Belgian Report on Science, Technology and Innovation 2001

The Belgian Innovation System: Lessons and Challenges

Volume II

Volume I of the Belgian Report on Science, Technology and Innovation 2001 gives a mitigated picture of the Belgian innovation system. Despite a strong technological and scientific background, Belgium seems to experience some difficulties transforming this advance into concrete economic realizations.

Consequently, this second Volume has for objective to study in more details the scientific, technological and innovation system in Belgium. For this purpose, the contributions of 12 experts are collected to give some explanations on the achievements of Belgium in terms of R&D indicators, compared to the European average.

It appears that the answer relies in some structural features. The dynamism of federal and federated authorities in launching initiatives aimed at stimulating and promoting R&D, should allow Belgium to be able to better transform its experience into achievements in the medium term.

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Volume II

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Federal Office for
Scientific, Technical
and Cultural Affairs

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Foreword

It is a great pleasure for me to present the second volume of the "Belgian Report on Science, Technology and Innovation 2001" (BRISTI).

The first part of this report was received with interest by both Belgian and foreign readers. In it we described and examined the initiatives implemented by the various Belgian authorities in regard to policies for science, technology and innovation. We also presented a large number of indicators which can be used to measure the extent of the success (or failure) of these policies.

In the second part, we wish to analyse the situation from another angle. Everyone knows that the European Union has access to great scientific potential but finds it difficult to convert this to economic benefits. Belgium seems to suffer from this same paradox. We would therefore now like to bring to your attention some ideas on this matter from Belgian university circles. These have been summarised in an introduction written by the project's scientific coordinators, Prof. M. Cincera of the Université Libre de Bruxelles and Prof. B. Clarysse of the Vlerick Leuven Gent Management School.

I hope that you will enjoy reading this work and can already tell you that the next part will appear in 2003. By then we will be in a position to give you an update, based on the new information which will be available, on research being done in Belgium.

Ir. Eric Beka
Secretary General of the OSTC

P.S.: You can also visit our web site www.belspo.be where you will find full information on all current R&D.

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Volume II

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The Belgian Innovation System: Lessons and Challenges

BELGIAN REPORT ON SCIENCE, TECHNOLOGY AND INNOVATION • 2001

The Belgian Innovation System: Lessons and Challenges

Michele Cincera and Bart Clarysse

As described in the first volume of this report[1], Belgium scores slightly above the EU-average on most indicators of its science, technology and innovation system. In this second volume, we collect a series of papers, focusing on parts of the Belgian science, technology and innovation system using academically accepted methodologies. They offer insights on why Belgium performs better or worse than the EU-average and suggest further improvements.

In the first volume, we mentioned that Belgium's government budget appropriations or outlays for R&D (GBAORD) are still lagging behind, despite the efforts undertaken to catch up with the other European countries. We attributed this partly to the fact that Belgium does not undertake defence related R&D. If we take only the civil budgets for R&D, then Belgium still scores below the EU-average, although to a lesser degree. However, not only is the size of the GBAORD important, but also an efficient allocation of the resources is needed. The first two papers in this second volume, the first, by Dominique GRAITSON (CESRW), Claire LOBET-MARIS (DGTRE), Marc OSTERRIETH (ULB) and Mary VAN OVERBEKE (Federal Planning Bureau)[2], and the second, by Jan LAROSSE (IWT)[3], explain what efforts have been made in the Walloon and Flemish Regions respectively to allocate the resources efficiently.

The paper by Dominique GRAITSON *et al.* explains how the Walloon Region used a "technology foresight" exercise to identify 40 key technologies, which can be of importance to the region. In a second step, an experimental programme was launched in order to stimulate innovation clusters surrounding one or several of these key technologies. Finally, the efficient functioning of the different actors in the innovation system was targeted. Three efficiency improvements were the goal of this action:
1. improved exploitation of university research results;
2. the organisation of a structural support network for the enterprise sector; and
3. improving the availability of risk capital for innovative projects.

* Original text in French and Dutch.

To get in touch with the authors, see pages 4 and 5.

[1] Belgian Report on Science, Technology and Innovation 2001, volume I.

[2] "Innovation support scheme in Wallonia: lessons from the Prometheus programme".

[3] "The evolution of innovation policy and the emergence of a 'New Economy' in Flanders".

Jan Larosse emphasises the path dependency of the Flemish science, technology and innovation policy and describes in detail the evolution of the Flemish science, technology and innovation system. In the second part of his paper, he focuses on the economic rationale of government intervention in the field of R&D. In the debate to which extent governement intervention is desirable, the "additionality" question takes a central place. In his paper, he defines "additionality", as the results that would not have been realised by the private sector without the public instrument, e.g. subsidies, tax credits. Indeed, given the existence of market failures, some activities and functions may be insufficiently fulfilled by private initiatives. The main argument is that in the knowledge economy, the market mechanism is not longer firm based, but network based. As a result, the additionality problem for public policy should not longer be analysed using the firm or the sum of firms that benefit directly from it as a point of departure. Instead, the network of firms being involved directly and indirectly should be the target. This means that existing innovation policy activities, which target individual firms or organisations – e.g. R&D subsidies or new research laboratories – are not sufficient. Although they might help to correct the deficiencies of the firm based market mechanism, they do not address the requirements of the network based market mechanism. Jan Larosse points to the need for network oriented innovation stimuli and cluster policies in the Flemish Region to correct for these shortcomings in addressing the network based market.

In the first volume of the Belgian Report on Science, Technology and Innovation, we concluded that Belgium scores above average in terms of education, scientific publications and international S&T collaborations. Belgian researchers produce an above average number of scientific publications, which are widely cited and internationally recognised. It is important to know what the exact mechanisms are, which result in this good performance, and to explore whether these conditions are sustainable.

The paper of Françoise Thys-Clément (ULB)[4] analyses how the working conditions of the researchers have an impact on their productivity and international exposure. She points to the increased pressure on researchers and academics in most universities in the OECD countries due to the huge increase in the number of students, which these universities have been receiving since the mid-sixties. Despite the increased pressure to teach, Belgian academics prefer research activities to teaching responsibilities. Her contribution suggests that, in order to maintain a high performance in research output, it is necessary to increase multidisciplinary research activities and to create an incentive structure, which motivates researchers at all levels of the hierarchy. Especially, senior researchers and young academics (level lecturer/senior lecturer in the Flemish community or "Chargé de cours" in the French community) are very poorly paid and have few incentives in the current system. Given the increased teaching pressure in some disciplines, policy makers should question how to maintain and even improve the research capacity in this context.

Not only has the teaching load increased, as suggested in the contribution from Françoise Thys-Clément, but budgetary constraints on universities also call for more emphasis on the valorisation of research activities. As discussed in the first volume, in the past few years the Belgian universities have made major efforts to improve their

[4] "Changes in research management: the new working conditions of researchers".

management of Intellectual Property Rights (IPR) to create interface services and play an active role in spinning off high tech start-ups. The joint paper by Bernard SURLEMONT, Hélène WACQUIER and François PIRNAY (ULg)[5] describes the spin-off activity of Belgian universities. Three generations of spin-offs are distinguished: a first generation of spin-offs that was created without the collaboration of universities. A second generation of spin-offs, starting in the early nineties, was created without much support from universities but using some successful first generation pioneers as business models. The third generation of spin-offs benefits from the current changes that have taken place in universities. Despite the change in mentality, accelerated by budgetary pressures, spin-off activity is not at an equal level in all Belgian universities. Only a few of them show exceptionally good results. In this context of increased emphasis on the commercialisation of research output, it will be a challenge for them to continue their basic research activities, which result in international publications and simultaneously to increase the commercialisation of their research activities.

In the first volume of the Belgian Report on Science, Technology and Innovation, it was shown that the Belgian labour force has one of the highest education levels in the world with a high percentage of scientists and engineers. This suggests that Belgium is well prepared for the knowledge economy, although intra-regional differences can be expected.

The papers by Rosella NICOLINI (IRES-UCL)[6], André SPITHOVEN and Peter TEIRLINCK (OSTC)[7] address the regional and local dimension of technology clusters. They show that there is a clear agglomeration effect taking place which should not be neglected in technology policy actions. Building a high-tech cluster from scratch does not take into account the path dependency of these agglomeration effects. This agglomeration effect also calls for clear cluster policy or network initiatives as suggested in the paper of Jan LAROSSE.

The paper by Rosella NICOLINI aims at assessing the R&D intensity in Belgium using spatial data analysis. The existence of positive spatial auto-correlation for R&D investments is specifically tested for a sample of industry sectors by means of a few statistical indices showing the general tendency of the R&D expenditures to cluster spatially. The results of the study suggest that the local environment may influence company decisions in R&D matters. Data confirm that the proximity to other firms, investing in R&D, affects the involvement of each firm in R&D activity and proximity produce positive externalities which may reduce the amount of capital invested in research. Finally, on the basis of the last cohesion report of the EU, the Belgian regions are compared with the European ones.

André SPITHOVEN and Peter TEIRLINCK analyse the intra-regional patterns of R&D expenditure in the private enterprise sector. Taking historical as well as political factors into account, the authors illustrate, by means of some examples, the importance of social and physical factors in any given spatial environment to “the attraction” of R&D activities. They examine the regional concentration and specialisation of R&D activities at the district (NUTS 3) level as well as the regional pattern dynamics of these activities through a shift and share analysis.

[5] “Belgian universities spin-offs in 2000: an economic analysis”.

[6] “R&D and regional development in Belgium: some perspectives”.

[7] “The regional structure of R&D expenditure in the Belgian enterprise sector”.

The paper by Henri CAPRON (ULB)[8] highlights the relevance of a territorial approach to innovation systems in analysing a federal country such as Belgium composed of a federal state, regions and communities, each entity having its own responsibilities in the field of S&T policy. He emphasises the need for a new mode of institutional governance to fully grasp the opportunities offered by the transition towards a knowledge-based economy. In a first step, Belgian regions are positioned from a S&T perspective within the broader European context. Then the main components of regional innovation systems are identified. It is shown, in particular, that the innovation potential is limited to a number of districts specialising in certain technological sectors. Finally, the institutional and organisational effectiveness of the Belgian regional government systems are analysed in particular from the point of view of the position of the Belgian regions along their learning path to move towards the knowledge economy.

Belgian companies make an intensive use of opportunities offered by the European Commission to get involved in collaborative research projects with international partners. Of course, above average international partnering is in line with what one would expect from technology based companies in a small and open economy. However, the high score obtained by Belgian companies in terms of international collaborations indicates that the country has a strong position in the technological landscape. We should not only look at international collaborations, but also at intra-national partnerships. Whereas international collaborations highlight the import or export of knowledge, intra-national collaborations are a strong indicator of a country's ability to internalise spillover effects stemming from its own research activities and, where possible, to capture economic returns from these efforts. The paper by Henri CAPRON and Michele CINCERA (ULB)[9] quantifies the commitment of Belgian research teams to world-wide research networking and transfer. This exercise is undertaken on the basis of pre-competitive collaborations financed under the successive Framework Programmes of the European Union, the near-market co-operations under the EUREKA initiative and strategic alliances formed by private R&D companies. The results indicate a high participation of Belgium in European RDT programmes, particularly influenced by cultural and geographic distance. This high score contrasts with the low level of involvement of Belgian business enterprises in international strategic alliances. Furthermore, the weakness of intra-national collaboration links indicates that Belgian S&T organisations do not optimally exploit their research complementarities.

But international R&D collaborations are not the only mechanism of (international) technology transfer. Foreign direct investment, foreign technology payments, publications in scientific journals or the migration of scientists and engineers are other channels of S&T diffusion[10]. These channels are often associated with an economic transaction but knowledge transfer is not necessarily synonymous with economic transaction. Knowledge and new ideas may be borrowed from the innovative activity of rivals because of the imperfect appropriability of knowledge associated with new products and processes. For instance, reverse engineering, imperfect patent protection or the difficulty of keeping inventions secret are all examples of such knowledge spillover phenomena, which are not easily measured.

[8] "Transition towards the knowledge-based economy: growth potential and learning regions".

[9] "The participation of Belgium in European R&D programmes".

[10] Unfortunately, regarding this last channel, no systematic indicators have so far been collected for Belgium.

The paper by Ruslan Lukach and Joseph Plasmans (UA-UFSIA)[11] examines the importance and direction of technological externalities taking place in the Belgian economy. The analysis is conducted using patent citation data from patents granted to Belgian firms at the European and the US patent offices over the period 1996-2000. After a discussion of the advantages and limitations of patent citation information, the authors implement an econometric model for the qualitative response variable and their findings give evidence of significant differences in the citation behaviour patterns across industry sectors and as a result in inter-industry and intra-industry knowledge exchanges. On the whole, inter-industry knowledge spillovers tend to be less important in sectors with lesser technological complexity or more "uniform" technological orientation. The incentives to collaborate in R&D are higher in these industries and this calls for a differentiated public action towards the regulation of R&D activities of firms in different industries.

Some interrelations between the indicators or components of the S&T system are also noteworthy. For instance, Belgium's gross domestic expenditure on R&D (GERD) as a percentage of the gross domestic product (GDP) is slightly above the EU-average, while its main component business enterprises R&D (BERD) is well above the average. This could mean that Belgium has relatively little R&D activity going on in the public sector. Increasing the public funding of BERD could further leverage the important presence of the enterprise sector in the science, technology and innovation system.

Public subsidies are one of the policy instruments governments can implement to stimulate the R&D activities carried out by firms. Fiscal incentives and publicly performed research such as in the public laboratories also affect the level of private R&D investment. The paper by Bruno van Pottelsberghe de la Potterie and Carine Peeters (Solvay Business School – ULB)[12] examines the impact of these different instruments on R&D activities and productivity performance. The authors also present recent trends for different R&D instruments and compare the Belgian position with that of its neighbours and other small industrialised countries. The results suggest a negative impact of public R&D on business-funded R&D which can be due to an increase in the costs of R&D (government spending increases the demand for scientists) or to a direct displacement (firms substitute public support for their own). However, this crowding-out effect tends to be limited to defence related R&D activities. For other R&D activities, public R&D seems to be complementary to private R&D. This finding supports the argument that private R&D is more short-term oriented and public R&D might play a major bridging role between the basic research activities in the higher education sector and the R&D in the enterprise sector. As for the impact of R&D subsidies and tax breaks on private R&D, the authors report a positive effect, the impact of R&D tax credits being more rapid. For the authors, tax breaks, in contrast to R&D subsidies, directly benefit on-going R&D projects and firms do not have to start new R&D programmes that meet government requirements. Furthermore, whatever policy instrument is used, stability over time appears to be crucial to maximise its impact.

[11] "A study of knowledge spillovers from the compatible EPO and USPTO patent datasets for Belgian companies".

[12] "S&T policies, R&D, and economic growth".

Using a linear econometric approach, the paper by Wim MEEUSEN and Wim JANSSENS (UA-RUCA)[13] analyses the "additionality" problem[14] of public R&D subsidies in the enterprise sector. They find that the additionality is significant in the category of small and medium-sized enterprises. Additionality is much less clear in the category of large firms. Since most of the Belgian R&D is performed by enterprises, R&D subsidies might have a very important effect on these R&D activities. However, R&D activities in enterprises can not completely substitute R&D performed in public laboratories. In fact, unless there is a clear presence of corporate research laboratories, R&D activities in enterprises are much more short-term oriented. This might indicate a gap between the basic research performed by the higher education sector and the short-term development activities in general carried out by the private sector. Public R&D laboratories tend to fill in this gap in most countries.

Further, the Belgian BERD figure seems to be composed mainly of subsidiaries of foreign multinationals. This is also reflected by patent indicators showing that the number of patents involving Belgian inventors is higher than the equivalent number of patent applied for by Belgian companies. Technology invented in Belgium seems to be protected by headquarters outside Belgium. The implications of this high dependency on multinational companies deserve a closer look. Is there a brain drain or a brain gain to be expected from this? Do multinationals invest in Belgium because of its high quality research system and import the technological knowledge to realise the economic returns outside the country? Or, is the balance more positive and do multinationals only invest in development activities using technology invented in other parts of the company outside Belgium?

The paper by Reinhilde VEUGELERS (KUL)[15] addresses these questions and analyses the importance of multinationals in Belgium. Reinhilde Veugelers concludes that subsidiaries of foreign multinationals, which are active in Belgium, are highly innovative and rely on internal as well as external sources for innovation. Nevertheless, the transfer of information between headquarters and affiliates suggests that it predominantly runs from headquarters to affiliates. This questions the pervasiveness of globally linked innovations in these subsidiaries. It also means that the local science base is of little importance as a source of innovation, as is also found in the first volume of the Belgian Report on Science, Technology and Innovation. An important result of this paper is that transfers to the Belgian economy are more likely to come from firms that are buying and co-operating internationally. Those affiliates of foreign multinationals that have access to international technology markets might thus play an important role in the Belgian science and technology system. Also those affiliates that are the best integrated in the multinational innovative process are likely to generate local transfers and collaborate with local partners. In other words, it is not necessarily detrimental for Belgium to host many subsidiaries of multinationals, at least in terms of being able to benefit from the spillovers from this know-how. Of course, local technology intensive companies are also needed, which have the capacity to absorb and integrate these spillover effects.

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[13] "On the effectiveness of R&D subsidies to firms in the Flemish Region".

[14] See above for a definition of "additionality".

[15] "How important are multinational firms for the local innovation system? Some empirical evidence from Belgium".

Despite the relative efficiency of the Belgian science and technology system, Belgium's innovation system appears to leave considerable room for improvement. Among the few indicators available to measure the various aspects of the innovation system, two of them were retained in this report: classical innovation indicators measure the extent to which incumbent companies are able to bring new products to the market or implement new processes; entrepreneurship indicators highlight a country's capacity to introduce drastically new innovative ideas. Unfortunately, the reliability of Belgium's classical innovation indicators is subject to much controversy, so that results should be treated with great care. It seems, however, that Belgium is below the EU-average for this. The general entrepreneurship indicators, which seem to be more reliable, point in the same direction. In terms of entrepreneurship activity, Belgium scores extremely low. We might therefore conclude that Belgium suffers from the same disease as Europe: a strong science and technology base, but a low ability to turn this position to economic benefit. Is there a Belgian paradox comparable to the one observed for the European Union?

Innovation support scheme in Wallonia: lessons from the Prometheus programme*

Dominique Graitson, Claire Lobet-Maris, Marc Osterrieth and Mary Van Overbeke

1. Introduction

"Even more so that the preceding one, the 21st century that we are entering will be the age of science and technology. More than ever, research and technological development activities are proving to be the greatest bearers of the future."

This statement, delivered by the European Commission in its report entitled "Towards a European research space", has, for a few years now, inspired industrial restructuring policies implemented in a number of countries which are convinced that innovation constitutes one of the determining factors for economic growth, competitiveness and employment.

In the Walloon area, perhaps more than anywhere else in Europe, innovation and technological development constitute the main focus for restructuring the regional economic base, the products of which, although they have long since been acknowledged as being of a high technological nature, come mostly from sectors considered today as traditional. The economic performance of the Walloon Region is showing a gradual tendency to catch up with that of other very dynamic European regions such as Flanders. The return to positive growth in the value added for the Walloon manufacturing industry in average terms between 1993 and 1997 is particularly significant in this respect. Nevertheless, strengthening innovation and research policies remains necessary in order to ensure more complete adjustment in the long term.

Furthermore, although encouraging signs have appeared in high growth-potential sectors over the past few years, often based on technological research activities, the latter represented only 7.7% of Walloon salaried domestic employment in 1998 compared with 9.5% for the country as a whole. Significant progress has been recorded in recent years. Thus, during the 1993-1998 period, employment in the high-tech sectors of the manufacturing industry grew by 0.6% per year. However, greater efforts are required for the Walloon area to reach the corresponding level of its partners.

* Original text in French.

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Wallonia is gradually catching up in the field of research and innovation following an initial situation characterised by weak R&D expenditure intensity, insufficient development of research compared with the existing potential and more limited public budget resources being devoted to R&D. Assessing the Walloon Region's position in this area is not, however, an easy task: the indicators traditionally used are essentially focused on certain types of input and output (R&D expenditure and personnel, patents) but make it difficult to ascertain whether resources devoted to R&D are sufficient and of good quality in order to meet the Region's needs.

The Walloon Region has allocated substantial additional resources to research and innovation over the past few years. These increased resources were necessary but not sufficient. The role of the Public Authorities continues to evolve in this area and the tools developed must be adapted continually in order to secure a better return on public funds and ensure improved functioning of the innovation support scheme.

In 1996 and 1997, the Walloon Region had initiated several programmes aimed at taking stock of the potential and deployment of the Region's research and technology activities. On the basis of this diagnosis, a consensus has emerged in order to focus further work on the following objectives:
• providing greater transparency with regard to existing competencies in the Region;
• clarifying the role of the different players in research and innovation;
• making their work more interactive and sparking off synergies and partnerships;
• raising the obstacles to research valorisation, especially within the university institutions or at university level;
• strengthening innovation in those companies that are not very innovative or not innovative at all.

The Region has therefore launched the *Prometheus* programme, as part of the European Union's *Regional Innovation Strategy* scheme. This operation has thus generated close relations with other European regions, enabling a clear picture to emerge with regard to Wallonia's region's strengths and weaknesses compared with these other regions.

Furthermore, this "benchmarking exercise" has been facilitated thanks to the assistance of the international experts cooperating in this programme.

2. Prometheus' three areas of work

Prometheus is structured on three major complementary areas of work:
1. better recognition of Wallonia's innovation potential;
2. the promotion of partnerships and synergies through setting up clusters in priority fields;
3. building an incitative framework for generating innovation and for instance, a services network adapted to the needs of the companies.

The main emphasis has been placed more on the technological aspects of innovation than on the management, marketing and finance side due to the regional institutional organisation as well as the significance of the technological potential existing in Wallonia and its possible impact on the production structure. Nonetheless, the problems of those companies displaying little or no innovative have been taken into account in specific terms.

The **first area of work** has been devoted to the carrying out of a study aimed at illustrating Wallonia's potential in technological fields that are expected to expand in the short and medium term. This approach did not cover basic research, the directions of which are more difficult to predict. This analysis led to the identification of 40 key-technologies based on one side on the evolution of social demand, for technologies, and on the other side on Wallonia's assets in the scientific and industrial domains. Five major technological fields have been investigated:
1. Materials – chemistry
2. Capital goods
3. Information technologies
4. Life and food-processing technologies
5. Environment – energy – transport – municipal.

This work was supplemented by a study of the growth potential of the sectors applying these technologies.

Cross-checking of the results of these two studies highlighted technologies that on one hand play a part in the development of basic sectors, essential for the good functioning of the economy and society (transport, telecommunications, energy, environment) and on the other hand are crucial for expanding sectors (ICT, biotechnology, aeronautic, new materials, ...), calling for specific action.

The objective of this approach was to provide all the players affected by research and innovation with a tool to aid decision-making: Public Authorities, companies, research centres, universities and colleges. It was also aimed at improving the transparency – internal and external – of the competencies available in the Walloon area.

The **second area of work** comprised the launching of an experimental programme aimed at motivating the formation of innovation clusters organised around one or more of the 40 acknowledged key-technologies. In view of the challenges presented by globalisation, cooperation between firms is an essential strategy in the fight to maintain and strengthen competitiveness, facilitating the dissemination of knowledge and know-how, and enabling common resources to be shared.

The objective was to strengthen innovation dynamics within the enterprises by encouraging new forms of partnerships leading, for instance, to the creation of innovative products and services emanating from the combination of complementary activities with a high technological content.

Five pilot clusters are currently supported in this scheme. The contribution of the Public Authorities comprises financing the work of an expert commissioned to provide assistance in helping the cluster to organise itself, analysing the cluster's needs and objectives, and drawing up a plan of action. The clusters also receive external methodological and technological support. The role of the Region is therefore that of a "facilitator", with the process initiated and carried out by the enterprises.

The lessons drawn from this experimental programme will make it easier to define the conditions for successful public policies oriented toward building a network of players and setting up a methodology that can be transferred to similar operations. The **third area of work** is centred on the functioning of the innovation support scheme, the positioning of the different players, their activities, their missions, and their relations. Oriented towards supporting enterprises, this scheme revolves around four kinds of players (see illustration below): universities, support structures, financiers and project sponsors, and administration.

Three specific issues have been decided on as a priority:
1. constraints on valorizing university research results;
2. organising the network of enterprises support structures;
3. access to venture capital for innovative projects.

In view of the subject matter of the present report focusing on the innovation system, this contribution will confine itself to reviewing statements and conclusions resulting from the third area of work.

3. The innovation system: player dynamics

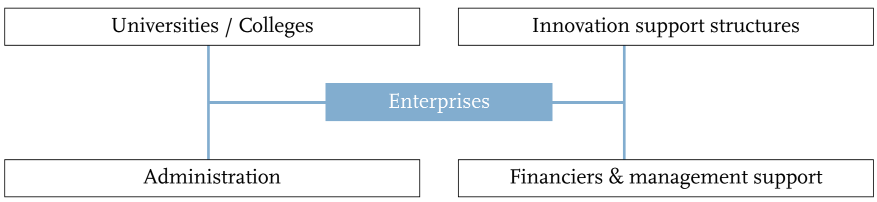
3.1 Introduction

Innovation may be defined as an approach to the creation or improvement of products, techniques or organisation methods.

Several players take part in the innovation process set up by enterprises:
- the **support structures** that help the enterprises to innovate by offering them services responding to their needs in the field of activity concerned;
- **universities and colleges** promoting the good use of the results of their research through existing companies (technology transfer) or new enterprises (business start-ups);
- the **purveyors of venture capital**, who ensure financing of the projects and structures offering management support;
- the **administration**, which assists in different stages of the process via appropriately adapted tools.

The dynamics of each group of players has been the subject of discussion by working groups.

Innovation players



The objective of the approach was twofold:
1. to study the way in which the different groups of players function, highlight the mechanisms that work well and those in need of improvement;
2. to analyse the connections and collaboration existing between these structures and recommend measures enabling better use of their complementarities.

3.2. Innovation support structures

The implementation of an innovation strategy within an enterprise requires three different stages:
- raising awareness on the importance of an innovation approach;
- analysis of the problems of the enterprise and setting up of a project;
- implementation of the project.

As indicated in the table below, enterprises will express specific needs at each stage according to their type:

	Stage 1	Stage 2	Stage 3
	Instilling awareness / culture of innovation	Project development	Implementation – assistance required
SMEs not very innovative or not innovative at all	• Raising awareness • Close contacts • Success stories • Market information? • Choosing an adviser, a sponsor • Raising awareness of executives - training	• External audit of needs • Market analysis and economic feasibility study • Orientation towards appropriate services – establishing contacts with partners	• Resolving technical problems • Integration of new techniques – product development • Adaptation of procedures • Keeping up with technological innovations and competitiveness
High-tech SMEs		• Information on technological advancements • Looking for partners	• High-tech collaboration (with universities and others)
Medium– large enterprises		• Keeping up with technological innovations • Looking for partners	• Search for partnerships in highly specialised domains

Who meets these needs?

There are numerous structures developing activities that meet these needs or part of them. They can be classified in two categories:
- *Technological supports*: i.e. collective research centres and similar institutions, centres established according to Objective 1, public centres, certain university or inter-university centres, research centres associated with higher industrial institutes and technological advisors;
- *Non-technological supports*: i.e. university interfaces, European enterprise and innovation centres, and chambers of industry and commerce.

Among structures offering technological support, there are 10 **collective research centres** established on a sectorial basis in the Walloon area. Their resources come from the obligatory contributions of sectorial enterprises, from coordinated financing at the federal level under the 3C/4C agreements, from their generic research and various additional revenues, which vary greatly from one centre to another, bound on the one hand to research projects financed by public funds and, on the other hand, to fixed-price services carried out on behalf of enterprises. There are also six **centres**, known as "private" centres, which were established more recently with a regional purpose and whose resources stem mainly from contracts with enterprises, from local subsidies and from participating in European programmes.

University centres - structural funds have been developed in the Walloon area (Hainaut Province) on the basis of European co-financing (Objective 1). The aim of their creation was to generate value added in the areas where they were established through stimulating innovation within the enterprises There are six of them. The standards required for creating these centres were extremely strict: submission of R&D-type projects qualifying for European financing, guaranteeing the continuation of the activities after the five-year financing period. These two obligations have made difficult for these centres to meet simultaneously research and service criteria.

The **technological advisors** are affiliated to the collective research centres (De Groote centres and the like, and private centres) as well as a number of joint academic centres (ARAMIS, technological food processing centre) and receive 80% of their funding from the Walloon Region. Their involvement in the SMEs is free of charge.

The intervention of the technological advisors focuses essentially on phase 2 of the SMEs' needs, i.e. the technological audit of problems linked to procedures and products on the basis of the technological surveillance organised in their centres, on the one hand, and the orientation of SMEs towards technological competencies suited to solving their problems and possibly towards sources of financing to support the technological project, on the other hand.

Non-technological contributors essentially include university interfaces and EICs (Enterprise and Innovation Centres). Apart from these, we may consider chambers of industry and commerce as non-technological intermediaries.[1]
The main individual characteristics of the *EICs* and *CICs* are:
- being local and carrying out actions within a network of enterprises located on their "territory";
- approaching and dealing with enterprises involved in all kinds of fields and sectors, often small in size and operating on very specific markets (niches);
- acting mainly as a strategic adviser, precisely with regard to assisting enterprises in their innovation approach, a role consisting of essentially helping the enterprise to formulate its strategy, to define innovation projects and to support their realisation through by finding financing and partners;
- offering free services most of the time;

[1] Also worthy of mention here are the inter-municipal economic development organisations, which - regarding the support of innovation projects - mostly act through the EIC they are associated with.

• not having substantial financial resources for assisting individual cases but, on the other hand, being able to facilitate the development of the enterprise's activities via accommodation facilities and network activities.

The *university interfaces* ensure the promotion of academic competencies and facilitate the collaboration between university teams and their external partners (dissemination of information, project set-up support, drafting and negotiating contracts, etc.). Apart from managing the university's intellectual property rights their function is also to provide support for the creation of enterprises, which includes training project leaders, drawing up business plans and setting up project financing.

