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The role of academic technology transfer organizations in improving industry science links

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Abstract

The transfer of scientific and technological know-how into valuable economic activity has become a high priority on many policy agendas. Industry Science Links (ISLs) are an important dimension of this policy orientation. Over the last decades, multiple insights have been gained (both theoretical and empirical) as to how "effective" ISLs can be fostered through the design and the development of university-based technology transfer organizations (TTOs). In this paper, we document and analyze the evolution of "effective" university-based technology transfer mechanisms. We describe how decentralized organizational approaches and incentives that stimulate the active involvement of the research groups in the exploitation of their research findings might be combined with specialized central services offering intellectual property management and spin-off support. More particularly, we analyze how the creation of:

(1) an appropriate balance between centralization and decentralization within academia;
(2) the design of appropriate incentive structures for academic research groups;
(3) the implementation of appropriate decision and monitoring processes within the TTO

has brought about critical elements in fostering an "effective" commercialization of the academic science base.

Keywords: Economics of Science; Technology transfer

1. Introduction

It is now widely recognized in the economic literature that the performance of a (national) economy in terms of innovation and productivity is not only the result of public and private investments. It is also strongly influenced by the character and the intensity of the interactions and learning processes among producers, users, suppliers and public authorities (David and Foray, 1995; Freeman, 1991; Lundvall, 1992; Nelson, 1993; Patel and Pavitt, 1994).

A central issue within the "knowledge distribution power" perspective of an innovation system, are the

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links between industry and science. Theoretical and empirical work in innovation economics provides support for the use of scientific knowledge by creating and maintaining industry-science relations to positively affect innovation performance (see for instance: Feller, 1990; Rothwell, 1992; Rosenberg and Nelson, 1994; Dodgson, 1994; Mansfield and Lee, 1996; Mansfield, 1991, 1997; Branscomb et al., 1999; OECD, 2000). In a similar vein, the work on the "Triple Helix" model, which rose to prominence in the technology policy literature during the second half of the 1990s (e.g. Etzkowitz and Leydesdorff, 2000) draws our attention to the interaction between industry, academia, and government.

But at the same time the empirical evidence, especially for Europe, shows that the flow of basic research into economic exploitation is not without obstacles, cf. the so-called "European Paradox" (EC, 2002). A better comprehension of industry science links has thus figured high on the policy agenda in many OECD countries. In search of effective practices to improve the commercial applications of basic research, major benchmarking exercises were conducted (OECD, 2001; Polt, 2001). These authors conclude that low levels of Industry Science Links (further abbreviated as ISLs) in EU member states can be attributed mainly to a lack (1) in demand at the enterprise side, i.e. a specialization on innovation paths that do not require scientific knowledge or expertise, and (2) of incentive structures and institutional factors at the science side.

This paper deals with ISLs while taking a science-side perspective. It discusses and analyzes the practices that have been identified to cope with the barriers to the exploitation of basic research. The focus of the present analysis will be on the use of appropriate incentive systems and governance structures in science institutions. The contribution of university technology transfer offices (further abbreviated as TTO) as a mediating institution for improving the link between science and innovations will be considered. To better understand the design and the development of effective TTO organizations, we analyze the case of the K.U. Leuven TTO, comparing it with TTOs at other European academic institutions. Before turning to the empirical analysis, we first define the phenomenon of Industry Science Links and we review the existing literature.

2. The rise in industry science links

"*Industry-Science Links*" refer to the different types of interactions between the industry and the science sector that are aimed at the exchange of knowledge and technology. Typically, the following formal forms are considered:

- start-up of technology-oriented enterprises by researchers from the science-base generated at the research institute;
- collaborative research, i.e. defining and conducting R&D projects jointly by enterprises and science institutions, either on a bi-lateral basis or on a consortium basis;
- contract research and know-how based consulting by science commissioned by industry;
- development of Intellectual Property Rights (IPRs) by science both as a tool indicating their technology competence as well as serving as a base for licensing technologies to enterprises. Those IPRs are not limited to the establishment of patent portfolios, but also include the protection of design topologies, the establishment of frameworks for Material Transfer Agreements (MTAs), the protection of databases, the property rights on tissue banks, etc.;
- others, such as co-operation in graduate education, advanced training for enterprise staff, systematic exchange of research staff between companies and research institutes.

Behind this multitude of formal relationships lies a myriad of informal contacts, gatekeeping processes and industry-science networks on a personal base. These informal contacts and human capital flows are ways of exchanging knowledge between enterprises and public research, which are more difficult to quantify, but nevertheless extremely important and often a catalyst for instigating further formal contacts (see Allen, 1977 or Matkin, 1990).

Empirical studies in the economics and the management literature have attempted to quantify knowledge transfers from academic research, mostly for the US, through various proxies. Several papers have examined the emergence and the nature of academic spin-off activities (Shane, 2002; Zucker et al., 1998; Audretsch and Stephan, 1996; Bollinger et al., 1983). Shane (2002) investigated the licensing of university generated innovations. Henderson et al. (1998) and Mowery (1998) looked at citations to academic patents. Siegel et al. (2003a) studied university science parks. The use of public science by firms can also be documented in the number of references to scientific publications in patents, as in Narin et al. (1997), and more recently in Verbeek et al. (2002) and Branstetter (2003). Finally, university-industry collaborative research has received substantial attention in empirical studies (Hall et al., 2000; Cockburn and Henderson, 2000; Mohnen and Hoareau, in press; Belderbos et al., 2003).

Most recent empirical studies using various industry science link indicators, all suggest an intensification of the interactions between universities and industry over time. For instance, Branstetter (2003) and Verbeek et al. (2002) have shown that the number of scientific references in corporate patents have nearly tripled during the 1990s, although they are still highly concentrated within a limited number of technology domains as measured by the patent classes in which they occur. So called “science-based technologies”, defined as fields with frequent references to scientific knowledge, are biotechnology, information technologies, and advanced materials. Especially these science-based technologies are strong contributors to technological progress, as for instance observed by the increasing prominence of patents in these fields.

Underlying this positive trend is a change in the institutional environment, with public policies especially aimed at encouraging the commercialization of scientific discoveries and subsequent inventions. Universities and other public research institutes are increasingly expected not only to be producers of graduates and basic knowledge. The know-how they generate should also be transferred more efficiently and at higher speed into commercial activities, the reasoning goes. The recent surge in university patenting in the US is mostly attributed to the Bayh–Dole act of 1980, which gave the universities the right to license inventions from federally funded research (Nelson, 2001; Mowery et al., 2001). At the ISL demand side, corporations appear to look more extensively towards public science as one of the external sources allowing rapid and privileged access to new knowledge, especially in the life sciences (Cockburn and Henderson, 2000; Zucker et al., 1998; Mowery, 1998). At the same time, public research institutions are searching for new funds to compensate for the increasing budgetary stringency of public funding alongside the ever-increasing cost structures of state-of-the-art interdisciplinary research.

While on average the evidence suggests a growing trend in – and a positive effect of – knowledge transfers from science to industry, there is nevertheless a strong suggestion of an inadequate scale and intensity of those transfers, with the link between science and innovations neither direct nor close. Hall et al. (2000) report that in the US only a small minority of research partnerships (a modest 15%) registered under the NCRA and NCRPA act include a university, although the trend is positive. And, even despite the growth in university licensing in the US, Thursby and Kemp (2002) find substantial evidence of persistent inefficiencies across universities. Thursby and Thursby (2002) qualify the growth in commercial activities from universities as being mainly a growth in patent applications, but less in terms of invention disclosures, while the number of licenses executed was even found to have declined. Furthermore, these links often remain geographically restricted (Jaffe et al., 1993; Audretsch and Stephan, 1996). In Europe, the gap between high levels of scientific performance on the one hand and their minimal contributions to industrial competitiveness and new venture entrepreneurship on the other hand appears particularly large. This gap, also known as the “European paradox”, has been attributed to a low intensity of industry science links. For instance, evidence from the Community Innovation Surveys shows that only 10% of innovative firms in the EU have cooperative agreements with universities.

