The “G” in the Triple Helix: Government as an Entrepreneur

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Abstract:
A growing body of evidence has recently emerged suggesting a shifting government role in science, technology and innovation policy, from a passive investor to a pro-active entrepreneur that initiates and supports wide-ranging and targeted interventions with a multiplier effect in the economy This paper provides new insights into the dynamics of this shift by presenting the experience of the Flemish government in consolidating the innovation potential of Flanders, in general, and enhancing University-Industry (U-I) links and the development of the entrepreneurial university, in particular. The impact of these policies is exemplified by the evolution of entrepreneurial activities at the Flemish Catholic University of Leuven (K.U.Leuven), the largest Belgian university and one of the most successful entrepreneurial universities in Europe and internationally. The Flemish experience suggests that for a successful outcome, top-down government entrepreneurial policies and programmes need to be combined with effective bottom-up organizational and management initiatives adopted by the university and local and regional structures (business firms, local and regional authorities, etc), and also need to be closely connected to the economic setup of the region/country.

1. Introduction

Government role in the economy has dynamically changed over the last two decades, under the influence of factors like socio-economic, political or financial crises (e.g. Etzkowitz and Brissola, 1999; Etzkowitz et al. 2008), decentralization, or failure to create alternative industries in a timely fashion (e.g. Svensson, Klofsten and Etzkowitz, 2011). After the mixed success of the neoliberal reform policies of the1990s, generally associated with the so-called "Washington Consensus" (Williamson, 1989), the strong belief in the free market and reduced government intervention in the economy was significantly disrupted. A shift towards a more active government role has become more visible, both in industrial policies and in science, technology and innovation policies, which have become more and more interconnected over the last 20 years. For example, a simultaneous pursuit of alternative strategies and stronger government role in facilitating the formation of new technological systems and enhancing existing systems rather than rectifying individual market failures was proposed in the early 1990s (Carlsson and Jacobsson, 1994). The UK's Technology Foresight Programme emerging in the 1990s also exemplifies government attempts to determine critical technologies, inform priorities and promote longer-term thinking beyond the business plan (Georghiou, 1996; Miles, 2003). Later on, in the early 2000s, the European Union's renewed focus on "industrial champions" emerged in the context of concerns about deindustrialization, repeatedly expressed by various Member States and the European Council, but also following the commercial and industrial success of Airbus and Europe's weak performance in other high-technology sectors (Maincent and Navarro, 2006). Various measures to promote entrepreneurial activities in smaller and more flexible firms have been adopted, as many large firms in traditional manufacturing industries have been gradually losing their competitive edge in the transition to the knowledge society (Audretsch and Thurik, 2001; Gilbert, Mc Dougall and Audretsch, 2006). Such developments have not been limited to Europe, but have also been major developmental challenges for East Asian economies as well (e.g. Ebner 2007).

The recent economic crisis has further intensified the global revival of government pro-active policies. "Industrial policy is no longer taboo" said Mario Monti, a former competition commissioner , in anticipation of the European Commission's new, active industrial strategy to be unveiled later in 2010, which will focus more on manufacturing and less on services and "knowledge" industries (*The Economist*, 5 August 2010). In the same vein of "new interventionism" examples, we can also mention Obama administration's new innovation strategy launched in 2009 that focuses on critical economic growth areas, including the promotion of competitive markets spurring productive entrepreneurship (The White House, 2009), or the UK's Labour government £750 million Strategic Investment Fund set up in 2009 to support investments in hi-tech manufacturing, advanced manufacturing, digital and biotechnology to help the UK economy emerge from the recession.

These examples are part of a growing body of evidence suggesting a shift in the government role in science, technology and innovation policy, from a passive investor to a pro-active entrepreneur that initiates and supports wide-ranging and targeted interventions with a multiplier effect in the economy (e.g. Huang and Murray, 2010; Link and Scott, 2010). This paper provides new insights into the dynamics of this shift by discussing a few key features of the science technology and innovation policy of the Flemish government promoted over the last three decades - more precisely, a set of three 'generations' of policy measures that aimed to stimulate the innovation potential of Flanders, in general, and consolidate University-Industry (U-I) links and the entrepreneurial university, in particular. The impact of these policies is exemplified by the evolution of entrepreneurial activities at the Flemish Catholic University of Leuven (K.U.Leuven), the largest Belgian university and one of the most successful entrepreneurial universities in Europe and internationally. The Flemish experience suggests that for a successful outcome, top-down government entrepreneurial policies and programmes need to be combined with effective bottom-up organizational and management initiatives adopted by the university and local/regional structures (business firms, local and regional authorities, etc), both closely connected to and shaped by the economic setup of the region and of the country.

The remainder of the paper is organized as follows: in Section 2 we discuss some key features of the three generations of innovation policy of the Flemish government adopted since the 1980s to present, followed in Section 3 by a brief presentation of the K.U.Leuven entrepreneurial activities and the way they have been coordinated by its technology transfer office, Leuven Research and Development (LRD). In Sections 4 and 5 we present the methodology and findings of the analysis of the impact of top-down and bottom-up policies discussed previously on the entrepreneurial activities of K.U Leuven. Section 6 concludes the paper with a discussion of policy issues emerging from the analysis.

2. The innovation policy of the Flemish government

The evolution of the Flemish government role in promoting innovation is discussed here as a succession of three policy 'generations', each introducing new principles and instruments that supplemented rather than replaced the previous ones (Goorden, 2004).

a) *The first-generation innovation policy* is considered to start in the early 1980s, when the first Flemish government launched the so-called *'Third Industrial Revolution Flanders'* (Derde Industriële Revolutie Vlaanderen, DIRV). A strong technology-push strategy and a dominance of the linear model were the key features of this period, with encouragement of basic research at the international level, creation of spin-offs and a 'picking winners' focus on selectively fostering critical directions in science and technology. This approach encouraging new science-based industries came in response to the 1960s-1970s decline of traditionally strong Belgian industries, such as the steel, coal, textile and ship-building industries, and expansion of multinational companies in Flanders, attracted by the region's strategic central location in Europe. The 1983 policy document '*DIRV Action, Vision of a Renewed Flemish Industrial Policy'* recognized the need for structural innovation, new products, markets and production methods. Consequently, generic technology fields like micro-electronics and biotechnology were encouraged by the creation of the Flemish Micro-Electronics Programme (1982), the Inter-university Micro-Electronics Centre (IMEC) (1985) and Plant Genetic Systems (1985). In 1981 a regional venture capital fund (GIMV) was established to finance high-technology start-ups and helped create the first generation of university spin-offs. Also, four generic technological research programmes in biotechnology, new materials, energy technology, and environmental technology were developed in the second half of the 1980s and implemented at the beginning of the 1990s (Goorden, 2004). In 1989, most of the S&T policy authority was transferred from the federal to the Flemish government[1], an S&T department was established under the responsibility of the Flemish minister-president and an institutional context emerged that emphasised the central role of research actors in the innovation system.

b) *The second generation of innovation policy* is considered to start in the early 1990s, when the Flemish S&T policy took a stronger orientation towards innovation and U-I interaction, and created the premises for the emergence of the Flemish Innovation System, with key institutions and instruments to manage the interactions of the actors in the system (Larosse, 2004). This period marks the transition to a more interactive innovation model, with two strategic objectives: improving the quality of academic research, and enhancing innovation in the business sector, by taking into account, besides technology, other non-technological elements of critical importance for innovation, such as market orientation, financing, intellectual property, management, training, etc. A key measure in this new policy orientation was the 1991 creation of the *Institute for the Promotion of Scientific and Technological Research in Flanders (IWT)* (currently the Agency for Innovation through Science and Technology), which aimed to streamline all the funding instruments for industrial R&D and

[1] This was a consequence of the regionalization process in Belgium, which gave the regions the authority to coordinate S&T policy and industrial R&D issues, while the federal government remained in control of scientific research supporting federal policies and international agreements or other topics that are beyond the concern of a single region and community (social security, defence, etc.).

technology transfer in the Flemish industry[2]. IWT took up the management of the four technology programmes mentioned above and adopted a 'bottom-up' funding procedure of companies. Over time, it has provided increasing support to different types of research (industrial basic research, prototype research and mixed research) and significantly boosted the U-I links of Flemish large and small companies (SMEs in particular), through three core tasks:

(i) *Subsidies* for basic research, development and exploitation of results through high-tech commercialization;

(ii) *Services* for successful commercialisation (technology transfer and commercialisation of companies' own research results, professional advice on 'make or buy decisions', partner search and facilitation of foreign contacts, participation in technology transfer networks inside and outside Europe, guidance on proposal writing for EU-funded research programmes); and

(iii) *Coordination* between innovative firms, research centres and Flemish intermediate organizations supporting innovation, via the Flemish Innovation Network (VIN) that allows companies, especially SMEs, to access the knowledge and expertise of about 250 advisors.