Innovation support structures in the Walloon Region

Name	Location	Field
De Groote Centres and the like		
CRIF	Liège	Plastics processing
Centexbel	Chaîneux (Verviers)	Textiles
CRM	Liège	Metalworking industry
CSTC	Limelette	Construction
CRIBC/Inisma	Mons	Ceramics
CORI	Limelette	Painting
INV	Charleroi	Glass industry
CRR	Wavre	Road transport
IBS	Ghent	Welding
CTIB	Brussels	Timber
Private centres		
CEPESI	Charleroi	Tests and measures
Celabor	Chaîneux	Textile-chemistry-environment
Cebedeau	Liège	Water environment
CERER	Tihange	Fish farming
CEWAC	Liège	Assembling-drilling
CRECIT	Tournai	Textiles
Objective 1 centres		
CEDITI	Charleroi	Computing
Materia Nova	Mons	Materials
Multitel	Mons	Telecommunications
Certech	Seneffe	Chemistry
IBMM	Charleroi	Molecular biology
Terre & Pierre	Tournai	Materials
Public Centres		
Issep	Liège	Energy/environment/ mineral resources
CRA	Gembloux	Agronomy

Name	Location	Field
Universities or academic joint centres[2]		
CSL	Liège	Space
ATISA	Gembloux	Food processing
ARAMIS	Mons	Microelectronics
Pôle technologique agro-alimentaire	Gembloux	Food processing
Pôle métal	Liège	Metal
CELOFA		Vague logic
Centres linked with higher industrial institutes		
CRIG	Liège	
CERISIC	Mons	
CERISIL	Liège	
CRISIP	Virton	
SORGHAL	Huy	
Interfaces		
UCL/Administration de la recherche	Louvain-la-Neuve	
Interface UCL- REDE Hainaut	Charleroi	
ULB-Interface	Brussels	
ULg/Interface Entreprises-Université	Liège	
FPMS/Centre d'études et de recherches en haute technologie	Mons	
UMH/ Centre de liaison UMH-enterprises	Mons	
FUCaM	Mons	
FSAGx/Interface Université-société	Gembloux	
FUNDP/service des relations extérieures	Namur	
Cellule interface ADISIF-Enterprises	Namur	
Enterprise & Innovation Centres		
BEPN	Namur	
CTGA	Nivelles	
Maison de l'Entreprise	Mons	
ID-Brabant wallon	Tubize	
CDP Idelux	Arlon	
Heraclès	Charleroi	
Socran	Liège	
Chambers of Industry & Commerce		
CCI Charleroi Centre	Charleroi	
CCI Prov. Namur	Namur	
CCI Brabant wallon	Nivelles	
CCI Luxembourg belge	Libramont	
CCI Tournaisis	Tournai	
CCI Mouscron-Comines	Mouscron	
CCI Mons-Borinage	Mons	
CCI Liège	Liège	
CCI Arr. Verviers	Verviers	
CCI Eupen Malmédy St Vith	Eupen	

[2] The technological food-processing centre and the metal centre also combine research centres.

What problems are encountered?

A **study** has been conducted inside the technological innovation support structures. This concerns two main categories of players: the **technological intermediaries** intervening in the field of research and technological advice with regard to process or product innovation both at a collective level (sectorial) and at a level devoted more to the needs of an enterprise or of a group of enterprises; and the **non-technological intermediaries** involving themselves in management advice and the financing of innovative enterprise projects. The study carried out by the working group focused essentially on technological intermediaries, i.e. around thirty organizations. Special attention was paid to the areas of technological competencies and services offered by each of these structures to the enterprises.

The results of this study made it possible to corroborate and refine the **initial reports** based on the accounts of various people belonging to the relevant sectors and according to which the innovation support system in the Walloon Region is characterised by:

- **a multiplicity of players and a lack of structured collaboration networks;**
  - a lack of coordination or even competition between advisors and other non-technological intermediaries such as the EEICs;
  - insufficient collaboration between the collective research centres and universities. This is partly due to the fact that the creation of Objective 1 centres was not decided on the basis of a preliminary study of needs but, rather, as a result of competence bids from universities – hence a certain amount of overlapping between the competencies and functions of these centres and those of the centres already established, as well as difficulties in collaboration between these structures;
- **a lack of transparency - between them and vis-à-vis SMEs - of the competencies and goals of the support structures;**
- **a lack of evaluation of the technological cover of the research centres with regard to local needs;**
- **difficulties in defining a consistent regional policy for the financing of the research centres.** As a matter of fact, significant disparities are observed between these organisations, linked to the historical conditions of their creation. Thus, some of them receive recurring regional grants, while others are awarded 3C/4C financing and some others benefit from standard “research” allocations. Differences also appear in financing specific schemes as for instance technological advisors. Competitive distortions may appear as a result and endanger the survival of some centres.

These observations led to the conclusion that there is a need for:

- better recognition of support structures and improved transparency of the services they offer;
- better coordination between the different services to the SMEs (technological advisors and non-technological contributors);
- greater collaboration between research centres and between the latter and university laboratories and the higher industrial institutes;
- harmonisation of regional policy for the financing of research centres;
- regulation of the service rates charged by the research centres.

In order to address these concerns, several **actions** have already been initiated within the Prometheus framework.

An accreditation procedure for technological competence centres (TCC) has been proposed. This accreditation applies to De Groote centres and the like, the centres created under the Objective 1 scheme, the other centres and any structure fulfilling the conditions for approval.

The accreditation procedure sets the conditions which, in terms of activities and organisation, these structures may fulfil to benefit of public funding. As a result, the centres get the same rights and obligations regarding public resources in order to accomplish their basic mission, which is to participate in the dissemination of technologies in the Walloon industrial sector. The objective is also to encourage centres to develop activities such as technological surveillance more systematically and in a more structured manner.

Two kinds of criteria have been proposed for approval: **criteria linked to the activity of the centres on one hand and criteria linked to their functioning on the other hand.** Activities eligible for regional financing in the accredited centres would cover the generic research (with up to 50% funding), technological surveillance (up to 80% funding) and technological consultancy (up to 80% funding). The centres could also participate in basic research work on a sub-contract basis, on the understanding that the budget for this collaboration could not exceed 25% of the research costs.

These various activities should be a part of a two-year programme. Moreover, in order to guarantee TCC dynamism, they should have a minimum of 30% of their own revenue apart from the financing from the Walloon Region.

In addition, a **commercial services rate-scale charter** for research organisations has been drawn up by the working group. The players aimed at – referred to below as “the centres” - are the technological competence centres, universities and higher industrial institutes. The objective is for the emulation between these structures to be founded on the quality of the services provided rather than on the prices charged and to avoid distortions of competition between centres with different financing arrangements.

Membership to the charter will be on a voluntary basis and will provide the joining centres with a quality-label. In the case of TCCs, it will be one of the accepted criteria for obtaining the accreditation of the Region. By subscribing to the charter, the centre undertakes to set a rate for its commercial services that at least takes account of the operating cost calculated according to the generally accepted terms.

The DGTRE will be responsible for drawing up and publishing the list of signatory centres on a yearly basis.

3.3 Universities: valorization of research results

The expectations of society in relation to university research have changed. It no longer concerns the mere production of new knowledge, rather it also has to contribute to technological innovation within the industrial sector and, in doing so, to acquiring competitive advantages and creating new activities.

In general terms, universities have responded very positively to these new expectations, already making a significant contribution to regional development. Traditionally, university activities are dedicated to teaching and research. A third responsibility has been committed to them, related to activities such as continuing adult education, research and development, assisting SMEs, technology transfer, business start-ups and involvement in structural programmes for regional development.

Numerous initiatives have been undertaken in recent years in order to take better advantage of the potential offered by university research. These include, in particular:

- a significant increase in the budgets devoted by the Region to industry-oriented research carried out by universities;
- the launching of programmes in this context intended to strengthen research potential in expanding domains, such as "*From digital to multimedia*" and "*Bioval*" or "*Walloon University Development*";
- an increase in the numbers of funded researchers working in both laboratory and industry (FIRST) and the enlargement of the system in order to encourage business start-ups and completion of doctorates in close collaboration with enterprises;
- the transfer to universities of the ownership of research results funded by the Region (with patent costs also taken care of) and the setting up in the universities of small teams to ensure the valorization of such results;
- the creation of diverse venture capital funds, public or private (FIRD, SPINVENTURE, START-IT, etc.), sometimes linked to universities, for financing technological innovation and business start-ups;
- the setting up of competence centres combining different kinds of players (space and metal centres in Liège);
- the creation under the Objective 1 programme of research centres linked to universities, but oriented towards applied research, technology transfer and/or services to enterprises (CEDITI, CERTECH, IBMM, etc.).

Nevertheless, several factors still hinder the valorization of research results.

Obstacles to valorization

- **Valorization is not yet sufficiently acknowledged as a specific university function**

Within universities, attitudes regarding the emergence of valorization and regional development activities are varied. Some of those directly affected see this as an opportunity to expand their services, while others involved in research activities of a more academic nature do not feel concerned. Many, without being openly hostile, wonder about the extent of the university's functions. They fear that resources increasingly allocated in accordance with economic interests, will no longer allow the hindsight and critical reflection peculiar to university activities.

As a matter of fact, a significant part of the research carried out at universities is directed at consolidating knowledge as such, placing emphasis on values that completely elude the commercial logic, such as the disinterested nature of research, the intellectual freedom of the researcher and unhindered dissemination of the results within the scientific community. As for applied research and valorization, these are part of a very different logic, according to which considerations of effectiveness take over from strictly scientific aspects.

The coexistence of these two cultures at universities is a source root of not inconsiderable internal tension, making dialogue singularly more difficult between the universities and their external partners, who remain perplexed in the face of contradictions peculiar to the university environment.

Furthermore, the emergence of a real consensus on the functions of the university is hindered by the division of competencies between the French Community, foremost in teaching and university research, and the Walloon Region, whose competence lies in applied research and economic exploitation of the emerging results. The consequence of this divide is that the organisation of the universities, the status of their employees and their financing mechanisms are governed by wording that makes no allowance for valorization. Research is financed by different bodies and according to criteria that vary depending on whether it concerns basic research or applied research, which excludes programming as a whole. Teaching, academic research and applied research are the subject of separate evaluations that do not illustrate the complementarities that precisely constitute the strong point and specific nature of universities.

- **The way in which universities function is not entirely adapted to valorization**

All the positive experience gathered, in Belgium as well as abroad, shows that explicit support that is ongoing and unambiguous on the part of the academic authorities constitutes an essential condition for harmonious development of the universities' valorization activities.

The problem is, however, profound. Many researchers who could make useful contributions to regional development do not do so, either because they are not interested or because the applicable rules and procedures are not clearly defined or, finally, because the activities concerned are not sufficiently acknowledged or supported within the institutions.

Within the institutions, members of the academic staff owe their status to the teaching duties allocated to them, mostly based on criteria that are strictly academic (publications and scientific awards).

The ability of researchers to pursue a career at university and mobilise resources in order to develop their research depends to a crucial extent on acknowledgement by the scientific community and therefore on publications. Valorization activities are taken into account to perceptibly lesser degree and thus considered less attractive, at least by those researchers wishing to remain at university.

The rules and procedures applying to valorization activities are not always clearly defined and members of the academic community do not have a clear idea of what is expected from them, or of their rights and obligations vis-à-vis the institution. This is particularly true with regard to the intellectual property and profit sharing of researchers, matters that are frequently governed by imprecise rules not familiar to the academic community.

- **The valorization dimension is not given sufficient consideration when defining research projects**

The valorization of research results in the interests of regional development presupposes that these results have a real economic impact. The main difficulty in this regard is to direct researchers' creativity towards those fields that are of genuine economic relevance and, therefore, to integrate the "valorization" aspect at the time of defining research projects[3].

Although the research programmes conducted by the collective centres are directly founded on the needs of enterprises, the same – and this is a positive aspect - does not apply to universities, with the exception of industrial contracts. The choice of research topics is in the hand of the researchers, whose main concern is to publish and receive acknowledgement from their peers accordingly. The university institutions themselves have little room of manoeuvre when it comes to directing the activities of their researchers.

- **Collaborations between research teams (university and others) are still under-developed**

Everybody recognises that advanced research requires substantial resources, that financing a lot of small projects instead of concentrating resources on bigger ones is not effective and that the coordination of research work should be improved.

The current system of allocating funding for the functioning of universities, which entails sharing a given budget between the institutions according to the development of the number of students admitted (and, with regard to postgraduates, the number of diplomas awarded), encourages competition and in no way motivates universities to specialise in certain directions, though there is a slight incentive for Ph.D. (and postgraduate) studies organised at inter-university level. The situation is much the same for contractual research financing mechanisms, which force research teams and universities to compete for available resources, although networks are financed in certain cases (PAI, WUD). In other instances (ARC), a system of pre-established sharing does not enable incentives to be linked to collaborations.

[3] However, the question is not one of directing all university research only according to the needs of existing companies. **Fundamental research, as a whole, should not depend on an economic logic, and one of the main issues in the present context is precisely that of maintaining it at a good level** even if its economic effects are not immediate. University research must also **address other needs of society.** Some scientific or technological fields must be explored even though they do not meet any of the expectations of existing enterprises, because they could give rise new economic activities. And we must always bear in mind that excessive directional planning has never stimulated anyone's creativity and that the impact of research is sometimes remote and unpredictable.

Collective research centres (and the like) occupy a very singular position in our system. Generally coming from the industry, they are particularly well placed to know all the needs and disseminate university research results in an extensive manner. Unfortunately, the present situation is characterised by extensive partitioning and increased competition between research centres (who would like to increase their activities in the field of the basic research) and universities (who multiply technological support actions for the enterprises). Collaboration between centres and universities is rare, and information does not travel well. This situation is regrettable for various reasons, in particular because information held by the centres in relation to sectorial needs could certainly help university research to become more needs- oriented.

• **The valorization support structures are not strong enough and act in isolation**

The management of valorization activities is a complex undertaking that requires substantial resources as well as advanced and diverse competencies. The mistrust of a section of the academic community towards valorization activities is partly due to a misconception of the valorization process and the different methods and techniques it calls for.

We can initially distinguish between three kinds of functions in this regard:
- **promotion** of university competencies, and **facilitating collaborations between university teams and their external partners** (dissemination of information, project set-up support, drafting and negotiation of contracts, etc.). This was, up to recently, the main if not exclusive objective of university interfaces;
- **active management of the university's intellectual property rights**, including detection and assessment of inventions, management of the patent portfolio and negotiating licence agreements (technology transfer): the resources available to universities in this regard have just been substantially strengthened through the provision of valorization experts by the Region;
- **business start-up support**, including the training of project leaders, drawing up of business plans and setting up project financing (even extending to profit-sharing by universities in some cases).

These three functions correspond to three different occupations that cannot be easily performed in an efficient manner by the same body, even within a university. **Networks of complementary structures -** possibly specialising in certain niche technologies, provided with legal structures and resources suited to their functions, and linking with external partners where needed - are probably in the best position to perform adequately.

In order to be efficient, these structures must satisfy three conditions, which are not always met at present:
- having human and material resources at their disposal that are, both in quantitative and qualitative terms, suitable for the goal pursued. Currently, the number of people really competent and likely to bring real value added to projects is very limited;
- having internal legitimacy as well as sufficient authority within the university institutions;
- being in close touch with the political, economic and social environments.

Bearing in mind that the local dimension is important and that each university wishes to have its own instruments, a number of activities could be organised more efficiently through collaboration. Actions of this nature have already been initiated by the CRef.

The main difficulty, in fact, lies in establishing a dialogue with enterprises.

- **Research results are not adequately endorsed**

Complementary research work (full identification of certain effects, completion of an initial prototype, optimisation of modus operandi, etc.) is often necessary to be able to assess the impact of the results and thus obtain a complete technical file. This validation stage, essential to good valorization, is presently hindered by two major obstacles: on the one hand, it does not always address the necessities inherent in the career of the researcher and, on the other hand, it goes beyond the financial capacities of the university teams and is seldom subsidised by the Public Authorities. Under such circumstances, validation, which needs to ensue quickly, takes months, or the results are even just left as they are in some cases.

Furthermore, detailed assessment of the impact of the results and identifying industrial partners really eager to valorize are difficult operations that require a thorough knowledge of the state of art and of enterprises (Walloon and foreign) likely to be interested. Universities must be able to access specialised information sources and bring in specialised external as the need arises.

- **Information on competencies and research results is incomplete and difficult to exploit**

All universities disseminate relatively abundant information on their research-related competencies and activities via different channels (booklets, brochures of the main laboratories, annual reports, centralised or team-related websites, etc.). Enterprises find this information, often conceived according to academic concerns, difficult to use.

Websites of research units, for instance, typically pose different problems in term of access to information (number of stages, lack of an effective research tool, etc.) and suitability to the needs of enterprises (rapid response to a specific questions, identifying the appropriate person, etc.), not to mention the drawbacks stemming from the strictly local organisation of the sites (no references to other sources likely to deliver more adequate answers). These questions have not been solved by the launching of a collective site at CRef level that simply points (although this is very useful) to the sites of the different institutions.

The situation is still more alarming when it comes to research results ready for valorization, for which no inventory presently exists. The difficulty here is to find the right balance between the need for publicity (the university achievements and the requirements of enterprises must be sufficiently known and well documented) and the need for discretion (protection of ideas, projects and intellectual property). It will only be possible to address this challenge through permanent and constructive dialogue between universities and enterprises.

- **Quality management in university laboratories is no longer suited to the needs of enterprises**

The introduction of a quality system makes it possible to ascertain the performance of the equipment and facilities used, as well as the quality and reliability of the results obtained through the use of recognised methods that can be reproduced by monitoring operations. Enterprises feel an increasing need to set up such systems, which also forces them to deal only with subcontractors following the same rules. Quality control is in itself an essential prerequisite for valorization as this is the only way to ensure the reproducibility of research results.

The generalisation of quality management practices within those university laboratories wishing to collaborate with enterprises has thus become imperative. Despite a real recognition of this necessity on the part of researchers and heads of institutions, this kind of approach meets with several obstacles linked with organisational difficulties and the cost of implementation.

- **Possibilities of business start-ups are not fully exploited**

Possibilities of business start-ups on the part of universities are numerous, but are still not exploited sufficiently.

Classic spin-offs are enterprises established in order to make the best use of university research results and are aimed at gradually breaking away from the university. Among these spin-offs, only a few, and these are the most interesting, have real prospects of growth.

The main difficulty concerning these *classic spin-offs* lies in setting up the team required to ensure the management of the project and securing good cohesion between this team and the researchers initiating the project. University researchers willing to set up a company and possessing the necessary competencies are few in number, probably because their training did not prepare them for this approach and their environment is not necessarily conducive to this (see above).

A second difficulty relates to project supervision. Some universities participate in or are associated with enterprise centres likely to host spin-off enterprises and provide them with various services, especially with regard to the drawing up of business plans and the search for necessary funding. However, these centres do not always seem to have played a determining role in establishing university spin-offs up to now. In any case, financing partners still complain regularly about the summary nature of the proposals submitted to them.

Finally, a third difficulty concerns project financing, particularly in the initial phases. Most of these spin-off projects are not sufficiently structured at the outset, or present a risk that is too big for them to be considered by the financial sector, while “seed capital” is especially hard to find.

Various universities have tried to fill this gap by themselves taking shares in the capital of the companies newly established in their sphere of influence. Some of them, sometimes collaborating with financial institutions, have set up financial companies to manage these holdings or participate in supporting projects. These questions are dealt with by working group no. 3, which specialises in innovation financing.

A second group of enterprises created in the wake of the universities could be called **spin-arounds**. These are companies emanating from university laboratories to valorize or exploit an expertise or a particular infrastructure with the objective responding better to demand (accreditation, marketing) or to benefit from a more favourable situation (taxation, autonomy, etc.). These enterprises constitute, so to speak, a different type of extension of activities previously undertaken by the universities. The main difficulty with such enterprises is to find a legal form enabling, simultaneously, a clear division of activities and the respective assets of the company and university, while also facilitating a kind of management unity. It appears that the cooperative-company form is the most suitable in this type of situation.

Finally, an extensive category of enterprises – which could be referred to as **spin-ins** – have their origin outside universities and/or prior to the university research phase. The approach here is to reverse the usual valorization scheme, whereby the company is established according to a linear process passing successively through the stages of fundamental research, basic research, applied research, development etc., with each of these stages requiring specific contributors and financing formulas. This conventional pattern is no longer necessarily ideal for all scenarios, and it may be better (and quicker) to set up a company before the initial stages of the process, with the company playing a unifying role by availing itself of the necessary competencies at source as the need arises. This new approach challenges the traditional ways in which different operators function. Universities have to accept that part of the basic research they carry out will be managed from a valorization perspective within the framework of set-ups over which they have no control. Public Authorities must be able to quickly allocate funds in order to support budding companies that lack industrial maturity. Financial operators, ultimately, must make use of their imagination to find financing formulas suited to this type of project.

Valorization action leads

The main outlines of an integrated and coherent plan of action for encouraging more systematic valorization of university (and university level) research results for the benefit of regional development have been drawn by the working group. This plan revolves around four main goals. It comprises several practical leads, some of which have already started to be implemented.

- Clarifying the universities' valorization function make it more transparent and consistent with teaching and research.
- Directing research according to needs by (1) setting up strategic management of research activities (2) developing synergies and (3) promoting quality management.
- Reinforcing the valorization activities of universities through (1) consolidating and organising appropriate structures into networks (2) developing competencies (3) increasing capacities for evaluating and validating results (4) supporting entrepreneurial attitudes.
- Improve the transparency of competencies, services offered and available results.

3.4 Project initiation players: from supporters to financiers

Different development stages of a project to be financed

The different development stages of a project to be financed can be defined as follows:

- **Seed-capital stage**: search for fertilisation or instigating capital to finance the initial stages of a project. This stage is located between the finalisation of research and marketing the new product or service. The conception of the new product or process has been completed, but its commercial viability must still be demonstrated. This is a high-risk stage. Financing here is a long-term exercise because the potential gains will take some time to materialise.
- **Start-up capital stage:** search for start-up capital to finance the product and its marketing (capital for enterprises of less than two years).
- **Expansion-capital stage:** search for capital to finance the growth and/or development of the enterprise (increase in production capacity, development of markets or products, etc.).

The seed capital and start-up capital constitute the “venture capital”. The latter is thus really concerned with the financing of innovation projects and is associated with a high level of risk.

An analysis of capital supply revealed in 1997 that there was insufficient venture capital investment available in Belgium and particularly in Wallonia compared with other countries such as the Anglo-Saxons nations or the Netherlands. Institutional investors (insurance companies, pension funds), in particular, do not engage in this type of financing to any great extent, stating the reason that the expected profitability of non-listed companies is too low.

Invested capital in initial and start-up phases • 1997

	% of GDP
USA	0.045
Netherlands	0.047
Belgium	0.014

Source: Manigart e.a. 1997

Nonetheless, the overall venture-capital investment portfolio in Belgium displayed strong growth in 1998. However, 88% of these assets seem owned by Flemish investors.

Invested capital in initial and start-up phases • 1998

	% of GDP	Growth rate (%)
USA	0.055	39.6
Netherlands	0.048	9.7
Belgium	0.065	361.7

Source: European Commission, DG Research.

And, yet, there is theoretically no lack of capital funding, especially in the current context of globalisation of the financial markets.

In this regard, the situation has even improved recently in the Walloon area with the launching of new public or mixed (FIRD, Technowal, Start It, Spinventure) instruments aimed, among other things, at boosting the creation and/or development of private funds.

The fact remains that the resources available still have the tendency to be directed towards the expansion and development stages, to the detriment of the initial and start-up stages.

Obstacles to investment in venture capital

- **Lack of "good" projects**

The Walloon Region suffers from a shortage of "good" projects displaying satisfactory chances of survival.

Weaknesses are evident at the level of preparing the relevant dossiers as well as in the phase of supporting projects during the initial stages of their implementation. The risk of failure of these projects is substantial with the result that the average profitability of this type of investment is greatly inferior to what is expected by venture capitalists.

This situation, which can be observed for the whole of Belgium, is illustrated in the table below:

Profitability rates required by venture capitalists		Profitability rates realised					
Average	Investments in initial stages	Average			Investments in initial stages		
		Belgium	UE	USA	Belgium	EU	USA
17.5%	35-45%	5%	18.6%	16.5%	-10%	5.7%	14.2%

Source: Planning Office, 1998; Manigart e.a., 1997.

The development strategy for seed & start-up capital in the Wallonia must be based in the future on efforts aiming at increasing the viability of projects. This implies strengthening the support for promoters in the initiation phase of the project as well as during the early stages of implementing the projects.[4]

A number of institutions, both public and private, fulfil this function in the Walloon area: European enterprise and innovation centres (EEIC), chambers of industry and commerce, inter-municipal economic development organisations, university interface groups, consultants.

[4] This is especially aimed at services provides, such as training, legal reports, market research, assistance in obtaining patents and licences, finding industrial partners, finding executives, drawing up business plans, project follow-up, finding financing, etc.

Some financing companies, public, mixed or private, also take on this role, even though this not always their initial objective (except in the case of certain venture capitalists or business angels bringing heads of companies together and whose goal is for promoters to benefit from their expertise and experience). However, they are sometimes required to compensate for a deficit in order to ensure the profitability of their investments. In any case, this approach enables them to back up their decisions to a greater degree and control the use of the funds. In some cases, they act in partnership with an organisation more specialised in supporting projects.

Local networks have been set up in the Walloon area, bringing together various players active in the field of innovation: for instance, "Liège Group for technological diffusion" in Liège (CCI, Socran, Fabrimétal, certain research centres such as Crif, Crm, Cewac, Issep, etc., university interfaces, colleges, other SME support institutions, ...); "R&D Committee in Charleroi", grouping the same type of partners. These networks enable better circulation of the information on existing competencies.

• **A lack of transparency of the project supporters network**

However, the system as a whole suffers from insufficient transparency. A survey of the institutions referred to above was therefore carried out in order to better know their resources, the type of services offered and the profiles of the enterprises availing of their assistance. The survey was aimed at 289 institutions. These included:

- 33 "institutional supporters": EECIs, CICs, inter-municipal economic development organisations, university interface groups, incubators;
- 40 financing institutions active in venture capital operations (public, mixed and private institutions), the list of which was drawn up on the basis of a directory published by the Walloon Enterprise Union;
- 216 consultants (sample selected from the directory of consultants authorised by the Walloon Region consultants for consultancy support).

Indirect consultation was also carried out:

- with the banks, through the Association of Belgian Banks;
- with the professional federations, through the Walloon Enterprise Union;
- with the regional offices of the SME Union through the central office.

The results can be summed up as follows:

- **Generally, support institutions have limited human resources in quantitative terms** (less than 10 employees). Nevertheless, most of them belong to or more European networks. A significant number of them are also part of a regional (Walloon area) and/or local network (province). In addition, a majority of them establish partnerships or subcontracting with other structures. However, these cooperation relations, whether within networks or only of a selective nature, usually occur within the "public" sphere and the "private" sphere, with crossovers between these two worlds rare.
- With regard to the services offered, **duplications appear in certain domains while, in others, the supply does not meet the needs.** Thus, activities related to the drawing up of business plans, finding partners, finding financing and monitoring projects during the initial stages of execution are developed by a large number of institutions. On the other hand, the technological assessment of projects, assistance in obtaining

patents and licences, the legal reports and market research play a far more limited part in the services provided by the institutions surveyed. And, yet, these aspects are of major importance in validating business plans.
- Most of the interventions concentrate on VSEs (in the process of being established or already in existence).

In this context, an **increase in the operational capacities of the supporting institutions** is certainly desirable in order to be better able to respond to the relevant needs. In this respect, it would be appropriate, among other things, to increase and consolidate the resources of the institutional support centres, particularly those of the **EICs**, whose financing is quite precarious. This measure must go hand in hand with intensifying collaboration between these institutions as well as between these and other types of players (universities, colleges, research centres, consultants specialising in certain technical, economic or legal fields) in order to complete the range of services provided and enable orientation of demand towards the most appropriate competencies that exist in the Walloon Region. Furthermore, these partnerships could help to address the needs of medium-sized enterprises that do not appear to be covered adequately by the present system. In fact, the needs of this type of enterprises sometimes go beyond the operational capacities of the structures they address.

Cooperation between institutions mainly involved in support and financing institutions must likewise be encouraged in order to enhance the effectiveness of the system through greater task specialisation and to promote complete and coherent processing of inquiries.

- **Insufficient capacity for technological expertise**

Providers of funding are sometimes not very inclined to finance the start-up of a project by virtue of the capacity of their expertise for technological assessment being inadequate.

Solutions have been elaborated in this respect within the framework of the new public or semi-public instruments put in place in the area of risk capital. The FIRD fund, for example, set up by the Walloon Region to finance projects stemming from research results it has itself supported, relies on the expertise of the DGTRE. In addition, SRIW, which finances the Technowal fund (aimed at financing projects that do not emanate from research financed by the DGTRE) and is involved in the Start It fund, uses an expertise network structured around the universities and the DGTRE.

This experience could serve as basis for the implementation of schemes enabling the dossiers to be scrutinised with the help of experts in the relevant fields.

- **Management costs discouraging investment in small-sized dossiers**

The substantial management costs linked to the follow-up of a large number of small-sized dossiers discourage capital providers from investing in this type of project.

A number of mechanisms have been put in place, both in the Walloon Region and abroad, in order to address this problem. They are based on collective structures that select projects at the outset and subsequently provide assistance with financing and support.

In this respect, we can mention the example of the Israeli “incubators” and, closer to us, the Wallonia Space Logistics (WSL) company, financed by the Walloon Region and Spinventure[5], whose aim is to support projects originating from research as well as stimulate financial and industrial partnerships in the fields of space activities. WSL assesses the economic viability of the projects and directs the researchers/promoters towards the appropriate competencies in line with their needs and the development of the project (business plan, market research, commercial aspect, finding financing, etc.). WSL also provides premises and helps financially budding companies in the acquisition of equipment, purchasing patents and licences, calling in a private consultant, etc.

One of the conditions for this type of instrument to be successful is that it functions as a network. The difficulty will be to find the best way of integrating the players concerned (contributors, financiers, universities, research centres, enterprises) and establishing their interrelations.

- **Capital supply unknown to project promoters**

The supply of risk capital is often not recognised by promoters. They have only negligible information at their disposal with regard to sources of finance or concerning the selection criteria applied by investors.

In order to address this problem, a **risk-capital fair** has been organized for the 16 - 17 October 2000 in order to facilitate the coming together of those supplying and seeking venture capital seekers and encourage promoters to draw up quality business plans in line with the criteria expected by financiers. This initiative has enabled forty project initiators to submit their dossiers to a panel of investors from various origins (venture capitalists, business angels, public or mixed financing institutions, stock exchange dealers, commercial banks).

This event is seen in a very positive light by the participants, who have recognised an opportunity to reduce the gap between the worlds of enterprise and finance. It has also drawn the attention to the fact that there is **important creativity potential and numerous enterprise projects** in the Walloon Region. It has acted as a signal for investors and particularly venture capitalists, placing emphasis on the importance of promoting innovation by facilitating access to the financing of high-tech and strong-growth enterprises.

This initial experience is likely to be repeated over the coming years.

3.5 Administration

Aid from the Walloon Region, especially from the DGTRE, represents an important support scheme for the dynamics of innovation in enterprises and particularly in SMEs. Two types of intervention have been put in place to this end:

[5] Start-up fund co-financed by ULg and Meusinvest (50/50).