The empirical evidence suggests that the contributions of science to innovation and the relations between research institutions and enterprises are not at all straightforward, resulting in market failures in the market for scientific knowledge. A match of knowledge supply and demand provides a first necessary condition for establishing ISLs. The supply factor for ISLs relates to a well performing and competitive science base. The demand for ISLs requires the active presence of innovation strategies in the enterprise sector (Pavitt, 1998). But even if there is adequate supply and demand for ISLs, effective industry-science interactions may still not materialize, as the empirical evidence suggests. The extent to which this potential is utilized depends on the barriers within an innovation system. The economics and technology management literature has started only very recently to investigate in more detail how the fruits of academic research can be better exploited in a market environment. In Section 3, we will therefore review the emerging literature on the factors shaping ISLs from the perspective of the science base, integrating the research insights obtained from economics and management. In Section 4, we will review the empirical literature evaluating best practices in ISLs. Spin-offs, being a key dimension in ISLs, at present receiving wide policy attention, will be discussed in more detail. Sections 5–7 will then discuss the TTO role in fostering ISLs.

3. Management of ISL from the perspective of the science base

The science base includes various types of institutions such as publicly funded research organizations, universities and other higher education institutions. The organizational composition of the science base "landscape" is an important variable determining the performance of the public research sector, since each of the types mentioned has its own views and policies on ISLs. *Universities* cultivate industry contacts to ensure additional financing, allowing to expand their research capabilities beyond what core funding would allow and to secure good job prospects for their students. Leading research universities have even more ambitious goals as they seek ISLs to consolidate their position in innovation networks and to obtain and maintain a strategic position in the knowledge market. Recent research (Van Looy et al., 2004) has pointed to the positive effects of ISLs on the research performance of academic research groups. By obtaining access to state-of-the-art industrial research, academic research groups may be better able to focus and shape their own research agendas, embedding them better within the relevant R&D community (Debackere and Rappa, 1994). But universities need to balance the quest for ISLs with their teaching and basic research mission. *Publicly funded research organizations*, especially the specialized organizations with an applied research mission, have developed their linkages with the relevant industries almost organically. In many instances, the intensity and the frequency of those linkages is often seen as a direct performance indicator for those publicly funded research organizations.

When considering the science base, our focus will be on the university side. Since science-based innovations increasingly have a multidisciplinary character and build on "difficult-to-codify" people-centered interactions, university-based systems of ISLs, which combine basic and applied research with a broader education mission, are seen as enjoying a comparative advantage relative to research institutes (OECD, 2001). Universities in particular are required not only to play an active role in education and science and technology development, but also increasingly to turn those scientific developments into useful innovations whenever possible and desirable. However, as the economic pressure on academic research grows, universities have to cope with their new multi-tasking environment, i.e. how should they reconcile teaching, the "exogenous" (i.e. curiosity-driven invention) and "endogenous" (i.e. market-driven innovation) component of the academic research.

The highly uncertain and the non-codifiable nature of scientific know-how results in high transaction costs and in systemic failures in the market for this know-how, explaining the difficulty of organizing ISLs. A factor that has received quite some attention as a necessary condition for smooth ISLs is the presence of a transparent and well-articulated *intellectual property rights* regime (Link et al., 2003). The ownership of publicly funded research has thereby been shifted from the state to the research sector, cf. the Bayh–Dole act in the US. This has created stronger incentives for universities to look for commercial applications of their research. The allocation of ownership and subsequent proceeds from exploitation within the university sector (i.e. between the institution and the individual researcher) often remains a more unsettled issue, mostly left to the discretion of the research institute. Although, also here, framework conditions and arrangements can be suggested or even imposed by the state. While the effects of the Bayh–Dole act stress the importance of intellectual property rights for universities in order for effective knowledge transfers to occur, there remains the issue of the effectiveness of intellectual property rights and regimes of appropriability for firms to engage in ISLs (see Dechenaux et al., 2003). Hall et al. (2001) provide qualitative evidence for the US on intellectual property barriers that inhibit the formation of public–private research partnerships.

A major issue that universities face is whether researchers have sufficient *incentives* to disclose their inventions and to induce researchers' cooperation in further development following license agreements. Although the Bayh–Dole act stipulates that scientists must file an invention disclosure, this rule is rarely enforced. Instead, the university needs to have proper license contracts in place as incentive scheme, specifying a share for the inventors in royalties or equity. This is studied in Macho-Stadler et al. (1996) and Jensen and Thursby (2001) for the moral hazard problem relating to inventor cooperation in commercialization and in Jensen et al. (2003a) as far as inventor disclosure is concerned. Lach and Schankerman (2003) provide strong support for the importance of inventor royalty sharing rules for university performance in terms of inventions and license income. Analyzing panel data on US universities, they find that private universities with higher inventor shares have higher licensing incomes, suggesting a Laffer curve effect. The incentive effects seem to work both at the level of effort and the selection of researchers.

Even when disclosure is stimulated through appropriate incentive schemes, not all inventions will be patented and licensed by the university, which may have to, or prefer to, "shelve" inventions. This relates to another problem in the market for technology transfer, namely the *asymmetric information* between industry and science on the value of the innovations. Firms typically cannot assess the quality of the invention ex ante, while researchers may find it difficult to assess the commercial profitability of their inventions. This problem is studied in Macho-Stadler et al. (2004). A partner's lack of understanding of the other partner's culture and *conflicting objectives* among partners may further impede good industry science relations, notably the conflict of interest between the dissemination of the new research findings versus the commercial appropriation of new knowledge (Siegel et al., 2003b).

Surprisingly little attention has been devoted to the *organizational structure* of technology transfer activities within science institutions as a conditioning factor for ISLs. Bercovitz et al. (2001), using a sample of US universities, provide evidence of the importance of the organizational structure to link with industry within the university to explain the performance achieved in terms of patents, licensing and sponsored research. Universities with a high record in ISLs most often apply a decentralized model of technology transfer, i.e. the responsibilities for transfer activities are located close to research groups and individuals. Associated with a decentralized model is the provision of adequate administrative support which allows the researcher to concentrate on R&D efforts and knowledge exchange, leaving most administrative activities associated with transfer activities (such as legal agreements, financial issues, etc.) at specialized organizational units. Furthermore, specialized support should also include the commercialization of R&D results via patenting and licensing where specific legal and marketing know-how is needed.

Within a decentralized model of technology transfer, creating a specialized and decentralized *technology transfer office* within the university is instrumental to secure a sufficient level of autonomy for developing relations with industry. This provides a better "buffer" against possible conflicts of interest between the commercialization and the research and teaching activities. A dedicated transfer unit also allows for specialization in supporting services, most notably management of intellectual property and business development. A higher degree of financial and managerial independence further facilitates relations with third parties, such as venture capitalists, investment bankers and patent attorneys.

In addition, a TTO can be instrumental in reducing the asymmetric information problem typically encountered in the scientific knowledge market. TTOs may have an incentive to invest in expertise to locate new inventions and sort profitable from unprofitable ones. The sunk costs to acquire this expertise can be overcome if the size of the invention pool is large enough such that the TTO can exploit economies of sharing expertise. Using an asymmetric information framework, where firms have incomplete information on the quality of inventions, Macho-Stadler et al. (2004) develop a reputation argument for the TTO. The TTO being able to pool innovations across research labs, will have an incentive to "shelve" some of the projects, thus raising the buyer's beliefs on expected quality, which results in less but more valuable innovations being sold at higher prices. However, the TTO will not have enough incentives to maintain a reputation when the stream of innovations of each research lab is too small and/or the university has just a few of them. Their reputation model for a TTO is thus able to explain the importance of a critical size for the TTO in order to be successful as well as the stylized fact that TTOs may lead to less licensing agreements, but higher income from innovation transfers (Siegel et al., 2003a).

Against the benefits that a TTO can deliver, there is however the issue of scale as smaller universities often lack the resources and the technical skills to effectively support such organizational arrangements and investments. And, at the same time, a separate unit needs to be able to maintain close enough relationships with the researchers in the different departments. A dedicated TTO needs to assure appropriate incentive mechanisms with its researchers overcoming moral hazard problems to ensure generation and disclosure of research projects (see e.g. Jensen et al., 2003b).

While basic research results can either be channeled to industry via collaborative research schemes or licensing arrangements of patented university inventions, *spinning off* is the entrepreneurial route to commercialize public research. The latter attracts a great deal of policy attention in the current wave of stimulating start-ups and new venture creation processes in many countries. Assessing the spin-off formation rate is often seen as a key indicator for the quality of ISLs (OECD, 2001).