In addition, IWT also played an important role in innovation policy development and in advising the Flemish government in its innovation policy-making.

IWT also kept a close interaction with the universities, which have been important partners, originally based on their influential role in the process of Flanders' political emancipation that often originated in universities as a cultural movement (Goorden, 2004), and later based on their role of key 'industrial' players with own strategies, patent portfolio management, research contract policies and research funds (Larosse, 2004). This interaction is exemplified by the participation of several academics in the IWT Board and expert groups, as well as by the fact that since 1999, IWT chairmanship has been ensured for several years by a– the Managing Director of LRD, the university technology transfer office of K.U.Leuven. This collaboration also illustrates the co-evolution of academic and industrial R&D in the context of government innovation policies.

The provision of scientific or social services to society, referred to as the 'third function' of the university, next to education and research, has been a policy issue in Flanders as early as the 1970s, but wasn't explicitly recognized until the *February 1995 Decree* (equivalent to a law at regional level), which regulated the provision of scientific services by the universities to third parties, the forms they could take, and the commercialisation of academic research results. The Decree had a major importance for the commercialisation of academic research, equivalent to that of the 1980 Bayh-Dole Act in the US, as it allowed universities to commercialise and retain profits from academic patents, licences and other intellectual property rights derived from Government-funded R&D. It also allowed academics to take an active part in the creation of university spin-offs and entitled the university to a financial contribution in cases of common exploitation of academic knowledge within these spin-offs.

The 1995 Decree permitted the creation in universities of the so-called *interface services*, meant to stimulate the technology transfer between academic research laboratories, companies and society, through five functions: information exchange between university, companies and society; marketing; innovation; logistics (provision of support and advice in the conclusion of contracts) and co-ordination between industry and university (Deleener, 1995). The development of interface services proved to be a slow and complex process, involving several factors, such as specific characteristics of the university and of the business sector, integration of such interfaces into the general functioning of the university, and the need for a change of mentality regarding academics' preparedness to work with industry. This explains the different approaches taken by the Flemish universities, ranging from centralisation within the university structure (e.g. University of Gent) to separation between government-funded research and industry-funded research (e.g. K.U.Leuven, where industry-funded

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[2] For example, shortly after its inception, for purposes of tighter budgetary follow-up and bureaucratic simplification, IWT took over the Fund for the Promotion of Industrial Research – Flanders (FIOV) - another important mechanism for funding industrial R&D created in 1987.

research and the whole U-I interface are co-ordinated by LRD, the university technology transfer unit, while government-funded research is managed by the Research Co-ordination Office).

The emphasis placed by the Flemish government since 1995 on supporting academic research for industrial innovation was also translated into a 50% increase of the total science policy budget from 1995 to 2002, which was primarily directed at funding basic research in universities, industrial R&D and scientific institutions (Steunpunt O&O Statistieken 2003, p.24). This budget increase was accompanied, from 1995 onwards, by a number of policy instruments in support of innovation, such as:

- *The SMEs-Innovation Flanders Programme* (1997), which subsidised researchers in SMEs, in partnership with and training from research institutions or high schools;
- *Clusters policy* (1997), which supported the networking of enterprises and research organisations for R&D, product development and training purposes, in a government attempt to stimulate endogenous growth and jobs in Flanders[3]. At the end of 1998, the cluster concept was replaced by the *'technology valleys'* concept[4], focusing on high technologies and enterprises in the start-up or growth phase as a growth engine. Over 15 'valleys' have been developed all over Flanders, covering several hi-tech fields: e.g. Flanders Multimedia Valley, Flanders Graphics Valley, the Biotech Valley, Flanders Drive based on the formerly famous Flanders Language Valley of Lernout & Hauspie Speech Products, etc.
- *The HOBU (Non-University Higher Education)-fund* (1997), coordinated by IWT, which supported technological research in Flemish polytechnics and colleges and helped SMEs keep in touch with the latest technological developments.
- *The university-industry interfaces* (1998), aimed at facilitating the commercialisation of academic knowledge and academic entrepreneurship.

All these policy changes paved the way for the *1999 'Innovation Law'*, which set the principles for the expansion of the Flemish government's R&D policy to an integrated innovation policy. The Law introduced the notion of 'innovation centres' applied to clusters and collective research centres, broadened the direct support for industrial R&D by giving new roles to IWT (renamed the *Institute for the Promotion of Innovation by Science and Technology in Flanders*), and improved policy planning. It also included significant support for university interfaces with industry, creation of spin-offs, exploitation of research results in industry and protection of intellectual property rights in universities. Consequently, a broad array of new programmes has been created (see Box 1 in Appendix), replacing or adding to the earlier initiatives discussed previously. In 2001, three implementing regulations of the 1999 Innovation Law entered into force[5]:

- The support for collaborative innovative networks – through the so-called 'Flemish Innovative Networks' ('Vlaamse Innovatie Samenwerkingsverbanden', VIS);
- Subsidies for 'interface activities' such as commercialisation of university research, creation of academic spin-offs and collaboration between Flemish universities and companies;
- Subsidies for R&D in companies.

Further to the 1999 Innovation Law, the Flemish government's *2000-2004 Policy Note on Scientific and Technology Policy* highlighted two important issues: (i) the growing scarcity of researchers both in industry and in academia; and (ii) the development of basic research infrastructure. The Policy Note defined strategic S&T policy objectives around seven axes, including objectives like strengthening the role of university interfaces with companies, encouraging new spin-off creation and

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[3] The government designated six clusters: (i) textile machinery/textiles/clothing industry; (ii) agriculture/biotechnology/food; (iii) environment/chemistry; (iv) transport /telecommunications/ multimedia; (v) construction and housing; and (vi) utility companies. In 1994, this top-down approach was abandoned in favour of a bottom-up mechanism of encouraging clusters. Twelve very diverse bottom-up platform projects were recognised, from furniture to digital signal processing (Goorden, 2004).

[4] As an expression of the government wish to emulate the success of Silicon Valley.

[5] Source: European Trend Chart on Innovation, Country Report: Belgium, January 2001-June 2001, p. 10.

improvement of business incubation facilities, and optimising the protection and commercialisation of intellectual property rights.

c) *The third generation innovation policy* is considered to start in the early 2000s and is characterised by a systemic vision of innovation and a shift from S&T objectives to horizontal strategic objectives such as Sustainable Growth, employment, competitiveness and environmental sustainability, where universities and intermediary organisations play a key role. Some key policy documents that define the main features of the new orientation include the *Pact of Vilvoorde* (2001) that laid the foundations of a new social contract for the 21st century, the *Innovation Pact* (2003) that promoted a stronger knowledge base of the Flemish economy and society and engaged all innovation actors in meeting the 3% Action Plan, the *Memorandum: Science and Technological Innovation 2004-2010*, which outlined five STI policy priority themes for the Flemish government (the Flemish Innovation Policy, the innovation chain, innovation means -human capital, infrastructure and financial means, internationalisation and evaluation), the *2006 report Flanders in Action*, which ambitiously defines the socio-economic strategy to make Flanders a top region, not only in Europe, but worldwide and reconfirms the important position of innovation as an integral aspect of all policy areas and government activity. More recently, the *Policy Letter 2008: Science & Innovation* outlines Flemish government's focus on entrepreneurship and internationalisation, and the *Policy Note 2009-201: Scientific Research and Innovation* includes new ambitious measures to stimulate innovation and entrepreneurship (e.g. economic clusters, thematic spearheads and 'grand projets'; basic research as the basis for innovation; research infrastructure and a more streamlined and output-driven innovation model).

These policy guidelines have also been translated in a broad mix of policy instruments. To mention just a few, one could outline here *IWT's SME programme* (2001) that supports activities providing SMEs with the technological as non-technological knowledge required to innovate (e.g. studies or projects initiated by the companies that are aimed at product, process or service innovation); the *Entrepreneurship Action Plan* (2003) that provides a variety of supports measures for entrepreneurs; the *TETRA Fund (TEchnology TRAnsfer)* (2004) that supports joint projects between higher education institutes (HEIs), companies and other organisations in order to implement innovative results in enterprises (among others); the *Flemish Innovation Fund (VINNOF)* (2005), which provides three types of capital (seed, incubation capital, and project financing) to young, innovative companies to transform their ideas or technologies into a business plan and bridge the gap towards private early stage financing; the *Winwin Loan Programme* (2006) that aims to increase the availability of private capital for start ups, by giving investors a tax reduction of 2.5 % of the winwin loan. *The Competence Pole Programme* (2006) is another key innovation support measure that aims to create and diffuse knowledge between relevant science, technology and industry actors in a non-linear multi-actor process. The Competence Poles are bottom-up initiatives from the industry, which cooperate with research institutes in problem-driven, open and collective R&D activities. The Competence Poles are part of the *Flemish Cooperative Innovation Networks Plan* of the government, initiated in 2006. Nine different competence poles, each with a specific focus, have been created, most of them with a thematic approach (e.g. mobility, materials etc.).