1. assistance facilitating the setting up of products, procedures and new services; it concerns:
   - subsidies, supporting basic industrial research projects;
   - recoverable advance, supporting applied research and development projects;
   - First-Enterprise, enabling the reinforcement of scientific and technological potential of enterprises through the appointment and training of young researchers and know-how transfer from research centres;
   - various mechanisms available in a selective way under the programmes co-financed by the structural funds and aimed at addressing specific needs either upstream or downstream from research (assessment of innovation capacity, acquiring technologies or research results, finding European partners, evaluation of the technical commercial and financial contexts, maintaining research results).
2. assistance aiming at removing financial and technical uncertainties relating to an innovation project; this assistance is aimed exclusively for SMEs; it concerns:
   - *RIT* (Responsible Technological Innovation) aid facilitating the appointment of one person for one year to elaborate one or more technological innovation projects;
   - assistance under the heading of *technical support*, covering the technical side of project feasibility through financing exploratory trials;
   - *technical-economic study* assistance covering the strategic marketing aspect;
   - *sectorial study* assistance, financing an analysis of technological developments likely to occur in a field of activity in order to target the niches potentially accessible for SMEs;
   - *innovative software feasibility* assistance, aimed at computing service companies to finance an analysis of the technical and economic opportunities for new software that can be marketed to several industrial users;
   - *RIT Europe*, which provides support for feasibility studies concerning technological cooperation with one or more SMEs located in one or more E.U. Member States other than Belgium.

These mechanisms have had very positive effects at the level of promotion of innovation:
- by encouraging enterprises that are not very or not at all innovative to become involved in an innovation approach;
- by facilitating the acquisition of new knowledge by enterprises that can be used in their various fields of activity;
- by facilitating access to high-tech scientific equipment;
- by promoting the development of relations between enterprises and universities;
- ...

The assistance mechanisms provided by the Walloon Region were not subjected to detailed examination by the working groups. Nevertheless, some comments were made on the need for:
- taking account of the needs of medium-tech and low-tech enterprises, mainly developing innovations of the incremental type;
- supplementing the tools already available with a view to conducting a strategic evaluation of the projects, with due regard for the commercial aspects;
- encouraging more partnerships within the industrial world. In fact, contacts with other enterprises constitute one of the main channels for acquiring knowledge in most firms[6];

[6] In this respect, the cluster policy developed in an experimental way by the DGTRE is likely to produce an interesting response (see report "An innovation policy catering for the regional ambitions").

- simplifying assistance instruments on the basis of evaluating their relevance and make them more accessible, especially through a more “proactive” attitude on the part of the Administration, which could strengthen its collaboration with a number of intermediaries in this respect[7];
- setting up an integrated system of innovation support, encompassing the different aspects of this process (technological, organisational and commercial aspects,) through opening up the various competencies of the Region in this field.

4. Future orientations

New orientations are arising from the Prometheus programme concerning the strategies to be pursued in order to continue strengthening the role and position of research and innovation in regional development. These various issues constitute a message for all the players involved in the field of research and innovation, enjoining them to subscribe to a general line of action defined by a common consensus.

Several central themes have been defined in this context. The main ones are:

- **Implementing a strategic approach to research at all levels** in order to ensure more needs-oriented research and contribute in this way to optimum valorization of the results.
- **Refocusing public resources** on certain targets in order to ensure the development of a quality infrastructure and to support the expanding sectors. This strategy must, however, reserve sufficient space for basic research in generic domains.
- **Establishing networks of players** in order to facilitate exchanges of knowledge and experience, reaching the critical size suitable for effective action, avoiding duplications and promoting excellence-generating specialisation.
- **Strengthening the role of the Public Authorities in supporting and promoting the innovation process** in order to ensure the convergence of the supply and demand of scientific and technological services, as well as stimulate cooperation and re-groupings and stimulate the debate on the orientation of R&D activities.

These objectives will have to be pursued within the framework of a **permanent dialogue** between all the research and innovation players in the Walloon Region.

Prometheus has, from the outset, relied on broad-based consultation will all the parties concerned.

This participatory approach is destined to continue in the future. One of the programme’s objectives was, indeed, to create new dynamics to bring together all the players, public and private, to reflect on how to better exploit the available resources for the benefit of innovation.

In this context, the Walloon Region is busy preparing a “Prometheus II” programme aimed at consolidating the initiatives launched during the first phase and continuing with the convergence and consensus process inaugurated in this framework.

[7] Some portal sites designed to assist enterprises and the DGTRE website provide answers on this matter.

The Evolution of Innovation Policy and the Emergence of a "New Economy" in Flanders

Jan Larosse

1. Introduction

Since the 1990s, a new policy paradigm has emerged that is gradually reshaping the traditional "science and technology policy" into an "innovation policy". This is the direction in which policy-makers in Flanders have been moving.

This contribution discusses recent policy developments in Flanders, as well as the "rationale" of policy development, in the context of the new "innovation systems" paradigm. We will start by giving a brief historical overview of the recent emergence of an autonomous Flemish Innovation System, in "co-evolution" with the structural renewal of the regional economy. Following this, we present an account of the institutional development of the Flemish Innovation System from a decentralised Belgian Innovation System, looking at further stages of completion and adaptation to new challenges. We will then place these historical elements within the context of a general discussion on the justification for an innovation policy in an emerging knowledge-based society, thereby introducing the concept of "systemic additionality". We will end by examining some current policy challenges from this point of view[1].

2. Historical background

Since the 1980s, Flemish economic policy has actively supported the structural transformation of the Flemish economy through the promotion of a new technological knowledge base. In 1982, the Flemish regional government launched the intense mobilisation of industrial and scientific actors for a "Third Industrial Revolution in Flanders" (DIRV). The bi-annual technology fairs, "Flanders Technology", were mass events. Another strategic action of the Flemish government was the creation of IMEC, the interuniversitary research institute for microelectronics, in 1985. The DIRV actions succeeded in

* Original version.

To get in touch with the author, see page 4.

[1] Thanks to Paul Zeeuwts and Vincent Duchêne (IWT) for their comments on an earlier version. The author is solely responsible for the present content.

creating widespread public support for future-oriented activities in a period in which Federal industrial policy was still pre-occupied with the restructuring of the traditional industrial sectors, which had been severely hit by the successive Oil Crises in the 1970s. The first wave of "New Technology-Based Firms" (NTBFs) in microelectronics and biotechnology developed in the wake of this new long-term policy programme.

In the 1980s, the federalisation of the Belgian State accelerated, bringing economic policy into the regions - partly as a result of the economic crisis that made the divergence in economic development needs very clear. The Walloon part of the country was, historically, the leading region of the First Industrial Revolution in continental Europe, with steel remaining the driving force of development one and a half centuries later. The Flemish region of the country did not experience massive industrialisation until after World War Two - apart from a textile industry rooted in a longstanding medieval tradition and isolated industrial centres in different sectors. With the creation of the European Community in 1957, this centrally located region and its well-educated, multi-lingual - and still relatively cheap - labour reserves were opened up to multinational investments in production plants set up to supply the entire Community. The harbours welcomed shipments for the chemical, automotive and other industries producing mass consumer articles, which were to become the dominant industries of the sixties. Flanders quickly developed into one of the most prosperous regions of the EU. Nearly a generation later, however, this late adoption of a Second Industrial Revolution model was challenged by the overall structural changes in the global economy. Technological changes and deregulation of post-war "Keynesian" institutions were very quickly eroding the existing basis of value creation in the "industrialised countries". Response to these changes demanded huge social and economic efforts that were no longer compatible with the existing framework of national stabilisation policies. Although this sense of incompatibility was exacerbated in Belgium with its longstanding cultural divides, the country seized these energies to achieve new development outcomes based on regional capabilities.

The institutional reforms and the regionalisation of most economic competencies in 1989 accelerated the decentralisation of the Belgian innovation system. This Belgian innovation system, characterised by a strong "engineering" tradition, but hampered by the immobility of the old "Belgian" holding capitalism, was relatively weakly represented in Flanders, which was developing new entrepreneurial initiatives. Although most of the new industrial innovators in Flanders were not strong enough to become world players themselves and therefore went into alliance with foreign capital - as with Janssen Pharmaceutics or Gevaert Photo Products - they could often maintain a large degree of autonomy inside the new corporation thanks to their innovative performance. This was also the case for the local managers of many multinational production plants, who were able to emancipate themselves to a status of "competence centre" thanks to their engineering skills and innovative performance. The basis of this mixed position of capital weakness and managerial strength lies in the specific circumstances of late industrialisation in a developed country. The educational system in Flanders was rooted in a rich cultural tradition (Leuven having one of the oldest universities in Europe) and had progressively brought high quality training to the broader population since the beginning of the century. The "democratisation" of university participation since the sixties provided the country with an important supply of human capital. The universities that produced the cultural elite, which would lead the political emancipation, also produced a large base of engineers and scientists that were very internationally minded. International mobility ("brain drain" to the US) stimulated openness towards new technological developments and business models.

This was the situation the Flemish policy makers were facing in the 1980s: the development of the region seemed burdened by the legacy of a "Belgian" model that had become obsolete. Large chunks of the traditional economy in the textile, coal or shipping sectors no longer offered any future. Unemployment and budget deficits rose. A large part of industrial activity in Flanders was concentrated in foreign-owned subsidiaries that were initially the driving force of exogenous growth, but were now constantly cutting down their operations and transferring jobs to low-wage countries. However, the possibility of generating an endogenous Flemish economic base was limited because of a poor tradition in financial capital. Homespun growth by Flemish companies was mostly the result of SME activities. Many of these were local suppliers to the multinational enterprises (MNEs) and urgently needed to diversify their international customer base and/or specialise their product base towards competitive niches in order to survive in the emerging global economy. Their endogenous growth potential was restricted because of a lack of local financing and the extreme openness of company legislation with regard to foreign take-overs. Nonetheless, whatever the capital source for economic development, local competence and local knowledge had to be Flemish! Flanders was greatly challenged and highly motivated to start the long haul towards the "knowledge-based economy".

But at the beginning of the 1990s, the debate on economic development strategy was still centred on the policy question of how to "anchor" economic decision-making power - anchored in (Flemish) ownership or anchored in (Flemish) management? This debate reflected the mixed character of the economic elite, i.e. partly self-made men and partly managers of MNEs. In the years to follow, this "defensive" anchorage debate faded away in favour of an open stimulation policy addressing all dynamic forces. An important reason for this was the "offensive" development of a Flemish risk-capital sector, which propelled Flanders into an advanced position in Europe (third in the Venture Capital/GDP ranking). A second wave of NTBFs was launched thanks to this new availability of risk capital and the exit possibilities offered by the boiling stock market. However, the success of this new spread of innovative activity points to the heart of the "strategy debate", i.e. securing the development of a new economy means anchoring innovative companies in a well balanced and efficient innovation system! All of the conditions supporting innovation must be present and interact coherently: not only financing, but also education, research, communication networks, policy, etc.

Since the DIRV, the promotion of the "knowledge-based society" has become a permanent objective of Flemish policy-makers. They experienced it as a demanding and all-encompassing process, going through successive periods of expansion and contraction marking sharply the process of "creative destruction" that brings about a new economy. Although technology is the key, a mere technology(-push) policy is not enough. Companies are the core players, but what is the additional role of government? These were the underlying concerns of the development of a new innovation policy.

Policy learning is not a scholarly process in Flanders; it is primarily a process of "learning by doing". Flanders sometimes appeared as an early adopter of new policy trends, but lagged behind on occasions. Most of the time, Flemish policy was based on implicit theoretical premises, catching "what was in the air". To foster future policy development, however, a more reflexive stance is necessary, proceeding from a better empirical and theoretical understanding of the forces that shape institutions in the innovation system.

3. Evolution of the Flemish innovation system

The Flemish innovation system has evolved within a decentralised Belgian innovation system. This "de-centralisation" is the result of the combined effect of regionalisation and globalisation, which made the prevailing national policies increasingly obsolete. With the launch of the "DIRV" ("Third Industrial Revolution in Flanders"), regional economic policy endeavoured to distinguish itself from traditional industrial policy, which responded in a very reactive manner to the crisis experienced by the established "national" sectors in the 1980s. Following the regionalisation of most economic development competencies in the 1990s, science & technology and innovation policy came to the fore in Flanders as the most appropriate modern industrial policy, corresponding better to the needs of the emerging knowledge-based economy and the role of government as a catalyst. As a result, a self-standing regional innovation system has developed.

The evolution of the Flemish innovation system to date can be summarised in three stages:
- A first "formative" stage in which the preconditions for the development of an independent system were set in place in the 1980s;
- A second stage in which the critical elements and the institutional structure of the system were developed and put in place in the 1990s;
- A third stage of maturation that has just started.

We will focus in the following paragraphs on the creation of the new institutions that support the Flemish innovation system and the way in which they respond to the restructuring of the Flemish economy. The co-evolution of economic structure and institutional framework is a focal point of the system's approach of innovation policy. The present industrial specialisation of the Flemish economy is very much determined by its openness and central location in Europe, i.e. metal, chemical and automotive industries have made their base here for historical reasons and constitute important industrial clusters. The growth of the tertiary sector, together with technological changes, provides opportunities for restructuring these areas of specialisation. The endogenous development of NTBFs in Flanders and the rapid deployment of new knowledge-intensive business services (with the proximity of Brussels as an international "hub" for these new activities) can represent a driving force for innovation and restructuring. However, up-scaling the knowledge intensity of existing industrial enterprises is the factor that will have the most impact on the future development of the economy.

It is significant that the role of knowledge institutions is increasing in the institutional set-up. The traditional organisation of economic policy, with institutionalised consultation procedures between the "social partners" (employers and unions), has been extended through the emergence of new institutions comprising the knowledge producers - particularly universities - as important "innovation" partners. The increased importance attached to the role of these knowledge players has been indirectly augmented by the important function of academics as counsellors, jury members and advisors in all kind of bodies and fields of expertise. This shift is not without controversy concerning a "balanced representation" of the different players in the new institutions.

3.1 From scratch

The institutional framework of the Flemish Innovation System was thoroughly transformed following devolution of most areas of competence for S&T policy to the regions in 1989. A new administration had to be established from scratch: the Administration for Science and Innovation. The centrepiece of the new policy structure was the creation, in 1991, of a new technology agency, IWT (The Institute for the Promotion of Scientific and Industrial Research in Industry). The IWT put together all the subsidy instruments for supporting technology transfer, prototype development and basic research with industrial finality, something that was previously handled individually by different departments. The funding process was placed under the supervision of an autonomous Board, on which university experts were predominant. The IWT was put in charge of the administration of large thematic technology programmes for industrial research in biotechnology, new materials, energy and the environment that were launched as part of the DIRV-campaign. Apart from these "impulse" programmes on generic technologies carried out on behalf of different ministries, an important part of the IWT budget was reserved for "autonomous" activities, allowing funding of qualitatively suitable projects presented by companies in a "bottom-up" procedure. Besides this predominant financing activity, the allocation of PhD grants for applied research and the organisation of services in support of European collaboration and technology transfer (Innovation Relay Centre) were also part of the IWT's functions.

Although this institutional reform (or "break") offered an opportunity to make a new start with a more efficient organisation, it still was very much tributary to the past "science push" approach. The institutional set-up continued to reflect the linear model of innovation. The selection procedures (embodied in the staff comprising almost exclusively scientists and engineers), which focused on the "scientific value" of the project, confirmed the belief that good research should "automatically" find its way into the market. It was only afterwards that the economic and environmental dimensions were more explicitly (but subordinately) incorporated into the evaluation procedures. The effect of "path dependency" (Arthur 1995) on institutional evolutions is very important: the established thinking on policy instruments is rather inert, even where entire organisations are replaced.

The role of the IWT was, however, without precedent in Flanders. It was to become a strong lever for the political programme of the DIRV. One of the particular features for strengthening the financial support function of the IWT lay precisely in the institutional division of competencies in Belgium, i.e. bringing subsidy instruments to the regions while maintaining fiscal policy at federal level. This imposed a role of generic support policy instrument on the IWT's subsidy mechanism.

3.2 Cluster policy experiences

Another important new policy initiative in the early 1990s was the launch of a cluster policy. The industrial cluster policy was, at the beginning in 1993, intended to become a cornerstone of new regional economic policy. The Flemish government, in search of a new rationale for regional economic policy, was one of the early adopters of Porter's cluster approach to regional competitiveness (PORTER, 1998). The idea was to encourage new trans-sectoral platforms in areas of local strength that would provide new growth and new jobs by organising and supporting inter-company cooperation at different levels, such as joint market development, training and research. The policy was coordinated by the Department of Economic Affairs and was to be supported by new forms of institutional consultation in Flanders' Social and Economic Council (SERV). At that time, however, this political ambition was not equalled to a sufficient extent by the development of cluster dynamics itself. The important economic agglomerations that existed in the Flemish economy in the early 1990s were largely firm-based rather than network-based following individual, firm-based restructuring strategies to overcome the severe recession of the period.

The cluster policy was redirected on two occasions.

- Firstly, the top-down approach in the early stage was altered to make way for a bottom-up scheme of accreditation and support for platforms that could meet the criteria of establishing synergies through collective initiatives. This scheme was adopted at the end of 1994 and resulted, in the following years, in the "recognition" of twelve official cluster organisations of a very heterogeneous nature, ranging from furniture to digital signal processing.
- Secondly, the range of activities supported was focused almost exclusively on technological innovation. This was formalised at the end of 1998 through a new policy favouring the creation of "technology valleys" (Flanders Graphics Valley, Flanders MultiMedia Valley, Flanders Drive, etc.) and explicitly promoting the development of "new" economic activities, in contrast to the cluster policy in more "mature" sectors.

This approach was modelled on the archetypal Silicon Valley model as well as the promises of the Flanders Language Valley, the cluster science park initiative of the then successful speech-technology leader Lernhout & Hauspie Speech Products. Although the focus was, on the whole, confined to the technology sector, the range of support was broadened to all aspects that could secure innovative success, especially the establishment of regional knowledge centres and cluster animation by new intermediary cluster platforms. The administration of the cluster scheme was assigned to the IWT.

However, the admission of new organisations was halted by flaws in the institutional base (mainly due to the lack of a legal basis for the extension of R&D to innovation support). This temporary setback in the late 1990s coincided with an upsurge of private cluster initiatives reflecting the growing impact of new business models (outsourcing and strategic alliances) and the formation of competence networks in different parts of the economy. These new platforms and networks are still fragile. A well-established cluster policy can enhance the institutionalisation of new networking relations in the Flemish Innovation System.

3.3 From technology-push to technology diffusion

In the 1990s, a growing awareness of the importance of technology diffusion led to the introduction of new features into the support mechanisms. The idea of thematic technology programmes was gradually abandoned in favour of a trans-disciplinary approach. The share of autonomous "bottom-up" financing in the IWT budget became predominant. Enhancing cooperation in research became a central concern of S&T policy, and was often "rewarded" with a bonus in terms of support. The link with the Flemish knowledge base and the involvement of smaller companies in research consortia are an ongoing concern in the new programmes. The support for the relatively high level of participation of Flanders in the EUREKA framework (ITEA and Medea in particular) also expresses this concern for cooperation at international level.

At the end of the decade, two new IWT programmes specifically targeted the user perspective in technology development. The "Strategic Technologies for Welfare and Well-being" (STWW) programme supported the development of larger-scale research programmes in universities that addressed the needs of industry and society, as represented in the programme's follow-up mechanism. The "HOBU" programme encourages technological research in non-university institutes of higher education that is specifically adapted to the needs of local SMEs. It has succeeded in involving hundreds of smaller enterprises in the user panels of technology diffusion projects supported by the IWT.

Another important step towards a structured technology diffusion approach was the establishment of "interface services" at all universities, following the successful example of "Leuven Research & Development".

This growing emphasis on technology diffusion and technology adoption also led to the scope of S&T policy being broadened to include the non-technological aspects of innovation. SMEs received support for intangible investments in technology procurement, including the cost of patent applications. A special programme to encourage training in new technologies was also set-up (Hefboomkredieten). Further specific programmes were initiated to stimulate private financing of innovation, such as a Guarantee Fund for risk capital investments and the support of the newly established Business Angel Networks. All these schemes were launched by the Department of Economic Affairs and demonstrated a growing need to develop a more horizontal approach to innovation.

Another signal of change in perspective was the establishment by the Flemish Government of a "Flemish Technology Observatory", which started assembling innovation indicators and supporting a research programme on the "Flemish Innovation System".

3.4 Putting things together: the Innovation Decree

The institutional set-up of the new Flemish Innovation System in the 1990s was the result of a series of "ad hoc" operations, following the timing of the transfer of new competencies. At the time, however, it could not incorporate the new approach to innovation as an integrated process since there was no formal "innovation" policy by virtue of a legal basis existing only for "R&D" support.

Different components of the innovation system were developed more or less in parallel. Universities started to develop or enlarge their "interface services" for technology transfer. Public research institutes were streamlined, confirming the dominant role of universities in the innovation system. After the establishment of the IMEC (Inter-university Micro Electronics Centre) in 1985, a new inter-university coordination effort was initiated on the initiative of the Flemish government in the field of biotechnology, bringing 700 of the best researchers together in the VIB (Flemish Institute of Biotechnology). Whereas the IMEC was built on central research facilities, the VIB is essentially a virtual institute. But a further stage saw the construction of incubator facilities near the central office. The third public institute, the VITO (Flemish Institute for Technological Research), emerged from the regionalisation of the non-nuclear research activities of the national nuclear research institute, SCK. These activities focused mainly on the environment, energy and materials and, in recent years, on support for sustainable development.

Although these organisations are important strategic instruments for Flemish innovation policy, they continue to represent a minor share of total Flemish R&D expenditure. Government R&D expenditure in terms of GDP is below the European average. The primary concern at present, however, is to improve the return on public investments for the local economy in basic research and to strengthen technology transfer capabilities. The management agreements between the government and these research institutes have been progressively directed towards the "valorisation of research".

The overall budget allocations for S&T of the Belgian authorities had further lagged behind in the period of regionalisation. The Flemish government launched a major catch-up operation in 1994, increasing the budget for S&T from € 317 to € 575 million in 1999. In the next decade, a further important financial action was started to restore the level of direct public funding of research in universities after this had stagnated in comparison with third party financing and threatened to undermine the universities' long-term research capacity.

These financial endeavours run parallel wit the attempt to design a new innovation-policy framework aimed at integrating all existing policy instruments and providing a legal basis for innovation support. The "Innovation Decree" of 1999 - after a long period of preparation - defined a new reference framework enabling R&D policy to be extended to innovation policy. The conceptual framework of the Decree is in line with the integrative view of innovation of the systems approach. It underlines the economic finality and the non-technological dimensions. The decree defines a coherent framework to streamline the financial instruments created on an "ad hoc" basis in the previous period. It confirms the central role of the IWT as a "one-stop" innovation support agency as well as the coordinator of "intermediaries" as a first line of contact. The trans-disciplinary, bottom-up financing mechanism becomes the only channel of R&D support. The reformulation of the acronym IWT as the "Institute for the *Promotion of Innovation* through Science and Technology" is very symbolic.

Three regulatory decisions are needed to clarify the technicalities regarding the position of interface services, the organisation of financial support given by the IWT to project-based research and the support provided to collective innovation. The first two were passed into official decisions in 2001. The Decision on "Flemish Innovation Cooperation" (VIS-Besluit) is intended to replace all historically differentiated support mechanisms and provide a competitive basis for funding the innovation-support activities of existing "intermediaries" (e.g. Collective Research Centres, regional development agencies), as well as existing and new cluster platforms. These will be able to receive quasi-structural funding (up to four years) on the basis of a programme of specific services comprising technology advice, innovation stimulation or collective research. This will enable the traditional sector institutions established under the 1947 federal "De Groote" law to be integrated into the regional institutional structure.

The Decree is an important step towards an "inclusive" innovation policy. It brings into line a complete set of policy instruments that can be mobilised for the stimulation of innovation across the entire trajectory of the innovation process. It clears the ground for a horizontal policy that offers a stable range of incentives for bottom-up initiatives in support of innovation. The Innovation Decree marks the coming to maturity of the Flemish Innovation System.

3.5 Completion of the innovation system

Implementation of the Innovation Decree has not ended the maturing process of the new Flemish Innovation System. This is, indeed, a process of institutional learning that is not linear, either. This is illustrated, for example, by the evolution of the administrative support structure for innovation policy. The Ministry of Science and Technology, which had been in place since 1991, was split up in 1999 after a change of government in order to return the responsibility for science policy to the Minister of Education, and technology and innovation policy competence to the Minister of Economic Affairs. The new administrative reforms, however, are intended to re-unite these competencies in one Ministry from 2003.

Strengthening the policy functions has become a major concern. Evaluation of S&T programmes and management agreements with public institutions must become a standard feature of policy preparation. The establishment of Support Points at universities has started (including one for R&D Statistics and one for Entrepreneurship, Enterprises and Innovation) for the purpose of strengthening analytical capacities. The establishment in 2001 of a Parliamentary Institute for Technology Assessment to assist the Flemish Parliament in policy debates on the socio-ethical aspects of new technologies represents the continuation of further institutional completion of the governance structure for the Flemish Innovation System, adding a dimension of social debate to policy-making.

The generation of new institutions only partially answers to an underlying rationale, with institutional compromises and path dependencies generating the imbalances of all life situations. Self-analysis from a systemic point of view can, though, help to give a new sense of direction to policy choices. The Flemish innovation system is still an incomplete innovation system that needs, at the same time, to adapt to and shape the emerging "new economy". In this process of mutual adaptation of institutions and economic restructuring, there is a need for a well-considered "rationale" for innovation policy.

4. "Additionality" revisited

The rationale of innovation policy is the subject of international policy debate (see OECD 2000) and concerns the legitimacy and efficiency of policy-making. In the 1980s, we witnessed a fundamental shift in the character of the innovation process, which has had a profound impact on the perception of the role of policy in modern innovation systems. The shift from a "linear" to an "interactive" innovation model is part of the structural change from an industrial economy to a knowledge-driven economy. In fact, policy-making is still trying to "digest" the impact of these changes, which have not yet stabilised in any clearly evident manner.

In 1996, the IWT organised a conference within the framework of the Six Countries Programme (an international policy discussion group on technological change and innovation) on the subject "R&D subsidies at stake? - In search of a rationale for public funding of R&D". This Conference took stock of the readjustment of the respective roles of the private and public sectors in S&T and innovation policy. Following the misfortunes of the "picking winners" approach in the 1980s, industrial policy in market-based economies had to rediscover its complementary role. The main players in the innovation process are companies, but how should government best fit in? According the conference results, the rationale of public intervention in S&T had to be adapted in terms of the "positive externalities" in knowledge production and the "additionality" of public incentives with respect to private R&D. "Additionality" basically addresses the question of "What difference does it make?" if policy is evaluated in a market economic perspective.

Meanwhile, a broad innovation policy approach – wider than that for R&D - has gained general acceptance, though without putting an end to the debate on the role of public incentives in stimulating the innovation performance of firms. Although this debate has a general theoretical basis in terms of the consideration of "market failure", the various forms of market failure concerning innovation have profoundly changed in the context of the emerging knowledge-based economy. Furthermore, the debate in Flanders is also linked to the opportunities and challenges presented by the relative "flexibility" of the Flemish Innovation System initiated by the regionalisation process. The importance of these structural and institutional changes causes us to reconsider the "additionality" of innovation policy in the present context in Flanders.

Innovation is a dynamic process by nature. The uncertainties and external effects involved create *"market failures"* that are at the origin of traditional public policies as R&D support to firms. However, the shift of the economic structure as a whole towards a "new economy" is a type of structural innovation that is of a different order to individual adjustment to changing market circumstances. It concerns not only the adaptability of market players, but also the flexibility and coherence of the institutional framework that needs to be put in place to operate the innovation system. At this level, *"systemic failures"* may call for new types of "change management" in the innovation systems, in which governments may have an important role to play. However, the role of governments in accompanying minor or major shifts in economic and technological regimes is performed without an explicit rationale most of the time. This may be a source of *"government failure"*, since governments are also players with specific incentive structures that can be counterproductive in circumstances in which policy decisions are not reached on the basis of well-founded and well-debated strategies. (Re-)stating the rationale of the role of the state in the innovation system in relation to the debate on the type of incentives and policy instruments that are best suited to achieve policy goals is therefore a basic prerequisite for effective change management.

4.1 Value of the additionality argument

The basic rationale for public policy is that there are necessary activities and functions that are inadequately performed by private initiatives. This usually implies "externalities", i.e. these constitute "untraded" effects on the economic costs and benefits of other economic agents (industrial pollution being a typical case). Traditionally, the "additionality" of S&T policy is linked to this market-failure analysis of "welfare economics" (as formulated by K. Arrow in 1962). Governments will not "substitute" market forces for economic activities, except in cases where markets are sub-optimal in terms of social welfare (allocation of costs and benefits). This additionality argument is a popular rationale for the legitimacy of government support to R&D by virtue of R&D "under-investment" in a market economy according to the standards of efficient allocation of resources. Knowledge spillovers prevent economic agents from reaping the full benefit of their R&D investments. However, private R&D is not worthwhile if private costs do not meet private benefits, even if the social benefits outweigh these costs. Financial incentives provided by government can balance this private calculus to a level at which it is more in line with social cost-benefit accounting. In doing this, it can increase the level of R&D activity with "additional" projects (either through subsidies or granting a temporary monopoly in the form of patents). However, if there is no scope for additionality, public financing of private R&D will not change (R&D) behaviour and will only be a substitute for private financing.

This *quantitative* additionality only considers economic behaviour from the point of view of the direct allocation activity of market agents. It is conceptually clear but empirically difficult to operate because it is not easy to establish the level of "underproduction" of knowledge or evaluate the degree of additionality of governments. Recent econometric research has confirmed the additionality of IWT subsidies in the 1990s (Meeusen 2000). In the Netherlands, recent estimations (MEET report) conclude that on the level of economic impact one guilder of support generates (in the long term) ten times as much in social return (direct and indirect)! This finding is not, however, without controversy as the measurement issue is difficult to assess in a multi-causal context, particularly at project level.

This is one of the reasons for an extended view of additionality gaining acceptance (see TAFTIE). There are other aspects of a *qualitative* nature in which R&D support conditions can make a real difference from a welfare point of view: changes in the *composition of the R&D portfolio* (towards more socially useful technology), in the *propensity to collaborate* (and to allow spillovers), in the *organisation of innovation management* (e.g. including environmental concerns). The additionality argument is, therefore, a very useful criterion by which to select S&T policy options within a broader perspective.

At the level of structural policy (or innovation policy at the structural level), this line of argument can be extended through a dynamic perception of the innovation system, where new activities emerge and old activities take a new direction. The evolution of innovation systems itself is an adaptive learning process. Furthermore, the capacity for scientific-technological learning is heavily influenced by the capacity for institutional and policy learning. Policy-making must be able to put in place the institutional framework that fosters the new economy. The additionality argument needs to be reworked in order to be of use in this context.