New technology ventures originating at universities fulfill a bridging function between curiosity-driven academic research on the one hand and strategy-driven corporate research on the other hand. These new ventures have the potential to introduce technological disequilibria that change the rules of competition in existing industries. They allow for a multitude of experiments with often-competing “dominant designs” and “business models”, only a few of which will ultimately survive. Hence, new ventures are the gene pool from which new industries may emerge in the longer run (Roberts, 1991; Utterback, 1994; Thurow, 1999). Academic entrepreneurship in biotechnology is probably the most striking example when it comes to describing these phenomena. Universities can play an important role in this process, as they can be a breeding ground for new venture creation.

However, although significant research efforts have been devoted to measure technology entrepreneurship (e.g. Shane, 2002; Zucker et al., 1998; Bartelsman et al., 2003), these studies have not been very successful in developing a detailed understanding of the growth of technology-based new firms (Autio, 2000). The differences in origin and growth patterns across various categories of start-ups as related to the intensity of their links to scientific activity require further analysis. In addition, there are few studies that have explicitly approached the analysis of spin-offs, as compared to other start-ups, and within spin-offs, comparing university-based spin-offs to others (e.g. Franco and Filson, 2000; Klepper and Sleeper, 2000; Nerkar and Shane, 2003). This body of literature has provided different predictions about the nature of innovations and new products introduced by spin-offs (imitation, innovation, differentiation from the parent organizations, etc.), the linkages with their parent organizations (competition versus cooperation), and their post-entry performance. For instance, Klepper and Sleeper (2000) show that in the US laser industry, spin-offs have outperformed other start-ups.

In the literature on start-ups and spin-offs, careful attempts at matching empirical results and economic theories are still at a pioneering stage. As a consequence, the motives for spinning-off in innovative, high-tech industries and the process governing their formation are still not well understood (Klepper, 2001). Theory has focused on the interactions between the intellectual property rights regime and the market for complementary assets that are required to commercialize new technologies (Teece, 1986; Gans and Stern, 2003). In addition, the nature of technology is important. General-purpose technologies, with many potential applications and buyers, are more likely to be exploited by technology entrepreneurs through cooperative arrangements (licensing contracts) with incumbents, whereas more specific technologies offer smaller opportunities for potential entrants. General-purpose technologies, such as in biotechnology and software, then favor the emergence of a market for knowledge and a division of labor between entrepreneurial innovators and established firms endowed with complementary assets (Arora et al., 2001; Torrisi, 1998).

4. In search of effective practices for improving ISLs

Fuelled by the notion that smooth interaction between science and industry becomes more important for the success of innovation activities and ultimate economic growth, the search for good practices in ISLs has started to receive attention by policy makers, both in the US and the EU. In this section, we review the main conclusions from these studies on universities that want to improve their industry link (see e.g. Branscomb et al., 1999; Siegel et al., 2001; OECD, 2000; EC, 2002; Polt, 2001). They relate to an evaluation of both the knowledge supply and the knowledge transfer capacities of universities.

In terms of *knowledge development*, reaching scientific excellence in research is a necessary first condition for ISLs. Attractiveness for industrial partners demands competence at universities both in short-term oriented R&D and in long-term oriented strategic research. Developing scientific excellence requires the presence of the necessary resources related to personnel qualification and capabilities, as well as a clear research orientation and research mission of the university. More particularly, obtaining scientific excellence in those disciplines that link to science-based technologies like biotechnology, life sciences, nanotechnology and ICT, will create a high demand for ISLs.

The main competitive advantage of universities in the knowledge market is their competence in generating new original findings and new approaches to problem solving. It is highly important that this basic R&D competence is directly available within the research group or department that is engaged in joint R&D with and transfer activities to enterprises. Research units should be involved both in basic and applied research. A good research team structure allows exploiting the complementarity between basic and applied research, with basic research enhancing the efficiency of applied research, but also applied research providing positive spillovers for basic research. Teaching and applied research may further be mutually reinforcing activities with graduates providing the necessary contacts and absorptive capacity for applied research with industry and an applied research profile of the university acting as an attraction pole for students. A university that can exploit the complementarities between teaching, basic research and applied research will thus be a strong player in the knowledge market.

Focusing on *knowledge transfer capacities*, efforts to improve ISLs at universities are shown to be especially successful when they implement ISLs as a central component of the institutions' mission and when they take the ISL activities into account in researcher evaluations, providing both individual and organizational incentives. A joint public–private set-up in terms of ownership, funding or the presence of advisory and steering boards also stimulates industry contacts, but is no precondition for successful transfer activities (Polt, 2001).

Universities that are successfully engaged in ISLs do not solely rely on contract research with industry. Rather, they show a balanced portfolio of financing by the government for long-term oriented, fundamental research combined with industry financing via contract research and collaborative R&D projects, as well as with competition-based public financing.

A sufficiently wide portfolio of different ISLs is important not only from a financial risk and diversification point of view, but also in view of the complementarity between the different modes of ISLs. Patents, for instance, may become much more important when viewed not in isolation as a mere source of income from royalties, but as a negotiation chip in sponsored research contracts with industry (see e.g. Thursby et al., 2001). In the mix of ISL mechanisms, contacts and networking are key, underscoring the importance of personnel mobility between industry and science (see also Van Dierdonck et al., 1990). Also as far as university spin-offs are concerned, their portfolio of R&D collaborative agreements with industry is viewed as a critical success factor for survival and to secure financing (e.g. Zucker et al., 1998, in biotechnology).

With respect to *organizational structure*, a decentralized model of technology transfer, through a dedicated and specialized Technology Transfer Office, characterizes most of the universities with a high record in ISLs (see Bercovitz et al., 2001, for the US). Further evidence from the U.S. in terms of good practices for technology transfer units is provided in Siegel et al. (1999). Based on interviews at five major research universities, the authors identify several critical organizational factors for university technology transfer offices. The most prominent ones are: adequate faculty tenure, promotion policies, adequate royalty and equity distribution systems, as well as the staffing practices within transfer offices, requiring a mix of scientists, lawyers and managers acting within a highly professional environment. They furthermore indicate as an important skill for technology officers a "boundary spanning" or "gatekeeping" role, serving as a bridge between the firms and scientists.

Benchmarking studies within the EU on *specialized technology transfer offices* do not provide clear evidence on the effectiveness of these intermediaries and their role in ISLs (Polt, 2001). Many critical success factors for ISLs (e.g. appropriate incentive schemes and institutional settings, the level and orientation of R&D activities at both industry and academia, the legal context) cannot be shaped by the intermediaries themselves. They therefore will often fail to foster ISLs if other barriers to interaction exist. In the EU, most intermediary organizations are rather small and they are therefore often below the necessary critical mass to stimulate ISLs effectively (Polt, 2001). Nevertheless, at least some of them seem to be more effective. Factors that distinguish these units from their less successful peers are (Polt, 2001):

- their focus on combining basic and applied research within research teams, regularly auditing the research strategy of the group in order to cope with changes in economy and society;
- the direct transfer between researchers and industry (i.e. avoiding intermediaries);
- their day-to-day proximity to the researchers themselves;
- their emphasis on building the complementary assets needed for the research groups to be effective in their ISLs (contract law, intellectual property management, spin-off development, access to venture capital, etc.);
- the design of sufficiently attractive individual remuneration packages that reward successful transfer activities.

An activity profile that specializes on specific science-based technologies further characterizes these successful units. Furthermore all these successful units are characterized by a strong profile on own commercialization avenues through spin-offs, suggesting a pivotal role for spin-off activities in successful university TTOs.

5. Assessing university technology transfer units as a mechanism to improve ISLs: a methodological framework

This section proposes a governance structure that integrates the mechanisms found in the various evaluation studies as critical to adequately deal with ISLs in universities: decentralization, the creation of proper incentives and pooling of critical specialized resources. This governance structure will then be tested in Section 6 on specific cases, most notably the case of K.U. Leuven R&D, which will be compared to other European cases in Section 7.

