acceptable terms.

Table 10 - Contracts with other institutions: research levels 5 to 7 biannual average, 1997 to 2002

Research Level/ Period	1997/1998[1]	1999/2000 (a)	2001/2002 (b)	(b/a)
Applied - Disciplinary (levels 5-6)	6 (40%)	29 (55%)	50 (45%)	1.73
Exploratory (level 7)	9 (60%)	24 (45%)	60 (55%)	2.50
Total (level 5 to 7)	15 (100%)	53 (100%)	110 (100%)	2.08

Note: 1. Data for 1997 and 1998 were incomplete when database was being implemented.

Source: Own elaboration based on Unilever Research database of contracts.

In summary, our empirical work shows that the demand for university knowledge tends to be concentrated at the research level, rather than at the technological development or manufacturing levels. The fieldwork identified a relative concentration of demand at the level of exploratory research. Unilever sought out a variety of sources of information, including both local and foreign universities and other institutions. Hence, universities contributed to Unilever chiefly via its research activities, and to a lesser extent (and more human resources based) via technological development and manufacturing. Links to universities were quite similar at the same level of activity for the two product categories studied. So our sample shows that the type of product technology did influence the types of links undertaken. If anything, margarine is a technology linked to Unilever from its inception and this reflects in the fact that the company seeks to connect to international academic networks. Deodorants is a relatively newer technology to Unilever, and here the company drew upon universities to obtain specific knowledge inputs.

6 Conclusions

This paper analysed the university-industry links across the technological activities and capabilities of two product categories of a large company - Unilever. We found that the composition and intensity of university-industry links from the perspective of manufacturing, technological development and research activities is not homogeneous. Heterogeneity happened because links with universities became substantial only at the level of research activities. The paper reached this conclusion by undertaking a novel approach to university-industry links, analyzing them in a cross-sectional fashion at the level of the firm.

Heterogeneity was identified as the composition and intensity of the links with universities were not very substantial at both the levels of manufacturing and technological development activities, apart from links related to the recruitment of human resources. The corporate structure at these levels drew upon knowledge supplied largely through intrafirm channels. Other external sources of knowledge such as customers and suppliers were deemed as relevant at these levels, whereas the bulk of university links occurred by means of human resources. University-industry links became quite varied and intense at the levels of applied, disciplinary and exploratory research.

Within research activities, the most varied and intense links were held at the level of exploratory research. At the levels of applied and disciplinary research there were not very substantial differences in the composition and intensity of the links. However, links for the product category margarine tended to be more internationalised than the links for deodorants.

The main finding of the paper is that there was a steep change in the intensity and composition of links between both manufacturing and technological development and research activities. This finding contradicts assumptions that there might be a gradual increase in the composition and intensity of university-industry links as the technological activities and capabilities become more elaborate. The research was limited by the case study approach choose for its implementation. Our findings are quite specific with respect to the cases analysed, and different evidence may be identified even in the context of Unilever should different product categories be studied.

In this sense, our approach might be tested in a number of ways in future research. For instance, the composition and intensity of university-industry links might be examined across different companies or industry in a survey research. Likewise, this approach might be tested for different types of product technologies, particularly those closer to the science frontier such as aerospace and novel drug technologies, where the results obtained may be more varied than the ones presented here.

Our findings that different compositions and intensities of university-industry links may occur for different types of technological activities have potential implication for policy. For instance, one would expect that policies to foster collaborative research between university and industry might be more effective for companies that actually undertake research activities as part of their R&D efforts.