4.2 Dynamic knowledge spillovers change the context of additionality

The market failure in relation to R&D (or knowledge creation) has to do with the special nature of *knowledge* as an economic good. Knowledge is not the same as a private good that can be completely seized, traded and consumed by individual owners. Immaterial goods as knowledge have the characteristic of being not tightly embedded in a unique physical shell that is costly to reproduce. On the contrary, most knowledge can be shared without hampering use by the original owner. The use value might even increase if others utilise the same knowledge (see e.g. the network externalities of communications software). Moreover, in a dynamic knowledge environment, knowledge production is cumulative: knowledge produces knowledge, and therefore knowledge spillovers, which represent a "loss" for individual producers, but a "gain" for society. Indirect returns on knowledge production through spillovers have developed into a multiple factor of the direct returns. These dynamic effects of knowledge spillovers have made remedying this "market failure" more complex. New issues arise in the form of the problem of "lock-in" or "natural monopolies" caused by "increasing returns to adoption", this is the advantage of increasing the user base (B. Arthur, 1995). The pervasiveness of spillovers (enhanced by decreasing marginal costs in the reproduction of "weightless" knowledge products) and the collective productivity of knowledge communities generate a new dynamics of *increasing returns* of knowledge (re)production (in contrast to the *decreasing returns* in de production of material goods). Increasing returns for knowledge goods (promoting productivity gains) are a source of social welfare. They prosper within the framework of more intense knowledge flows and knowledge interaction. From the point of view of the development of the innovation system, the balance between the inducement of knowledge *creation* (compensating for the "under-production" of knowledge by individual firms in which IPR is very important) and the inducement of knowledge *circulation* (stimulating increasing returns to scale through interaction) has shifted towards the latter.

4.3 From a firm-based to systemic additionality

The "connectivity" of the innovation system is a general condition of knowledge productivity. The big challenge for institutional change in favour of a new economy, is to encourage the "internalisation" of non-traded flows of economically useful knowledge (or spillovers) in the organisation of the innovation process. New patterns of interaction have to be stimulated. Free competition in a firm-based economy tends to create efficient allocations for industrial goods. In the network-based knowledge economy, *competition* policies that stimulate renewal have to be supplemented by *cooperation*-enhancing policies that stimulate synergies and productivity-enhancing integration.

The "new" economy is exposing this mixture of new incentive structures. Nowadays, the *firm-based* market structure is giving way to a *network-based* market structure. The industrial organisation of the vertically integrated firm has exploded into virtual and semi-integrated business structures in which buyers and suppliers interact together with non-market players. The pressure to concentrate on core competencies is at the heart of this combined fragmentation-recombination process. The success of the innovation process in firms has become primarily dependent on the relations with external agents. Sometimes, the new industrial organisation develops into industrial complexes, such as "clusters", which generate collective productivity advantages for all the participants (PORTER, 1998). The new industrial organisation is of a hybrid nature since it involves more and more non-market organisations, such as research institutes, public transfer organisations and (self-)regulatory bodies. These hybrids can best be described as (complex) systems composed of different institutional layers. "Systems theory" is a new instrument, intended to improve our understanding of the present dynamics of innovation (see the OECD work). In analysing the interactions between all layers, we can better understand "systemic failure": lack of connectivity, weak coherence, dysfunctions in the institutional set-up, vicious circles in development. At the level of this system dynamics, governments or public organisations can find a new "systemic" additionality, e.g. in promoting knowledge flows and self-organisation among mutual dependent actors.

This complementary role of government in system regulation also extends to the structural and institutional adaptation problems of technological transition and system dynamics. How complementary can the funding of innovation activities by government be in relation to industrial R&D and risk capital for innovative ventures? How can a match be accomplished between the knowledge infrastructure and the industrial specialisation pattern of a country? How, in particular, is the management of growing uncertainty and the shortening of time horizons in innovation affecting the role of policy at an institutional level? Government is itself a part of the "infrastructure" that is necessary to sustain innovation. In periods of instability, policy choices are of strategic importance in focusing unstable expectations on possible technological development paths.

4.4 Sustainable development as a guiding principle

The "systemic additionality" of innovation policy is linked to the innovation process as an interactive techno-economic system of its own as well as to (technological) innovation as an instrument of realising policy objectives at other levels of the overall social system. Innovation is instrumental to a wide range of policies concerning the advance of education, conservation of the environment and care for the elderly. These social goals, imposed on the innovation process, help in making a selection among the multiple technology trajectories possible (see also L. Leydesdorff, 2001).

One of the main driving forces of social welfare at present is the policy of *sustainable development*. Innovation policy that contributes to sustainable development can stimulate the generation of important positive externalities considered from the point of view of private investment, e.g. impact on climate deterioration or reduced consumption of non-renewable resources. To promote the positive external effects of the actual industrial innovation processes and/or to place innovation directly at the service of this policy of sustainable development, different types of economic instruments need to be used. These economic instruments must, for example, help to internalise environmental concerns into new practices of innovation management (e.g. eco-design). This can be stimulated by financial incentives that help overcome "short-termism". In the long run, it can be maintained that competitive firms have a definite interest in adopting eco-efficient processes and products: eco-efficiency is a win-win situation according to the "Porter hypothesis" (see R. Mohr, 2000). The Flemish government programme clearly stated that innovation should be directed towards supporting sustainable development. The IWT has to develop specific incentive mechanisms to promote ecological innovation.

Innovation policy may stimulate the development of less resource-intensive activities and industries. Government procurement of eco-innovations or the promotion of eco-innovation enhancing norms (standards) are other instruments. This level of policy regulation needs to achieve a new "match" between the industrial specialisation patterns and the institutional architecture of the innovation system that attracts those industries most compatible with it. "The old industrial economy will have to give way to the knowledge and service economy" ("Kleurennota" of the Flemish government, July 2000). In the 21st century, the programme of knowledge-driven growth has become intertwined with the programme of ecological transformation of the industrial society.

4.5 Policy matrix for achieving "additionality"

In order to be effective, government action should "make a difference" to the economic optimum that can be achieved by market forces. The discussion on the "additionality" of government in innovation policy is less a theoretical deduction from a given school of thought than an empirical question that needs rational clarification and guidance for action. Several new theories of industrial dynamics (new growth theory, evolutionary economics, theory of innovation systems) are instrumental in meeting these challenges. The reconstruction of the recent trajectory of Flemish innovation policy illustrates the explanatory power of the systems approach and indicates how a closer interaction between policy analysis and policy development might improve the policy-making process.

To clarify the various aspects involved, we have drawn up a matrix outlining the different types of additionality, based on four dimensions.

Additionality policy matrix

	Process / market agents	Structure / institutional set-up
Types of additionality		
Static spillovers / Linear innovation model	• Individual innovation • Firm-based incentives *Individual additionalty*	• Knowledge infrastructure • Science-based policies *Strategic additionality*
Dynamic spillovers / non-linear innovation model	• Collective innovation • Network-based incentives *Network additionality*	• Systemic composition • Cluster-based policies *Systemic additionality*

The **vertical axis** describes the types of spillovers that are addressed. The **horizontal axis** points to the level of systemic impact. *Static spillovers* are linked to a linear model of innovation, while *dynamic spillovers* occur in a non-linear model. The *process level* describes the market dynamics and is the locus of market-based incentives. At the *structural level*, we consider the institutional set-up, including non-market dynamics. In each quadrant we can identify a specific rationale for specific policy actions according the types of types of additionality that are concerned.

In the **first** quadrant we can find the traditional policies that affect the individual firm, e.g. R&D subsidies. In standard economics, the additionality argument is limited to this domain of "comparative statics": comparing individual behaviour with and without certain incentives, "ceteris paribus" (all other factors remaining constant). However, since knowledge is increasing the extent to which everything is interlinked, this kind of rationale seems increasingly inappropriate. Although subsidies continue to be used as a lubricant for a change in behaviour, particular effects cannot be attributed to one policy incentive alone, such that subsidies are more effective in an integrated policy approach.

In the **third** quadrant, the classic stimulation policy is extended to the establishment of new knowledge infrastructures that have a strategic additionality impact on the system. They can be implemented as one-off initiatives that should "automatically" generate a return for society. The IMEC case, however, demonstrates a departure from this starting point, as it is only with the help of specific technology transfer programmes that industrial benefits can be harvested. The linear innovation model has proven to be limited.

In the **second** quadrant, the impediments to technology diffusion are central because knowledge flows are the driving force for capitalising on dynamic spillovers. In any dynamic context, incentives for networking and technological communication between different institutions can make an important contribution to good performance of the system. In the knowledge economy it is not merely knowledge creation but knowledge circulation and knowledge use that is at the source of welfare gains. Additionality of public policies is directed towards the promotion of self-organisation of the actors since cooperation is a public good.

In the **fourth** quadrant, we find policies aimed at using knowledge spillovers in a structural sense, i.e. to change the system towards increased knowledge intensity. Cluster policies strengthen prevailing specialisation patterns or may change them according to strategic choices. The types of dynamic externalities that give rise to systemic additionality also extend to social externalities by virtue of knowledge affecting the social and ecological characteristics of society. Cluster policies are also particularly well-suited to the implementation of policies for sustainable development as clusters span larger parts of the value chain and have a strong potential leverage on the product life cycle.

5. Challenges ahead

The development of the Flemish innovation system over the coming period will be determined by the combined evolution of a new economy and new institutions that interact with each other. The new economy of the 21st century in Flanders is a competitive knowledge-driven economy that is contributing to sustainable growth thanks to specialisation in new economic activities that substitute energy and material intensive activities for immaterial services. The institutional configuration that can (re)produce this type of renewal has to be an innovation system that brings about intense knowledge flows to increase collective productivity.

A good example of the worthy interplay between the institutional setting and the economy is the emergence of the "Knowledge Corridor" in the Leuven region, around the Leuven University and IMEC (Larosse *et al.*, 2001). The important generic role of science and entrepreneurial scientists is demonstrated by the establishment of a large number of spin-offs in this region. This process is supported by new institutional forms of technology transfer and risk financing that are very much embedded in local networks (e.g. "Leuven Inc") and international cooperation. This local institutional configuration is a totally new and pro-active form of clustering.

5.1 New cluster policies

Because of its strategic importance for innovation policy we will digress, at the end of this overview, on the importance of cluster policy and the corresponding changes in the government institutions with regard to knowledge intensification and interconnectivity, following a systemic approach to innovation.

The further development of the Flemish Innovation System can be strongly enhanced by policies that stimulate the "connectivity" of the system, strengthening the networking structure of the economy. Clusters are the economic backbone of a regional innovation system (Merit, 2000). They are structures of specialisation and "co-opetition" that exploit local strengths and synergies (Jacobs, 1997). Cluster policy is of prime importance in stimulating the creation of the "public good" of cooperation between companies. Cooperation in networks is a specific mechanism of coordination (of a different nature to the price mechanism) that is well suited to *"internalise"* the spillovers produced inside clusters in the creation and diffusion of knowledge. Personal interaction in local networks can also *"externalise"* the know-how or tacit knowledge (often knowledge we are not explicitly aware of) that really makes the difference. Networks, which function on the basis of social norms such as trust and reciprocity, are a solution for exploiting the "non-tradable" inter-dependencies that emerge in local clusters but which, because of "positive externalities", are under-exploited. Cluster policy will therefore stimulate those networks that enhance the knowledge flows in the strongholds of the local economy. It is no paradox that globalisation compels firms and governments to focus on the remaining localised (immobile) resources and capabilities that emanate from the innovation system to strengthen competitiveness.

The recent establishment – with varying degrees of success - of different platform organisations for innovative clusters in Flanders is evidence of the emergence of networks as a new coordination mechanism for the collective advancement of technological knowledge. The institutional order needs to adopt more associative governance structures in order to master the costs and complexity of the present innovation processes. Cluster platforms are a new institutional structure for the organisation of cooperation and coordination among all players: companies, knowledge institutes, intermediaries and government. They can be important instruments for achieving strategic convergence of expectations and objectives. All this will improve the functioning and stability of the overall innovation system. Collective innovation in Flanders has been offered a new legal basis in the "VIS" Decision (Vlaamse Innovatie Samenwerkingen). This instrument is, however, still in need of a strong policy message that can foster pro-active initiatives.

A current policy issue in Flanders concerns the extent to which the "primacy of policy" can be combined with a firm belief in a bottom-up policy, trusting in the actors' full responsibility for the management of research and innovation. The policy debate often opposes "bottom-up" and "top-down" policy. However, the history of the evolution of the Flemish Innovation System demonstrates that a combination of both is necessary. In the past, the Flemish government has taken several strategic decisions that have been shown to be of great importance to the structure and performance of the innovation system, starting with the establishment of the public investment company GIMV in 1980, which became a leading international risk capital fund with an important role in the financing of innovation. The creation of IMEC (1985) and VIB (1995) also proved to be real springboards for new growth opportunities linked to the knowledge base. The initiative, in 1996, to create Telenet, a second fixed-wire telecom operator that is building a broadband network on the basis of the existing cable network in Flanders and which will be the densest in the world, will also prove to be of strategic importance for the innovation system. It will provide access to advanced information and communication services for the entire population by 2003. This initiative was recently supplemented by ordering the public broadcaster VRT to develop a digital platform for accessing the libraries of the broadcaster and introducing new digital services via television.

All these pro-active initiatives mark a "difference" for the evolution of the innovation system. The sole provision of bottom-up instruments might risk incurring a reactive attitude that will not be able to take advantage of the opportunities offered by the new networking economy. The establishment of IMEC and the creation of Telenet have proven to be very important leverages for ICT development in particular. A recent study on the ICT basis in Flanders, conducted on behalf of the Flemish government (PWC, 2001), shows that the Flemish Innovation System is rather unbalanced in this prime domain of ICT. In comparison with the bench-marking regions, the ICT sector and ICT research are doing very well, though the adoption of ICT in the general population and the development of related government regulations and policies are lagging behind in relative terms! A move towards actions at the level of ICT awareness and education of the population and more intensive application of ICT in other sectors can best be assessed in terms of the specific development needs and business opportunities in different economic clusters. An appeal for "self-organisation" at this particular level of the economy is an important policy signal.

5.2 Horizontal policy structures

A second observation, inspired from the systemic viewpoint, concerns the organisation of innovation policy itself. Government needs to learn to behave as one of the institutions of a systemic order that has an important impact on the structure of this order. It needs, therefore, to adapt to the vital function of connectivity in the system through the development of horizontal policy structures. Although the systemic or integrative approach to innovation policy is gaining widespread adherence, it is not easy to overcome the institutional inertia that impedes the implementation of new approaches. One of the main challenges is to transform the vertical ministerial governance structure. Innovation policy is a horizontal policy that needs to align different ministerial policies, secure integration of all policy instruments that enhance innovation, and integrate innovation into other policies.

Policy coordination is the key to the success of systemic coherence. The Flemish government already operates a horizontal S&T budget, but is still working on shaping new horizontal policy structures within the framework of current administrative reforms. The operation, from 2003 on, of the new Ministry of S&T as a horizontal policy department interacting with the Ministries of Economic Affairs, Education, Environmental Policy, etc. will be the next big challenge. This is a demanding task in terms of knowledge management and "people" management.

In this new direction, strategic interaction with the actors of the Innovation System is a key factor. New initiatives, such as the "Digital Action Plan" or the "Flemish Future Conference", contribute to the implementation of an "inclusive" policy philosophy by virtue of their spanning different Ministries. New forms of coordination are being experimented with.

A point that has not yet been developed is coordination with supra-regional levels. Important levers for innovation policy still exist at the federal level: possible fiscal deductions for innovative companies will have an impact on the regional policy mix. The increased support provided under the 6^{th} Framework Programme will also increase the urgency for new policy coordination mechanisms at international level between the EU and the Member States and between the Member States themselves. Regional authorities must find suitable international interfaces according the principle of "subsidiarity": this is "additionality" in policy making levels.

6. Conclusions

Ever since the awareness-raising campaign for a "Third Industrial Revolution in Flanders" (DIRV), the Flemish government has given high priority to the knowledge intensification of the Flemish economy. The Flemish Innovation System has evolved into a fully autonomous regional innovation system since the devolution of essential areas of competences to the region in 1989, leading to the setting up of new institutions, instruments and programmes. The search for a new rationale for regional economic policies in the nineties converged with the important changes in the innovation process and in policy thinking on innovation at international level. Flemish policy-makers adopted the paradigm shift from a linear to a horizontal policy model. R&D policy is complemented by other (knowledge) elements in a broader innovation policy and coordination with complementary policy domains has been put on the agenda. The Innovation Decree of 1999 gave a legal framework to the concept of technological innovation (larger than that for R&D) and streamlined the existing instruments. Innovation policy now has a formal basis and has been positioned as a horizontal policy that will be guided by a horizontal policy plan.

Further implementation of this paradigm shift will be a demanding task over the coming period. The adaptations needed at different levels of the innovation system require a capacity of "institutional reflexivity" (P. Cooke, 2000). Initial experiences with cluster organisations, for instance, need to be more carefully studied in order to derive better policy lessons. The government, as a learning organisation, has to improve its capabilities in relation to monitoring, evaluation and foresight ("learning by learning" in addition to "learning by doing").

The debate on the additionality of innovation policy is a contribution to this institutional reflexivity. The additionality argument can help to focus policy choices in the following ways:

- Additionality focuses policy actions on activities with *important positive externalities* (knowledge spillovers, as well as other social benefits that are not accounted for in private returns).
- Additionality focuses policy-making on the *dynamics* of knowledge creation and distribution that constitute the essence of the "new economy". Knowledge distribution has become ever more important, hence the "knowledge distribution power" (David and Foray, 1995) of the innovation system.
- Additionality focuses policy design on the *complementary role* of government in the innovation system, in addition to market-driven innovation. Governmental innovation policy can make a difference, while not being a substitute for what innovative firms and innovative scientists can do best themselves. Many market processes with "positive externalities" need governments or other non-market organisations as a catalyst to promote the necessary interactions in the innovation system. There is also a need for proactive management of the innovation system at the structural level in order to correct systemic failure or promote the development of new future-oriented activities in which government participates as a strategic player in close interaction with the other key players in the innovation system.

The Flemish Innovation System has matured. The innovation system has become the most important "anchor" of economic development. Further development of the policy governance structure (in particular the improvement of connectivity) is a condition for restructuring into a "new economy".

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Changes in research management: the new working conditions of researchers*

Françoise Thys-Clément

"We have no formal procedure for generating hypotheses and theories in a quasi mechanical fashion" claims Karl Popper.

"If we were to create them from scratch we would be unable to predict what we were creating". A. Boyer (2001).

Introduction

The European summit at Lisbon in 2000 made research an integral part of its political agenda. The European Commission, through the Commissioner for Research, Ph. Busquin, made European "research area" the frame of reference for matters on research policy in Europe (European Commission [2001a]). These policy developments is are occurring at a time when worrying observations on the situation of European research are voiced, concerned as much with the lack of funding as with examination of the difficult demographic situation in terms of human resources. The OECD (1995, 1998a, 1998b) is also concerned about the operating conditions for research and has recently created two groups to examine these conditions. One, the DSTI (2001), is concerned with public policies to be implemented, while the other, (2000b) steered by the IMHE, deals with changes to university management in the face of the effects of the major changes in the working conditions of researchers.

There are numerous publications available on the various aspects of how research is conducted. These are particularly plentiful on the behaviour and motivation associated with research according to educational sciences and by the sociological approach but there are few publications dealing with the systematic, theoretical and empirical approach of economics. One of the rare American reports on issues being dealt with by economists pleads for the implementation of a proper programme for research on these issues. Accordingly, P. Stephan (1996) emphasises the importance of real motivation amongst researchers and their ability to manage their laboratory and research programme. However, in summarising statistics obtained from analysing the labour market for researchers, she points out that few scientific data have been obtained on

* Original text in French.

To get in touch with the author, see page 5.

the demand for research personnel by universities and governments. What is more, she notes that forecasts on these matters lack credibility because of the erratic changes in public financing.

This paper presents points of view and empirical results obtained from studies recently carried out in Europe or which have included European countries in their scope of investigation. Their fragmented character, in a geographical, thematic or temporal sense, and the unusual empirical evidence, sometimes result in an ad hoc juxtaposition of arguments, and consequently this study makes no claims to being exhaustive. We will thus consider the researcher in the university environment and focus on the problems of fundamental research without taking into account the specific problems of the working conditions of the researcher, particularly in the innovative phase of products or processes.

The first section considers that endogenous growth has led to progress in the scientific understanding of the links between research and economic development. This comprehension is vital to interfaces, channels for the diffusion of scientific development and its technological and organisational applications which have brought about the explosion in the knowledge society. Furthermore, it explains public policies on training and research which form a solid base for action. It is the basis of the argument for employing several individuals to increase research potential, such as that presented at the UNESCO/Europolis meeting (2000), where training a new generation of researchers was discussed and the enlarged European Union was considered as the crucial element.

The second part refers to the development of the motivation of researchers and the multidisciplinary scientific programme in which it is necessary to recognise the importance of scientists' satisfaction in the research and discovery process.

The third part of the article deals with the major changes in universities, who have had to contend with a number of challenges because of the increased expectations of their partners in the projects they undertake. They are also subject to major changes in their management and governance methods imposed by financial restrictions originating in the public sector. It can therefore be said that the paradigm of the university as an institution is undergoing a major transformation, which can be expressed by the concept of "academic capitalism" (L. Leslie and Sh. Slaughter [1997]).

The fourth point looks at research training. Research schools for the systematic preparation of writing theses have been set up in the United States, whereas there is no one system in European universities. In this section we will look at the European situation using recent comparative studies (R.G. Burgess [1998], J. Huisman and J. Bartelse [2000]), taking as examples the respective situations of the Flemish and French Communities.

The trend towards an approach to research training that is much more systematic, indeed professional, leads to a discussion in the fifth section of the international, national and regional context of research funding within the framework of the European Union.

The subject of researchers' salaries is dealt with in the sixth section, where two features of the labour market, namely the very low representation of women in academia and the variable degree of union membership according to country, are examined. Salaries will be analysed by examining European differences in Marie Curie grants, comparing salaries in the private sector, presenting a microeconomic example and finally offering information on the salaries of Belgian academics (the Flemish and French Communities).

Our conclusions will call for a proper multidisciplinary research programme for scientific activity as well as for an accompanying institutional and financial policy to allow Europe, and particularly Belgium, to update its scientific knowledge.

1. Economic development conditioned by research or the concept of endogenous growth

Research programmes on endogenous growth lead to an understanding of the various mechanisms of scientific overlapping which play a decisive role in economic development (P. Aghion and P. Howitt, 2000). Economists have long emphasised the effect of work and capital factors on economic growth; however a renewed approach to its fundamental elements demonstrates that its principal force rests in the development and dissemination of knowledge. In this way P. Romer (1986; 1990) makes technical progress endogenous in rejecting it as "manna from heaven".

Including knowledge as a factor in production takes account of the fact that it is a collective or non-rival property because an economic agent who sells information to another in fact still retains possession of it, unlike material property which is rival property. However, knowledge can also be produced by private activity because the incentive of profit can be maintained, and information can be property, the consumption of which is sometimes forbidden: it can be hidden or protected by patents. However, there is a fundamental external factor linked to the production of knowledge: knowledge can grow and be disseminated almost without limit. So if economic growth depends on the level of knowledge, it is produced with increasing yields and not, as has often been thought, with static or decreasing yields.

An analysis of the channels through which education contributes to economic growth demonstrates a positive correlation between educational variables and investment in physical capital, thus producing the positive effect of human capital on the productivity of physical capital. Accordingly, an empirical study specifies a characteristic of human capital (B. Jovanovic, S. Lack et V. Lavy, 1993): if the growth rate of production depends on the growth rate of the stock of physical capital, this is what is fundamentally linked to the level of stock of human capital in the economy. P. Aghion and P. Howitt (2000) also recall that the volume of research and the size of the growth rate can increase when individuals become more "adaptable", confirming the thesis of R. Lucas (1993) for whom the key to success of certain developed countries is the great inter-sectorial mobility of their qualified workforce.

However, at an even more fundamental level, endogenous growth explains how historical "accidents" in the political sense can activate or provoke the passage of equilibrium, or in fact implement the conditions for virtuous or vicious circles of development. This ability is connected to the phenomenon of globalisation of the economy, which is translated by a new hierarchy of the world economy. While this globalisation imposes constraints on national and regional macroeconomic policies, it still reinforces the strategic character of microeconomic policies and policies for public action as indicated by M. Porter (1990).

2. Development in the work motivation of researchers

From the outset, an analysis of what motivates the researcher should be conducted outside strictly economic concepts. In fact, the correct determination of the working conditions of the researcher is a matter of a complex scientific and multidisciplinary programme which deals with their psychological and sociological motivations.

Since *Homo Academicus* by P. Bourdieu (1984 and 1987), the sociologist, subjected to criticism of his scientific method, which takes one's own world as an object, has had to "exoticise" the domestic to approach sociology in a university environment.

P. Stephan (1996) refers to empirical evidence which states that a great deal of the researcher's satisfaction is gained not just in discovery but more in the process of the search for discovery. This economist also points out that scientific analysis of what "counts" for researchers owes a great deal to the old works of R. Merton (1957, 1968, 1969) who demonstrated that the first aim of the scientist was to establish the priority of the discovery and that recognition or recompense of this priority was recognition, by the scientific community, of being "the" first. The custom, practised for several centuries, of connecting the name of the researcher with the discovery is also sacrificed by granting the prestigious prize, itself conditioned by harsh analysis of publications where peers play an essential role.

An economic analysis of the process of determining scientific quality by peers has been the subject of several studies. Our paper examines two aspects of this: the effect of scientific assessment on the funding of researchers and universities will be dealt with in the following section. Another interesting aspect of this process has been recently brought to light by T. Coupé (2001) who studied the possibility of conflicts of interests, or indeed of collusion, in the practice of assessment by peers, where the assessor might adopt a technique which favours members of his own institution. Empirical analysis demonstrates that this type of bias does not occur to any significant degree in England.

The scientific community can hardly be described as homogenous and idealised, and operating according to Mertonian criteria because scientific development by nature entails particularly marked internal segregation of disciplines. Thus the motivation of researchers, which can be associated with the economic concept of the cost of opportunity, will be defined here as the remuneration "of opportunity", that is, the capacity to follow, in a largely independent way, a personalised research programme. This capacity is, of course, at the heart of the researcher's career. Different according to discipline, more individual in the humanities and necessarily linked to a group in natural sciences, this capacity intersects and regroups several constraints of academic life which range for the difficulty of raising funds to the recruitment of scientific personnel, the essential basis for the realisation of scientific projects.

A distinction can therefore be drawn between:
• the dependence of the researcher on:
- the academic world where intermediate entities, for example the dean of the faculty or the head of the department, wield significant influence;
- the public sector (widely speaking, ranging from the international to the local) and the private sector because of its quest for funding and the demand for results, the nature of which vary, depending on the agreements.
• and similarly his dependence on the world of training and teaching so that:
- he can be helped as early as possible in the repetitive and "ancillary" part of research;
- he can identify as early as possible the students who seem best suited to carry out quality research work.

If, of course, the matter of financial remuneration also plays an important role in career choice, the above paragraph suggests that the researcher's salary as comprising, in general, two components: the first is linked to the general status of the researcher and the second to his personal characteristics. The latter can be directly linked to his pre-eminence in the scientific domain as assessed by his peers; but they should equally be linked to his ability to act out a role in analysing the transmission of his knowledge. It is certain that the effect of knowledge on the transformation of society also has an important role here. However, it must also be said that the role of the specialist researcher, consultant, populariser or simple communicator has not yet been properly studied.

In returning to the scientific analysis of the motivations of the researcher and their consequences, the fact that there is inequality in science should be borne in mind. To be third often means to be nowhere. R. Merton (1968) brought this phenomenon to the fore when he coined the phrase the Matthew effect or the effect according to which the essential motivation of the researcher is to work with the best other researchers, thus reinforcing his personal status. A. Geuna (1998) emphasised the tendency of a good researcher to be attracted by centres of excellence where the situation as regards physical and human capital allows him to attain an excellent level of research himself.

This link between human and physical capital in current scientific development returns to the essential aspect of the motivation of researchers of being "master" of their laboratory, which implies a hierarchy in the research team and the obtention of important financial aid. This aid concerns technological equipment as much as the recruitment of a sufficient number of researchers with suitable levels of qualification. Many head scientists highlights the growing importance of the time dedicated to this collection of funds, the sources of which is extremely diverse, given the nature of the Public Authorities concerned (international, European, national, regional and indeed local) and the peculiar conditions for obtaining private funds.

Finally, D. Foray (2000) points out that the priority rule is a very effective tool for offering non-trade incentives for the production of public goods. The world of researchers is not, of course, an ideal open environment, and as D. Foray (2000) also notes, the importance of the context of "competition" created by the priority rule and the size of the associated prizes can lead to some bad behaviour. However, this culture heavily influences the behaviour of researchers and it is possible to say that at the end of the day it plays a positive role in the establishment of co-operative networks.

3. The development of research and of the operation of universities

Differences exist between institutions as regards the position of university research in scientific systems. The OECD (1999c) offers a number of profiles to clarify the complexity of the European situation:

- in Anglo-Saxon countries universities are considered to be the seat of fundamental research par excellence. They co-exist with public research in areas of national interest such as defence, medicine, agriculture, etc.;
- in Germany and France, for example, university research co-exists with public laboratories for fundamental research such as the Max Planck Institute or the National Centre for Scientific Research, but it is also carried out in cooperation with applied research on the provision of infrastructures in research and development, as it is for example in Germany;
- elsewhere fundamental research is undertaken in universities but in cooperation with a significant (Norway) or a limited (Sweden, Switzerland) number of public agents for applied research;
- finally, the organisation of research in Eastern Europe is again different with the specific role of academies of sciences.

Our study is limited to the university context as, according to Ph. Busquin, (2001) "its weight" in the field of research can be compared to that of American universities: in 1998 the total value of research carried out by universities was practically identical on both sides of the Atlantic (€29.1 billion).

The university plays an essential role in organising research, as one of the most significant conclusions of a recent study of three university systems suggests. Here M. Kogan *et al* (2000) emphasise that, even though on the whole, their reports are heterogeneous, a generalisation can be applied to the three systems studied – England, Norway and Sweden – : universities have emerged as the principal agents in the field of research as far as both the academic staff and the policy process are concerned. This confirms the stance of the OECD (1998b) that "universities and higher education establishments are the keystones to the scientific system in all OECD countries for both carrying out research and training researchers".

Universities and higher education establishments all over the world are undergoing important changes: there have been massive increases in the number of students and profound external changes in the expectations of university partners regarding the roles they should play and which results in them being faced with changes in organisation, management and even governance. F. MAYOR (1998) expresses this change in the university system by describing universities as "universal". The OECD (1998a) draws attention to the point where this context upsets the equilibrium between research, training, and other roles of universities, and their long-term contribution to fundamental research.

In the course of the study of these developments it should be remembered that economists have conflicting opinions on the perception of higher education.
They might think:

- either that universities are institutions whose purpose it is to respond to the needs of the community; in which case their activities can be described as public property and they are financed by the Public Authorities;
- or, on the contrary, that universities can be considered as businesses that provide individuals and enterprises directly with teaching and research services and make a profit from this, and therefore they should have to pay the price.

It is also common knowledge that the income scale within the general operation of the labour market varies according to qualification, and that being in possession of a recognised qualification strongly increases the likelihood of receiving a high salary.