The governance structure focuses on an appropriate organizational structure, processes and context within the university to channel academic R&D toward exploitation. An appropriate *structure* should provide adequately designed incentive and organizational mechanisms, which translate into effective processes, i.e. day-to-day operations of knowledge creation and innovation management within the academic environment. *Processes* central to managing academic R&D toward commercial exploitation are knowledge management and new venture creation. But of course, an appropriate structure needs to be embedded in a supportive context. *Context* is related to the institutional and policy environment, the culture and the history that has unfolded within the academic institution. It shapes and configures the norms, values and attitudes of academic researchers towards combining "curiosity-driven" research and actively seeking for "market-relevant" opportunities that originate from this same research.

In terms of *incentive mechanisms*, the management of intellectual property rights and the evaluation system are important. The *ownership of intellectual property rights* creates strong incentives for universities to look for commercial applications of their research. While ownership of publicly funded research has been shifted from the state to the research sector, the allocation of ownership and the distribution of the proceeds in case of successful exploitation within the research sector (i.e. between the institution and the individual researcher) is often left to the research organization. This requires an optimization of the coordination costs of managing, enforcing and exploiting intellectual property rights. In order to ensure the researchers' interests in and commitments to commercialization, they should enjoy a fair share of any resulting lump-sum payments or royalties. At the same time, *evaluations of researchers* should not be exclusively based on research criteria, but should also take into account that excellence in research and teaching has become, at least partly, more tied to applications in industry.

In terms of *organizational structure*, *decentralization* is shown to be important. Creating more responsiveness from universities towards ISLs requires that public authorities give universities sufficient autonomy and freedom to develop their research policy and relations with industry. Also inside the university organization, decentralization is important. Creating a *specialized and decentralized technology transfer office* within the university is instrumental to secure a sufficient level of autonomy for developing relations with industry, allowing for specialization in supporting services, reducing the transaction costs in scientific knowledge markets. There is of course always the issue of resources to effectively support such organizational arrangements. And, at the same time, a separate unit needs to be able to maintain close enough relationships with the researchers in the different departments.

Different organizational arrangements within the university may result in different propensities to engage in the commercial exploitation of the university's (basic) research. If the university opts for an organizational arrangement known as the *professional bureaucracy*, marked by traditional faculty and departmental organizational boundaries and structures, one can assume the university's commercial orientation to be limited. Obviously, universities that organize their activities solely along disciplinary lines show little strategic intent to engage in the commercialization of their research results.

As the strategic intent to exploit their (basic) research commercially develops and grows, universities may find their traditional disciplinary boundaries and departmentalization unfit for setting up linkages with industry. Most often, the second step in the evolution towards the development of full-fledged ISLs then consists in the creation of a divisional structure whose sole mission is the exploitation of the know-how and intellectual property of the university. This approach often results in the university setting up a *division for research exploitation* or a holding structure. The advantage of this type of set-up is that it clearly demonstrates the intention of the university to commercialize and to allow economies of scale in supporting services. The disadvantage, however, is that such a divisional structure very often generates new boundaries within the institution, making a smooth integration of an activity portfolio consisting of basic research, education and commercial exploitation of research at the level of the research groups difficult. In other words, divisional structures and set-ups may demonstrate the institution's intent towards commercial exploitation, though it often lacks the decentralized approaches and incentive mechanisms that are required to engage and to involve the researchers and their groups as active partners in the exploitation process.

A next step in the evolution towards more professional ISL development is the creation of a *matrix structure* within the academic institution. Such a matrix structure allows the research groups to be actively involved and engaged in the commercial exploitation of their own research findings. In a matrix structure, the aforementioned division of research exploitation indeed becomes decentralized and integrated within the research groups themselves. Only a minimal central technical support infrastructure remains that assists the decentralized divisional structure(s) with issues like intellectual property management, contract drafting and negotiation, and aid with business plan development for spin-off creation. By adopting a matrix structure, the university assumes a high degree of commercial orientation since it does not only commit resources to commercialize (basic) research findings, capitalizing on scale economies in supporting services, but it also directly provides incentives to its researchers and their groups to participate in the process. Indeed, in such a matrix structure, accountability (both with respect to revenue and expense generation) is located at the level of the research group, which should act as a direct incentive for the researchers themselves to actively manage and grow their portfolio of explorative and exploitative research activities.

6. University technology transfer units as a mechanism to improve ISLs: the case of K.U. Leuven Research & Development

The technology transfer unit of the K.U. Leuven, K.U. Leuven Research & Development, further labeled as LRD, is one of the intermediary institutions identified as best practice in the EU benchmarking exercise (Polt, 2001). The next section will detail the context, structure and processes that explain the performance of LRD. Since the demand and supply for ISLs, as well as the institutional framework shape the prospects for a technology transfer unit to effectively link science and industry, we first briefly sketch the characteristics of the Belgian innovation system in Sections 6.1 and 6.2, before we zoom in on LRD in Section 6.3.

6.1. The institutional framework for ISLs in Belgium

The federal-regional political system in Belgium introduces a high level of complexity that impedes the development of a consistent policy promoting ISLs. In Belgium, the public promotion of ISLs is therefore less significant, both in terms of volume and influence (Polt, 2001). Nevertheless, there are some programs established in recent years to stimulate ISLs. The liaison or interface offices that universities are establishing to improve their ISLs receive some public support from the regional governments. Nevertheless, many of these interfaces are too small to be efficient; LRD being the notable exception (Polt, 2001).

The legal basis for research contracts between universities and third parties, articulated by government Decree in Flanders since 1995, stipulates that all costs directly linked to the execution of contract research (namely the use of infrastructure, services or personnel from the university) are at the expense of the principal of the contract. It also determines that all research contracts have to be approved by the university administration. There are no other regulations for Flemish universities. So, most of them have their own internal regulations that arrange and monitor these matters. These internal regulations determine the minimum overhead costs that must be applied in these contracts, the method of payment and the possibility of personal remuneration for researchers.

Intellectual property rights belong to the policy area of the Communities in Belgium. In Flanders, the transfer of research results that can lead to exploitation (including patents, licenses and other intellectual property rights) must be arranged between the university or research center and the principal of the contract. The Decree of 1998 determines that the property rights from research carried out by university researchers belong to the university. This leaves out the possibility for researchers to obtain the rights to their own research results, unless the university fails to exploit these results within a time span of 3 years or rejects the researcher's request for filing a patent.

The Decree of 1995 also determines the criteria that need to be fulfilled before a university can invest in *spin-offs*. Financial participation is only possible if the research results that lead to the creation of a spin-off, as well as other intangibles, are exploited. The university can accept shares in exchange for these intangibles, but it can never own the majority of the voting rights. The university is further entitled to participate in specialized venture funds that are created to support this financial participation.

6.2. The National Innovation System in Belgium

In terms of knowledge production structures relevant for ISLs, Belgium does not belong to the group of countries, which are considered to be leading the way, such as Finland, Sweden and the US. Overall, Belgium's R&D indicators such as public R&D spending as a percentage of GDP, are often around the EU average (see Tables 1 and 2). As in most countries, the majority of R&D expenditures is accounted for by

Table 1
Selection of main innovation indicators—EU15 comparison

	EU	BE	NL	FI	FR	DE	IT	UK	SW
New S&E Graduates (% of 20–34 years age class)[a]	6.85	6.19	3.62	11.39	12.29	4.79	3.53	10.04	7.38
New S&T Ph.D.'s per 000 population aged 25–34[b]	0.55	0.36	0.35	0.97	0.71	0.75	0.17	0.63	1.17
Public R&D expenditures (GERD-BERD) (% of GDP)[c]	0.67	0.56	0.88	0.98	0.77	0.72	0.53	0.66	0.94
Share of government budget allocated to R&D[b]	1.99	1.36	3.25	2.11	4.95	1.90	1.36	1.87	1.40
Business expenditures on R&D (BERD) (% of GDP)	1.28	1.45	1.14	2.68	1.36	1.80	0.53	1.21	2.84
Seed and start-up venture capital—investment per 000 GDP[b]	0.38	0.9	0.91	0.56	0.39	0.50	0.13	0.19	1.08
EPO patent applications (per million population)[b]	125	120	170	265	118	244	61	95	289
USPTO patent applications (per million population)[b]	69	80	93	135	69	122	28	69	171
Scientific publications per million[b]	613	810	963	1157	652	657	457	949	1431
Number of highly cited papers (% of total number)[b]	1.20	1.45	1.52	1.25	1.09	1.24	1.12	1.50	1.16

[a] European Commission (2003), "Third European Report on Science and Technology Indicators, 2003, Towards a Knowledge-based Economy".
[b] European Commission (2001), "Towards a European Research area, Key Figures 2001, Special Edition: Indicators for benchmarking of national research policies", Luxembourg: Office for Official Publications of the EC.
[c] European Commission (2002), "2002 Innovation Scoreboard", Commission Staff Working Paper. EC, Brussels.