3. K.U.Leuven and its entrepreneurial activities

K.U.Leuven is located in Flanders, the northern Dutch-speaking area of Belgium. Founded in 1425, it is the oldest Catholic university in the world and the oldest university in the Low Countries. It is the largest Belgian university, with approx. 37,000 students in 2009-2010 (including over 5,000 foreign students), and a personnel of approx. 9,000, of which over 5,000 researchers. K.U.Leuven has the legal status of a private institution, but receives a large share of its budget from the Belgian government, both directly and indirectly (competition-based) (Debackere and Veugelers, 2005). The university has a strong research orientation, with a 330 MEuro research budget in 2009, and a solid reseach output (e.g. 4,047 publications in international peer-reviewed ISI-recorded scientific journals in 2008, 537 PhD graduates in 2008-2009, and 79 active spin-offs[6]), which allowed it to become a member of the Coimbra network of leading European universities and a charter member of the LERU Group (League of European Research Universities). The university also holds a prestigious position amongst world and European universities, ranking 65th in the 2009 Times Higher Education–QS World University Ranking of the top 200 world universities.

Entrepreneurial activities at K.U.Leuven are co-ordinated by K.U.Leuven Research and Development (LRD), the technology transfer unit of the university in charge with all aspects related to commercialisation of research results and science-industry interface. LRD played a key role in the development of entrepreneurial capabilities within the university since its inception in 1972 and exerted an important learning effect for several generations of faculty and researchers who have evolved in their careers alongside and often based on interaction with LRD (Debackere and Veugelers, 2005). In the early days of the 1980s, when Government support for academic entrepreneurship was in an incipient stage and policy priorities focused primarily on support to technological innovation in firms, especially SMEs, LRD was the main form of institutional support to entrepreneurial activities within the university, which were promoted primarily by some US-trained academics attempting to use their experience and business skills in the Flemish context. These academics created the first 'pioneer' entrepreneurial research groups at LRD, which evolved successfully until present, ranking among the most productive research groups within the university and serving as role models for new research groups. Later on, in the 1990s and the 2000s, the innovation support measures adopted by the Flemish government (discussed in the previous section) gave a stronger impetus to the institutional support provided by LRD.

LRD activities

In pursuit of its mission to promote wealth creation through technology entrepreneurship, LRD has developed a broad range of services focused on the transfer of knowledge and technology from the university to industry and to society. This wide array of activities developed over 30 years of existence illustrates LRD's search for the "right mix of context, structure, transfer and innovation mechanisms" that universities need in order to become significant players in managing entrepreneurial activities (Debackere, 2000). Since 1997, LRD activities have been restructured to ensure a more integrated approach to technology transfer and commercialisation of academic knowledge. At present, they focus on several poles[7]:

- *Research collaboration*: consultancy, management of R&D contracts, innovation advice and technology brokerage, negotiation of research agreements, etc. This activity is the oldest and most profitable of LRD activities, providing a significant share of the university's R&D budget (e.g. about 24% in 1999, cf. Debackere, 2000).
- *Intellectual property rights management*: LRD pursues an active policy of patenting and licensing university research results to generate funds for further scientific research. This activity has been more formally organised since 1999 with the creation of an internal Intellectual Property Liaison Office, a patent fund and a network of formal collaboration with European patent attorneys. LRD's strive for the quality and value of its patent portfolio is reflected by the university's leading position among other Belgian universities and research institutions, and internationally. For example, K.U.Leuven ranked first among six Belgian universities in terms of EPO patent applications during 1995-1999 (Saragossi and Van Pottelsberghe de la Potterie, 2002), and second, after the Interuniversity Microelectronics Centre (IMEC), in terms of USPTO patents in 1991-2001 (INCENTIM internal records, 2002). Revenues from royalties, patents ands overhead amounted to 7% of university total revenues in 2007 (Hendrickx, 2008).

[6] Source: http://www.kuleuven.be/overons/feitenencijfers.html

[7] Source: http://lrd.kuleuven.be/en/mission-statement.

- *Creation and management of research-oriented spin-offs* that receive LRD's business counseling and access to venture capital through its seed capital fund Gemma Frisius Fund K.U.Leuven[8], as well as accommodation in two incubators and in two science parks. In 2009 LRD managed 89 active spin-offs that were created over time since 1972 and evolved successfully (e.g. a combined total turnover of well over 400 MEeuro and employing more than 3,500 people[9]). LRD spin-offs are active in several fields, ranging from ICT, mechanical and electrical engineering and microelectronics, to data processing, medical and pharmaceutical products, etc. The variety of activity domains has been a deliberate strategic option for ensuring a broad range of competencies and cross-fertilisation for innovative entrepreneurship. A higher concentration of activities in ICT and business and engineering emerged in the 1990s, due to IMEC's presence and the successful development of some early university ICT spin-offs, like Ubizen (Surlemont et al. 2001).
- *Stimulating entrepreneurship and innovation networking* initiatives such as Leuven.Inc (Leuven Innovation Networking Circle)[10] and technology clusters such as DSP Valley[11] and LSEC (Leuven Security Excellence Consortium);
- *Involvement in regional development* through close collaboration with the city of Leuven, the province of Vlaams-Brabant, and the Flemish and European government. Leuven is also part of the ELAt-network which connects the knowledge regions of Eindhoven, Leuven and Aachen and constitutes a European technological top region.

LRD organisational structure

The LRD organisational structure is based on the concept of *'research divisions'* (or research groups), consisting of university researchers from one or more university departments/faculties, who work together to integrate their different partnerships with industry in a research division at LRD. At present, LRD includes 55 research divisions (see http://organigram.kuleuven.be/ext/1/50017594e.htm) active in engineering, bio-medical sciences, bio-sciences and sciences. Humanities and social sciences, although underrepresented, have increasingly developed their entrepreneurial activities within LRD over the recent years. The contact between LRD and the research divisions is ensured by a number of *innovation co-ordinators*, who are generally researchers or assistant professors within the LRD divisions and are paid by LRD on a part-time basis (approx. 20% of their salary), while the rest of their time comes from the university(Debackere, 2000; Debackere and Veugelers, 2005). The innovation coordinators are supported by the LRD management through specific mechanisms, such as training and meetings that are meant to enhance their bridging role and trust-building between faculty and the researchers they are serving (Oosterlinck, 1999).

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[8] Gemma Frisius Fund K.U.Leuven is a seed capital fund, established in 1997 as a joint venture between K.U.Leuven, KBC Private Equity and Fortis Private Equity (now BNP Paribas), to stimulate the creation and growth of university spin-offs. The Fund provides seed capital in the very early phases of the firm, typically on a 7 to 10 year-investment period. Investment is not restricted to a specific technology domain, but is open to any opportunity to exploit the university knowledge, technology or intellectual property. As a seed capital fund, GFF mainly focuses on first round financing, but a second round can also be provided if necessary, in co-operation with other external partners. LRD has an extensive network of local and international investors and business angels, who assist in raising a higher starting capital from a strategically selected consortium of investors. Moreover, these investors often participate in subsequent capital rounds. Currently, the Fund has invested about 24.5 MEuro for the development of 36 spin-offs. The growing interest in the commercialisation of academic research encouraged the creation of new academic seed-capital funds in other Flemish universities, but the Gemma Frisius Fund remained distinctive from the other academic seed capital funds by the higher amount of money granted to spin-offs (see further details at http://lrd.kuleuven.be/en/spinoff/gff-information#mission).

[9] Source: http://lrd.kuleuven.be/en/spinoff/creation#history.

[10] Leuven.Inc is a network for high-tech entrepreneurship created in 1999 to bring together academic researchers, high-tech start-ups, consulting firms, venture capitalists, and established companies in the Leuven region. The network was created as a non-profit organisation by LRD in partnership with Arthur Andersen, IMEC and two major Belgian banks, and in collaboration with the Cambridge Network. It aims to stimulate local prosperity and the growth of knowledge-intensive companies in the region by sharing business experience through informal events, Entrepreneurs' Cafés, Roundtables, Info Sessions, Visionary Workshops and keynote seminars (see further details at http://www.leuveninc.com/).

[11] DSP Valley is a technology network organisation, focusing on the design of hardware and software technology for digital signal processing systems. It brings together universities, research institutes and industrial companies, from small start-ups up to large international groups (http://lrd.kuleuven.be/en/hitech/networks).