C. FEOLA, M. TAVERNIER and L. WILKIN (2001) have analysed the dynamics of the reforms imposed by the Public Authorities in the last twenty years, based on the Eurydice report (2000b). These researchers demonstrate that in spite of the great diversity between European countries, three main courses of action can be identified, to wit:

- the progressive disappearance of borders between the two higher education sectors (that is, university and non-university education);
- the more interventionist public policies from the nineties onwards;
- the increased responsibility of universities as regards their management policies.

C. FEOLA *et al.* note that this new context does not seem to have really increased the margin of universities for manœuvre, because if they are seen to be granted "increased autonomy over their production process, (they) should in return justify this by the products and results obtained". Finally, they also point out that there are important differences in the dynamics and the extent of the reforms undertaken and that there are also different modes of governance. Here the authors also quote the need for carrying out more detailed studies "to establish a typology for modes of governance which serve as critical work tools for the agents responsible for the future of the higher education sector".

An explanatory summary of the changes in this sector can be found in D. FARNHAM (1999) who resumes the major changes in the national higher education systems, as reproduced in *Table 1* below.

TABLE 1 **Rate of change in national higher education systems** • after 1980

Group 1	Australia, United Kingdom	**Extensive**
Group 2	Finland, the Netherlands, Sweden, Belgium (Flemish Community), Canada	**Significant**
Group 3	Ireland, Spain, Belgium (French Community), Malaysia, United States	**Moderate**
Group 4	France, Germany, Italy, Japan	**Limited**

Source: D. FARNHAM (1999).

Furthermore, there have been important developments in relative reductions in public funding of universities, and universities in several countries are now obliged to find additional financial resources either from other public (at international or regional level) or private (enterprise and individual sources) sources of funding in an environment of increased competitiveness (CRE [1997, 2000]).

Below A. GEUNA, D. HIDOYAT and B. MARTIN (1999b) state that the following cases of scientific assessment of the allocation of resources should be highlighted:
- where resources for university research are, at least in part, allocated on the proviso that research is assessed (United Kingdom and Hong Kong where assessment is carried out by peers and Australia and Poland using indicators);
- where research funds are granted, jointly with financing from the teaching sector, as a part of universities' general institutional financing (Germany, Italy, Sweden and Norway and, to a different extent, Finland and Denmark);
- the negotiation process between universities and policy-makers (Austria, without research assessment, and France with an establishment contract);
- the special case of the Netherlands where assessment of the performance of research is carried out but is used for the distribution of funds between universities.

In Belgium research funds are granted partly jointly with funding from the teaching sector.

In an empirical study specific to the English case, I. MC NAY (1999) indicates that the process of assessing research (referred to as RAE – Research Assessment Exercise) was supposed to instigate selective funding for institutions with the best research units. However his empirical study demonstrates that half of the directors questioned think that ultimately funds have been directed to improving the performances of units that are less well classed because it has been noted that the better research centres do not earn anything because as long as they improve, they receive funds!

These changes were noted by the OECD (1998a, 1998b, 1999c) who identified important developments in the conditions for granting public funds to universities:
- the enormous increase in the number of students has meant that teachers have had to cut down on research activity because public funding has not been allocated to research;
- generally speaking, basic funding is on the decline in relation to "direct" funding for projects (targeted or competitive funding) and governed by criteria that are more specific and sometimes conditional on additional funding from industry (see the case of the European Union and Regional Authorities);

- universities have diversified by creating technology centres, university-business enterprises or even businesses;
- the cost of research has increased considerably by the introduction of priority strategic choices;
- finally, the practice of creating centres of excellence has allowed the realisation of disciplinary or interdisciplinary priorities, with the additional goal of appointing prospective agents for collaboration with enterprises.

A slow increase has been observed (OECD, 1999c) in funds from the private sector, but only in a very few countries (the United Kingdom, Germany, Switzerland and Finland) do they exceed 5% of university research.

European funds in the form of the “Framework programme” and “Structural Funds” are increasing. Macroeconomic international funds may represent 10% and more of funds allocated to research (OECD, 1999c). Similarly, funds at infra-national levels are increasingly being used in the funding of infrastructures or projects.

These major developments imply changes for the management, governance and status of universities (F. Thys-Clément, 2001). They disrupt the organisation of higher education establishments which subsequently operate under a twofold process :
- being held to greater account than before to public funding authorities;
- being subject to the constraints of negotiation of markets shares and of competition in welcoming and training students, as well as being responsible for the funding and organisation of their scientific and applied research activities.

Understanding these changes gives rise to a new model which can be called “academic capitalism” (Sh. Slaughter and L. L. Leslie, 1997), a term used mainly in an American context. This concept clarifies the changes underway in the governance and management structure of universities faced with competition for outside funds to ensure both peripheral and central funding. This additional funding is subject to competition from areas of the market (as much from other university institutions as from private firms) that assumes changes in both the organisation of scientific research and the recruitment and training of students.

Sh. Slaughter and L.L. Leslie thus describe this phenomenon by pointing out that in Australia, the United Kingdom and the United States this competition leads to the reassessment of all aspects of work in the faculties and university teaching itself.

The authors coin a completely new phrase to describe the competitive context in which universities have to act as “academic capitalism”. They emphasise that this concept appears to be an oxymoron, as it both facilitates understanding of the profound changes that universities face in expressing it as well as identifying the university as entrepreneur and the capitalist nature of research for profit in the academic world. In this context, members of a university are simultaneously “employees” in the public sector and are more and more independent of it. They are capitalists within the public sector and entrepreneurs subsidised by the state.

The authors' central theory is that at institutional level this change in the paradigm in turn brings about important changes in the professional relationships of academics and researchers both in their own faculty or department and in the university's central organisation where those who attract substantial funding (the particular discipline may also influence this) might also play a role which is not in the interests of the discipline or the institution as a whole. Within the framework of the informal procedures implicit in the operation of universities, academic capitalists act as agents in the private sector who are considered as performing and who consider it normal to earn gain rewards linked to the funding obtained.

H. Buchbinder and Rojagopol (1993) had already pointed out one of the consequences of this evolution, that university administration is becoming more powerful and more technological and that the role of those concerned is developing beyond that of academic heads with the result that the governance process is weakening to the detriment of management.

From this Sh. Slaughter and L.L. Leslie (1997) call for the Public Authorities to ensure the provision of training adapted to students' needs.

These developments indicate that in addition to the profound external changes in the expectations of partners as regards the roles that they should fulfil, on this subject see the concerns of the Conference of European Rectors (CRE, 1998), universities are also faced with organisational changes in their internal operation as indicated in the study by D. Braun and F.-X. Merrien (1997) on certain European university systems.

The fact remains that the Public Authorities want to open universities up to the world of business as is the case of Canadian federal policy which grants large research grants preferably to inter-university groups, which in return have to work in cooperation with private enterprises involved in research and development. For P. Leduc (2001), member of the Quebec Council for Research Development, this is a new environment where those who are willing to adapt are guaranteed significant funds and advanced infrastructures. She also points out that a top quality researcher is much sought-after, that said researcher might be "poached" and that often universities have to pay out a lot to keep the researcher given the intense competition between universities in North America.

As regards Belgium, see also the proposals of the French-speaking inter-university group "Université-Entreprise" ("University-Enterprise") and the study of M. Durez *et al.* (2001) on technological and technical transfer in Belgian universities.

The new stakes brought to the fore by this transformation of the model of the effects of research and by the increased importance of the societal role of higher education establishments assume the implementation of adapted studies and education policies which respond to and support them. The IMHE and OCDE have thus implemented an international project on the university management of research headed by J.-P. Contzen, R. Geiger, L. Meek and F. Thys-Clément, with H. Connell acting as reporter, to examine the problems generated by developments in the organisation of research and in the related decision processes.

Finally, one should bear in mind that a number of doubts have arisen about the capacity of universities to satisfy all the demands made on them. These doubts are even applicable to the two fundamental activities of the production and transmission of knowledge. For some (see M. Romainville, 1996), teaching and research are the "cursed couple" of universities and for others a debate on the myths of research is necessary (Ch. Ball [2001]).

If these affirmations merit being questioned, current majority opinion still supports the essential complementarity of teaching and research projects. However it should be acknowledged that if scientific studies on this subject are rare and not empirical, L. Wilkin and M. Tavernier (2001) have recently identified the changes which bring with them the implementation of new governance structures as well as the consequences of the new methods of management on the organisation of university work for university teachers.

Table 2 below summarises the main features of the survey carried out by L. Wilkin and M. Tavernier (2001) at the Free University of Brussels (ULB) on the use of teachers' time in comparison with conclusions drawn from an international survey (U. Teichler, 1996).

TABLE 2 **Research activities and funding**

	Germany	Sweden	England	United States	ULB
% of number of participants					
Currently employed in research projects	84	94	95	96	89
Collaborating in research projects[1]	77	86	79	76	82
In receipt of outside funds[1]	72	90	62	70	79
"My university expects me to have an on-going research project"[2]	84	78	97	92	79

Source: L. Wilkin and M. Tavernier (2001).
Notes : 1. % of those engaged in one or more research projects.
2. % who "Completely agree" and "Agree".

It can therefore be noted that in line with their European and American colleagues, the vast majority of responding academics are involved with research projects.

The study carried out by these researchers also deals with self-definition of the role that academics give themselves. The results are given in *Table 3* below.

TABLE 3 **Self-definition of role: survey of ULB academics**

	%
1. **According to a single activity**	
• Teacher	7.5%
• Researcher	6.3%
• Manager	0.6%
2. **According to two activities**	
• Teacher-researcher	22.7%
• Researcher-teacher	15.1%
• Teacher-manager	3.8%
• Researcher-manager	3.1%
• Manager-researcher	1.3%
• Manager-teacher	0.6%
3. **According to three activities**	
• Teacher-researcher-manager	39.0%

Source: L. Wilkin and M. Tavernier (2001).

It is clear that 47% of participants consider themselves to be dedicated to two tasks and that 39% consider themselves involved in three tasks. Management activities are cited in 45% of cases, indicating the degree of importance attached to this activity. The authors state that this issue is considered not only according to the proportion of time devoted to it, but also by its weight in hours. They emphasise that in fact, of all the configurations where management appears, an overall number of hours greater than the average is cited. The average amount of work hours for configurations where management is not involved is 48, in contrast to 54 hours for others. Investment in management therefore does not seem to be counterbalanced by a reduction in the workload of other activities.

An earlier empirical study (F. Thys-Clément and L. Wilkin, 1995) has also demonstrated the importance of the teaching-research combination in an international survey of European university heads which shows that fundamental research and first- and second-year teaching are the two principal tasks assigned to academic heads in their respective universities. (*Table 4* below).

TABLE 4 **Importance attached to a selection of tasks by 20 European university heads**
• on a scale of 1 to 10*

Nature of task	Current "average" score	Status	Future "average" score	Status
1st/2nd year teaching	8.5	2	9	1
3rd year teaching	7.5	3	8.5	2
Teaching of senior citizens	2	8	3	8
Continuing education	4.5	6	7	5
Fundamental research	9	1	9	1
Applied research	6.5	4	8	3
Social services	4	7	5	7
Cultural services	4.5	6	5.5	6
Contact with industry	5.5	5	7.5	4

* 1 = task considered the least important / 10 = task considered the most important.
Source: F. Thys-Clément and L. Wilkin, 1995.

An analysis of the new working conditions of researchers assumes, by their very nature, a multidisciplinary approach. It is also interesting to note the recent work of M. Kogan, M. Bauer, I. Bleiklie and M. Henkel (2000) on the changes in the world of higher education. These researchers in education and public organisation studied the major changes in this sector from the perspective of analysis of social sciences and reached conclusions on the relationship between the development of knowledge and the influence of policy. Their conclusions question those of the economist as they state that the changes in formal structures (such as educative reform) and in the explosion in the number of students have not necessarily brought about changes in general or social behaviour, for example behaviour related to power or autonomy, but that on the contrary sociological behaviour has probably been more influenced by the scarcity of financial resources! This conclusion conforms with that reached by Sh. Slaughter and L.L. Leslie (1997) in their study.

4. Apprenticeship or systematic training for research and its careers

Whereas research training has been organised in the United States by research schools for a long time (B. R. Clark, 1993), the European situation is markedly more varied. Studies relating to Europe are recent and not systematic and require "spade-work" on the creation of databases and drawing up of practical inventories.

A study by S. Blume for the OECD identifies the need to rethink research training and related practices in a particular selection of countries (Australia, Canada, Finland, Italy, Japan, United Kingdom, United States and the Czech Republic).

R. Burgess (1998) has identified a network (the United Kingdom, Germany, Austria, Spain, Portugal, Greece and the Flemish Community of Belgium) to highlight the trends of postgraduate education. Given the relative absence of previous scientific work, this research comprises basic information, on the information collected and on policies carried out and practices followed. In spite of the heterogeneous nature of the articles of the work, R. Burgess identifies a series of themes which are listed below:

- **the organisation of postgraduate study**: this is very dynamic in the United States but has undergone different development in Europe. In the United Kingdom a change towards the American system is noted. Italy groups universities in consortia for third year education while in the Netherlands research schools have been set up.
- **education versus apprenticeship** is the subject of debate in the investigation of whether third year work constitutes direct preparation for the doctoral thesis or rather that training techniques for theses can be learnt in apprenticeship.
- **strictly more professional vocational programmes** directed towards "lifelong learning" and preparation for future careers.

R. Burgess emphasises the delays in Europe caused by legislation but also notes that the current organisation is in the process of change with notable differences from country to country: if the selection criteria are different everywhere, funding these studies will always pose a problem. Lastly, he poses the question of the relevance and appeal of these specialised qualifications for employers outside the sphere of university education.

For Cheps J. Huisman and J. Bartelse (2000) led a group for the Netherlands, the United Kingdom, Finland, Flanders and Germany under the auspices of an agreement with Dutch Technologiebeleid to examine the situation of the Netherlands in its closest international environment. Again, they point out the specific nature of practices but add that society wants to create a more qualified population trained in research, and not only to replace the large numbers of academics who will leave to retire from European universities in the next few years. They also state that an academic career, like human resources management, requires initiatives to make the prospect of preparing theses more attractive.

While I. Beuselinck and J. Verhoeven (1998) describe the Belgian system for postgraduate training in research at length, J. Verhoeven (2000) documents the recent evolution in the number of Flemish PhDs in the Cheps study (see *Table 5* below).

TABLE 5 **Number of doctorates in Flemish universities** • 1992-1998

	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
Total number of doctors	514	596	586	598	580	672
% soc/humanities	21.8	21.6	23.9	23.4	21.9	20.8
% sciences	63.8	60.6	55.5	62.9	62.1	56.9
% medicine	14.4	17.8	20.7	13.7	16.0	22.3
% women	27.2	28.5	29.2	31.4	32.6	33.2
% foreigners	19.5	27.4	26.5	27.3	26.9	26.8

Source: Vlaamse Interuniversitaire Raad, compiled by I. Beuselinck and J. Verhoeven (1998).

M. Durez, I. Hondekyn and D. Verheve (2001) studied the development in the number of doctors in the French Community of Belgium. *Table 6* below summarises their findings.

TABLE 6 **Number of doctorates in French-speaking universities**
• 1990-91 to 1997-98

University	Exact sciences	Health sciences	Social sciences	Applies sciences	Human-ities	Agricultural sciences	Total
UCL	384	231	300	233	232	156	1,536
ULB	528	216	109	78	127	29	1,087
ULg	362	197	72	130	72	0	833
FUNDP	175	1	9	0	0	0	185
UMH	84	0	34	0	0	0	118
FUSAGx	0	0	0	0	0	105	105
FPMs	0	0	0	73	0	0	73
FUL	3	0	0	0	0	0	3
FUCaM	0	0	2	0	0	0	2
FUSL	0	0	0	0	0	0	0
Total	1,536	645	526	514	431	290	3,942

Source: CReF, "Les étudiants et le personnel des institutions universitaires francophones de Belgique. Données statistiques" ("Students and staff in French-speaking universities in Belgium Statistical data". Data collected by M. Durez *et al.* (2001).

Key: UCL: Université catholique de Louvain (Catholic University of Louvain); ULB: Université libre de Bruxelles (Free University of Brussels); ULg: Université de Liège (University of Liege); FUNDP: Faculté universitaire Notre-Dame de la Paix à Namur (Notre-Dame de la Paix Faculty of Namur); UMH: Université de Mons-Hainaut (University of Mons-Hainaut); FUSAGx: Faculté universitaire des Sciences agronomiques de Gembloux (Gembloux Faculty of Agricultural Sciences); FPMs: Faculté polytechnique de Mons (Mons Polytechnic); FUL: Fondation universitaire luxembourgeoise (Luxembourg University Foundation); FUCaM: Facultés universitaires catholiques de Mons (Mons Catholic Faculties); FUSL: Facultés universitaires Saint-Louis à Bruxelles (Saint-Louis Faculties at Brussels).

A study carried out by the University of Mons-Hainaut (see M. Durez, D. Verheve and I. Hondekyn [2001]) concerns the doctoral research of 356 people who had attained the title of doctor (1992-1998) in a university in the French Community of Belgium. This sample covers 122 theses in exact sciences, 47 in applied sciences and philosophy and arts, 41 in medicine and dentistry and then in descending order for other disciplines. The study highlights the double difficulty Ph.D. students have to face in the French Community of Belgium because of the low levels of funding in scientific research. The reality of this situation means that there is a great number of different statuses and this forces researchers to find additional funding.

This is particularly evident in the adapted *Table 7* by M. Durez *et al.* (2001).

TABLE 7 **Financial difficulties and differences in status of Ph. D. students in the French Community of Belgium**

Status	At beginning of thesis	with financial aid	% of difficulties
University assistants	78	13	17
Grants :			
• Funds for research in industry and agriculture	75	33	44
• National funds for scientific research	52	7	13
• University funds	22	10	45
• Federal department for scientific, technical and cultural affairs	18	4	22
• Others	14	5	36
• Private part-funding	10	1	10
• Foreign	10	5	50
• European	9	7	89
• Funds for collective fundamental research	8	-	-
• Actions for concerted research	5	4	80
Total	301	89	30

Source: M. DUREZ, D. VERHEVEN and I. HONDEKYN (2001).

Researchers at the University of Mons-Hainaut also demonstrate that at the level of personal difficulties, the most pressing is that of reconciling family life with a thesis project (20%). As far as discouragement is concerned, 12% of participants echo the conclusions of STERNBERG (1981) as regards the importance of a quality supervision for arduous and long-term work. 13% cite financial problems and 10% encounter difficulties in managing a doctorate and a job. 39% do not experience any personal difficulties.

To return to general indicators, the OECD (2000c) has formulated a rate of attainment of a research diploma at a high level (doctorate or equivalent award) for 1998 for OECD countries and the Flemish Community in Belgium. Although caution should be exercised in comparing the data, the variations are indicative: taking the average as 1, this passes to 2.5 for Switzerland, 2.3 for Finland, 2.2 for Sweden, 1.8 for Germany, 1.2 for France and the United Kingdom and 0.7 for the Flemish Community. Several countries, including Italy and Japan, have rates of 0.5. The United States stands at 1.3.

The growing organisation of the mobility of researchers is of course related to this increasingly professional approach to the preparation of doctoral theses and to the scientific or economic value of these for postgraduates.

The EU makes the mobility of researchers an important priority in putting forward the "challenge of mobility" (Com. Europ., 2001b in point V below) to optimise the quality of European research. We will return to this point later. It should also be noted that of the European researchers who have taken part in "TMR Research Training Networks" and the Graz Conference (1998), 86% considered that having a "TMR Fellowship" was positive or very positive in enhancing their future career prospects and only 14% were neutral on the subject.

The individual organisation of this mobility poses problems which sometimes highlight the "course of the fighter" as far as administrative processes or the different level of attractiveness of the major variations in salaries are concerned (see the range of Marie Curie grants below). Universities claim administrative solutions as witnessed by the Conference of University Presidents (2001), the CPU, in France, which demanded exchanges of services between French and foreign teachers-researchers in the form of a system of agreements between French universities and their foreign counterparts.

One of the rare instances of putting the current rapid developments in perspective in this area of research training is provided by M. Henkel (2000) who traces the history of research education. She reminds us that the initial goal is preparation for an academic career which was evident before with major sociological implications as this practice meant that researchers had to share the same intellectual foundation and therefore the same epistemological rules as their academic heads. This education thus plays an essential role in the continuing development of disciplinary knowledge with differences according to whether it is a matter of natural sciences where apprenticeship is undertaken in teams or humanities where work is undertaken on an individual basis. This period, which is crucial for Ph. D. students, has a profound impact on the lives of academics as far as the implementation of their research programmes is concerned. The differences in national practices are particularly important here, whether they are related to the institutional nature of the place where work is carried out (universities, research centres or businesses) or to the status (student, paid employee or grant-holder) of the individual who undertakes it.

While she states that, up until very recently again, there was little formal teaching at doctoral level in Europe, M. Henkel also extricates the principal priorities for change that can be envisaged for the future. Thus she highlights the fact that the emergence of the society of knowledge creates a demand, not only for identification, but also for a more definite demarcation in the different stages of qualification in training for the preparation of research. This idea can be linked with the call of D. Foray (2000) to prepare for the different qualifying tasks of research.

From the perspective of training the researcher, the question of his or her capacity to manage is currently on the agenda and it is not surprising that groups proposing to undertake training on research management are being formed. Accordingly EARMA (European Association of Research Managers and Administrators), founded in 1995, proposes the establishment of a master degree in research management for duly selected individuals.

Finally, D. Gilliot (2001) provides relevant information on the general problem of recruitment in universities based on the report on Flemish universities. However she also proposes a general strategy for recruitment policy and policy concerned with the maintenance of academic staff in universities with particular emphasis on the need to provide them with a "career plan".

5. Funding: regional, national and from the European Union

Scientific activity is global as the primary goal is to expand our knowledge of nature and ourselves. Because of important external factors, appropriation poses ethical questions (witness the current issue of appropriation refused by Bill Clinton and Tony Blair on the discovery of the genome sequence and so the refusal to pay the price demanded by the pharmaceutical industry for the treatment of AIDS in South Africa) as well as strictly economic questions (see the issue of the price of generic medication). It is therefore at a global level that the nature of the organisation of research should be examined, and this is particularly evident as regards funding. As scientific studies show - M. Kogan *et al.* (2000), P. Stephan (1996), Sh. Slaughter and L.L. Leslie (1997) – funding researchers and research teams has major effects on the changes that their activities undergo, and involves groups of researchers up to the governance of the institutions that accommodate them, universities, but also affects individual perception of the capacity of the scientist to lead a personalised research programme (P. Stephan, 1996).

From this point of view, differences in funding by country play an essential role, and international comparisons show important differences, so the relative deficit for funding for research in the European Union cannot be considered as a simple fact but as a real argument for changing direction. This is all the more relevant when measured in terms of the growth of GDP which has itself undergone different developments since the United States experienced a spectacular increase in its creation of wealth. For Eurostat (2001), the 5th framework programme for research in the EU has shown a moderate decline since 3.7% of the Community budget is implicated in comparison with the previous value of 4%. Currently this programme represents 5.4% of total European contribution to public research. Even if research and development expenses have contributed to progress in absolute value to reach 141 billion Ecus in 1998, they only represented 70% of the equivalent research in the United States. In relation to GDP, in 1998 research in the EU represented 1.86%, a value much less than the 2.58% for the United States and 3.03% for Japan. This disparity can be particularly explained by the business sector where research and development in the EU is much less than that in the United States and Japan. Taking into account a relative term which is weakening, itself calculated according to stagnant income, indicates the weakness of the means available to European researchers: this poses a real problem for competitiveness from both the point of view of economic development and from that of scientific knowledge.

This evaluation of the efforts of the European Union is completed by examining indicators for human capital. Accordingly, a report by the French Senate (P. Lafitte, 2000) points out that: “The countries of NAFTA train 3.7 million graduates per year, the European Union trains 2 million and the four most industrialised countries in Asia (EDA) 1.6 million. Although the rate of science degrees per 1,000 young people between 20 and 24 (17% in the European Union, 22% in the United States and 26% in the EDA countries) results in, at least in relation to the United States, a lesser European lag in this area, this deficit in training has repercussions for scientific employment”. The situation as far as human resources is concerned is worrying as the percentage of researchers within the working population shows an unfavourable situation in Europe, this being 2.2 researchers per 1,000 inhabitants, in relation to the rate in the United

States and Japan where this indicator respectively stands at 3.5 and 4.4 (Eurostat, 2001). However, the French report indicates that as far as quality is concerned the "criteria for the number of scientific publications establishes the progress made by the European Union. So, between 1982 and 1997, the European Union has become the premier world area for scientific "production". Its global role in scientific publications has grown from 29.1% to 33.5%, while that of the United States has diminished from 36.7% to 32.5%, and that of Japan has increased from 6.6% to 8.5%". According to Ph. Busquin (2001), the number of citations of European publications has increased by 2.1% through the years, whereas that of American publications has dropped. The Belgian scientific performance is above that of the European Union. We can qualify this optimistic report bearing in mind that in science the "stock" effect plays an important role, i.e. the fact that effort made in the past, even in the distant past, means that practices can be memorised; this relative advantage risks subsiding in time. The question of the pertinence of the criteria for the number of scientific publications arises in a world where computerised communication completely changes scientific practices of communication.

This general analysis should bring to mind that the rate of scientific and technological effort (expenditure for research and development reduced to the GNP) of the different Member States varies widely. Sweden (3.8%) and Finland (2.7%) are positioned above or are close to the United States and Japan. A large group of countries (the United Kingdom at 1.9%, the Netherlands at 2.1%, France at 2.3% and Germany at 2.4%) are closely or far above the European average. At the other end of the scale, southern Europe is at the bottom (1%).

Finally, the measurement to be applied to scientific excellence should be qualified by the fact that it is not very evident in its relationship with fundamental research and its developments further down the scale and, because of this, in the funding of research carried out by enterprises. A detailed study of these developments expressed in figures can be found in the numerous OECD publications (see *bibliography*). Clarification of the situation where Europe has at its disposal a scientific and technological potential which is relatively strong but where relating discoveries and knowledge to industrial activities is done less easily as in the United States and Japan, is made in the report by H. Guillaume (1998) who identifies the weak links in the French plan for technological research.

Retracing the development of European framework programmes is outside the remit of this paper. However, such programmes have played an important role in putting European research into perspective and Philippe Busquin's ambition is to create a proper European research area. From a general point of view, and this text has already alluded to it, the EU has made mobility a main priority of its policy, and it is associated with the implementation of networks of researchers and therefore with an active policy of co-operation between universities. Within the context of endogenous growth, the practice of research within networks is essential in organising the transfer of research results and can be seen as a way of speeding up the transmission of external factors and confirms the importance of "proximity" in the diffusion of knowledge.

A. Geuna (1999a) closely examines the participation of universities in European framework programmes and a recent study of European research policy can be found in the five-year assessment of this (J. Majo, 2000).

The recognition and development of the mobility of European researchers should be accompanied by measures ensuring that researchers have the chance to meet which go beyond national legislation to construct attractive conditions for moving about. These obviously include adequate remuneration but go beyond this by taking into account the general environment of working conditions (laboratories, assistance, secretarial support, etc.). This problem is currently being studied by the European Commission's services in the High Level Group (Comm. Europ., 2001).

We will conclude by illustrating the importance of the financial context by the study of the Swedish Academy (2000) for Sciences and Engineering with regard to the quality of fundamental research and Swedish research projects in European framework programmes. The conclusions are particularly strong as they emphasise, in this country where funding for research is plentiful, that the main reason for participating in a European project appears to be the need for additional funding. This suggests that for the Swedes funding for the best research projects in Sweden is insufficient.

6. The labour market and researchers' salaries

Globalisation and the increasing mobility of researchers call for comparative studies on researchers' financial conditions and salaries. These studies are not currently carried out in a systematic way. If one were to use some bibliographical references, none of them would provide a complete study for both the link between salaries and the concept of the purchasing power of the individuals concerned or on temporal or spatial aspects. This is due to the conjunction of several difficulties linked most particularly to the lack of comparable international statistics (see *the diversity of status and definition of staff*), the difference between gross and net income (which is very different according to country because of heterogeneous tax and social security systems), and lastly - and this is even more difficult to understand - the researcher's financial contribution to the scientific results obtained or his or her capacity to personally lead research contracts for which it is possible to negotiate individual benefit. Finally, comparison of salaries should be made of the earnings of staff employed in a scientific capacity in the private sector, which is even more difficult to realise.

Before listing this information it would be useful to present two general features of the labour market of academics: the very poor representation of women and the variable degree of union membership amongst countries.

Table 8 below, taken from D. Farnham (1999), covers several European countries and includes the United States and Australia.

TABLE 8 **Percentage (approximate) of the representation of women**

Country	% of academic managers	% of teachers
United States	45	15
Finland	32	12
United Kingdom	31	8
Australia	28	12
The Netherlands	24	4
Spain	23	4
Canada	22	n.a.
Ireland	20	4
Japan	15	9
Belgium (Flemish Community)	12	5
Belgium (French Community)	10	7

Source: data supplied by authors of the study edited by D. Farnham (1999)

This information can be completed by a detailed *table 9* for all-Belgian universities taken from a monograph by G. Kurgan-Van Hentenryk (2000).

TABLE 9 **Women teachers in Belgian universities** • in % of the total number of teachers

	UCL		ULB		ULg		KUL		RUG		VUB	
	1992	1998	1992	1998	1992	1998	1992	1998	1992	1998	1992	1998
Full (extraordinary) Professors, Gewoon (buitengewoon) hoogleraar	2.5	2.9	10.3	11.4	3.8	7.0	2.1	2.3	6.5	8.8	10.7	12.7
Teachers, hoogleraar, gastprofessor	6.1	7.0	16.9	18.3	8.1	7.0	8.7	11.8	5.8	8.6	15.6	15.9
Assistant professors, Docent, Hoofddocent	12.0	21.0	16.9	21.6	12.9	10.8	6.4	16.3	7.3	15.0	12.7	20.9
Lecturers	9.1	20.2	17.7	22.2	–	–	–	–	–	–	–	–
Supply teachers	24.7	32.2	19.4	20.5	9.7	–	–	–	–	–	–	–
Total number of teachers	6.2	11.3	14.5	17.6	7.8	8.4	4.3	9.7	6.6	12.1	12.3	17.5

Source: G. Kurgan-Van Hentenryk (2000).
Key: UCL: Université catholique de Louvain (Catholic University of Louvain); ULB: Université libre de Bruxelles (Free University of Brussels); ULg: Université de Liège (University of Liège); KUL: Katholieke Universiteit Leuven; RUG: Universiteit Gent; VUB: Vrije Universiteit Brussel.

G. Kurgan-Van Hentenryk identifies several reasons why women's and men's careers vary in the academic world. Accordingly she specifies the distribution of social roles and selection procedures (explicitly or implicitly male candidates are overvalued while women are undervalued – see the researcher V. Vallian [1999]) and points out the new constraints ranging from financial difficulties to the pressure of preparing a thesis more quickly than before and even to the issue of self-censorship.