Table 2
ISL indicators

	BE	NL	FI	FR	DE	IT	SW
Percentage of innovative firms indicating high use of universities as information source, 1998–2000	4.8	2.1	3.1	2.3	7.1	2.2	24.5
Percentage of innovative firms indicating high use of public research institutes as information source, 1998–2000	2.3	3.0	4.1	2.6	2.4	1.7	21.2

Source: Eurostat CIS III survey.

the enterprise sector. Belgium has a less pronounced high-tech orientation of its industry. It specializes in the higher segments of medium-tech industries, such as engineering & machinery, chemicals, vehicles, electrical machinery, metals and commodity materials. It is fair to characterize the Belgian enterprise sector as being more oriented towards the rapid adoption of new (process) technologies, rather than towards the genesis of new technology breakthroughs. Another possible drawback in terms of industry structure for fostering ISLs is the large percentage of affiliates of multinational firms in the "large enterprise" sector. Although there is a large share of small to medium sized firms in Belgium, which is often viewed to hamper ISLs (e.g. Veugelers and Cassiman, 2003), the small-sized firms seem to be more innovation active as compared to other EU SMEs.

On the supply side, Belgium has a well performing science base, at least in terms of the quality of the publications generated by Belgian scientists (see Table 1). Belgium invests a relatively large amount in R&D at higher education institutions (further abbreviated as HEIs), most notably in its 17 universities, among which K.U. Leuven is the largest. Belgian universities are, more than in most other EU countries, highly dependent on external sources for funding, mostly acquired on a competitive basis. Public funding for basic research accounts for only one-third of the total R&D expenditures by universities in Belgium.

Beside the university system, Belgium has several public (or semi-public) research institutes (PSREs) with varying objectives, structures and sizes. Overall, their significance in the public science sector is limited, but many PSREs specialize in certain technologies and establish dense networks to the enterprises in the respective fields of technology. The two most prominent ones are IMEC in micro- and nanoelectronics and VIB in biotechnology[1].

In line with other EU countries, universities and public science institutes are not a major source of information for innovating enterprises in Belgium. Nevertheless, Belgian innovating firms rely more strongly on research results achieved at public science institutes, when compared to other EU member states, as is shown in Table 2. PSREs are less important compared to universities, which is surprising, given the specific mission of most of these institutions, but this can be related to the highly specific orientation of these institutions within the Belgian science system as well as to their rather young age. Similarly, the number of innovating enterprises that have cooperative agreements with universities is much higher in Belgium as compared to the EU average. This holds both across manufacturing and service sectors and despite a lower presence of Belgian firms in typical science based industries (see Table 3).

In Table 4, we report patent grants to Belgian public science institutions at the USPTO over the period 1990–2000. More than half of the patents originates from PSREs, which is not surprising given their specific mission. Among universities, K.U. Leuven is the most active in terms of granted patents in the USPTO system. Similar results, also with higher absolute numbers, are obtained when analyzing EPO patents. No information is available on income from royalties for HEIs.

In terms of research-based start-ups, Belgium is performing quite well according to EU standards (see also Table 1). According to a study by Degroof et al. (2001), the number of spin-off enterprises has increased

[1] IMEC, the Interuniversity Microelectronics Center (founded in 1984 as a spin-off from the Electrotechnical Department of K.U. Leuven) operates in the field of micro- and nanoelectronics, conducting research, promoting technology transfer and stimulating spin-offs. IMEC is located on the K.U. Leuven Campus. VIB's (founded in 1995), Flanders Interuniversity Institute for Biotechnology mission is to promote biotechnology in a broad sense (research and development, technology transfer including stimulating spin-offs, and public awareness of biotechnology). VIB combines eight university departments and five associated laboratories. K.U. Leuven is one of the founding members.

Table 3
ISLs in Belgium

Indicator	Belgium	EU
Cooperation in innovation projects		
Innovative manufacturing enterprises co-operating with HEIs in %	13.4	9.7
Innovative manufacturing enterprises co-operating with PSREs in %	8.5	8.3
Innovative service enterprises co-operating with HEIs in %	15.3	6.4
Innovative service enterprises co-operating with PSREs in %	5.9	7.0
Science as an information source for innovation		
HEIs used as information source by innovative manufacturing enterprise in %	6.7	4.2
PSREs used as information source by innovative manufacturing enterprise in %	4.8	2.6
Conferences, meetings and publications used as information source by innovative manufacturing enterprise	5.4	7.6
HEIs used as information source by innovative service enterprise in %	2.0	4.4
PSREs used as information source by innovative service enterprise in %	2.7	3.2
Conferences, meetings and publications used as information source by innovative service enterprise	13.7	15.3

Source: Newcronos, CISII, 1996.

exponentially in Flanders since the mid-1990s. The increase in number of spin-offs can be accounted for by the interplay of several factors, including the presence of pre-seed capital funds, as well as some successful and visible IPOs in the mid and late-1990s. Also, the development of university interface services and the creation of Business Angel networks have helped in creating a spin-off culture. Finally, changes in the Belgian legislative framework made it easier and less ambiguous to start-up companies for academics.

6.3. K.U. Leuven: ISLs as a mission

Founded in 1425, the K.U. Leuven is the oldest and largest university in Flanders and Belgium, encompassing all academic disciplines. It has the legal status of a private institution, but receives 85% of its funding from the Belgian Government, both in a direct and in an indirect competitive way. More than 1400 tenured professors and 3500 researchers are currently employed at K.U. Leuven, dealing with a student population of more than 25,000 students each year. The mission statement of the K.U. Leuven stresses three basic activities. The university ensures the intergenerational transfer of knowledge from generation to generation through its teaching activities, it performs fundamental research, and it provides services to the community by making its inventions and knowledge available to society and to companies. “As a university, it is an academic institution where research and knowledge transfer are both essential and complementary” (K.U. Leuven, Mission Statement, 2002).

Table 4
Number of patents granted by the USPTO to different Belgian non-market institutions between 1990 and 2000

Name of institution	Number of patent grants
Interuniversitair Microelektronica Centrum (IMEC)	107
Subtotal Belgian Public Research Institutions	132
K.U. Leuven R&D	51
Subtotal Belgian Universities	94
Total Belgian USPTO patent grants	232

The research and knowledge transfer mission have been promoted and supported by two specialized units. The Research Coordination Office deals with basic research: designing the basic science policy of the university, allocating intra-university research funding and research evaluation. The technology transfer mission deals with contract research, patents, spin-offs and research parks and is organized via K.U. Leuven Research and Development (LRD). The total research budget of K.U. Leuven amounted to € 190 million in 2003 of which 24% (€ 46 million) was derived via LRD. Of this total research budget, 55% supports research in exact sciences, 25% in biomedical sciences and 20% in humanities and social sciences.

K.U. Leuven’s research efforts and output have increased considerably over the past decade, both quantitatively and qualitatively, thus positioning the institution at the productive end of European universities. It recorded a total of 3126 publications in international peer-reviewed ISI-recorded scientific journals (Science Citation Index) in 2003. A total of 15% of these publications where in journals with an impact factor in excess of 4. The spearhead expertise of its researchers thus is the foundation for successful collaboration. The following domains are specific areas of excellence: Biotechnology, Electronics & Mechanical Engineering, Environment, Food Sciences & Technology, Medicine & Medical Research, European Integration and Materials Sciences & Technology.