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Appendix 1 – Unilever: evolution of joint-publications with universities, 1995 to 2000

Discipline/ Year	1995	1996	1997	1998	1999	2000	Total
1. Biological Sciences	14	7	13	16	20	14	84
2. Chemical Engineering	7	8	15	16	12	19	77
3. Medical Sciences	6	7	6	10	8	18	55
4. Agriculture/Agronomy	11	3	7	6	7	8	42
5. Chemical Sciences	2	3	6	6	6	6	29
6. Material Sciences	6	7	5	4	2	3	27
7. Physical Sciences	5	3	3	0	2	1	14
8. Multidisciplinary	0	1	0	1	1	2	5
9. Instruments/Mesauremt.	0	0	1	1	0	2	4
10. Social Sciences	1	0	0	1	0	2	4
11. Mechanical Eng.	0	2	1	0	0	1	4
12. Computing	1	0	0	1	0	0	2
13. Elect./ Electronics Eng.	1	0	0	0	0	1	2
14. Mathematics	0	1	0	1	0	0	2
15. Other Engineering	0	0	0	1	0	0	1
Total per year	54	42	57	64	58	77	352
Bi-annual average	48		60		68		

Note: Data about Unilever UK.
Source: Own elaboration based on SPRU database.

Appendix 2 – Patent evidence used in preparation for fieldwork

Unilever: Number of Patents Per Year and Inventors Out of Top 5 Patenting Countries (USPTO), 1971 to 2002

Periods	Patents	%	Patents/ Year	Inventors Out of Top 5 Patenting Countries[1]	% Participation - Inventors Out of Top 5 Patenting Countries
1998-2002	1,005	25.4	201	89	8.85
1989-1997	1,575	39.8	197	64	4.06
1980-1988	765	19.4	96	40	8.36
1971-1979	608	15.4	76	34	5.59
Total	3,953	100	Not applicable	Not applicable	

Note: 1. Excludes 35 inventors from: Denmark, Sweden, Spain, Austria, Moldova, Cote d'Ivoire, Honduras, Bahrain, Portugal, Greece, Ireland and Gilbert Islands.

Source: www.delphion.com (11/02/2003).

Appendix 2 – Patent evidence used in preparation for fieldwork (cont.)

Unilever: Number of Main Inventors (USPTO), 1970 to 2002

Ranking	Country	Number of Main Inventors in Patents
1	US	1,897
2	UK	1,245
3	Netherlands	662
4	Germany	187
5	France	96
6	Italy	39
7	Belgium	34
8	India	26
9	Japan	24
10	Switzerland	19
11	Canada	17
12	Australia	17
13	Brazil	12
14	Thailand	9
15	Denmark	7
16	South Africa	6
17	Sweden	6
18	Mexico	5
19	Spain	5
20	Austria	4
21	Argentina	3
22	China	3
Not applicable	Others	108
	Total	4,431

Note: Germany includes Federal Republic of Germany.
Source: www.delphion.com (last accessed 05/02/2003).

Unilever: Main Patent Class, 1971 to 2002

Ranking	International Patent Classification	% in Total Patents
1	Detergent compositions	20
2	Preparation for dental, medical or toilet purposes	14
3	Edible oils, or fats, e.g. margarines, shortening cooking oils	6
4	Foods, foodstuffs, or non-alcoholic beverages, not covered by sub-classes 23b to 23j, their preparation or treatment	5
5	Acyclic or carbocyclic compounds	3
6	Containers for storage or transport of articles or materials	3
	Total	51

Sources: www.delphion.com (last accessed 05/02/2003) and www.wipo.org (last accessed 06/02/2003).

Appendix 3 – Deodorant operations in Unilever UK

Technological Activity	Organizational Structure	Affiliate	Site	Product Categories	Related Areas in the Site
Research	Research Laboratory	Unilever Research	Port Sunlight	Deodorants (DeoRes) Other Home and Personal Care (HPC) products (hair care, household care, oral care, laundry)	Process Sciences (ProcSci) Disciplinary Research (e.g. Statistics) Multidisciplinary Research (e.g. Biosciences and Consumer Sciences) Groups Providing Specific Capabilities (e.g. Measurement Sciences)
Development	Global Technology Centre	Lever Fabergé	Leeds	Deodorants (mainly aerosol and roll-on applicators)	Related processes, marketing, market research
Manufacturing	Manufacturing Site	Lever Fabergé	Leeds	Deodorants (all aplicators) Other HPC products	Not applicable
Others	Head Office	HPC Division	Kingston-upon-Thames (Surrey)	Deodorants Other HPC products	Not available

Source: Own elaboration based on field work and www.unilever.co.uk (last accessed 30/09/2005).