The European situation of the participation of women in scientific activities can be found in a recent study on genre (Europ. Com., 2001d). Broadly speaking, this report highlights the massive number of female students enrolled at university but the continuing decline in the number of women on every rung of the scientific career ladder. It also deals with the essential waste represented by the lack of recruitment of women in the academic world for scientific research.

The rate of union membership of academics varies greatly according to country as indicated in *Table 10* below.

TABLE 10 **Estimate of the rate of union membership according to country**

High (more than 60%)	Ireland, Sweden, Finland, Australia, Canada
Intermediate (25 – 59%)	United Kingdom
Low (less than 25%)	France, Belgium (Flemish and French Communities), the Netherlands, United States, Spain, Italy, Germany, Japan, Malaysia

Source: data supplied by authors of the study edited by D. Farnham (1999).

D. Farnham identifies an important dichotomy here which separates northern and southern Europe and continues with his study by putting together a general table for determining the salaries of academics (*Table 11*).

TABLE 11 **Structure for determination of salaries** • 1998

	Centralised (public) higher education system	Decentralised (public or private) higher education system
Weak unions	*Regulated by the State* France, Germany, Italy, Spain, Japan, Malaysia	*Privately regulated* United States (principally private), Japan (private)
Weak unions	*National collective agreements* The Netherlands Belgium	*Local collective agreements* The Netherlands (public), United States (principally public)
Strong unions	*National collective agreements* United Kingdom, Finland, Sweden, Ireland	*Local collective agreements* Canada, Australia, Sweden (completely public)

Source: D. Farnham (1999).

Generally speaking, it is difficult in both a methodological and empirical sense (see A.B. Atkinson, L. Rainwater, T.M. Smeeding [1991]) to carry out relevant international comparisons of income. Therefore the economist highlights the problems of converting money as well as the effect of transfer between:

- gross and net income, that is, taxes, social security contributions or specific levies as well as transfers linked to circumstances as to dependants;
- perks granted by institutions;
- consideration of official and supplementary pensions;
- consideration of charges linked to children's health or education;
- the cost of living: accommodation, transport, food, etc.;
- discrepancies in conjunctural cycles;
- comparison of status and role definition.

In the United States systematic information is supplied by the National Center for Education Statistics of the U.S. Department of Education. It lists the salaries of staff of different status which vary according to institution. A general report is also supplied by the Staff Regulations Committee of the American Association of University Teachers which initiates major changes in salaries.

The situation regarding information is very different in the European Union, and without claiming to have completed a definitive investigation on national information, it can already be said that international comparisons are often partial. Consequently this paper will deal with:

- a comparison for all countries of the European Union on the basic salary of young researchers in receipt of Marie Curie grants;
- a comparison with salaries in the private sector on the basis of the particular case of university economists from the three large French-speaking universities;
- a micro example constructed from two real cases;
- and finally a comparison of two gross salaries of academics at the top and bottom of the salary scale in the two linguistic communities of Belgium.

Marie Curie grants for researchers vary greatly between countries as *Table 12* demonstrates.

TABLE 12 **Classification of countries according to the cost or net salary of Marie Curie grants**

Country in ascending order	Cost of the grant to the European Commission[1]	Net salary for the grant recipient[2]
Latvia	100	100
Bulgaria	100.9	100
Estonia	103.3	115.3
Lithuania	103.3	100
Cyprus	103.4	131.2
Slovakia	109.3	115.6
Romania	119.2	100
Ireland	120.5	130.7
Greece	122	130.7
United Kingdom	123.1	157.7
Czech Republic	124.6	115.38
Poland	130.2	115.3
Spain	131.5	142.3
France	141.6	134.6
Iceland	147.6	161.5
Finland	149.8	134.6
Italy	150	150
Portugal	151/122	146.1
Israel	152.5	146.1
Luxembourg	155.6	180.7
Slovenia	156.7	130.7
The Netherlands	166.2	142.3
Switzerland	167	203.8
Liechtenstein	167	192.3
Austria	168.4	142.3
Norway	169	165.38
Hungary	170	116
Denmark	172	169.2
Germany	177	146.1
Sweden	181.8	143
Belgium	196.7	150

Source: European Commission, Directorate-General for Research.
Calculations: C. Van Den Steen (Centre for the Economy of Education).
1. base 100 = 2.541 EUR.
2. base 100 = 1.300 EUR.

The particular case of Belgium clearly poses certain problems. Because of tax and parafiscal tax Belgium imposes the highest costs on the European Commission! However, the Belgian researcher receives a lower net salary than his colleagues in Luxembourg, Denmark, Norway, Ireland, the United Kingdom and Italy; but a relatively higher salary than his Dutch, French and German colleagues. This should be treated with caution as local conditions of reception can play an important role in the opportunity salary and a more general study is therefore needed on the merits of the various tax and parafiscal tax systems.

A comparison of the salaries of academics with those of academics working in the private sector can be obtained from the study carried out by the UCL, the ULB and the ULg on economists from their respective institution. *Table 13* below shows that teachers in higher education (including universities) are at the higher end of the table but the fact remains that there is a large difference with those based in international institutions. On the other hand, it should be noted that young assistants and scientific researchers are situated at the very end of the table!

TABLE 13 **Comparison with the private sector: the UCL, ULB, ULg study on gross income of economists** • in thousand EUR • 1994-1995

Sector	Average income	Number of persons in sector
International institution	76.3	11
Consultancies	60.2	41
Other services	52.3	40
Higher education (teaching)	51.9	17
Information technology, brokerage	50.6	20
Industry	50.5	32
Transport & communications	49.1	11
Financial services	47.6	116
Commerce, mass marketing	38.4	19
Trade unions, etc.	34.7	11
Public administration	32.2	52
Other teaching	24.7	11
Higher education (sciences)	22.9	35

Source: A.D.E.L., A.E.Br., A.L.D.Lg., Yess International Consultants, calculations: C. Vanden Steen.

The ULB undertook similar new studies for four French-speaking universities (FUNDP, UCL, ULB and ULg). Unfortunately, these do not use the categories shown above and do not allow an dynamic examination of the report for the years 1994-1995. However, one of the conclusions of the study is that median salaries in the financial sector are the highest (€ 69,410), along with salaries in industry and commerce (€ 61,973) and consultancies (€ 59,494). Finally, teaching and the public sector seem to yield the lowest salaries with € 37,184.

A microeconomic example has been put together to give an idea of the complexity of the financial conditions in which high-level researchers operate, and is given in *Table 14* below:

TABLE 14 **Based on 2 real cases of Belgian researchers travelling abroad and of an American researcher arriving in the French Community of Belgium**

	Personal salary	Opportunity salary
X	• Basic salary	• member of a centre of excellence • determination of future research subject
Y	• Seniority • Family supplement • general allowance - board - lodging • private bonus • bonus for children • holiday pay • social security allowance	• scientific personnel • administrative personnel • allowance for installation of scientific equipment and up-dating of this • allowance from department funds for study abroad, books, computer equipment, etc. • personal welcome • general quality of the infrastructure of the host country (schools, transports, etc.)

X + Y = Salary
Z = Net salary after direct taxation
X = 100%
X + Y = 119%
Z = 64%

Contribution to essential expenditure for consultancy work, personalised research contracts and personalised patents should be added to this.

There is little data available on international comparisons of salaries of researchers and academics in Europe. Even if one were to cite the works by D. Farnham (1999), J. Huisman and J. Bartelse (2000) and J. Enders (2000) for partial information by country and period, one would not find the systematic information there that is available across the Atlantic.

However this work is indispensable insofar as mobility and the matters of transparency and information requested by the EU High Level Group implies the comparison of financial data.

The comparability of these salaries is also requested by the National Fund for Scientific Research who have instigated research in this area.

As far as Belgium is concerned, the only data in these works used here is that published by K. Tavernier (2000) in the work edited by J. Enders (2000) as the figures quoted in the other works bring with them the problem of converting the exchange rate where conjunctural influence means that analysis is difficult to carry out.

K. Tavernier cites the salaries offered at the (Dutch-speaking) Catholic University of Louvain (Leuven) and distinguishes between starting salaries, the real average salary at the beginning of careers, the average age at the beginning and the final salary.

TABLE 15 **Salary of academics at the (Dutch-speaking) Catholic University of Louvain (Leuven)**
1998 • annual gross salaries in EUR

Grade	Starting salary	Real average salary at the beginning of careers	Average age	Final salary
Assistant	28,044	28,044	26	47,460
Doctoral assistant	34,740	40,296	32	54,156
Lecturer	35,748	42,108	35	52,692
Senior lecturer	40,944	46,788	43	64,320
Professor	47,928	52,140	46	73,164
Full Professor	53,688	59,340	46	82,020

Source: Catholic University of Louvain, K. Tavernier, monthly figures multiplied by 12.

According to K. Tavernier, it is striking that the age at the beginning of careers is the same for a full professor and a professor, illustrating the fact that promotion is not dominated by seniority but, on the whole, by the quality of the scientific curriculum.

B. Bayenet and O. Bosteels (1998) have proved the importance of divergence in university practices amongst the Flemish and French Communities in Belgium. This is why salaries of academics at the Free University of Brussels and the Vrije Universiteit Brussel have been given below.

TABLE 16 **Salaries of academics in the French and Flemish Communities in Belgium**
2000 • gross annual salaries in EUR

	French Community		Flemish Community	
Grade	Starting salary	Final salary	Starting salary	Final salary
Assistant	27,815	39,551	29,181	49,383
First assistant	35,244	49,533	36,145	50,655
Assistant professor	41,648	65,801	42,594	66,914
Professor	48,876	74,950	49,871	76,126
Ordinary Full professor	54,823	84,098	55,859	85,338

Sources: ULB, VUB, personnel department.
Calculations: C. Van den Steen (Centre for the Economy of Education, ULB, 2000)

Comparison of *Tables 15* and *16* clearly shows the different evolutions of the two language communities, as well as the exercise of autonomy in the Flemish universities.

As far as intellectual property of researchers is concerned, fairly general information is given in the study by B. Jongbloed, A. Amaral, E. Kasanen and L. Wilkin (2000) carried out for the Association of European Universities and based on 25 member European universities.

Table 17 below gives the results of their sample.

TABLE 17 **Who owns patents?**
based on a survey of 25 European universities • 1999

Owner	Frequency in % of cases
university	24%
faculty/department/individual	32%
researcher	20%
university and department/researcher	24%
university, researcher and contractor	0%
outside contractor	100%

Source: B. Jongbloed, A. Amaral, E. Kasanen and L. Wilkin (2000).

The authors of this survey conclude from this that there is a strong incentive for researchers to market their invention.

Conclusions

The new working conditions for researchers highlight the transformation of the paradigm linking scientific knowledge and social development: the initiation of a globalised world where local competency is essential. The scientist is at the centre of this process, pulled from every direction as much for the explosion of progress in knowledge as for his role in economic growth.

The motivation of researchers is however probably always governed by the satisfaction of the very process of discovery and researchers' work strategies comprise several individual elements which range from intellectual challenge to recognition by peers to the establishment of laboratories and teams work.

Europe is faced with determining a proper research policy which should more include more than simply economic considerations as researchers are also often university teachers. Consequently, universities are faced with new expectations where the enormous increase in student numbers (young and mature) requires reassessment of priority policies to be developed as internal changes in governance have taken place, even though they have not yet been properly constructed. Therefore confrontation between strategies for economic development, institutional changes and personal achievement have not been clearly examined and defined. Several warnings are formulated regarding arbitration between teaching and research activities, including the possibility of maintaining profitable disciplines and those strictly related to knowledge, and lastly to the actual opening-up of science, the very condition of its existence.

The message of this article is clear: it is imperative to add to multidisciplinary research on scientists' motivations and activities. It is also imperative, for Europe as a whole but particularly for Belgium, to assess the financial and human framework demanded by the maintenance and renewal of scientific knowledge and the tasks that accompany it:

its transmission at both the level of high-level training and its effects on the economy and society. This policy demands proper assessment of the physical scientific equipment necessary for research activity as well as proper salaries for researchers and, in particular, for the influx of younger researchers. This policy should be formulated for the long-term and should be forward-looking as far as the realisation of long-term scientific projects are concerned. Assessment of the issues to be accomplished can be made from the conclusions of the last assessment of the European research programme (J. Majo, 2000), another particularly important conclusion of this being the need for a more coherent strategy for research.

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Belgian University Spin-offs in 2000: an economic analysis*

Bernard Surlemont, Hélène Wacquier and Fabrice Pirnay

1. Objective of this contribution

The Belgian public authorities have recently become aware of the objective of developing entrepreneurial dynamism in the university and research environments. They have gradually realised that the activities of the young spin-offs in the high-tech sectors are contributing towards establishing the economic redeployment as well as the image and industrial conversion of our regions. The markets related to these sectors most often present the greatest potential for growth and internationalisation. Nonetheless, it was only very recently – in the second half of the 80s - that we saw the first practical and structured policy directed towards promoting the creation and development of such spin-offs. Although the establishment of the first enterprises of this type actually occurred in the mid-70s, this mostly concerned epiphenomena that were generally developed on the peripheries of the universities, sometimes against their will and frequently to their utter indifference. The tide has now changed and the measures taken to promote the development of spin-offs are really beginning to bear fruit.

This contribution follows on from a study conducted by the SME and Entrepreneurship Research Centre of the University of Liege in 1999. Its main objective was to cast light on the reality of Belgian university spin-offs ad observe possible important developments that could be linked to the recent development of practical policies for promoting entrepreneurship at Belgian universities. The number of university spin-offs has increased considerably since the previous study, especially with the momentum of the actions taken by the public and academic authorities.

The results of our analysis are broken down into two main sections. In the first part (descriptive analysis), we provide a picture of the overall spin-offs surveyed as at 31 December 2000 in terms of the university of origin, the sector of activity and the period of establishment. In the second part (financial analysis), we examine their contribution to the country's economic growth by way of analysing indicators such as the creation of employment, turnover and value added. We also look at their dynamics in R&D terms as well as their will to grow and internationalise. With regard to availability, the financial data used were those as at 31 December 1999.

* Original text in French.

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2. Demarcation of the field and the objectives of this research

2.1 Presentation of the Belgian university context

Belgium has 16 university institutions: 10 French-speaking and 6 Dutch-speaking (Fondation Universitaire, 1999):

• 6 Dutch-speaking institutions:

- Katholieke Universiteit Leuven KUL
- Universiteit Gent RUG
- Universiteit Antwerpen[1] UA
- Vrije Universiteit Brussel VUB
- Limburgs Universiteit Centrum LUC
- Katholieke Universiteit Brussel KUB

TABLE 1 **List of Belgian university institutions**

	Number of students registered as at 01/02/1999 (principal enrolments) [a]			
	Total	Humanities	Sciences	Health sciences
UCL	19,132	10,842	3,227	5,063
ULB	17,108	10,157	3,213	3,738
ULg	12,690	5,929	2,712	4,049
FUNDP	4,128	2,196	944	988
UMH	2,231	1,551	402	278
FUCaM	1,372	1,372	-	-
FUSL	1,300	1,300	-	-
FUSAGx	1,053	-	1,053	-
FPMs	806	-	806	-
FUL	133	-	133	-
Total	59,953	33,347	12,490	14,116
KUL	25,553	14,167	5,885	5,501
RUG	21,635	11,997	5,494	4,144
UA	8,910	5,721	1,418	1,771
VUB	8,707	4,980	2,025	1,702
LUC	2,145	1,259	588	298
KUB	773	773	-	-
Total	67,723	38,897	15,410	13,416

[1] Universiteit Antwerpen is a group comprising three university institutions based in Antwerp, i.e. Universitair Centrum Antwerpen (RUCA), Universitair Centrum Antwerpen (UFSIA) and Universitaire Instelling Antwerpen (UIA).

• 10 French-speaking institutions:

- Université Catholique de Louvain	UCL
- Université Libre de Bruxelles	ULB
- Université de Liège	ULg
- Facultés Universitaires Notre Dame de la Paix in Namur	FUNDP
- Université de Mons-Hainaut	UMH
- Faculté Universitaire Catholique de Mons	FUCaM
- Faculté Universitaire Saint-Louis à Bruxelles	FUSL
- Faculté Universitaire des Sciences Agronomiques de Gembloux	FUSAGx
- Faculté Polytechnique de Mons	FPMs
- Fondation Universitaire Luxembourgeoise	FUL

Table 1 gives a profile of each of the universities listed according to three criteria:

1. the number of students as at 01/02/1999 (divided into threes categories: social sciences, sciences and medical sciences),
2. the number of Ph.D. students as at 01/02/1999 (divided into threes categories: social sciences, sciences and medical sciences) and
3. staff as at 01/02/2000 (divided into threes categories: academic staff, scientific staff and administrative, technical and blue-collar personnel).

Number of Ph.D. students registered as at **01/02/1999** (principal enrolments) [a]				Staff ETP as at **01/02/2000** [b]			
Total	Humanities	Sciences	Health sciences	Total	Academic staff	Permanent scientific staff [c]	Temporary scientific staff [c]
1,294	549	579	166	3,332	612	115	968
1,045	383	557	105	2,750	397	189	874
902	185	508	209	3,033	370	214	1,153
168	13	147	8	769	133	47	281
69	15	54	-	460	68	39	148
5	5	-	-	152	44	8	42
12	12	-	-	145	37	9	41
108	-	108	-	441	32	24	160
61	-	61	-	338	50	24	115
39	-	39	-	86	4	11	32
3,703	1,162	2,053	488	11,506	1,747	680	3,814
1,757	588	928	241	6,113	907	3,016	
1,104	139	800	165	4,636	626	2,029	
616	179	332	105	1,422	363	865	
710	233	355	122	1,964	324	775	
119	18	87	14	1,179	106	204	
2	2	-	-	103	35	29	
4,308	1,159	2,502	647	15,417	2,361	6,918	

a. Source: 1999 annual report from the Fondation Universitaire, Service des Statistiques Universitaires, 193 p.
b. Source: http://www.cref.be/statistiques.htm (accessed 8 May 2001)
http://www.vlir.be/vlir/beheer/personeel/effectief.htm (accessed 8 May 2001)
c. The distinction between "permanent scientific staff " and "temporary scientific staff" is not applicable in the Flemish Community.

This table shows that:

1. The university education programme in the French-speaking Community is more fragmented than that in the Flemish Community to the extent that the 10 French-speaking institutions cater for around 60,000 students while only 6 Dutch-speaking institutions account for almost 68,000 students.
2. The demand for university education is focused very clearly on the humanities, which in terms of registered students account for the majority of study courses in both the French-speaking (55.62%) and the Flemish Community (57.43%).
3. However, this preponderance of the humanities disappears when we consider Ph.D. students. The most popular subjects among this section of the student population are the natural sciences, which account for 55.44% of Ph.D. theses in the French-speaking Community and 58.07% in the Flemish Community. It should be added, however, that the distribution of Ph.D. students amongst subject areas also differs considerably from one institution to the next. Thus, UCL, ULB and KUL display a strong concentration of Ph.D. students in the humanities with figures of 42.43%, 36.65% and 33.47% of their registered students respectively, while RUG and ULg show a greater emphasis on the natural sciences and medical sciences, with only 12.60% and 20.51% of registered Ph.D. students involved in the humanities respectively.
4. With regard to staff, although academic personnel account for around 15% of employees in each of the Communities (expressed in FTE[2]), there is a distinct difference between the other two staff categories. Scientific staff, for example, account for 44.87% of the workforce in the Flemish Community and only 39.06% in the institutions of the French-speaking Community, while administrative, technical and blue-collar staff make up 45.75% of the workforce in the French-speaking Community compared with 39.81% for the Flemish Community.

2.2 Objectives pursued and research topics

Following the summary of Belgian University institutions likely to create enterprises on the basis of results of research conducted there, we will now attempt to cast some light on the reality of spin-offs in Belgium. To be more precise, the objective pursued is to show, using data in the public domain, the contribution of these enterprises to the economic growth of a country and/or the renewal of its economic fabric.

In doing so, we also want to attract the attention of the public and academic authorities to the necessity of implementing practical support policies for the creation of spin-offs, especially through a higher rating of the university tech-transfer offices. In effect, this means filling the hiatus of information that exists between researchers and the public authorities with regard to evaluating the economic potential of university research activities. At the same time, we would like to encourage university researchers to take advantage of the economic potential of their research work. Furthermore, inasmuch as there is evidence of a lack of interest in scientific careers amongst the young in a number of countries, although such careers play an essential role in economic growth, the boost in spin-offs can help reverse this trend by enhancing the attractiveness of scientific careers at a high level (NAVARRE, 1999).

[2] Full Time Equivalent.

In this context, we attempt to relate response elements to questions such as:
- Which are the universities generating the most spin-offs? What is the level of advancement of the different university sites with regard to the creation of spin-offs? Which sectors are the busiest and have the most players?
- Do poles of excellence exist according to the different university sites? Do certain characteristics of the universities have an influence on their tendency to specialise in one sector of activity or another?
- How has the number of spin-off creations developed since the early 80s? How has it developed over the last five years? Can the impact of recent policies to promote entrepreneurship and the creation of university spin-offs be discerned in this development?
- What is the contribution of Belgian University spin-offs to the country's economic growth? What is the turnover generated according to sector and university? Do the spin-offs generate jobs? Do they create value added?
- Do the university spin-offs retain substantial R&D activities? What is their dynamism with regard to growth and internationalisation?

3. Methodology used

3.1 The concept of the university spin-off

A degree of caution has to be exercised with regard to the meaning we attach to the concept of the "university spin-off". It would appear from the work of authors and practitioners that the boundaries of this concept are not consistent or generally agreed on by everyone.
Based on an analysis of the literature dealing with the phenomena of university spin-offs, Pirnay *et al.* (2000) define a university spin-of on the basis of four points:
a. A new enterprise ...
b. ... emanating from a university ...
c. ... with the objective of exploiting knowledge developed there ...
d. ... by means of commercial activities.

a. A new enterprise ...

A university spin-off is a new enterprise with a distinct legal personality, implying in particular that it is not an integral part of the university from which it derives and that it has a certain freedom at this level with regard to choosing the mode of organisation best suited to its needs.

b. ... emanating from a university ...

Any member of the university community is able to create his/her own enterprise emanating from the university, regardless of the position held and the function performed. In this context, a university is understood in the general sense as being an institution that performs teaching, training and research activities (Rogers, 1986; Steffensen *et al.*, 2000), which rules out, in particular, research centres such as IMEC and VIB in the Flemish Community as well as WSL in the French-speaking Community.

c. ... with the objective of exploiting knowledge developed there ...

The creation of a university spin-off subscribes to the logic of a transfer of knowledge from the universities to the enterprises (Matkin, 1990; Harmon *et al.*, 1997; Bozeman, 2000). It represents a particular type of economic valorization of knowledge produced within the universities. Such knowledge is generally based on a particular technology (products and/or processes), but may also be of the nature of expertise or know-how.

d. ... by means of commercial activities

The remit of a university spin-off is to pursue commercial activities based on profitability objectives, which rules out, in particular, the numerous scientific organisations in which the universities participate within the context of their research activities.

In view of there not being any consensus on the definition of the "university spin-off" concept and the result of the creation of spin-offs tending to become a "political" element in the competition engaged in by some universities, we have opted, in order to avoid any controversy, to build our database from the information provided by the university interfaces themselves.

3.2 Inventory of spin-offs and building a database

In order to build a raw database, a written questionnaire was sent to those in charge of the tech-transfer offices of each Belgian university for them to provide a complete list of the spin-offs emanating from their respective institutions. The data were thus obtained directly from all the tech-transfer offices except those for the Limburgs Universitair Centrum, which stem from a database established by the Vlerick School (Ghent) on the enterprises emanating from Flemish universities. In order to only take account of completed operations in our analysis, we excluded spin-offs from our sample, which were created after 31 December 2000. This inventory stage led to the drawing up of a list of **166** spin-offs.

However, certain reservations need to be made in relation to this information base for several reasons.

Firstly, the lists supplied by the interfaces are not homogeneous in terms of their content. Some of them contain all the spin-offs created, including those that are no longer in existence (compulsorily wound up, takeover, liquidation, etc.), while others only show spin-offs still operating. For the sake of coherence and comparability, we have included only those enterprises still operating as at 31 December 2000.

Secondly, the lists provided sometimes contain companies that are evidently not university spin-offs but, rather, institutional legal instruments intended to promote the creation of them and directly controlled by the university authorities (e.g. GESVAL S.A., ULg and SOPARTEC, UCL). As far as possible, we have therefore not included these companies in our database.

Following these corrections, our database comprises **137** spin-offs still operating as at 31 December 2000 and for which we have information concerning the company name, the university of origin, the year of creation and the sector of activity.

We then gathered financial data from INFOBASE, a commercial database accessible via the Internet and containing, in particular, the annual accounts of companies available to the Belgian Central Bank. From these annual accounts, we have included the following financial indicators subject to their availability:
• turnover;
• number of staff (FTE);
• value added;
• VAP (Value Added per Employee);
• intangible assets;
• financial assets.

It should be added that the last annual accounts available in our databases date from 31 December 1999, which excludes all enterprises created in 2000 and some enterprises established during the course of 1999 from the "financial analysis".

3.3 Sectorial grouping

We draw the reader's attention to a methodological specificity relating to the sector of activity in which the spin-offs are involved. The NACE-Bel register, suggested by the databases consulted, does not always reflect the activities performed by the enterprises concerned. While this register provides an extremely detailed account of some activities and traditional industries, it does display deficiencies in describing certain activities involving new technologies or various service operations in a realistic manner.

In an attempt to faithfully reproduce the reality of the situation and for the sake of simplification and readability, we adopted an ad-hoc codification based on combining three types of information relating to the sector: the activity notified by the interfaces, the NACE code and the activity according to the ONSS. This codification assigns each spin-off to one of the following eight categories:
• Sector 1: "Pisciculture, aquaculture, agriculture, horticulture, food sector"
• Sector 2: "Pharmaceutical and medical, biotechnology and genetic engineering industries"

- Sector 3: “Chemical industry”
- Sector 4: “Environment”
- Sector 5: “Manufacture of machinery and equipment, instrumentation”
- Sector 6: “New information and communication technologies “
- Sector 7: “Business and engineering consultancy”
- Sector 8: “Other”

3.4 Use of data

To analyse these data we used a number of techniques originating from the descriptive statistics such as the sequential sorting, cross sorting, the sectorial and geographical mean, as well as the percentile analysis. There are two reasons that support of such a choice: (1) this study is primarily aimed at describing the Belgian situation regarding the creation of university spin-offs and, where applicable, ascertaining any sectorial and/or institutionally interesting contingencies, and (2) the statistical distributions of the data collected are poorly suited to the techniques for analysing sophisticated data (e.g. distinctive analysis) that have an explanatory rather than a descriptive purpose.

The percentile analysis is useful where a statistical distribution is particularly spread out and/or does not correspond to any easily determinable theoretical distribution, which prevents recourse to statistical indicators such as the mean value or the variance for rendering an account of its form and distribution (Hanke and Reitsch, 1994). In our case, an analysis of this type appears justified inasmuch as the data studied extend over a broad range of values. We therefore cite the example of the “employment” and “turnover” variables, which can assume values between 1 and 424 and between k€15 and k€42,734 respectively.

4. Presentation of the main results obtained

In the following sections we present the main results obtained from the analysis of our database. They are set out in two main parts: one devoted to a descriptive analysis, and the other to a financial analysis of Belgian university spin-offs.

4.1 Descriptive analysis

Geographical distribution of spin-offs

As *Figure 1* below shows, 80% of the spin-offs created and which were still in operation on 31 December 2000 emanated from KUL, ULg, RUG and UCL. Of these four universities, KUL has generated by far the most spin-offs, followed by ULg. Also revealed is the relatively low number of spin-offs emanating from the two institutions in the capital (VUB and ULB).

The dynamics of the creation of spin-offs is explained by several factors.

- **Early willingness of the academic authorities to valorize the results of research in economic terms**

KUL and ULg experienced a change of president in '92 and '97 respectively, which greatly influenced the development of a policy favourable to entrepreneurship and the creation of university spin-offs.

- **Availability of a critical mass of resources**

The universities generating the most spin-offs, except ULB perhaps, are also amongst the largest institutions. This means that they benefit from a critical mass of human and material resources that allows them to motivate entrepreneurial careers to a greater extent and generate a larger number of projects.

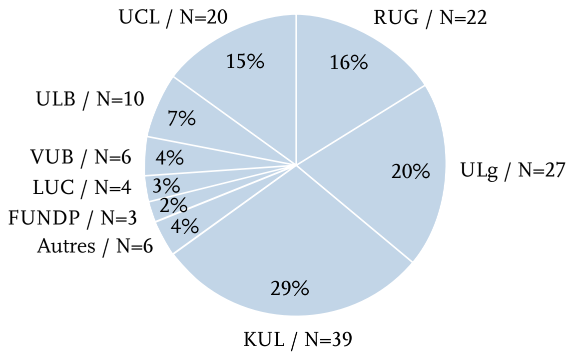
- **Presence of role models**

Each university successful at producing spin-offs has its individual jewels and success stories, which can, through the training effect, give rise to new promising initiatives. Particularly good examples of this are KUL with Ubizen, ULg with Eurogentec, RUG with Innogenetics, as well as UCL with IBA and IRIS.

- **Existence of scientific poles of competence**

A fourth factor that can explain the high number of spin-offs emanating from certain university institutions is the critical mass of (human and material) resources developed by such institutions in particular sectors of activity. Thus, as we will have occasion to show during the course of this report, it would appear that the specialisation of some institutions in one particular scientific domain or another plays a not inconsiderable role in the creation of spin-offs.

FIGURE 1 **Distribution of spin-offs according to university**

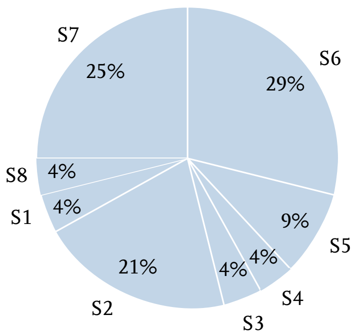


Sectorial distribution of spin-offs

There are three dominant areas of activity, i.e. sectors S6 (NICTs), S7 (enterprise and engineering consultancy) and S2 (pharmaceutical and medical, biotechnology and genetic engineering industries) that alone account for 75% of all spin-offs.