6.4. K.U. Leuven Research & Development: generating economic progress through academic R&D

Being embedded in the largest university in the Belgian Innovation System, K.U. Leuven Research & Development (LRD) was founded in 1972 to manage the industry component of the university's R&D portfolio. What started as a minor fraction of the total university R&D activity has, over the past 31 years, grown into a significant portion of the university's total R&D portfolio and employing 26 support staff professionals. It has evolved from a specialized division towards a matrix structure, operating via a number of specialized supporting services closely integrated with the research groups. In line with Roberts' (1991) and Thurow's (1999) insights on wealth creation through technology entrepreneurship, LRD has stimulated the exploitation of the university's research through a rich mix of mechanisms stimulating entrepreneurial behavior within its many research divisions.

6.4.1. The institutional framework of LRD

The fact that LRD has a history of 31 years is not unimportant. This "long" history implies that, by now, several generations of faculty and researchers have developed and built their careers alongside the presence of – and often based on – active interaction with LRD. As a consequence, the "contextual" impact of the *historic embeddedness* of LRD within the university is not to be underestimated. This historic presence is perhaps the single most important learning effect that has occurred within the university as to academic involvement in the processes of knowledge transfer for industrial and entrepreneurial innovation. It has enabled several generations of faculty and staff to become acquainted with industrial innovation; to understand its strengths and weaknesses; and to evaluate the benefits of academic entrepreneurship as a complement to the more traditional and established processes of industrial innovation. Hence, time and history are an integral part of the context that enables LRD to leverage the management and transfer of academic R&D at K.U. Leuven.

From its start, LRD has received a large amount of budgetary and human resource management *autonomy* within the university. This implies that LRD, although being fully integrated within the university manages its own budgets as well as the research personnel employed on those budgets. From an incentive point of view, creating a context with such high levels of budgetary and human resource autonomy is critical, since this allows for flexibility and degrees of freedom to operate that are often lacking within the "traditional" university administration. It allows the groups to actively manage their laboratory space and infrastructure. This autonomy, although highly necessary, also introduces a "creative tension" within the university itself. LRD indeed operates at the crossroads of academic and business value systems.

The context of autonomy to develop ISLs has to be embedded in a proper *organizational* approach. To this end, LRD introduced the organizational concept of the "*research division*". Researchers belonging to different departments at the university, even belonging to different faculties, can decide to join forces and to integrate the commercial-industrial component of their knowledge portfolio in a research division at LRD. As a consequence, the research division concept introduces a "de facto" interdisciplinary matrix structure within the university. This, of course, does not happen without any tensions given the "professional bureaucracies" that universities normally are. Today there exist 46 divisions, supported by about 220 faculty members and employing about 600 researchers and support staff, scattered across the various faculties and departments of the university. It is obvious that not all faculties are equally represented and involved. The majority of LRD activities stems from the divisions belonging to the engineering (54%), biomedical (24%), biosciences (9%) and the sciences (7%) faculty. The humanities and social sciences are underrepresented, although their activities via LRD have been increasing over the last 5-year period.

To ensure close contacts between LRD and the research groups, a group of *innovation coordinators* is established. The innovation coordinators are paid by LRD on a part-time basis (on average 20% of their salary) to act as a permanent liaison officer between LRD and its divisions. The rest of their time is spent as a researcher or junior faculty member within one of the LRD divisions.

Whereas the *incentive system* within the departments and faculties is promotion along the academic ladder, mainly based on the assessment of research quality and teaching ability, the LRD divisions have developed an incentive system that is based on budgetary flexibility and financial autonomy. LRD divisions enjoy complete autonomy as to balancing revenue and expenses from their ISL activities. In other words, LRD divisions are entitled to accumulate financial reserves based on the benefits they generate via ISLs. This is quite a unique situation, as most universities tend to centralize the profits generated via ISLs. The decentralized "modus operandi" that exists within LRD therefore acts as an incentive mechanism in and off itself. LRD divisions furthermore are entitled to participate both intellectually and financially in the spin-off companies that they have grown and developed. Finally, besides the aforementioned financial incentive mechanism at the level of the research division, incentives are given to individual researchers as well. Three types of incentive mechanisms at the individual level exist. First of all, researchers are entitled to salary supplements based on the net proceeds from their contract research and consultancy activities. Second, in case of lump sum and royalty payments proceeding from licensing agreements, individual researchers are entitled to receive up to 30% of the income generated (after expenses have been recuperated). Third, in case of spin-off creation, individual researchers can receive up to 40% of the intellectual property shares (i.e. the IP stock or founder shares) in exchange for the input of their know-how and goodwill. If they wish, they can also invest financially in the spin-off and will hence obtain a pro rata share in the common stock (capital shares) of the company.

This system thus implies that the university has created a *matrix structure*: research excellence prevails along the hierarchical lines of the faculties and their respective departments, whereas excellence in entrepreneurial and industrial innovation is rewarded along the lines of the LRD divisions. This structure, with sufficient degrees of coordination between academic research and innovation, as well as guaranteeing sufficient autonomy to the faculty and staff engaged in entrepreneurial and industrial innovation activities, is the basis of the university's approach towards managing academic science and technology towards commercial exploitation. This is in line with the model described in Section 5 of this paper. In addition, the dual incentive mechanism is at the core of a management process that enables the university to maintain a balance and a healthy tension between striving for scientific excellence on the one hand, and translating this excellence towards application and innovation on the other hand.

6.4.2. The activity profile of LRD

A distinct feature of LRD is the broad scope of its activity portfolio. Over time, LRD has developed three major activity poles that underpin its role in managing academic R&D as a business. Within its matrix structure, these central activities concentrate on contract drafting and negotiations, intellectual property management and business plan development. The first, and historically the oldest one, is the *contract research* pole. Over the years, LRD has grown to provide almost a quarter of the university's R&D budget via contract research activities. As will further become clear, those contract research activities have now reached significant levels both in terms of the volume and in terms of the quality of the work performed. LRD has developed and implemented the necessary processes for financial and personnel management that should support these activities. Also, the legal and intellectual property mechanisms that should underpin these activities are in place. A central LRD staff of 26 professionals assists the research groups with these activities.

The second activity pole consists of managing the university's *intellectual property portfolio*. This activity was first formally started in 1999 (although it existed organically well before that date), with the creation of an internal intellectual property liaison office and the establishment of a network of formal collaborations with different European patent attorneys. Internal procedures and the necessary information infrastructure were created to support this activity. Finally, a patent fund was established to help research groups cover the initial costs and expenses related to their patenting needs. End of 2003, there was an active portfolio of 171 patents (including both granted patents and pending applications). Given the differences between the nature and aims of academic versus industrial patent portfolios, the first criterion deployed by LRD in generating and developing the university's knowledge portfolio is "selectivity". The interest is not so much in generating a large portfolio of patents as in developing a valuable portfolio of patents. A full-time, in-house staff of 4.5 professionals (three of them holding Ph.D. degrees), complemented by long-term collaborations with a major patent attorney, supports this activity.

The third activity pole concerns the transfer of knowledge via the creation of *spin-off* companies. Here, LRD has developed the necessary mechanisms and processes that assist in business development and raising venture capital.

The university, in partnership with two major Belgian banks, created its own seed capital fund in 1997, i.e. the Gemma Frisius–Fonds, which has access to € 12.5 million in seed capital to fund start-up companies that exploit university-based know-how. By the end of 2001, Gemma Frisius had invested € 8.8 million in 15 spin-off companies. In July 2002, Gemma Frisius II was created with the same partners, pursuing similar opportunities as its predecessor fund, operating according to the same investment policies and principles. The first fund at present only does follow-on investments in its established portfolio. Both funds are 10-year closed-end funds that operate according to standard venture capital market principles. There is however no separate Investment Company as LRD together with two investment managers from both banking partners constitute the investment committee of Gemma Frisius. This investment committee does the day-to-day management of the Fund and proposes major decisions to the Board of the Fund. The Board of the university is at all times informed on the investment policy and has statutory rights to intervene in case the Fund would violate basic university policy or the rules set by the government Decree. Both versions of the Gemma Frisius Fund have the same shareholder structure: each banking partner owns 40% of the shares, LRD owns the remaining 20%.

In order to assist the start-up entrepreneur, LRD also has access to an "Innovation & Incubation Center" that is jointly owned and operated by the university and the local regional development agency. Accommodation and managerial support for its spin-offs is provided through this "Innovation & Incubation Center", which is located on the Campus and as such promotes close proximity with university laboratories and research units.