Although fully integrated in the university structure, LRD was from its start designed to operate on a large autonomy within the university with regard to its budgetary and human resources, which allowed a much higher degree of flexibility and freedom than in other units covered by the 'traditional' university administration and was an important incentive for the research staff of LRD divisions. LRD divisions have complete autonomy in managing the revenues from their entrepreneurial activities and are entitled to accumulate financial reserves based on the benefits generated via these activities, which is quite a unique situation compared to other universities, which usually centralise the benefits resulted from U-I linkages.

The 'research division' organisational concept created an interdisciplinary matrix structure within the university, based on the coexistence of a double reward and incentive system. Research excellence and teaching ability are rewarded through the hierarchical lines of academic promotion in their respective faculty and university departments, based on research quality and teaching performance. Entrepreneurial excellence is rewarded through the LRD incentives of budgetary flexibility and financial autonomy of the research division, as well as through financial incentives for individual researchers, in the form of salary supplements resulting from participation in contract research, consultancy and licensing agreements and participation, both intellectually and financially, in the university spin-offs.

> *"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" (Debackere and Veugelers, 2005: 19).*

The combination of LRD policy and structure discussed above stimulated a sustained learning process among and within research groups, which led to continuous technological specialisation and creation of technology portfolios of academic research groups; increasing awareness of commercial value and market opportunities for academic research, based on trial and error and learning from customers and markets; contacts with foreign partners; larger access to EU programmes; funding and training abroad. LRD's combined academic and business management approach makes a significant difference from other Flemish universities, where technology transfer activities are covered by the 'regular' university administration. These different organisation modes reflect the different approaches taken by Flemish universities in the construction and development of *interface services*, a concept based on the February 1995 Decree of the Flemish government, meant to stimulate university-industry-society exchanges (discussed in the previous section).

4. Methodology

The development of entrepreneurial activities at K.U.Leuven over time and the way it has been influenced by government policy and the economic structure of the region/country has been analysed on a sample of 22 KUL academic research groups (see Box 2 in Appendix) that were examined over the period 1986-2000. The sample was selected on the basis of their number and complexity of their U-I projects, and also with the purpose to cover a broad range of research disciplines. The choice of the academic research group as the unit of analysis is an element of novelty brought by this paper, in contrast to most empirical U-I studies that tend to use either *macro units of analysis* such as the university, and examine technology transfer outputs and impact (e.g. patents, licenses, start-up and spin-off firms) or *micro units of analysis,* such as the individual researchers.

The emphasis on the *academic research group* also has the merit to reflect key changes in the economics of knowledge production over the last decades, moving away from the Mertonian approach of the individual researcher, which has been shown to have a weak ability to explain research productivity in light of the collective nature of research (e.g. Dasgupta and David, 1994; Stephan, 1996; Stephan and Levin, 1997; Laredo and Mustar, 2000) to research groups that have increasingly gained recognition as the main unit of modern science (Ziman, 1994). The research group is also the level at which new organizational forms such as cooperative and joint venture laboratories have emerged, demonstrating the complementarity between public and private research (e.g. Crow and Bozeman, 1987; Joly and Mangematin, 1996). The contrast between scientific and industrial laboratories is no longer as clear-cut as emphasised in previous behavioural studies of academic communities, as research labs become more involved in activities that enlarge the traditional vision of scientific laboratories as loci exclusively devoted to basic and applied research (Laredo and Mustar, 2000).

The analysis of the U-I projects conducted by the 22 research groups over the period 1985-2000 focused on:

a) *Structure of the U-I projects*: this was assessed by categorizing the total number of U-I projects performed over the reference period by *type* (Research, Consultancy, Licence, Other) and by *funding source* (Industry, Government, EU, University). Projects funded by Industry have been further broken down by *company characteristics*, such as size, R&D potential, origin and type of governance (multinational or not, of Belgian or foreign origin) (see Tables 1 and 2 in Appendix for an overview of project variables). The research orientation of the groups and the profile of their collaborating firms have been assessed by means of several indexes, defined as follows:
   - Research Index: the ratio of Research projects to Non-Research projects (i.e. Consultancy, Licence, Other);
   - Size Index: the ratio of projects with large firms to projects with SMEs;
   - R&D Index: the ratio of projects with R&D firms to projects with non R&D firms
   - Origin Index: the ratio of projects with foreign companies to projects with Belgian companies
   - Multinational Index: the ratio of projects with MNCs to projects with non-MNCs

b) *The dynamics of the U-I project variables*: this was assessed by means of the exponential growth rates of the U-I project variables, calculated from regressions of each variable (natural log) on time (Table 3 in Appendix). Several growth patterns of U-I project variables have been identified through this analysis (Table 4 in the Appendix)

c) *The comparative group distribution of U-I projects*: this was assessed by means of a research group clustering of the respective variables (average values per year have been considered in order to remove the age bias, as the groups have been created at different points of time during 1985-2000) (Table 5 in Appendix). Among the resulting three clusters defined by the 33rd and 66th percentiles (Low, Medium, High) we focused on the top 'High' cluster, which highlights the most productive groups in terms of U-I projects and budgets (Table 6 in the Appendix).

d) *The effect of the February 1995 Decree, as a key policy measure for academic entrepreneurship adopted by the Flemish government, on the number of U-I projects and research budgets during 1985-2000:* this was assessed through a paired sample t-test performed on the pre- and post-1995 values of the two variables (Table 7 in Appendix). The growth rates of the respective variables in the pre- and post-1995 periods have been examined by regressions of the respective variables (natural logs) on the independent variable Year (Table 8 in Appendix). Further, we examined the causality between the research budgets and the total number of U-I projects in the two periods through a lead-lag (cross-correlation)[12] (Table 9 in Appendix) to see whether a cause-effect relation could be identified between the two.

[12] The principle of the cross-correlation analysis is that, by inspecting the correlation coefficients between the current values of a first time-series and the previous (or future) values of a second series, one can determine if the two series move in the same direction by similar amounts. If a strong relationship is found, the previous values of the second series may be useful for predicting new values of the first. The first series is known as a 'leading' indicator when current values of the first series are used to predict future values of a second series. If the two series are increasing or decreasing over time, they can always be lined up so that they appear to be highly correlated even though they are not related. In order to avoid this problem, each value of the original series is replaced by the differences between its adjacent values (changes) in the original series, so that the series becomes stationary in the statistical sense.

5. Findings and discussion

a) Structure of U-I projects

A total number of 1,255 U-I projects have been conducted by the 22 academic research groups over the 1986-2000 period. By *project type*, Research projects accounted for nearly three-quarters (74.34%) compared to non-Research projects (25.50%) (Research Index=2.91), which reflects the strong research orientation of U-I projects. Consultancy and Licence projects represented only 18.01% and 4.14% respectively. By *funding source*, Industry-funded projects were largely predominant (80.24%) compared to non-Industry funded projects (29.81%) (Industry Index =2.69). Among non-Industry funded projects, EU-funded projects were in a leading position (18.41%), while Government-funded projects and University-funded projects followed with 8.1% and 3.3% respectively. Moreover, the ratio of Industry-funded projects to Government-funded project = 10 shows the huge difference in the relative importance of these two funding sources.

By profile of the collaborating firms, we found a strong predominance of projects funded by large companies (75.52%), with R&D potential (92.78%), of foreign origin (57.38%), and multinational governance (72.89%). About 70% of the multinational companies were foreign. Projects with large companies exceeded over three times those with SMEs (Size Index = 3.08). Collaboration with R&D-intensive firms exceeds almost 13 times the collaboration with non-R&D firms (R&D Index = 12.87), while the collaboration with foreign firms was only moderately higher than the collaboration with domestic firms (Origin Index = 1.35). Multinational companies were found to be nearly three times more present in collaborations with the selected research groups than non-multinational firms (Multinational Index = 2.69). Moreover, among projects funded by multinational firms, those funded by MNCs of foreign origin were more than double of those funded by MNCs of Belgian origin.

The predominance of Research projects funded by Industry, mainly by R&D-intensive companies, comes as no surprise if we consider that such companies account for 54% of Belgian S&T activities, by far the highest percentage among industrialised countries (Patel and Pavitt, 1994). Belgian industry scores very high both as a sector of R&D performance and as an R&D funding source (OSTC, 2001: 34-35). Manufacturing industries (electrical equipment and electronics, industrial and other chemicals, drugs and medicine and machinery) provided the highest share (80-85%) of Business Enterprise Expenditure on R&D (BERD) in Belgium during 1993-1999 (OSTC, 2001: 36). Among them, the most R&D-oriented are chemical industries and electrical/electronic equipment, followed at a certain distance by machinery and equipment, rubber and plastics, metallurgy and metalworking. Many of these industries have high levels of intangible investments, which is suggestive of a high knowledge-intensive character (National Institute of Statistics 1998). They also have the highest innovation rates among the total firm population in Belgium (1994-1996 CIS2 data), e.g. 38 to 48% in the chemical industry (including petrochemical and pharmaceutical industry), computers and telecommunications, electromechanics, automotive, transport, rubber and plastics, and machinery (in a total firm population where 34% are innovative and 66% are not). In addition, another characteristic of the Belgian industry appears to be at work here: Belgian firms seem to be primarily oriented to Belgian universities in their R&D collaborations (nearly 16%), and less to foreign companies and foreign customers (about 15% each) (Capron et al., 1998). From a sectoral perspective, the highest shares of R&D collaborations with Belgian universities have been found in: machinery (28%), glass (25%), electrical equipment (17%), metal industry (17%), and chemical industry (16%). From a regional perspective, universities appear to be the most important partner for R&D collaborations in Flanders.