FIGURE 2 **Distribution of spin-offs according to sector of activity**

S1: Pisciculture, aquaculture, agriculture, horticulture, food sector/N=5
S2: Pharmaceutical and medical, biotechnology and genetic engineering industries/N=29
S3: Chemical industry/N=5
S4: Environment/N=5
S5: Manufacture of machinery and equipment/N=12
S6: NICTs/N=41
S7: Business and engineering consultancy/N=34
S8: Others/N=6

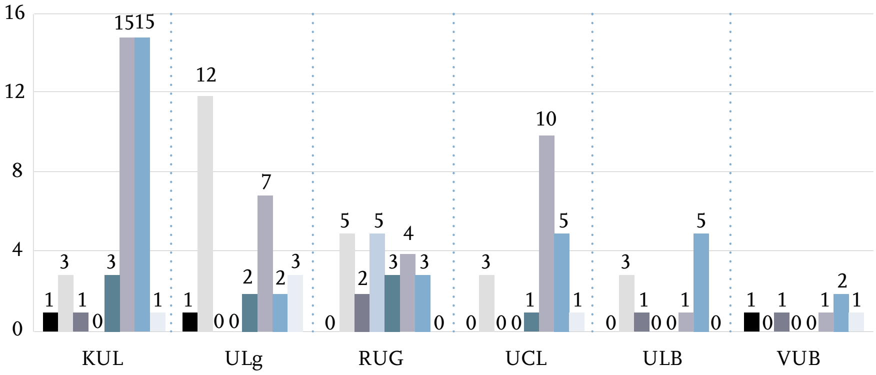


Poles of excellence regarding the creation of spin-offs

Figure 3 below sets out the number of spin-offs according to university and sector. It is intended to show the possible existence of poles of excellence or sectorial specialisations according to university or, simply, a tendency towards creating spin-offs in particular sectors of activity.

- KUL: Sectors S6 and S7 relating to NICT and business and engineering consultancy respectively are those most widely represented. The presence of the IMEC Centre close to the university is not insignificant in this regard. The role model played by Ubizen is also likely to have influenced the number of spin-offs created in the field of NICTs over the past few years.
- ULg: The University of Liege has a pole of excellence in the field of biotechnologies, which appears to be linked both to the presence of Eurogentec as a role model as well as a significant number of researchers working in this domain (it should be noted in this regard that, with 209 students enrolled as at 1 February 1999, ULg has the largest number of Ph.D. students in the life sciences).
- UCL: More than 80% of the spin-offs operate in the fields of NICTs and business consultancy.
- RUG: The spin-offs are split more or less equally between all the sectors without any real evidence of a pole of specialisation.
- ULB and VUB: Half of the spin-offs created at ULB come from the area of business consultancy while VUB does not appear to have any particular predisposition towards one sector or another.

FIGURE 3 **Distribution of spin-offs according to site and sector**



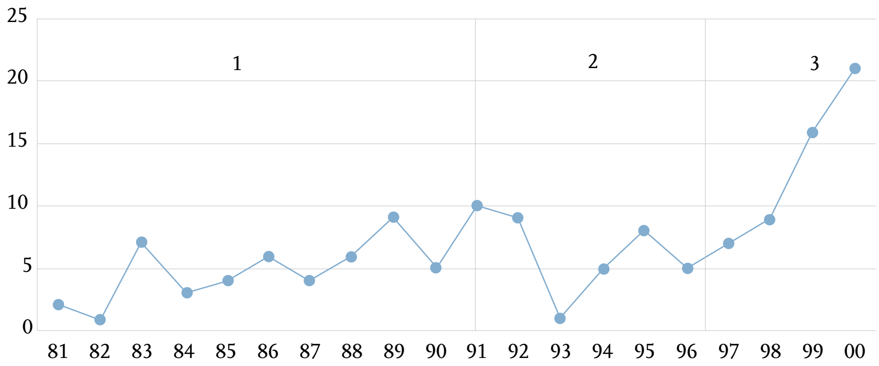
Development of the annual number of creations since the beginning of the 80s

An analysis of the number of spin-offs created per year reveals three periods, one of which goes up to the early 90s and can possibly be described as "amateur". The initiatives concerning the creation of spin-offs were entirely individual and developed on the peripheries, even contrary to the views of the universities. Accompanying measures by the universities were insufficient or even non-existent and the cultural context was not very favourable for supporting entrepreneurial processes. Despite this absence of a favourable institutional framework, the number of creations per annum increased gradually before reaching a peak of 10 in 1991. However, many of these "amateur" spin-offs met with little commercial success or were confronted with substantial financial problems. A second period followed from 1991-1992, which was characterised by a slowing-down or even a decline in spin-off creation initiatives. The year 1993 witnessed one single spin-off, for example. Although there was evidence of a slight recovery from '94, it was 1996 before the annual number of creations began to increase again constantly and 1998 before it climbed back to the same level as 1991. The year 1996 signifies the start of a third period, in which a distinct increase in the number of spin-offs created annually was observed, reaching a figure of 22 for the year 2000. This spectacular growth occurred under the impetus of various factors:

- The professionalisation of the players accompanying the creation of spin-offs;
- Increased willingness on the part of the academic authorities to valorize the results of research by way of the creation of enterprises;
- Current political debates translating the desire of the public authorities to see an increase in the number of university spin-offs as well as the quality of the valorization projects per spin-off;
- The recent interest shown by venture capital companies with regard to universities in general and research results in particular;
- The favourable climate that prevailed in the financial markets in the late 90s, enabling funds to be raised for a whole range of start-ups.

As can be seen below, the graph displays a bias associated with the fact that only the spin-offs still operating on 31 December 2000 are taken into account. The spin-offs that failed or were taken over are not included, which results in an underestimation of around 10% in the number of spin-offs created[3].

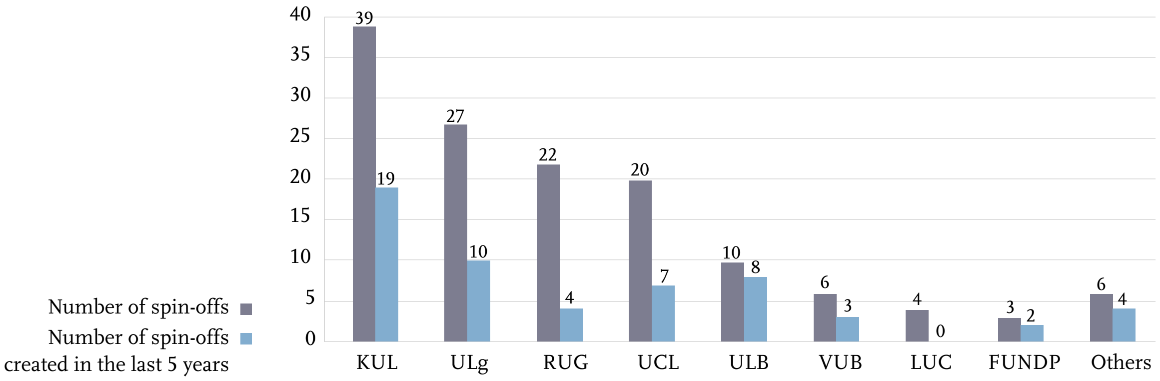
FIGURE 4 **Development of the number of spin-offs created per annum**



Development of the annual number of creations during the last five years

The professionalisation of the entrepreneurial process is particularly evident in *Figure 5*, which sets out the total number of spin-offs created for each university site as well as the number of spin-offs created during the course of the last five years (1996 to 2000). This figure provides an interesting picture of the tide of revival and the proportion of young spin-offs for each site. It does, nevertheless, display a certain bias in favour of recent enterprises, given that the enterprises that failed or were taken over - and are generally older - are not included in the analysis.

FIGURE 5 **Number of spin-offs per university site, with those created in the last 5 years**



[3] NLEMVO F., PIRNAY F., SURLEMONT B. (2000), "Technology transfer from university to industry by spinning-off new firms: An assessment of the Belgian situation", 11th Nordic Conference RENT, Aarhus from 18 to 20 June 2000, p. 21.

• **Regarding the most prolific spin-off institutions**

Apart from being the most prolific creator of spin-offs, KUL is also the institution that has seen the greatest number of creations over the past five years. With 19 of the total of 39 enterprises, almost half were created during that period. Although this proportion is lower for ULg and UCL, it is still actually very high with the number of creations rising to 37% and 35% respectively of the total number of spin-offs emanating from these two institutions. RUG, on the other hand, experienced a decline compared to the other sites with only 18% of new creations occurring between 1996 and 2000.

• **Regarding the other institutions**

There was a spectacular leap in the number of spin-offs created at ULB in the 1996-2000 period with 80% of them created during that period, allowing it to catch up somewhat with the major spin-off universities. There were also indications of the beginning of an entrepreneurial process at universities like FPMs, FUNDP, FUCaM, which had not produced spin-offs up to that time. Finally, it should be noted that, in contrast to the current tendency, LUC has not created any more spin-offs since 1994.

It is also interesting that, from 1996 on, the university institutions of the French-speaking Community created more spin-offs than their counterparts in the Flemish Community (32 as against 26) whereas previously (before 1996) the situation extensively favoured the institutions in the north of the country, with 46 spin-offs created there compared to 33 for the institutions in the southern regions. The origin of this tendency reversal can be found in what can be referred to as a contagious effect among the French-speaking universities and a contraction effect at the Flemish institutions. A more detailed analysis of the figures set out in *Table 2* shows, for example, that the French-speaking Community experienced a real budding of this entrepreneurial phenomenon, with seven university institutions creating one or more spin-offs from 1996 on, while there was evidence in the Flemish Community of a reverse phenomenon of concentration around KUL, which held the undisputed number one position in this domain with the creation of 19 spin-offs (of a total of 26 in Flanders) over the last five years.

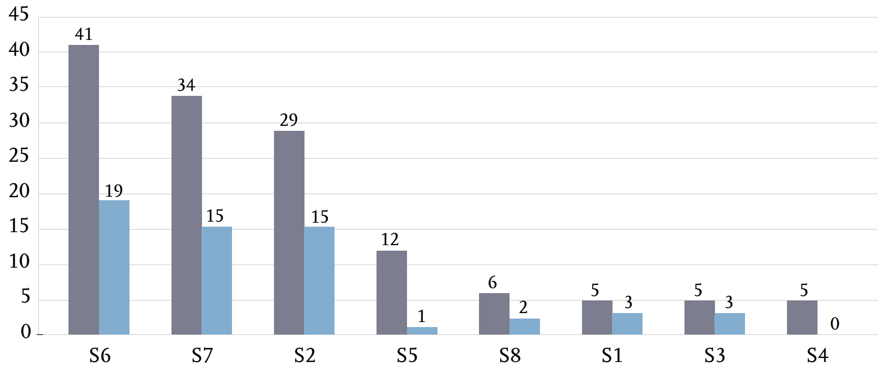
TABLE 2 **Distribution of the number of spin-offs created during the 1996-2000 period and before 1996**

	Total	< 1996	1996-00
University sites			
UCL	20	12	8
ULB	10	2	8
ULg	27	17	10
FUNDP	3	1	2
UMH	–	–	–
FUCaM	1	–	1
FUSL	–	–	–
FUSAGx	2	1	1
FPMs	2	–	2
FUL	–	–	–
Total	65	33	32
KUL	39	20	19
RUG	22	18	4
UA	1	1	–
VUB	6	3	3
LUC	4	4	–
KUB	–	–	–
Total	72	46	26

A similar comparison can be made on the basis of not only the university sites but also the sectors of activity for the purpose of illustrating the principal sectors. *Figure 6* below reveals that the NICT and business consultancy sectors as well as biotechnologies make up a substantial proportion of the new spin-offs created over the past five years, with 43.8%, 45.7% and 50% of new creations during that period respectively. The level of new creations in the fields of NICTs and biotechnology is especially helped by the reduction of the time span between a scientific discovery and its practical industrial applications, thanks in particular to the contributions of the new technologies and informatics. It also benefits from the recognition and extension of intellectual property rights to the universities. Another phenomenon favouring the commercialisation of university knowledge is the financial climate prevailing over the 1997-1999 period and, in particular, the recent establishment of venture capital funds in some strong potential growth sectors like the NICTs and biotechnologies The question that needs to be addressed now, of course, is that regarding the impact of the current reversal of the stock markets (especially in relation to technology enterprises, cf. NASDAQ) on the dynamics of these funds and the likelihood of their financing new technological enterprises.

FIGURE 6 **Number of spin-offs according to sector of activity, with those created in the last 5 years**

S1: Pisciculture, aquaculture, agriculture, horticulture, food sector
S2: Pharmaceutical and medical, biotechnology and genetic engineering industries
S3: Chemical industry
S4: Environment
S5: Manufacture of machinery and equipment
S6: NICTs
S7: Business and engineering consultancy
S8: Others



Finally, *Table 3* below shows the distribution of the number of spin-offs created over the last five years by cross-referring their sector of activity to their university of origin. Previously regarded by the university authorities as being deviant and unsound, entrepreneurial aspirations are now legitimate and positively encouraged by the same authorities, thus creating a climate that is infinitely more propitious to the creation of enterprises at universities. To this end, several Belgian universities have gradually put instruments and structures in place designed to promote and support the creation of new activities from the research conducted there. This progressive involvement of the universities in the process of creating spin-offs allows them to enjoy a certain level of control over the process, i.e. with regard to locating and identifying commercially promising research results (prospecting activity), providing equipment for certain projects to enable them to develop in the best possible physical conditions (incubation activity) and also by investing in the equity of the spin-offs (financing activity). Because they represent the first fruits of this involvement of the universities in the process, the spin-offs created since 1996 can, in some regards, provide us with a number of indications concerning the directions taken by the individual institutions in their deployment policies, especially in the attempt to set themselves up as a “pole of excellence” in a specific field.

The cross-related table shows that of the 19 spin-offs emanating from KUL since 1996, 15 perform their activities in the NICTs (S6) and consultancy (S7), while 6 of the 8 spin-offs created by UCL over the same period operate in these two sectors of activity. These universities thus appear to emerge as poles of excellence in the sectors mentioned inasmuch as they have together created 11 spin-offs in the NICT (of a total of 18) and 10 in the consultancy sector (of a total of 16).

ULg, for its part, would appear to confirm its status of being a pole of excellence in the biotechnology sector (S2), having created 6 new spin-offs of the 14 in this domain. Following ULg, ULB is in second place with the creation of 3 new spin-offs in the sector during the past 5 years.

TABLE 3 **Number of creations according to university and sector in the last 5 years**

	S1	S2	S3	S4	S5	S6	S7	S8	Total
KUL	1	2	1	-	-	7	8	-	19
ULg	-	6	-	-	1	1	1	1	10
ULB	-	3	1	-	-	1	3	-	8
UCL	-	2	-	-	-	5	1	-	8
RUG	-	1	-	-	-	2	1	-	4
VUB	1	-	1	-	-	-	-	1	3
FUNDP	-	1	-	-	-	-	1	-	2
FPMs	-	-	-	-	-	2	-	-	2
FUSAGx	1	-	-	-	-	-	-	-	1
FUCaM	-	-	-	-	-	1	-	-	1
LUC	-	-	-	-	-	-	-	-	0
UA	-	-	-	-	-	-	-	-	0
Total	3	15	3	0	1	19	15	2	58

Inasmuch as the Belgian institutions listed above are full universities (i.e. covering all the disciplines, with the exception of theology and veterinary medicine in some cases), it would be appropriate to ask about the reasons for the emergence of poles of specialisation as well as the uneven development of this phenomenon at Belgian universities. On initial analysis, a combination of facts can be put forward in this regard. Firstly, the existence of role models in each university that would, by emulation, have motivated entrepreneurial careers in a number of specific faculties. This is true for the biotechnology sector at the University of Liege in the case of Eurogentec and for the NICTs at KUL in the case of Ubizen. Secondly, the presence of academic teaching staff in certain faculties who are more open to the entrepreneurial spirit by virtue of having previously prepared their Ph.D. theses in an Anglo-Saxon context more favourable to entrepreneurial ventures. Thirdly, the absence of professional prospects in the private sector for those disillusioned with the university system (personnel that are highly qualified but have been unable to find a permanent research or teaching position at a university). For people in this category, the creation of a spin-off also represents a means of providing themselves with a job. In this regard, the distribution between permanent and non-permanent scientific staff produces an interesting indication concerning the potential of persons likely to envisage such a choice of career at the end of their appointment. Given the low percentage of scientific staff (assistants and researchers) occupying permanent positions (between 10% and 20% according to the institutions concerned)[4], it would appear that the entrepreneurial path can provide a means for many researchers to valorize the knowledge developed during their research activities.

[4] These data are only available for the French-speaking university institutions (see *Table 1*).

Influence of university size on the number of spin-offs created

As we have shown, the number of spin-offs created at a university institution depends on the latter's size inasmuch as this somehow has a determining influence on its potential for economic valorization through the creation of new activities. It is therefore no coincidence that the major universities in this regard include the likes of KUL and RUG in the Flemish Community and ULg, UCL and ULB in the French-speaking Community, which are undoubtedly the largest in terms of enrolled students and staff. Does this mean, however, that the "small" institutions are called upon to play a secondary role and that they perform less well than their "big" sisters do with regard to the creation of spin-offs? To answer this question, we drew up a series of indicators relating the number of spin-offs created to the size of the institutions, the latter being expressed with the help of criteria such as the number of students enrolled, the number of Ph.D. students registered and the number of persons employed (*Table 4*).

It should be noted, however, that these indicators were established in the form of ratios relating the elements to a different time span. While the numerator of these ratios is always formed by the number of spin-offs emanating from a university institution (such number can extend over a period of 20 years in some cases), the denominator of these ratios related to an estimation of the size of such institution assessed at a precise moment in time (1 February 1999 for the number of students registered and 1 February 2000 for the number of staff employed). To interpret the scores obtained by each institution for the different ratios, we opted to compare these with the community ratios calculated by grouping the university institutions of each community.

This table can be regarded at two levels, i.e. an intra-community and an inter-community level.

At the intra-community level, it is clearly shown that ULg and KUL perform best in relative terms with regard to the creation of spin-offs. Looking at the ratio relating the number of spin-offs created to the number of students enrolled for the three largest institutions in the French-speaking Community, we see that ULg's score (0.21%) is twice that of UCL (0.10%) and three times that of ULB (0.06%). Given that the number of students determines the size of universities to a great extent (operating budget, number of teaching staff, etc.) and that these universities have furthermore undergone similar developments in their student numbers over the past ten years, it would be reasonable to assume that this ratio fairly accurately reflects their relative levels of performance with regard to the creation of university spin-offs. It should also be noted that, having regard for their respective sizes, FPMs (Mons) and FUSAGx (Gembloux) likewise display quite appreciable levels of spin-off creations.

Of the four largest institutions in the Flemish Community (KUL, RUG, UA and VUB), KUL unquestionably scores highest in terms of the creation of spin-offs relative to its size. This situation is not surprising given that we have already shown that it alone accounts for more than half the total number of spin-offs created in Flanders and more than three quarters of the spin-offs created over the past five years.

At the inter-community level, there is a generally high degree of similarity between the scores obtained by the two communities. The ratio of the number of spin-offs created to the number of registered students, for example, displays identical values for each of the communities, as well as in relation to the total spin-offs created (0.11%) and the spin-offs created in the last five years (0.04% for the Flemish Community and 0.05% for the French-speaking Community). It should furthermore be noted that the institutions of the French-speaking Community created more spin-offs than their counterparts in the Flemish Community in relation to the number of Ph.D. students, with the exception of the humanities.

TABLE 4 **Ratios linking the creation of spin-offs to the characteristics of Belgian universities**

	# spin-offs		# spin-offs / # Ph. D. students		# spin-offs / # Ph. D. students not incl. humanities		# spin-offs / # students		# spin-offs / # students not incl. humanities		# spin-offs / # staff (acad. + scient.)	
	Total	96-00	Total	96-00	Total	96-00	Total	96-00	Total	96-00	Total	96-00
UCL	20	8	1.55%	0.62%	2.68%	1.07%	0.10%	0.04%	0.24%	0.10%	1.18%	0.47%
ULB	10	8	0.96%	0.77%	1.51%	1.21%	0.06%	0.05%	0.14%	0.12%	0.68%	0.55%
ULg	27	10	2.99%	1.11%	3.77%	1.39%	0.21%	0.08%	0.40%	0.15%	1.55%	0.58%
FUNDP	3	2	1.79%	1.19%	1.94%	1.29%	0.07%	0.05%	0.16%	0.10%	0.65%	0.43%
UMH	0	0	-	-	-	-	-	-	-	-	-	-
FUCaM	1	1	20.00%	20.00%	-	-	0.07%	0.07%	-	-	1.06%	1.06%
FUSL	0	0	-	-	-	-	-	-	-	-	-	-
FUSAGx	2	1	1.85%	0.93%	1.85%	0.93%	0.19%	0.09%	0.19%	0.09%	0.93%	0.46%
FPMs	2	2	3.28%	3.28%	3.28%	3.28%	0.25%	0.25%	0.25%	0.25%	1.06%	1.06%
FUL	0	0	-	-	-	-	-	-	-	-	-	-
Total	65	32	1.76%	0.86%	2.56%	1.26%	0.11%	0.05%	0.24%	0.12%	1.04%	0.51%
KUL	39	19	2.22%	1.08%	3.34%	1.63%	0.15%	0.07%	0.34%	0.17%	0.99%	0.48%
RUG	22	4	1.99%	0.36%	2.28%	0.41%	0.10%	0.02%	0.23%	0.04%	0.83%	0.15%
UA	1	0	0.16%	-	0.23%	-	0.01%	-	0.03%	-	0.08%	-
VUB	6	3	0.85%	0.42%	1.26%	0.63%	0.07%	0.03%	0.16%	0.08%	0.55%	0.27%
LUC	4	0	3.36%	-	3.96%	-	0.19%	-	0.45%	-	1.29%	-
KUB	0	0	-	-	-	-	-	-	-	-	-	-
Total	72	26	1.67%	0.60%	2.29%	0.83%	0.11%	0.04%	0.25%	0.09%	1.15%	0.41%

4.2 Financial analysis

In order to examine the contributions of Belgian university spin-offs to the country's economic growth, we now present an analysis of their situation according to the following indicators: turnover, workforce, value added, value added per employee, intangible assets and financial assets. These analyses are, in general terms, rendered in a two-fold dimension: geographic, i.e. according to university site, as well as according to sector. We also analysed the percentiles with regard to the criteria of turnover, workforce and value added so as to distinguish the sectorial and geographic means obtained according to these three indicators. A number of more precise methodological definitions are required at this juncture.

It should be stated at the outset that our approach is a purely photographic one. It does not include any development or any perspective of a dynamic nature. The last annual accounts available date from 31 December 1999, thus illustrating the situation of the spin-offs as shown on that date. The enterprises created during 1999 and 2000 are therefore not included in the financial analysis.

Furthermore, depending on the size of the enterprises, their annual accounts are sometimes published in full and sometimes in abbreviated form, which gives rise to discrepancies concerning the availability of certain financial data in the annual accounts, especially in relation to turnover, value added and workforce details.

A final precise definition needs to be added with regard to enterprises with multiple subsidiary operations abroad. In order not to unbalance the results, we have only taken the data relating to Belgium into account and not the consolidated data.
A separate paragraph is devoted to the latter (see page 125).

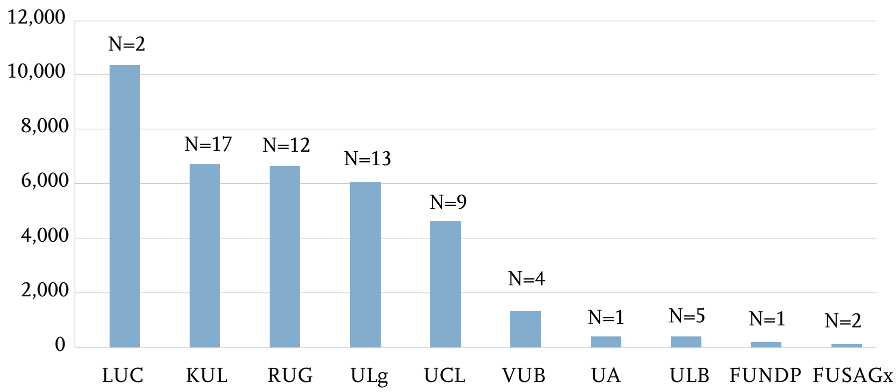
Turnover

Our turnover analysis is based on a total of 66 spin-offs, corresponding to around only half of the enterprises in the population. We do not have the necessary figures for the others at our disposal, either because they were created very recently or because they publish their annual accounts in abbreviated form and do not give details of their turnover.

• **Analyse of geographic and sectorial averages**

Figure 7 below shows that LUC has the highest average turnover at k€10,404. The mean value is based on only two enterprises, however, with Eurogenetics alone achieving a turnover of k€20,285. After this it is the four most prolific spin-off universities that generate the highest average turnovers, headed by KUL with k€6,783 and closely followed by RUG, ULg and, finally, UCL. This situation is explained by the fact that these universities were the forerunners in implementing policies favouring the creation of spin-offs and which generated enterprises that are well established today. The other universities, whose spin-offs were generally created more recently, display much lower average turnovers.

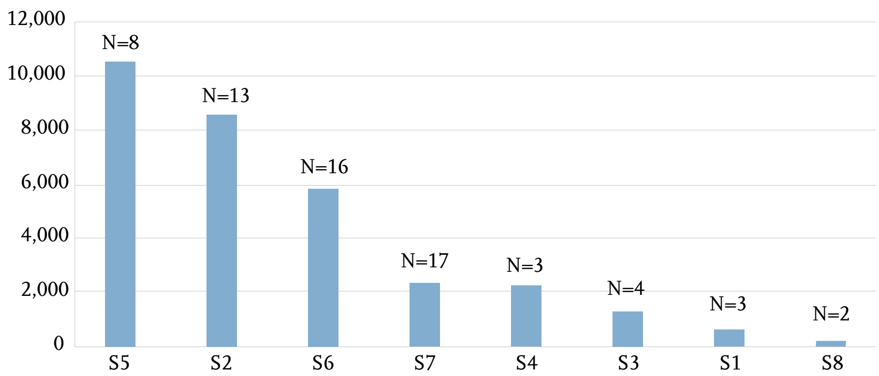
FIGURE 7 **Average turnover of spin-offs according to university** • in kEUR



A look at the distribution of turnover according to sectors of activity reveals that it is the manufacture of machinery and equipment and instrumentation that produces the lion's share with an average of k€10,608. This is followed by biotechnologies (k€8,601) and the NICT sector (k€5,903). Even though the others register lower average turnovers compared with these sectors, they are nonetheless substantial, varying between k€2,378 and k€685.

FIGURE 8 **Average turnover of spin-offs according to sector of activity** • in kEUR

S1: Pisciculture, aquaculture, agriculture, horticulture, food sector
S2: Pharmaceutical and medical, biotechnology and genetic engineering industries
S3: Chemical industry
S4: Environment
S5: Manufacture of machinery and equipment
S6: NICTs
S7: Business and engineering consultancy
S8: Others



• **Descriptive analysis of distribution (effective criteria and values)**

Table 5 relates the distribution of the number of spin-offs to turnover and is intended to describe the form of such distribution by presenting the values associated with the 10%, 25%, 50%, 75% and 90% percentiles. These values form positioning markers, which enable the spin-offs to be grouped into homogeneous categories. Thus, the last column in the table, for example, relates all the spin-offs for which we have relevant data at our disposal to turnover (N = 66). This shows that where the average turnover achieved by a spin-off is over k€5,247, it is still necessary to distinguish this value. In effect, this column reveals that one spin-off in ten achieves a turnover of less than k€100, that one in four has a turnover lower than k€272, that three quarters of the spin-offs generate a turnover under k€5,282, and that the biggest 10% achieve sales levels in excess of k€20,285.

Furthermore, on breaking down the 66 spin-offs according to the three periods previously referred to, the percentile analysis shows – unsurprisingly – that it is the spin-offs created more than ten years ago (period 1) that achieve higher sales levels than their young counterparts. The turnover generated by the 39 spin-offs created before 1991 is between k€16 and k€42,734, with the 18 spin-offs created between 1992 and 1996 generating sales of between k€108 and k€15,745, while the turnover of the 9 spin-offs created recently (after 1996) varied between k€15 and k€951. Furthermore, the distribution of the number of spin-offs tells us that although, within these respective intervals, 75% of the spin-offs created in period 3 achieve a turnover of less than k€260, only 10% of the spin-offs created in period 1 did not reach this level of operations. Given that the spin-offs created during the course of period 3 benefited from a much more favourable context than their predecessors in period 1, there is justifiable hope that the former will rapidly attain a level of activity comparable to, if not higher than that currently displayed by the latter.

TABLE 5 **Percentiles relating to turnover** • in kEUR

	Period 1 1981-1991	Period 2 1992-1996	Period 3 1997-2000	
Turnover				
Percentile (10%)	253.669	127.169	15.345	99.480
Quartile (25%)	1,176.404	158.528	36.564	272.586
Mediane (50%)	3,242.745	522.634	99.480	1,582.998
Quartile (75%)	10,691.995	2,003.302	260.288	5,282.735
Percentile (90%)	27,731.749	3,786.648	3,502.918	20,284.798
Min.	16.435	108.181	15.345	15.345
Max.	42,734.563	15,745.775	951.044	42,784.563
N	39	18	9	66
Sum	305,144.906	39,283.538	1,923.108	346,351.553
Mean	7,824.228	2,182.419	213.679	5,247.751

An examination of the cumulated distribution turnover figures in relation to the number of spin-offs reveals that 80% of these spin-offs (N = 52) generate 25% of the turnover (i.e. k€79,518.318) while the remaining 20% (N = 14) produce 75% of the turnover (i.e. k€266,833.235). Of these 14 enterprises, it should be noted that only one of them was created after 1992 (i.e. UBIZEN, KUL, created in 1995), that the majority of them perform their activities in the sectors associated with biotechnologies (6) and NICTs (5) and that they emanated from KUL (5), RUG (3), ULg (3), UCL (2) and LUC (1).

Creation of employment

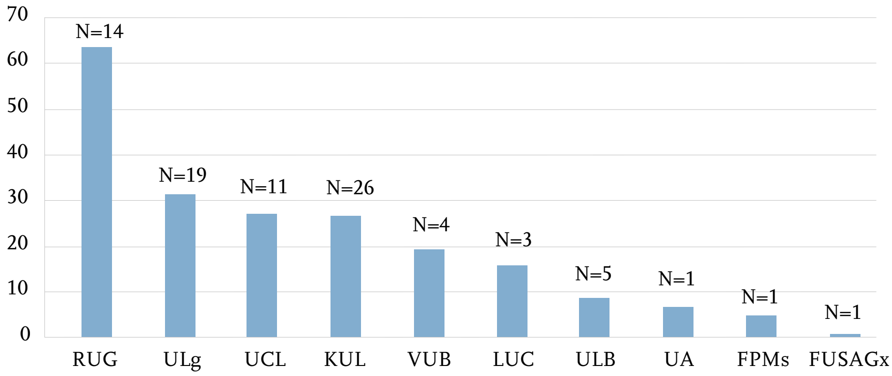
The creation of employment is a criterion for measuring the economic effects of chief interest to the public and political authorities. This capacity can be measured not only by way of the jobs effectively generated by the spin-offs but, rather, also by comparing these figures for each sector of activity. Our analysis is based on a total of 85 spin-offs for which we have personnel data at our disposal.

• Analysis of geographic and sectorial mean values

Figure 9 shows that the four most prolific spin-off institutions head the field in terms of the average number of persons employed. Of these, RUG has by far the highest average with 64 employees. This high figure essentially stems from enterprises like Innogenetics, Aventis Cropscience, as well as Peptisynthia et Cie. It should also be emphasised that the figures presented do not include jobs generated in foreign subsidiary operations.