In addition two science parks are available in the close vicinity of the K.U. Leuven that are open to new innovative companies. These parks not only house spin-offs of the university and other research institutions, but also the R&D departments of existing companies. A third science park is still available for development, in close collaboration with the City of Leuven and the Economic Development Agency of the Province.

6.4.3. Finding the right mix of mechanisms: structure meets process

Even with several generations of academic researchers involved in knowledge transfer, a university still has to find and balance the right mix of transfer and innovation processes in order to be performing. The following processes can be seen as critical in the success of LRD.

(1) The system to manage and monitor contract research includes the necessary know-how and processes for legal, financial and human resources management as to the volume of research contracts generated via LRD. A central staff of 26 collaborators, assisted by innovation coordinators in the divisions, has grown in expertise and experience over time, supported by appropriate processes to support the activities of the innovation coordinators and to generate trust with the faculty and the researchers they are serving, such as innovation coordinator meetings and proper training for innovation coordinators.

(2) An active knowledge management policy, including a patent fund and an intellectual property advisory group, has been established. The patent fund has been created to support financially those divisions that lack the means to set up their own patent portfolio. As stated before, the core criterion is one of selectivity in admitting new cases to the university's patent portfolio. To this end, the necessary mechanisms, tools and processes have been created to screen for novelty and inventiveness, to do a quick scan of the know-how's economic potential and to eventually assist the research groups in writing the patent and its claim structure. Once again, a lot of attention is paid to train and to educate researchers all over the university so that they become acquainted with the many intricacies of the process of managing their knowledge portfolios.

(3) A venture fund has been created (see above), including an advisory group, to assist academic entrepreneurs in creating their enterprise, taking into account up-to-date principles and best practices on corporate governance. A major focus of the LRD venture unit is to assist the entrepreneurs, first in developing their business plan, then into turning the business plan into a solid business model. Finding a proper funding structure, as well as the right management team, figures high on the agenda of the LRD venture unit.
(4) Finally, in 1999, Leuven Inc. was established which acts as a network organization bringing together "like-minded people" from academic research groups, entrepreneurial start-ups, supporting services such as consultancy and venture capital, and established companies in the Leuven area. The aim of Leuven Inc. is to support and to stimulate the exchange of business experiences between its members. To this end, events, opportunities for informal networking, information and training sessions are continuously being organized and generated. Leuven Inc. has close ties to the Cambridge Network.

6.4.4. *The performance profile of LRD*

This mix of structure, context and processes has enabled the university to generate an increasing flux of knowledge transfer contracts, patents, know-how licenses and spin-offs. By the end of 2003, annual amounts of contract research activities are about € 40 million and patent income is steadily on the rise. In 2003, the patent income of K.U. Leuven patents amounted to € 6 million (see Table 5 for a comparison based on European patent applications and grants).

By the end of 2003, the university had generated 60 spin-off companies, with a portfolio of 54 spin-off companies still active today. They are distributed across a wide variety of knowledge domains, ranging from mechanical and electrical engineering to bio- and life sciences. Their product-markets are as diverse as automotive, Internet security, 3D modeling, rapid prototyping, stress management and tissue engineering. In Fig. 1, we provide an overview of the evolution in the university's spin-off portfolio.

When taking into account the structure of the present spin-off "deal-flow", it is expected to result in a steady state of 3–6 new spin-off creations per year for the coming 5 years at least. By the end of 2003, these spin-offs generated a turnover of € 400 million and employed over 2000 people. Two spin-offs have realized a successful IPO on Nasdaq and Easdaq. There have been six failures. However, as the companies all exploit university technology (and thus engage in active knowledge transfer from the university to the company), the highest failure rate occurs during the phase of spin-off creation. About two-thirds of the projects never makes it to the actual stage of spin-off incorporation.

To conclude, more profound analyses of the performance and activities of the research divisions show:

(1) Over the years, only 10% of the LRD activities, in which the LRD research divisions are engaged, can be labeled as consulting or routine analyses. The bulk of the contractual LRD activities have evolved towards applied research and knowledge development for industrial purposes. In other words, over the years, the LRD divisions have not only grown with respect to the volume of their contract research activities, but they have also maintained a high standard of quality as far as the content of their LRD activities is concerned.
(2) In addition, the bibliometric performance of the research divisions is strongly correlated with the (monetary) volume of the industrial innovation activities in which they are involved via LRD, thus further corroborating the complementarity between basic and applied research and the remarks on both volume and quality of the LRD activities mentioned supra.
(3) Finally, the top-performers in terms of academic research and industrial contract volumes also tend to be amongst the top-generators of new technology ventures, further supporting the importance of a broad scope of complementary activities in the activity profile of a technology transfer unit.

7. Comparing K.U. Leuven R&D to other European universities

The specific structures and incentives described at K.U. Leuven R&D are not unique. A survey of 11 other European Universities (Karolinska Institute in Sweden,

Table 5
Patent performance compared, EPO patent grants and applications, period 1990–2001, for Public Research Organizations in EU (threshold set at 50 patents)

Name of assignee	CNT	EPO Patents
Commissariat à l'Energie Atomique (C.E.A.)	FR	>2000
Institut Français du Petrole	FR	1000–1999
Centre National de la Recherche Scientifique (CNRS)	FR	1000–1999
Société Nationale d'Etude et de Construction de Moteurs d'Aviation (S.N.E.C.M.A.)	FR	500–999
UK—Secretary of State for Defence	GB	500–999
Etat Français	FR	500–999
Institut National de la Sante et de la Recherche Medicale (INSERM)	FR	250–499
Institut Pasteur	FR	250–499
Institut National de la Recherche Agronomique (I.N.R.A.)	FR	250–499
Interuniversitair Microelektronica Centrum (IMEC, vzw)	BE	250–499
UK—Atomic Energy Authority	GB	250–499
C.N.R.	IT	100–249
Deutsches Krebsforschungszentrum	DE	100–249
MRC—Medical Research Council	GB	100–249
TNO	NL	100–249
EURATOM	LU	100–249
Societe Nationale des Poudres et Explosifs (S.N.P.E.)	FR	100–249
Centre National d'Etudes Spatiales (CNES)	FR	100–249
Office National d'Etudes et de Recherche Aerospatiales (ONERA)	FR	100–249
M.U.R.S.T.	IT	100–249
K.U. Leuven R&D	BE	100–249
VTT	FI	100–249
University of Manchester	GB	100–249
Centre de Recherches Metallurgiques (CRM)	BE	100–249
Agence Nationale de la Valorisation de la Recherche (ANVAR)	FR	100–249
Institut de Recherches de la Siderurgie Francaise (IRSID)	FR	100–249
Societe de Conseils de Recherches et d'Applications Scientifiques (S.C.R.A.S.)	FR	100–249
University College London	GB	50–99
European Community	LU	50–99
Universiteit Leiden	NL	50–99
University of Strathclyde	GB	50–99
University of Southampton	GB	50–99
Institut Textile de France-Centre Technique Industriel	FR	50–99
Consejo Superior de Investigaciones Cientificas (CSIC)	ES	50–99
E.N.E.A.	IT	50–99
Imperial College London	GB	50–99
Association pour la Recherche et le Développement des Méthodes et Processus Industriels (A.R.M.I.N.E.S.)	FR	50–99
Agence Spatiale Européenne	FR	50–99
Universite Paris VI (Pierre et Marie Curie)	FR	50–99
University of Bristol	GB	50–99
University of Sheffield	GB	50–99
Universiteit Groningen	NL	50–99
Universiteit Gent	BE	50–99
UK—Minister for Agriculture Fisheries and Food	GB	50–99
Laboratoires d'Electronique et de Physique Appliquée	NL	50–99
University of Birmingham	GB	50–99
Slagteriernes Forskningsinstitut	DK	50–99