The fact that most Industry-funded projects involved large companies (75.52%) may be explained by the higher innovative profile of large and small manufacturing firms in Belgium (OECD STI Scoreboard, 2001), suggesting a U-shaped innovation-firm size relationship that was confirmed by several studies. For example, Vandewalle (1998) provides evidence of larger innovation intensity for small and very large R&D firms, and lower innovation intensity for medium-sized R&D firms in the manufacturing sector as a whole, for most sub-sectors and at nearly all technological levels. Also, Veugelers et al. (1995) and Capron et al. (1998) found high R&D intensities in large and small firms, in contrast to medium-sized firms. By sector, higher R&D intensities in small firms were reported particularly in electrical equipment & components, and to a smaller extent in non-electrical machinery, while large firms display the highest R&D intensity the chemical industry (Scherer, 1965; Klevorick et al., 1995).

The fact that over 57% of the Industry-funded projects involved foreign companies, and about 73% of projects involved multinationals, predominantly of foreign origin, confirms the significant presence of such companies in the Belgian economy, especially in the chemical industry, pharmaceuticals, metallurgy, mechanical and electrical engineering, motor vehicles, rubber and plastics (Debacker, 2002). They are mostly Dutch subsidiaries (electrical engineering, food and drinks, paper), American (food and drinks, electrical engineering, chemicals, pharmaceuticals), French (electrical engineering, motor vehicles, food and drinks), and to a smaller extent German (chemicals, metal instruments, motor vehicles) and British (paper, rubber and plastics). Such companies recorded higher capital intensity, labour productivity, R&D intensity, etc. than domestic firms (Debacker, 2002: 36).

Foreign firms establishing subsidiaries in Belgium illustrate very well the shift in the R&D objectives of foreign subsidiaries, from supporting production and adaptation to local markets to a search for foreign complementary skills and knowledge. This shift marks a departure from the long-accepted ‘internalisation theory’ (Rugman, 1981), which argues that relatively little R&D is done in subsidiaries and is mostly directed to the adaptation of parent firm’s R&D outcomes to local markets, for which reason subsidiaries are not real innovators. Originally motivated by the larger European market rather than the small-sized Belgian market, multinational companies entered industries in which Belgium had initially no comparative advantage, and over time brought about a change in the country’s industrial structure towards capital- and scale-intensive industries (Debacker, 2002). The shifting R&D strategy of multinational firms in Belgium can also be interpreted in the light of Le Bas and Sierra’s (2002) taxonomy of corporate technology internationalisation strategies. It thus appears that foreign firms establishing subsidiaries in Belgium followed initially a strategy of adapting parent technology to the host country market, but over time, once with Belgium’s shift towards capital- and scale-intensive industries and higher R&D skills, they moved to a strategy seeking comparable technology strength in local companies and centres of excellence.

b) Dynamics of the U-I collaborative projects

The growth patterns of U-I project variables (Table 4 in Appendix) suggest several important trends. On the one hand, one can note the *increasing orientation towards Research projects*, reflected by the higher growth rate of Research projects compared to non-Research projects, and the steady growth of the Research Index. Among the non-Research projects, Consultancy projects had an accelerated, though not significant decline, while Licence and Other projects had positive, steady, but non-significant growth rates.

On the other hand, there is also *an increasing role of both Industry and non-Industry funding in U-I activities,* as reflected by the positive steady growth of Industry- and non-Industry funded projects The latter appear to increase at a much higher rate, due to both EU- and Government-funded projects’ higher growth rates than Industry-funded ones. It is also interesting to note that EU-funded projects increased faster than Government-funded ones. Indeed, EU-funded projects had the most significant growth (Figure 1 in Appendix), especially in two periods: first, during 1991-1994, and the second, during 1995-1998, corresponding to the 3rd and 4th EU Framework Programmes. This result is consistent with literature reports that indicate that KUL researchers almost doubled their participation in the 4th EU Framework Programmes compared to the 3rd, recording the highest participation and funding among all Flemish universities (Dengis, Dewallef and Lories, 2001).

Another noteworthy trend is the *steady increase of U-I projects with both large firms and SMEs*. The greater involvement of SMEs in U-I linkages is also visible in the accelerated, yet non-significant decline of Size Index. In addition, a *steady increase of projects with R&D-intensive companies of multinational type and foreign origin* can also be observed. Projects with R&D firms grew considerably faster than the projects with non-R&D firms, which had a positive, but not significant, accelerated growth rate. Projects funded by both foreign and domestic companies had a steady growth, higher for the former. Also, projects with MNCs, particularly of foreign origin, have grown faster than those with non-MNCs.

c) Comparative group distribution of U-I projects

The most productive research groups in terms of U-I projects and research budgets have been identified in the fields of Microelectronics and Sensors, Processing of Speech and Images, Mechanical Engineering, Polymers/Physical Organic Chemistry, Signals Identification/ Computer Security, Industrial Microelectronics, Metallurgy and Materials Engineering. The higher productivity of these groups is explained by their collaboration with major companies in the respective fields[13] and also by their role in the most important clusters in the Leuven area: mechatronics, telematics and telecommunications, micro-electronics and nanotechnologies and e-security. It is also important to note that this distribution of the most productive research groups matches well with the manufacturing industries with higher levels of BERD expenditure discussed above, which suggests a link between the strong research orientation of the academic groups and the R&D-intensive character of the respective industries.

d) The effect of the February 1995 Decree on the total number of U-I projects and the total value of research budgets during 1985-2000

The paired sample t-test performed on the pre- and post-1995 values of the two variables confirms the existence of a statistically significant difference. Furthermore, the regression of the two valuables over time indicates positive, accelerating growth rates in the pre-1995 period for both the number of U-I projects and for the total value of research budgets, which could be attributed to the start from lower levels. In the post-1995 period, only the total value of research budgets had a significant positive steady growth rate, while the total number of U-I projects had a steady growth, but not statistically significant. The cross-correlation of the two variables shows that in the pre-1995 period the number of U-I projects and the value of research budgets grow together, but the direction of causality is not clear, while in the post-1995 period only research budgets increased significantly, which suggests no influence of research budgets over the number of U-I projects. Corroborating these results, we conclude that in the pre-1995 period, the total number of U-I projects and the research budgets grew together in the same year, with a relative lead of U-I projects over the research budgets. In the post-1995 period, only the research budgets grew significantly, reflecting the funding increase promoted by the February 1995 Decree. This funding increase was not accompanied by a significant growth in the number of U-I projects in the subsequent five-year period, and no evidence of a lead-lag effect between the two variables was observed. This observation could suggest a stabilisation of U-I linkages and consolidation of intra- and inter-organisational learning of the examined research groups, rather a stagnation of collaborative projects. Another possible explanation is the fact that the growth rate of the number of U-I projects may have been influenced more strongly post-1995 by other factors,

[13] For example, in metallurgy and materials engineering, partner firms include the R&D divisions of Agfa-Gevaert, Siemens, Bell Telephone Manufacturing, Exxon Chemical, Raychem, Shell, Bekaert, Philips, BASF, Bayer, Union Minière, etc. In chemistry, collaborating firms include Exxon Chemical, Dow Chemical, Agfa-Gevaert, Philips, Shell, Raychem, GE Plastics, Procter & Gamble, Janssen Pharmaceutica, BASF, Mitsubishi Paper Mills, Volkswagen, Bekaert, Elf Aquitaine, Solvay-Interox, etc. In mechanical engineering: Fokker, AEG, Bertin & Cie, Ford, Picanol, Siemens, Bell Telephone Manufacturing, Nissan European Technological Centre, Bosch, Alcatel Bell, Volkswagen, Renault, Bekaert, Bosch, etc. For instance, Alcatel Belgium (microelectronics, telecommunications, multimedia, data and Internet), hosts one of the six main Research Centres of the Alcatel group.

such as the nature of the research field, technological opportunity, technological specialisation of the group, etc.