Appendix 4 – Margarine operations in Unilever UK

Technological Activity	Organizational Structure	Affiliate	Site	Product Categories	Related Areas in the Site
Research	Research Laboratory	Unilever Research	Colworth	Margarine and other foods products (beverages, ice-cream and frozen integrated into the Food Resarch Centre)	Corporate Research[2], Safety and Environmental Assurance Centre, underlying disciplines (e.g. Life Sciences) Multidisciplinary groups (e.g. Process Sciences, Physical Chemistry, Material Sciences, Process Sciences) Specific capabilities (e.g. Measurement Science and Knowledge and Information Service)
Development[1]	Global Technology Centre	Unilever Bestfoods	Vlaardingen (the Netherlands)	Margarine	Not applicable
	Regional Innovation Centre	Unilever Bestfoods	Purfleet	Margarine (mainly health products)	Manufacturing, oil refining
Manufacturing	Manufacturing Site	Unilever Bestfoods	Purfleet	Margarine	Innovation, marketing, market research
Others	Head Office	Food Division	Crawley	Margarine and other food products	Marketing

Note: 1. Includes a Dutch operation relevant for the UK. 2. Corporate Research increases in importance over time in Colworth.

Source: Own elaboration based on www.unilever.co.uk/ourvalues/sciandtech/foods_randd (last accessed 30/09/2005).

Appendix 5 – The Unilever Centre for Molecular Informatics

The Centre was created as a result of an invitation from the head of the Chemistry Department at Cambridge to the then head of Corporate Research in Unilever to sit on its department steering committee. Both parties realized that their respective organizations were interested in storing large amounts of information on molecules. After seeing the Cambridge University electronic database of molecules, the head of Corporate Research realized that this method of storing simulated molecules and compounds saved research resources.

The primary focus of the new Centre was computational simulation of the development of molecules and associated knowledge management methods. The Centre was set up on the basis that it would not be possible for Unilever to keep an in-house capability in computational chemistry that answered all its needs. The company provided academic freedom for an academic research group to investigate scientific advances in the area, including those of interest to Unilever. This occurs largely in the pre-competitive phase, when there is scope for collaboration with other companies, particularly in the calculation and measurement of molecular properties. However, Unilever reserved the right to retain the characteristics of molecules of interest to the company.

Unilever set up the Centre for Molecular Informatics at the Chemistry Department of Cambridge University in 1999, appointing a professorial director and a company liaison scientist. It initially committed £13 million to build the physical infra-structure and to hire the staff and academics on five year contracts. The Centre was inaugurated in 2001. In 2003, the Centre had four research groups, a professor, three group leaders, 25 post-doctoral researchers and 15 doctoral researchers.

Three main areas of the Centre’s research are of interest to Unilever: 1) the technique of electronically storing molecular information. This permits the development of new protocols to publish molecular data and is done by means of disclosing all the data generated from molecule simulation; 2) toxicological analysis simulation, used to filter out compounds that are likely to be toxicologically harmful; 3) docking techniques, which study the interactions between molecules with different characteristics, such as between proteins (in food research) and small molecules.

The Centre provides short-term training and coursework. These items were initially tailored to Unilever, which can access them at a reduced price. Up to early 2003, about 250 people (including Unilever personnel) had received training at the Centre. The course contents include: use of Java and XML computer languages, search for molecular information in the Internet, and data analysis and calculus of protein information.

In 2005, the Centre was working with about 15 other companies (including Glaxo SmithKline, Astra Zeneca and Pfizer, and some smaller companies). The Centre receives public funding from the EU and the UK Research Councils (EPSRC, BBSRC and NERC).

Sources: Fieldwork,
http://www.unilever.co.uk/ourvalues/sciandtech/external_partnerships and
http://www-ucc.ch.cam.ac.uk (last accessed 30/09/2005).