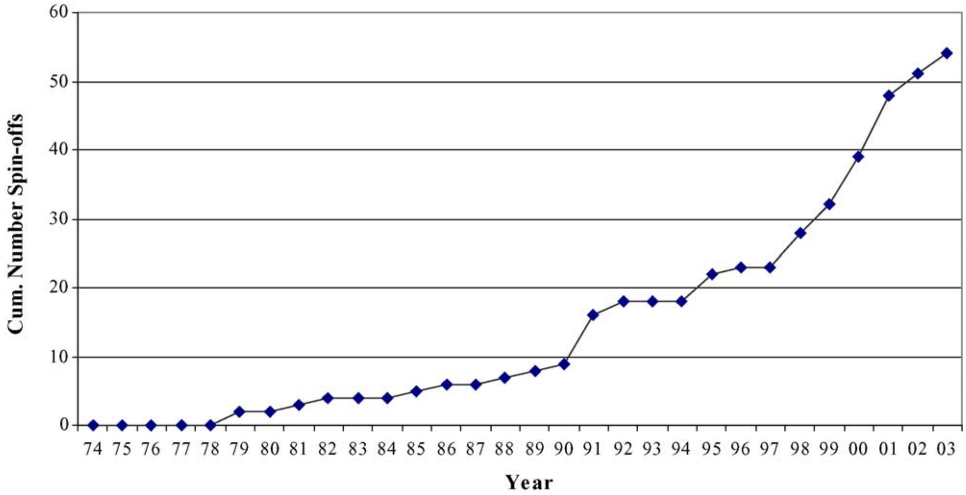

Fig. 1. Evolution of K.U. Leuven R&D spin-off portfolio.

the Universities of Oxford, Cambridge and Edinburgh in the UK, the University of Leiden in the Netherlands, the University of Geneva in Switzerland and Université Louis Pasteur in Strasbourg, University of Heidelberg and Münich in Germany, University of Helsinki in Finland and University of Milan in Italy), all members of the League of European Research intensive Universities (LERU), shows high levels of similarity in the approaches adopted towards managing ISLs as well as to the incentives provided at the respective institutions. It is obvious that the level of maturity with TTO structures and ISLs can differ amongst the institutions surveyed. However, the basis approaches and tenets are quite similar. More specifically:

- The universities surveyed consider the exploitation of research activities as an explicit mission of their institution. However, there is quite some variability as to the current stage of development of the exploitation activity at the various institutions. Some universities have a long-standing experience in the field of technology transfer, with a well-developed structure and team to conduct those activities, while other institutions (most notably in Germany and Finland, because of the specific intellectual property arrangements) only recently started structuring their technology transfer activity. The objectives and the (emerging or established) activity portfolio of exploitation activities (i.e. a mix and a balance of contract research, licensing and intellectual property management and spin-off creation) are highly similar, though.
- There is quite some variation as to the intellectual property ownership regimes in the various countries represented amongst the group of universities surveyed. Some countries have quite well-established guidelines and rules as to the ownership of inventions residing with the institution, while other countries have the ownership rights and titles residing with the inventor/researcher (e.g. till recently Germany and still in Sweden and Finland). The variation in ownership regimes inevitably leads to variations in intellectual property management practices and TTO-organization at the respective institutions. In some cases (Germany, for instance), IP policies of the institutions are organized at a centralized, regional level rather than at an institutional level.
- All universities surveyed recognize the need to support the mix of activities that is also present at LRD. ISLs, intellectual property management and spin-off creation generate important spillovers amongst them. Therefore, every university surveyed combines the three activities in its TTO structure.
- Each university also recognizes the need to decentralize its TTO structure, stimulating frequent interactions with the research groups and with large levels of delegated decision power towards the TTO as it comes to decision-making with the research

groups on what to exploit under what conditions using which mechanisms.

- Each university has a well-established incentive policy towards its researchers that is comparable to the one described at LRD. The incentives, financial and administrative, occur both at the level of the individual researchers involved in exploitation of research as well as at the level of the research groups involved.
- Each TTO manages a patent portfolio in a way comparable to LRD. The number of spin-offs varies amongst the universities surveyed, over the last 10 years. Both patents and spin-offs are clearly on the rise as to their frequency of occurrence.

8. Conclusion

Building on the insights from the scientific literature on the barriers in the scientific knowledge markets, and the policy oriented literature on best practices in ISLs, we have discussed the context, the structure and the processes that universities can use to become active players in the scientific knowledge market, managing and applying academic science, technology and innovation from an exploitation perspective. This framework was reviewed on a sample of European research universities, and analyzed in more detail for the case of K.U. Leuven.

The development of an adequate structure and processes need careful attention and subtle support on behalf of the university's management as well as of the institutional context in which universities are embedded. *Transparent and unambiguous regulations* with respect to ownership titles and property rights are an important element in this respect. In addition, time is an important factor in shaping the "right" culture for effective technology transfer and learning as to how to optimize the various transfer mechanisms and monitoring processes through experimentation.

An appropriate context is needed to transform the awareness of the university's potential contribution to innovation into an appropriate and acceptable structure and processes within the university itself that allow this contribution to be effectively implemented. Creating the appropriate mix of *incentive mechanisms*, targeted to the research groups as well as to the individual researchers (allowing them to participate in the rewards and the proceeds from their transfer activities), is a critical success factor. As the exploitation of research findings requires extra efforts and risk-taking on behalf of the academic researchers themselves, these efforts should be recognized and rewarded properly. This has led to schemes where researchers and their groups can, for instance, appropriate a significant portion of the royalty streams that are generated on the basis of their inventions. Or, still, it has stimulated the liaison or interface office to elaborate schemes in which researchers and the groups with which they are affiliated receive a significant portion of the shares in a start-up company based on the findings of their research. Also, academic authorities should accept that this approach can only succeed with a *decentralized management* style within their institution. Decentralization implies sufficient freedom to engage and to operate for the researchers and their groups whenever transfer opportunities occur. Decentralization also implies that the research groups are pivotal in deciding how the proceeds from their exploitation activities will be used. Finally, decentralization also stimulates the research groups to compete with their findings and results in the market for exploitation and innovation.

As this transformation from mere awareness to hands-on implementation occurs, universities further have to play an active role in shaping their internal institutional contexts and structures to enhance and foster ISLs. More specifically, they should provide the interface or liaison units with the necessary autonomy and incentives to become more professional. As we have discussed in this paper, this professionalization should be accompanied by the necessary structural arrangements within the university. A matrix structure, integrating but yet differentiating exploitation and curiosity-driven academic exploration, through a network of research divisions and coordinators, was presented as a good structure that allows a university to perform well along both the dimension of scientific invention as well as the dimension of technoscientific innovation.

Finally, these structural arrangements should be complemented with the necessary processes at the level of the interface or liaison unit. First, a well-balanced process to manage and to monitor contract research in the area of industrial innovation is a critical issue. This includes the necessary know-how and processes for legal, financial and human resources management issues pertaining to the volume of research contracts generated via the liaison office. A central staff of professionals has to support this process. Appropriate coordination processes with the research groups, such as innovation meetings and proper training for researchers to be effective in technology transfer, have to be in place. Second, an active knowledge management policy, including a patent funding mechanism and professional intellectual property management, is yet another element in the day-to-day operational processes of the liaison unit. This set-up gains in expertise and experience as more cases are developed and managed. Once again, a lot of attention should be paid to train and to educate researchers across the university so that they become acquainted with the many intricacies of the process of managing their knowledge portfolios. Third, the availability of and the access to seed funding is highly desired, including a process to monitor the transition from invention to business plan to company start-up, so as to assist academic entrepreneurs in creating their enterprise, taking into account up-to-date principles and best practices on corporate governance. A major focus of the venture unit of a liaison office is to assist the entrepreneurs, first in coaching them to develop their business plan, then into growing the business plan into a solid business model. Finding a proper funding structure, as well as the right management team, figures high on the agenda of such a venture unit. To further assist the start-up entrepreneur, access to the physical infrastructure of an Incubation Center proves to be an asset. Finally, the liaison unit may provide the necessary opportunities for networking amongst its entrepreneurs and academics alike by creating network fora and opportunities to meet.

A matrix structure, integrating the supportive mechanisms for technology transfer with the organizational structure of autonomous and incentivized research divisions, coupled to the continuous development of the experience required, definitely helps to manage the exploitation of the academic knowledge portfolio, as was shown in the case of K.U. Leuven R&D and other European research intensive universities. Assistance and funding have helped in this process, though they cannot act as a substitute for the ambition, the strategic thinking and the drive for implementation of the researchers themselves. For academics, those lessons may be the hardest ones to learn since they require them to continuously move between processes of "thinking" and acts of "doing". This duality (or paradox) may therefore well be at the heart of the evolving concept of knowledge management at the university.

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