6. Conclusions

The analysis of the structure and dynamics of collaborative U-I projects at K.U.Leuven over the period 1986-2000 revealed that the entrepreneurial activities of the university have been significantly influenced by the innovation policy measures adopted by the Flemish government (discussed in Section 2), the internal entrepreneurial policy of K.U.Leuven (discussed in Section 3) and some specific features of the regional and national industry structure, such as company R&D potential, size, origin and multinational type of governance. These findings also provide an excellent example of co-evolution of Triple Helix actors, in the context of an open learning process structured at different levels, from university to business partners and to regional policy-making authorities. The K.U.Leuven example shows how the communication between the actors and the interplay between differentiation and integration ensures a permanent regeneration of the system in which such processes evolve. Localised cooperation between industrial sectors, universities and local government authorities can thus generate a new regional innovation environment that interacts with other elements at national and EU level.

On the one hand, the Flemish experience is highly specific, due to some particularities of the Flemish innovation system, such as the key role of universities in R&D performance as they are at the forefront of interaction with industry; strong presence of highly R&D-intensive foreign multinationals in the economy; and a strong regional dimension of innovation and academic entrepreneurship. On the other hand, a similarity with the Flemish case can be expected in countries/regions with the same predominance of foreign, highly R&D-intensive multinational companies, and strong role of universities in knowledge production, such as the UK (e.g. OECD, 2002). The main drivers of convergence seem to be both the economic and the political processes aimed at ensuring European integration and the emergence of a European system of competence-building and innovation, which would balance intra-national diversity and inter-national diversification and regionalisation (Lundvall and Tomlinson, 2000). This calls for stronger national/regional policies and strategies to support countries' competitive advantages and integration into the global economy, but also for national/regional policies designed in synergy with international developments. This intertwined process of dispersion of authoritative decision-making across multiple levels ('multi-level governance'), is very important in the European context, where two developments have been decisive over the past half century: European integration has shifted authority in several key areas of policy making from national states up to European-level institutions, while regionalisation in several European countries has shifted political authority from the national level down to sub-national levels of government (Hooghe & Marks, 2001).

The Flemish case also brings to the fore the question of the extent to which the economic benefits of joint U-I work are reaped by the local/regional scientific community and society, especially in the context of increasing investments in R&D and innovation from the public budget, if a large majority of U-I projects involve large, R&D-intensive multinational firms of foreign origin. The local benefits of such U-I projects can be enhanced by supporting the presence of domestic R&D-intensive SMEs in such partnerships, thus creating 'virtuous circles' of knowledge production and diffusion within the local/regional economy and an enhanced participation of SMEs in the 'knowledge economy'. This trend remains still weak; therefore, policy measures aimed at strengthening the R&D and innovation potential of domestic firms, in general and of SMEs in particular, can increase the local benefits from joint industry–academic research.

Appendix

Box 1: Major STI policy instruments in the Flemish Community

Support for STI activities primarily in companies

- Subsidy for development of prototypes and for industrial basic research, including EUREKA
- Subsidies to SMEs for innovative activities: the SME-Technological Innovation Programme

Support for R&D activities primarily in universities and public research centres

- Fundamental research at universities: structural support and subsidies for R&D activities: FWO and BOF funds for fundamental research, specialisation grants (IWT grants) and GBOU, for the financing of generic basic research at universities
- Support for interface cells at universities
- Subsidy to IMEC, VITO and VIB research centres and regional scientific centres
- Subsidies for research in collective research centres
- Subsidies for technological advisory activities in research centres
- HOBU-fund: subsidy to higher education establishments for the realisation of research projects in partnerships with enterprises

Support for STI activities in universities, public research centres and enterprises

- "Action" and "Impulse" programmes: subsidies to universities, research centres and enterprises for R&D activities in specific themes of regional relevance
- VIS -Vlaamse Innovatie Samenwerkingsverbanden (Flemish Co-operation Networks for Innovation)

Dissemination and awareness-raising activities

- Science and Technology Promotion: Technopolis, Experion, the Science Week, etc.
- VIA - "Vlaamse Innovatie Adviescentrum" , Innovation Relay Centre

Activities in support for STI policy

- Monitoring and support for STI policy
- STV - Stichting Technologie Vlaanderen (Flemish Foundation for Technology Assessment) and VIWTA – Vlaams Instituut voor Wetenschappelijk en Technologisch Aspectenonderzoek (Flemish Institute for Scientific and Technological Assessment)

Risk capital provision

- Regional risk capital provision fund GIMV and university risk capital funds
- Business Angel Networks
- Flemish Guarantee Funds

Support for Business Development

- Support for intangible investments in the form of subsidies
- Hefboomkrediet voor innovatie opleidingen (Leverage support for innovation training)
- Centres providing general business support: Medialab, KMO-IT centre, TIV, Innotek, VIZO, etc.

Source: Belgian Report on Science, Technology and Innovation (2001), p. 205

Box 2: Research fields of the 22 academic research groups at K.U.Leuven
Constructions & Construction Materials Metallurgy and Materials Engineering Industrial Microelectronics Electrical Energy Microelectronics and Sensors Processing of Speech and Images Signals, Identification, System Theory and Applications/ Computer Security

Telecommunications and Microwave
Surface Chemistry and Catalysis
Mechanical Engineering
Comparative Physiology - Zoology
Biopharmaceutical Sciences
Actuarial Sciences
Computer Sciences
Polymers and Physical Organic Chemistry
Hormone Research
Medical Imaging
Law
Energy
Clinical Research
Feed, Food & Health Research
Heart Research

Table 1 – Description of U-I project variables

Variable				***NAME***
Total value of research budget (MEuro)				**TOTVAL**
Total no. U-I projects				**TOTPRO**
•By project type:	No. Research projects			NRES
	No. Consultancy projects			NCON
	No. Licence projects			NLIC
	No. Other projects			NOTH
	No. Non-Research projects = NCON+NLIC+NOTH			NNONRES
	Research Index = NRES/NNONRES			RESINDEX
•By funding source:	No. of Industry-funded projects			NIND
	•By company size:	No. of projects with large-sized companies		NL
		No. of projects with small- and medium-sized companies		NSME
		Size Index = NL/NSME		SIZINDEX
	•By company R&D	No. of projects with companies without R&D potential		NRD0
		No. of projects with companies with R&D potential		NRD
		R&D Index = NRD/NRD0		RDINDEX
	•By company origin:	No. of projects with companies of Belgian origin		NOB
		No. of projects with companies of foreign origin		NOF
		Origin Index ORINDEX= NOF/NOB		ORINDEX
	•By company type:	No. of projects with companies that are not multinationals		NMNCN
		No. of projects with companies that are multinationals		NMNCY
		•By MNC origin:	No. of projects with foreign MNCs	NMNCBN
			No. of projects with Belgian MNCs	NMNCBY
		MNC Index MNCINDEX= NMNCY/NMNCN		MNCINDEX
	No. of Government-funded projects			NGOV
	No. of EU-funded projects			NEU
	No. of University-funded projects			NUNI
	No. of Non-Industry funded projects NPNONIND =NPGOV+NPEU+NPUNI			NNONIND
	Industry Index INDINDEX= NPIND/NPNONIND			INDINDEX

Table 2 - Breakdown of: (a) Total number of U-I projects; (b) Industry-funded projects

(a)Total number of U-I projects (TOTPRO) N=1255						
By project type*	**NRES**	**NCON**	**NLIC**	**NOTH**	**NNONRES (NCON+NLIC+NOTH)**	**RESINDEX (NRES/NNONRES)**
	933	226	52	42	320	2.91
	74.34%	18.01%	4.14%	3.35%	25.50%	
By funding source type**	**NIND**	**NGOV**	**NEU**	**NUNI**	**NNONIND**	**INDINDEX (NIND/NNONIND)**
	1007	102	231	41	374	2.69
	80.24 %	8.13%	18.41%	3.27%	29.81%	

(b) Industry-funded projects (NPIND) N=915*				
By company size	**NL**	**NSME**		**SIZINDEX (NL/NSME)**
	691	224		3.08
	75.52%	24.48%		
By company R&D	**NRD0**	**NRD**		**RDINDEX (NRD/NRD0)**
	66	849		12.87
	7.21%	92.78%		
By company origin	**NOB**	**NOF**		**ORINDEX (NOF/NOB)**
	390	525		1.35
	42.62%	57.38%		
By company type	**NMNCN**	**NMNCY**		**MNCINDEX (NMNCY/NMNCN)**
	248	667		2.69
	27.10%	72.89%		
By MNC origin		**NMNCBN**	**NMNCBY**	
		469	198	
		70.31%	29.68%	

* Total = 99.84% - The difference to 100% is due to the fact that some project types could not be determined from available information

** Total = 110.05% - The excess over 100% is caused by multiple sources of funding for some projects

*** Of the 1007 Industry-funded projects recorded during 1985-2000, only 915 (about 91%) have been funded by companies with identifiable characteristics

Table 3 – Regressions of U-I project variables (natural logs) on Year

Dependent Variable	**Model**	**Unstandardized Coefficients (B)**		**Rsq**	**Sig. F**
		B1	**B2**		
ln TOTPRO	**LIN**	**0.121**	**0**	**0.764**	**0.000**
ln TOTVAL	**LIN**	**1.245**	**0**	**0.688**	**0.000**
	QUA	**0**	**3E-04**	**0.689**	**0.000**
ln NRES	**LIN**	**0.150**	**0**	**0.828**	**0.000**
ln NCON	LIN	-5.E-04	0	0.000	0.984
	QUA	0	-1.E-07	0.000	0.983
ln NLIC	LIN	0.051	0	0.090	0.319
ln NOTH	LIN	0.390	0	0.713	0.072
ln NIND	**LIN**	**0.106**	**0**	**0.746**	**0.000**
ln NGOV	**LIN**	**0.120**	**0**	**0.459**	**0.006**
ln NEU	**LIN**	**0.187**	**0**	**0.579**	**0.001**
ln NUNI	LIN	0.040	0	0.059	0.473
ln NNONRES	**LIN**	**0.056**	**0**	**0.258**	**0.045**
ln NNONIND	**LIN**	**0.172**	**0**	**0.443**	**0.005**
ln RESINDEX	**LIN**	**0.094**	**0**	**0.542**	**0.001**
ln INDINDEX	LIN	-0.067	0	0.171	0.111
	QUA	0	-2.E-05	0.172	0.111
ln NSME	**LIN**	**0.091**	**0**	**0.451**	**0.006**
ln NL	**LIN**	**0.088**	**0**	**0.684**	**0.000**
ln NPRD0	LIN	0.048	0	0.078	0.315

	QUA	0	1.2E-05	0.078	0.314
ln NPRD	**LIN**	**0.100**	**0**	**0.704**	**0.000**
ln NOB	**LIN**	**0.080**	**0**	**0.418**	**0.007**
ln NOF	**LIN**	**0.107**	**0**	**0.704**	**0.000**
ln NMNCN	**LIN**	**0.090**	**0**	**0.250**	**0.048**
ln NMNCY	**LIN**	**0.100**	**0**	**0.750**	**0.000**
ln NMNCBN	**LIN**	**0.104**	**0**	**0.760**	**0.000**
ln NMNCBY	**LIN**	**0.083**	**0**	**0.550**	**0.001**
ln SIZINDEX	LIN	-0.009	0	0.008	0.750
	QUA	0	-2E-06	0.008	0.749
ln RDINDEX	LIN	0.057	0	0.124	0.199

Note: The regression model used for each dependent variable is $Y = B_0 + B_1X + B_2X^2$, where, Y = ln (variable), X = Year, and the linear coefficients B_1 express the exponential growth rate. The quadratic coefficients B_2 have been noted only for those variables where they were different from 0.

Table 4 – Growth patterns of U-I project variables broken down by project type and funding source

Criterion	*Project variable*	*Growth patterns*
Project type	Research projects (NRES) Consultancy projects (NCON) Licence projects (NLIC) Other projects (NOTH) Non-Research projects NNONRES) Research Index (RESINDEX)	Positive steady, significant Negative accelerated, not significant Positive steady, not significant Positive steady, not significant Positive steady, significant Positive steady, significant
Funding source	Industry-funded projects (NIND) EU-funded projects (NEU) Government-funded projects (NGOV) University-funded projects (NUNI) Non-Industry-funded projects (NNONIND) Industry Index (INDINDEX)	Positive, steady, significant Positive steady, significant, higher than NGOV and NIND Positive steady, significant, higher than NIND Positive, steady, not significant Positive, significant, faster than NIND Negative accelerated, not significant

Table 5 - Group clustering by the 33rd and 66th percentiles of U-I project variables (average values per year)

	Percentile values	**LOW**	**MEDIUM**	**HIGH**
		Groups	**Groups**	**Groups**
TOTVAL (mil euro)	33: 0.17 66: 0.95	16, 4, 15, 1, 6, 13, 2	9, 19, 7, 8, 3, 17, 5, 21	11, 12, 22, 10, 14, 20, 18
TOTPRO	33: 2.27 66: 6.21	15, 16, 8, 4, 6, 13, 2	18, 1, 17, 9, 19, 7, 3, 5	10, 11, 22, 21, 12, 14, 20
NRES	33: 1.45 66: 4.95	13, 15, 2, 16, 8, 6, 4	1, 18, 3, 9, 7, 17, 19, 5	11, 10, 22, 14, 21, 20, 12
NCON	33: 0.3 66: 0.84	8, 15, 16, 17, 18, 19, 4	6, 5, 9, 10, 11, 1, 7, 13	3, 22, 2, 21, 12, 20, 14
NLIC	33: 0 66: 0.2	2, 4, 6, 7, 8, 9, 12, 15, 16, 18, 19	3, 5, 21	1, 10, 11, 13, 14, 17, 20, 22
NOTH	33: 0 66: 0.26	1, 4, 9, 14, 15, 16, 17, 19	2, 6, 7, 8, 13, 21, 22	3, 5, 10, 11, 12, 18, 20
NIND	33: 1.65 66: 3.47	15, 16, 8, 7, 13, 2, 4	18, 6, 3, 1, 17, 9, 19, 11	10, 5, 22, 21, 20, 12, 14
NGOV	33: 0.06 66: 0.57	6, 9, 15, 16, 18, 19, 4, 8	21, 5, 1, 7, 13, 17, 2	10, 12, 3, 20, 22, 14, 11
NEU	33: 0.049 66: 0.97	1, 4, 6, 8, 15, 16, 18	2, 5, 9, 13, 17, 19, 21	3, 7, 10, 11, 12, 14, 20, 22
TOTPRO	33: 2.27 66: 6.21	15, 16, 8, 4, 13, 6, 2	18, 1, 17, 9, 19, 7, 3, 5	10, 11, 22, 21, 12, 14, 20
NSME	33: 0.40 66: 0.84	9, 15, 4, 21, 13, 1, 18	5, 6, 11, 17, 2, 8, 7, 10	16, 19, 20, 3, 12, 14, 22
NL	33: 1.32 66: 2.69	16, 7, 2, 15, 3, 13, 4	18, 6, 19, 9, 1, 17, 11, 10	8, 5, 22, 12, 20, 14, 21

NRD	33: 1.31 66: 3.30	15, 2, 7, 16, 13, 1, 3, 4	18, 9, 6, 17, 19, 11, 10	8, 5, 22, 12, 20, 21, 14
NRD0	33: 0 66: 0.32	16, 15, 13, 18, 6, 19, 9, 11, 10, 21	4, 5, 20, 17, 22	14, 7, 2, 3, 1, 8, 12
NOB	33: 0.60 66: 1.63	15, 16, 18, 6, 13, 10, 7, 9	4, 17, 19, 2, 3, 8	1, 5, 11, 21, 20, 22, 12, 14
NOF	33: 0.80 66: 2.80	2, 4, 7, 1, 15, 3, 13, 11	16, 9, 17, 18, 6, 19	10, 5, 8, 22, 12, 20, 21, 14
NMNCY	33: 0.83 66: 2.69	16, 2, 7, 4, 15, 1, 13	3, 18, 9, 6, 19, 17, 11, 10	8, 5, 22, 12, 20, 14, 21
NMNCN	33: 0.54 66: 1.02	15, 21, 13, 5, 18, 9, 6	7, 17, 11, 8, 10, 2, 4, 16	19, 3, 20, 1, 22, 14, 12
NMNCBY	33: 0.04 66: 0.80	16, 7, 15, 13, 18, 6, 10	4, 1, 19, 12, 2, 3, 17, 8	9, 5, 11, 22, 14, 20, 21
NMNCBN	33: 0.68 66: 2.47	16, 2, 4, 3, 7, 1, 15	13, 11, 19, 9, 17, 18, 6, 10	5, 8, 22, 12, 12, 20, 21, 14

Legend –Scientific fields of research groups

1 - Actuarial sciences;
2 - Construction and construction materials;
3 - Computer Sciences;
4 - Comparative Physiology -Zoology;
5 - Surface Chemistry and Catalysis;
6 - Biopharmaceutical sciences
7 - Law;
8 - Energy;
9 - Electrical Energy;
10 - Microelectronics and Sensors;
11 - Processing of Speech and Images;
12 – Signals Identification /Computer Security;
13 – Telecommunications and Microwave;
14 – Industrial Microelectronics
15 – Feed, Food and Health;
16 – Heart Research;
17 – Hormone Research;
18 – Leuven Clinical Co-ordination Centre;
19 – Medical Imaging;
20 – Metallurgy and Materials Engineering;
21 – Polymers/ Physical Organic Chemistry
22 – Mechanical Engineering

Table 6 - Most productive research groups (average values per year)

MOST PRODUCTIVE RESEARCH GROUPS		
By project type	***Research projects***	• Processing of speech and images • Microelectronics and sensors • Mechanical engineering • Industrial microelectronics • Polymers/physical organic chemistry • Metallurgy and materials engineering • Signals identification/computer security
	Consultancy projects	• Computer sciences • Mechanical engineering • Construction and construction materials • Polymers/physical and organic chemistry • Signal identification/computer security • Metallurgy and materials engineering • Industrial microelectronics
	Licence projects	• Actuarial sciences • Microelectronics and sensors • Processing of speech and images • Telecommunications and microwave • Industrial microelectronics • Hormone research • Metallurgy and materials engineering • Mechanical engineering
	Other projects	• Computer sciences (computer training courses) • Surface chemistry and catalysis • Microelectronics and sensors • Processing of speech and images • Signals identification/computer security • Clinical research • Metallurgy and materials engineering

By funding source	***Industry-funded projects***	• Microelectronics and sensors • Surface chemistry and catalysis • Mechanical engineering • Polymers/physical organic chemistry • Metallurgy and materials engineering • Signals identification/computer security • Industrial microelectronics
	Government-funded projects	• Microelectronics and sensors • Signals identification/computer security • Computer sciences • Metallurgy and materials engineering • Mechanical engineering • Industrial microelectronics • Processing of speech and images • Comparative physiology-zoology • Law
	EU-funded projects	• Computer sciences • Law • Microelectronics and sensors • Processing of speech and images • Signals identification/computer security • Industrial microelectronics • Metallurgy and materials engineering • Mechanical engineering.

Table 7 – Paired-sample t-test (pre- and post-1995 values)

Variable	**Pre-1995 Value, Mean**	**Post-1995 Value, Mean**	**95% C.I. of the Difference**		**t value**	**df**	**Sig. (2-tailed)**
			Lower	**Upper**			
TOTPRO	33.17	117.17	111.07	-56.93	-7.978	5	0.000
TOTVAL (MEuro)	2.72	14.82	-20.09	-4.13	-3.900	5	0.011

Table 8 – Pre- and post-1995 growth of the number of U-I projects and research budgets

PRE-1995					
Dependent	**Model**	**B1**	**B2**	**Rsq**	**Sig. F**
ln TOTPRO1	LIN	**0.1651**	**0**	**0.698**	**0.003**
	QUA	**0**	**4.1E-05**	**0.698**	**0.003**
ln TOTVAL1	LIN	**0.15**	**0**	**0.458**	**0.032**
	QUA	**0**	**3.8E-05**	**0.459**	**0.031**
POST-1995					
Dependent	**Model**	**B1**	**B2**	**Rsq**	**Sig. F**
ln TOTPRO2	LIN	0.05	0	0.129	0.485
	QUA	0.05	0	0.129	0.485
ln TOTVAL2	LIN	**0.262**	**0**	**0.657**	**0.050**
	QUA	**0.262**	**0**	**0.657**	**0.050**

Note: The regression model used for each dependent variable is $Y = A + B_1X + B_2X^2$, where X = Year, Y = ln (TOTPRO1), ln (TOTVAL1), ln (TOTPRO2), ln (TOTVAL2). (1) refers to the pre-1995 values, and (2) refers to the post-1995 values, and the growth rates are expressed by the B_1 regression coefficients.

Table 9 - Cross-correlation coefficients: (a) TOTPRO1-TOTVAL1; (b) TOTPRO2-TOTVAL2:

(a)

Independent variable	**Dependent variable**
Step 1	**TOTVAL1 (leading)**
TOTPRO1 (Lag 0)	0.742*
TOTPRO1 (Lag 1)	0.641
TOTPRO1 (Lag 2)	0.377
Step 2	**CHTOTVAL1 (leading)**

Independent variable	**Dependent variable**
Step 1	**TOTPRO1 (leading)**
TOTVAL1 (Lag 0)	0.742*
TOTVAL1 (Lag 1)	0.765*
TOTVAL1 (Lag 2)	0.768*
Step 2 (changes)	**CHTOTPRO1 (leading)**

CHTOTPRO1 (Lag 0)	0.262
CHTOTPRO1 (Lag 1)	0.068

CHTOTVAL1 (Lag 0)	0.262
CHTOTVAL1 (Lag 1)	-0.323

* Correlation is significant at the 0.05 level (2-tailed).

(b)

Independent variable	**Dependent variable**
Step 1	**TOTVAL2 (leading)**
TOTPRO2 (Lag 0)	0.595
TOTPRO2 (Lag 1)	0.921*
TOTPRO2 (Lag 2)	0.213
Step 2	**CHTOTVAL2 (leading)**
CHTOTPRO2 (Lag 0)	0.438
CHTOTPRO2 (Lag 1)	0.867

Independent variable	**Dependent variable**
Step 1	**TOTPRO2 (leading)**
TOTVAL2 (Lag 0)	0.595
TOTVAL2 (Lag 1)	-0.353
TOTVAL2 (Lag 2)	-0.873
Step 2 (changes)	**CHTOTPRO2 (leading)**
CHTOTVAL2 (Lag 0)	0.438
CHTOTVAL2 (Lag 1)	-0.648

* Correlation is significant at the 0.05 level (2-tailed).

Figure 1 - Evolution of EU-funded projects, 1985-2000

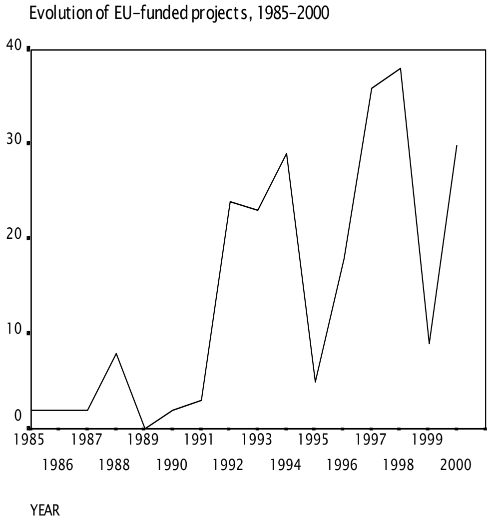
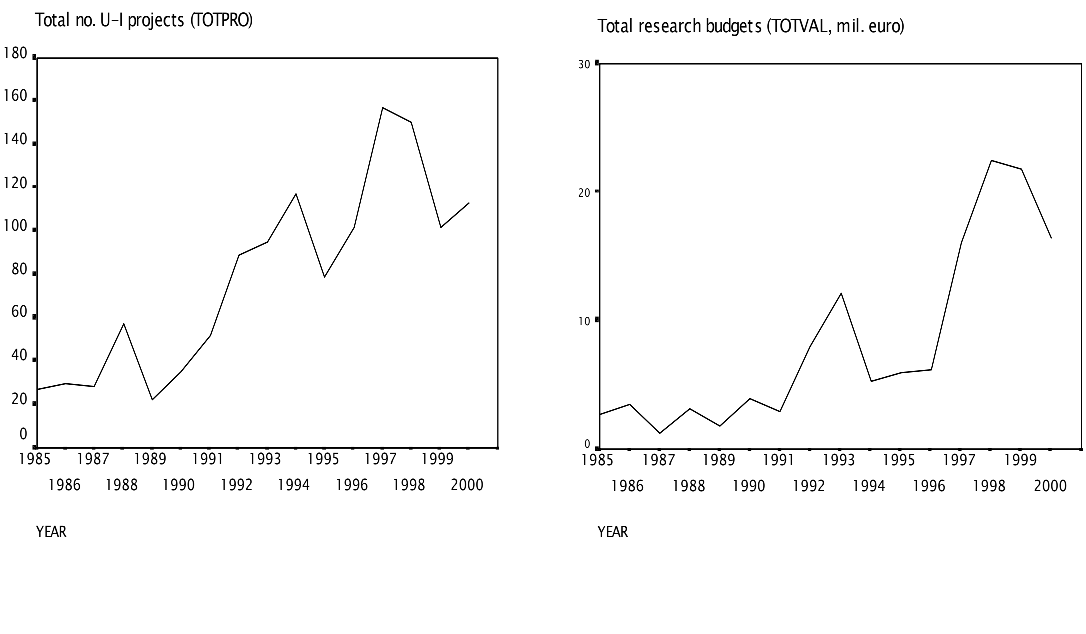


Figure 2 – Dynamics of U-I project variables, 1985-2000:

(a) Total number of U-I projects;

(b) Total research budgets (MEuro)

(a) (b)



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