These four are followed by ULg, UCL and KUL with mean values of 32, 27 and 27 employees per spin-off respectively. These averages are pushed up by, amongst others, Eurogentec, NRB and Spacebel in the case of ULg, by IBA and IRIS in the case of UCL and by Ubizen, LMS International and ICOS Vision system in the case of KUL. These enterprises, which are somewhat older, have experienced substantial growth and are well established in the Belgian University spin-off landscape.

FIGURE 9 **Average number of employees according to spin-offs of the different university sites**

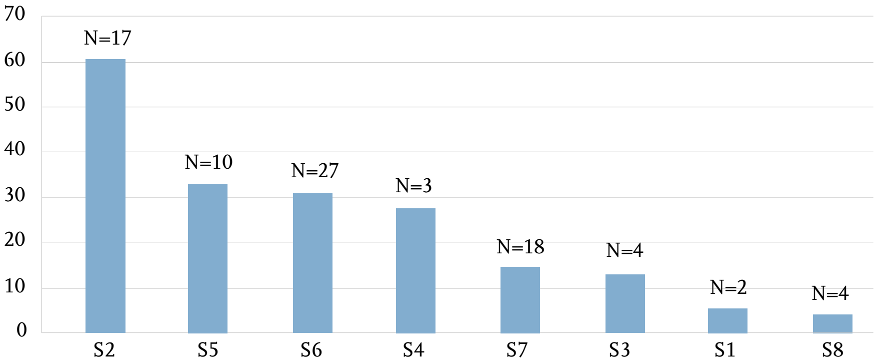


In terms of the sector of activity, the enterprises involved in biotechnologies account for the highest mean number of workers with an average of 61 employees. These are followed by the enterprises operating in the manufacture of machinery and equipment (33), the NICT sector (32) and environmental technologies (28).

The enterprises involved in business consultancy have a much lower mean number of workers, which can be explained by the fact that they are most frequently concerned with the exploitation of "implied" knowledge accumulated by a single researcher in the course of a research project rather than exploiting codified knowledge (research report, computer program, technical object, equipment, etc.), which is much more tangible and associated less with an individual.

FIGURE 10 **Mean number of workers per spin-off according to sector of activity**

S1: Pisciculture, aquaculture, agriculture, horticulture, food sector
S2: Pharmaceutical and medical, biotechnology and genetic engineering industries
S3: Chemical industry
S4: Environment
S5: Manufacture of machinery and equipment
S6: NICTs
S7: Business and engineering consultancy
S8: Others



- **Descriptive analysis of distribution (effective criteria and values)**

Although the average level of employment displays a very respectable score close to 32 persons per spin-off, it must be said that the situation is more contrastive than this mean value leads to believe. The percentile analysis shows that one spin-off in four employs fewer than 4 persons (25% percentile), that one in two have fewer than 9 employees (50% median), that three quarters employ fewer than 26 people (75% percentile) and that only 10% provide employment for more than 92 persons (90% percentile). Furthermore, although the distribution over the three creation periods under consideration unsurprisingly reveals that the spin-offs created in period 1 employ the greatest number of persons (2,174 jobs generated out of a total of 2,697), it also illustrates the particularly pronounced "small boutique" nature of the spin-offs created during period 2. It can be seen that the spin-offs created between 1992 and 1996 have a median (50% percentile) amounting to 3 jobs (which means that 50% of spin-offs created during that period employ a maximum of three persons) while the enterprises created after 1997 display a median value of 4 persons.

TABLE 6 **Percentiles relating to employment**

	Period 1 1981-1991	Period 2 1992-1996	Period 3 1997-2000	
Turnover				
Percentile (10%)	4	1	1	1
Quartile (25%)	8	1	2	4
Mediane (50%)	16	3	4	9
Quartile (75%)	68	12	6	26
Percentile (90%)	133	47	9	92
Min.	1	1	1	1
Max.	424	177	14	424
N	46	22	17	85
Sum	2,174	446	77	2,697
Mean	47.261	20.273	4.529	31.730

An examination of the cumulated distribution of the number of jobs in relation to the number of spin-offs shows that 80% of the spin-offs (N = 67) create 25 % of the employment (i.e. 653 persons) while 20 % of them (N = 18) generate 75 % of the total employment (i.e. 2,014 people). Of these 18 enterprises, only UBIZEN was created after 1992 (which confirms that it is the enterprises created over 10 years ago that provide the most jobs). Furthermore, these 18 spin-offs are divided up on a geographical and sectorial basis as follows:

- institutions: KUL (5), RUG (5), ULg (4), UCL (2), VUB (1) and LUC (1)
- sectors of activity: S2 (5), S3 (1), S4 (1), S5 (2), S6 (8) and S7 (1)

Creation of value added

The economic viability of the spin-offs can be judged by their capacity to creates value added or, in other words, by their contribution to national GDP and, therefore, to the country's economic growth.

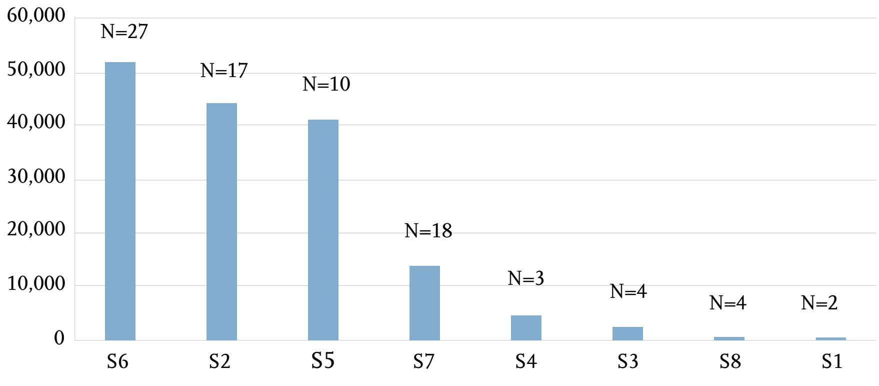
In this section, we first present a comparative table of the global value added generated by the spin-offs according to university and sector. We then look at the mean value added and, finally, at the value added per employee at both these dimensions. These analyses are based on a total of 85 spin-offs for which we have the relevant information.

• Global value added

In 1999, Belgian university spin-offs together generated global value added to the order of k€161,400, or 6.5 billion Belgian francs. Eighty-five percent of this value added is created by three sectors, with the NICT sector producing 31%, biotechnologies 28% and the manufacture of machinery and equipment 26%.

FIGURE 11 **Distribution of global value added according to sector** • in kEUR

S1: Pisciculture, aquaculture, agriculture, horticulture, food sector
S2: Pharmaceutical and medical, biotechnology and genetic engineering industries
S3: Chemical industry
S4: Environment
S5: Manufacture of machinery and equipment
S6: NICTs
S7: Business and engineering consultancy
S8: Others

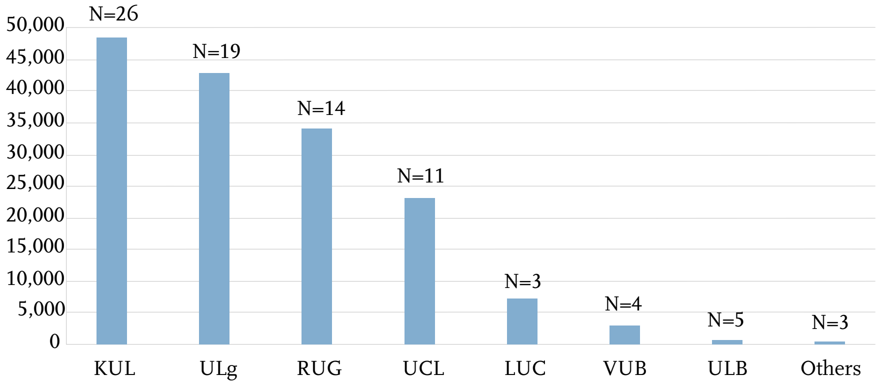


The distribution of global value added according to university is strongly linked to the number of university spin-offs emanating from each of these sites - and on which we base our analysis - as well as to the sectors in which these spin-offs operate.

Not surprisingly, it is those producing the most spin-offs that generate the major share of global value added - not only by virtue of being at the source of the creation of a large number of spin-offs, some of which have already reached a phase of maturity, but also because a not inconsiderable proportion of them operate in high value-added sectors. KUL, in particular, is very active in the field of NICTs, as is ULg in the biotechnology sector.

In the following section, we compare the mean value-added figures according to spin-off, sector and institution, which eliminates the bias linked to the number of spin-offs taken into consideration.

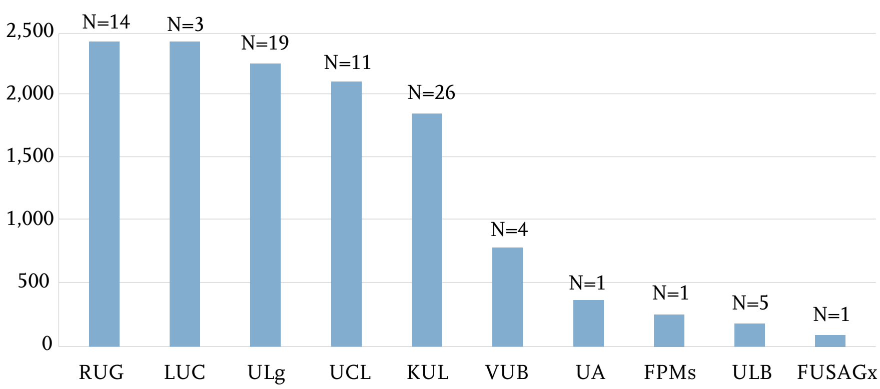
FIGURE 12 **Distribution of value added according to university** • in kEUR



• Mean value added

In 1999, Belgian University spin-offs generated a mean value added of close to k€1,900 or 76.6 million Belgian francs. The sites whose spin-offs generated the highest mean value added include the four prolific spin-off institutions, headed by RUG with a figure of k€2,442, followed by ULg (k€2,270), UCL (k€2,122) and, finally, KUL (k€1,868). We see that LUC appears in the top five with a mean value added of k€2,440, almost equivalent to that of RUG. However, this mean value added is only calculated for three enterprises, of which Innogenetics alone generates a value added of k€7,003.

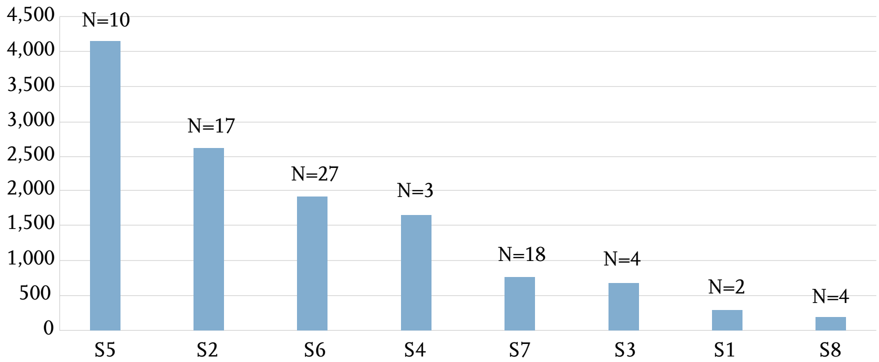
FIGURE 13 **Distribution of mean value added of spin-offs according to university** • in kEUR



In terms of mean value added according to sector, the manufacture of machinery and equipment largely exceeds the others with a figure of k€4,154 calculated on the basis of 10 enterprises. This is followed by the biotechnology sector (k€2,616), NICTs (k€1,930) and environmental technologies (k€1,669).

FIGURE 14 **Distribution of mean value added of spin-offs according to sector** • in kEUR

S1: Pisciculture, aquaculture, agriculture, horticulture, food sector
S2: Pharmaceutical and medical, biotechnology and genetic engineering industries
S3: Chemical industry
S4: Environment
S5: Manufacture of machinery and equipment
S6: NICTs
S7: Business and engineering consultancy
S8: Others



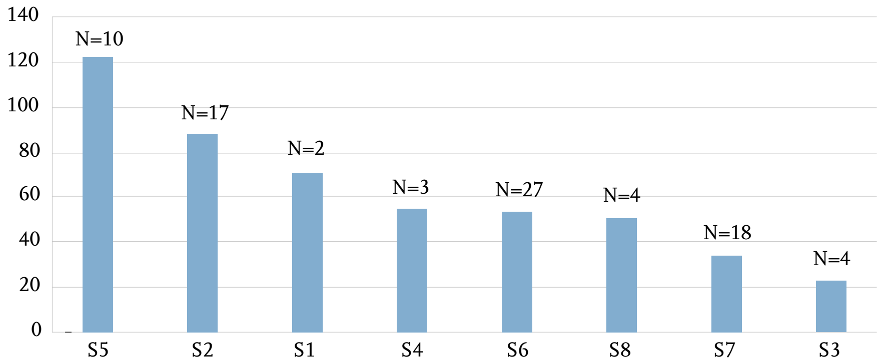
• Mean value added per employee

Because of the diversity inherent in the nature of the sectors of activity, some spin-offs are more or less labour or capital intensive. As limiting the analysis to the total amount of value added can be misleading, it is interesting to examine the value added created per employee (VAE).

The schema for the distribution of VAE does not differ very much from that for mean value added. The machinery and equipment manufacturing sector again heads the list in this respect with a mean VAE of k€123, followed by the biotechnology sector (k€89), while the aquaculture, agriculture and food sector comes in third with a mean VAE of k€72.

FIGURE 15 **Mean value added per employee according to sector of activity** • in kEUR

S1: Pisciculture, aquaculture, agriculture, horticulture, food sector
S2: Pharmaceutical and medical, biotechnology and genetic engineering industries
S3: Chemical industry
S4: Environment
S5: Manufacture of machinery and equipment
S6: NICTs
S7: Business and engineering consultancy
S8: Others



• **Descriptive analysis of distribution (effective criteria and values)**

Although the Belgian University spin-offs generated an average value added of close to k€1,900 , it should be said that in real terms they present a more heterogeneous picture than this mean value would lead to believe. In this regard, the percentile analysis shows that less than one spin-off in four actually reach this mean level of value added (75% quartile) and that this latter quartile is almost exclusively made up of spin-offs created during period 1, which once again confirms that these spin-offs, although created in an unfavourable context, make a more significant contribution towards the country's economic growth. Such a result, though not surprising, has the merit of showing the economic effects that can be expected in the more or less short term on the part of spin-offs created in a much more favourable context propitious to their development.

TABLE 7 **Percentiles relating to value added**

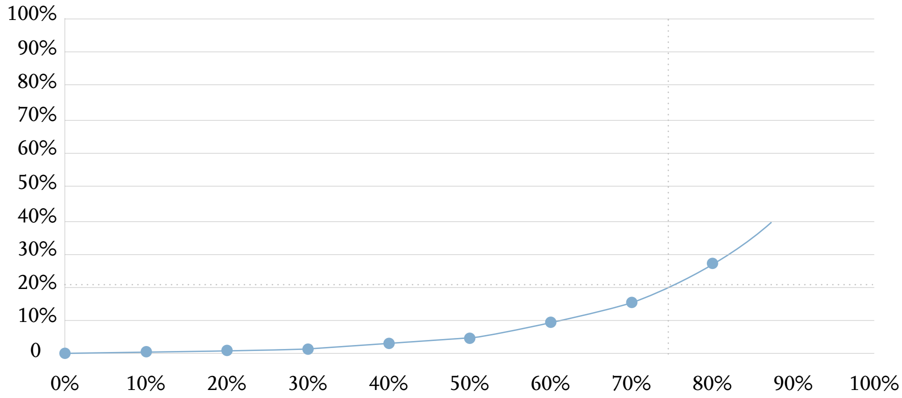
	Period 1 1981-1991	Period 2 1992-1996	Period 3 1997-2000	
Turnover				
Percentile (10%)	150.174	-777.617	-99.852	-37.080
Quartile (25%)	396.857	83.466	-11.006	122.038
Mediane (50%)	1,478.759	187.93	44.720	370.650
Quartile (75%)	3,589.176	370.650	157.065	1,757.615
Percentile (90%)	8,377.636	2,500.452	236.292	6,238.014
Min.	-3,450.936	-2,179.604	-160.833	-3 450.936
Max.	20,026.006	4,652.013	534,111	20,026.006
N	46	22	17	85
Sum	144,694.194	15,340.066	1,395.100	161,429.631
Mean	3,145.526	697.276	82.065	1,899.172

In addition, *Figure 16* presents the cumulated distribution of the creation of value added in relation to the number of spin-offs under consideration. Only those enterprises showing a positive value added have been included in this analysis, which reduces the number to 74 enterprises.

This figure reveals that 75% of the spin-offs (N = 56) generate only 20 % of the total value added (i.e. k€34,304.055), while the remaining 25% (N=18) account for 80% of the total value added (i.e. k€133,961.426).

Of these 18 spin-offs, it emerges that only one was created after 1992 (UBIZEN once again), that they perform their activities in the sectors associated with the NICTs (8) and biotechnologies (5), and that they essentially emanate from KUL (6), ULg (5) and RUG (4).

FIGURE 16 **Cumulated value added in relation to the number of spin-offs**



Total value added = 168,285.481 kEUR
Number of spin-offs under consideration N = 74
75% of the spin)offs (N = 56) create 20% of the value added (corresponding to 34,304.055 kEUR)
25% of the spin)offs (N = 18) create 80% of the value added (corresponding to 133,961.426 kEUR)

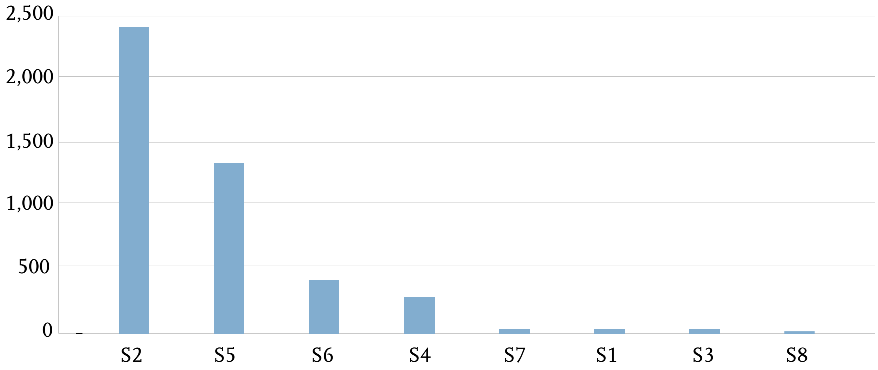
Analysis of the 18 spin-offs :
• Only one was create after 1992 (Ubizen, KUL, create in 1995)
• Geographical distribution: KUL (6), ULg (5), RUG (4), UCL (2) and LUC (1)
• Sectorial distribution: S2 (5), S3 (1), S4 (1), S5 (2), S6 (8) and S7 (1)

Dynamics concerning R&D

In order to gain an idea of the dynamics of Belgian spin-offs in terms of R&D, we collected data from their annual accounts relating to the amount of their intangible assets and calculated sectorial averages. The analysis shows that the biotechnology sector has by far the greatest mean value in terms of intangible assets with an amount of k€2,437, which reveals substantial R&D dynamics. This is followed by the machinery and equipment manufacturing sector (k€1,365) and then by the NICTs and environment technologies (k€432 and k€305 respectively). The spin-offs in these sectors – even though they have detached themselves from the university in order to commercially exploit research results – retain substantial R&D activities as enterprises. The other sectors do not really have intangible assets, which means that the activities of their enterprises do not generally revolve around the exploitation of patents or licences. Activities like business consultancy or the development of computer software are evidently less suited to the lodging of patents by virtue of their intangible nature or being difficult to describe.

FIGURE 17 **Distribution of the mean intangible assets of spin-offs according to sector** • in kEUR

S1: Pisciculture, aquaculture, agriculture, horticulture, food sector
S2: Pharmaceutical and medical, biotechnology and genetic engineering industries
S3: Chemical industry
S4: Environment
S5: Manufacture of machinery and equipment
S6: NICTs
S7: Business and engineering consultancy
S8: Others



Dynamics concerning growth and internationalisation

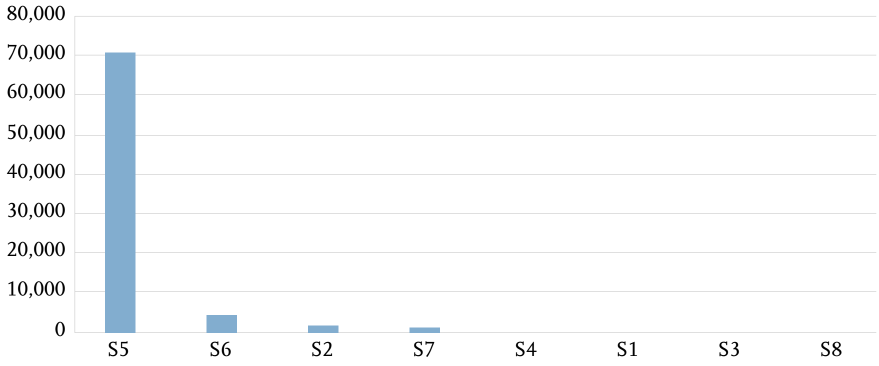
This section attempts to estimate to what extent Belgian university spin-offs have set up operations abroad, either through establishing subsidiaries themselves (internal growth) or by taking over existing companies (external growth). As the fact of developing subsidiaries or taking over or acquiring a substantial holding in other enterprises is generally associated with a desire for growth and/or internationalisation, we collected information on the financial assets of the spin-offs studied as well on the consolidated accounts for a number of them in order to measure their dynamics in this respect.

With regard to financial assets, *Figure 18* below is not particularly lucid insofar as the machinery and equipment manufacturing sector displays disproportionate figures compared with the others. Indeed, the average financial assets for this sector is around 15 times higher than those of the other sectors, amounting to k€71,400. This situation is due to one single enterprise, IBA, whose financial assets amount to no less than k€570,510.

Apart from this sector, the NICTs and biotechnologies appear to be the most dynamic in terms of growth and internationalisation strategy with mean financial assets of k€4,925 and k€2,234 respectively. With a sectorial average of k€1,451, some enterprises in the engineering and business consultancy sectors are also developing a strategy in this area to a lesser degree.

FIGURE 18 **Distribution of the financial assets of spin-offs according to sector** • in kEUR

S1: Pisciculture, aquaculture, agriculture, horticulture, food sector
S2: Pharmaceutical and medical, biotechnology and genetic engineering industries
S3: Chemical industry
S4: Environment
S5: Manufacture of machinery and equipment
S6: NICTs
S7: Business and engineering consultancy
S8: Others



We also attempted to obtain consolidated data on turnover, value added and employment volumes for ten of the largest spin-offs. Following several contacts (telephone, e-mail, etc.), *Table 8* contains an amount of information that we were eventually able to collect. This table shows that the data taken from the annual accounts (non-consolidated data) in some cases reflect the significance of the activities of certain spin-offs to only a very partial extent. Thus, in terms of the creation of jobs, for example, we see very considerable differences for enterprises such as IBA (UCL) and IRIS (UCL). On a non-consolidated basis, these enterprises employ 154 and 55 persons respectively whereas, in consolidated terms, each has a workforce of between 1,150 and 1,200 employees. The same picture emerges in relation to turnover. The consolidated figures for IBA (UCL) and UBIZEN (KUL), for instance, are six and five times higher respectively than the amounts shown in the non-consolidated accounts.

TABLE 8 **Overview of the consolidated accounts: turnover, staff and value added** • in KEUR

	Turnover (kEUR)		Workforce (ETP)		Value added (kEUR)	
	Consolidated	Non- consolid.	Consolidated	Non- consolid.	Consolidated	Non- consolid.
Name of company						
IBA (UCL)	141,647	23,326	1,150	154	n.d.	20,026
Ubizen (KUL)	75,636	15,746	550	177	26,507	4,432
LMS International (KUL)	70,427	27,732	528	133	59,193	8,378
Icos Vision (KUL)	52,534	42,785	n.d.	92	28,911	13,688
Iris (UCL)	42,142	12,374	1,200	55	n.d.	3,467
Innogenetics (RUG)	32,716	13,306	550	424	17,612	-3,451
Eurogentec (ULg)	17,761	13,778	170	134	8,427	6,800
Materialise (KUL)	8,500	n.d.	130	67	n.d	3,589
Samtech (ULg)	6,247	3,579	75	39	n.d	2,780
Frontier Design (KUL)	5,326	3,426	45	25	n.d	1,719
N	10	9	9	10	5	10
Sum	452,936	156,051	4,398	1,300	140,650	61,428

Spin-offs quoted on the stock exchange

The ultimate success dreamed of by many spin-offs is to be listed on the stock exchange. In this regard, it should be noted that although there have been many calls, only very few have been taken up. Only 5 spin-offs (i.e. less than 4%) are currently quoted on the stock exchange with capitalisation of between € 36.8 million and € 655 million. The largest stock exchange capitalisations besides the special case of Aventis Cropscience are IBA, Innogenetics and Ubizen[5].

These enterprises mainly operate in the NICT, biotechnology and equipment sectors and originated at the most prolific spin-off universities. It can be seen in this context that ULg is the only one of the four top institutions to have not (yet) had a listed company among its spin-offs. Finally, all of these companies except one (Ubizen) were created before 1990. These figures show, on the one hand, the importance of being able to identify within budding university activities which of them present real growth potential and are capable of becoming world leaders in niche markets and, on the other hand, of giving these enterprises time to reach a critical size.

TABLE 9 **Information concerning spin-offs quoted on the stock exchange**

Name of company	University of origin	Year created	Sector	Listing	Stock exchange capitalisation (kEUR)	Reference participation
Aventis cropscience	RUG	1982	Biotech	Nasdaq	Integrated in Aventis	Public and petro-chemical res. Hld
IBA s.a.	UCL	1986	Equipment	Euronext	655,055	Public & management
Innogenetics	RUG	1985	Biotech	Easdaq	517,288	Public & management
Ubizen n.v.	KUL	1995	NTIC	Euronext / Easdaq	420,758	Public, Telindus & Concentra BC
Icos Vision Systems n.v.	KUL	1987	Equipment	Easdaq / Nasdaq	165,106	Mainly public
Iris s.a.	UCL	1987	NTIC	Euronext	36,813	Public & KBC securities

[5] Aventis Cropscience is in fact the parent company of Plant Genetic System, which incorporated the Aventis group quoted on the NASDAQ. Only the turnover corresponding to the future ex-spin-off has been included in our figures.

Conclusions

At the end of 2000, university spin-offs accounted for 137 enterprises generating a global value added in excess of k€160,000, or more than 6.5 billion Belgian francs, and employing almost 2,700 people in Belgium.

The spin-off phenomenon, which signalled the start of an "amateur" mode in the 80s, has enjoyed a spectacular surge over the past few years through the momentum provided by practical policies and accompanying measures developed to benefit entrepreneurship at Belgian universities. This development is reflected, in particular, by a substantial rise in the number of spin-offs created during the last five years. The annual number of spin-offs created in 1999 was 17, increasing to 22 in 2000, with the average since the early 80s rising to 6 new creations per year.

A core of four universities heavily involved in the creation of spin-offs emerges from the analysis, i.e. KUL, ULg, UCL and RUG. Together, they account for 80% of the total of 137 spin-offs created, 92% of the value added and 93% of the jobs generated by these spin-offs.

Compared with the previous study carried out in 1999, there is evidence of a spectacular boost in the number of creations engendered by ULB, which is gradually catching up with the more prolific spin-off universities. We can also see the beginning of entrepreneurial dynamism at universities such as FUSAGx, FPMs and FUNDP, which had not previously developed any proactive policy in this area. It is further shown that the universities in the French-speaking Community created more spin-offs than those in the Flemish Community (32 as opposed to 26) during the course of the last five years, representing a substantial reversal of the situation prior to that period. This suggests that the universities in the French-speaking Community are gradually catching up with their Flemish counterparts in this area.

Seventy-five percent of the activities of the spin-offs appear to be concentrated in three dominant sectors: NICTs (29%), business consultancy (25%) and the pharmaceutical and biotechnology industries (21%).

An examination of the distribution of spin-offs according to sector and university site and, in particular, the distribution of enterprises created over the past five years reveals the emergence of poles of excellence according to the university concerned. The tendency to create university spin-offs in one or more particular sectors of activity stems, amongst other things, from each university's individual specialisation, which can be principally measured in terms of the number of Ph.D. students registered in one field or another. It is also explained by the existence of role models within the universities. ULg proves to be the most active in the areas of biotechnology and genetic engineering, UCL and KUL in the NICT and business consultancy sectors, while RUG does not appear to have any real dominance in sectorial terms.

With regard to the contribution made by spin-offs to the country's economic growth, which is generated at the level of turnover, the creation of jobs and producing value added, it can be seen that in overall terms 20% of the enterprises generate 75% of total turnover, employment and value added. These enterprises mainly originated at one of the most prolific spin-off universities, were seldom created recently and operate most of the time in the biotechnology, NICT or machinery and equipment manufacturing sectors.

Besides these enterprises, it should be noted that the majority of spin-offs are micro-enterprises that employ fewer than 10 persons and generate much more modest turnovers and value added. This suggests that the Belgian University landscape comprises a majority of spin-offs in the start-up or development phase, with a lot fewer enterprises having developed to the maturity phase. Patience is therefore needed to allow these enterprises to develop, become stronger and become more firmly established in the Belgian University landscape.

A final interesting aspect concerns the dynamics of spin-offs in R&D terms. Our study shows that the biotechnology, machinery and equipment manufacturing, and NICT sectors have greater average intangible assets than the other sectors. This suggests that the enterprises in these sectors have detached themselves from the university for the purpose of commercially exploiting research results while maintaining, as enterprises, intensive R&D activities. These are the very sectors in which the enterprises display the greatest dynamism and will in relation to growth and internationalisation, with their average financial assets outstripping those of the other sectors.

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R&D and regional development in Belgium: some perspectives*

Rosella Nicolini[1]

Abstract

This study presents a territorial analysis of the distribution of research and development (R&D) activity carried out by Belgian enterprises. On the base of the information included in the *R&D Survey (1998)*, our aim is to locate geographically the firms that invest in research projects in an almost permanent basis. After having established a framework for separating the firms by region and by sector, we proceed to evaluate the sectors in which they tend to localize in very close proximity to each other, both at national and regional level. We also concentrate on how the presence of spatial autocorrelation can affect both the firms' agglomeration process and the intensity of R&D expenditure.

Finally, we comment the results obtained by comparing the Belgian case with other European situations. On the base of the contents of *Second cohesion report*, we also make a number of comments concerning the role of R&D in the European regional development process.

1. Introduction

In the economic literature, the study and dynamics of R&D investments is tackled form different points of view. Due to its nature, R&D activity naturally interacts with other economic and/or institutional players in whatever field in which it is present. The consequence of this permeability is the creation of a stock of knowledge intended for circulation among a more or less bounded group of agents. This phenomenon covers a broad range of topics. We propose not to concentrate on the problems involved by the acquisition of this knowledge, but to focus on the localisation phase of the enterprises that invest in R&D.

* Original text in French.

To get in touch with the author, see page 4.

[1] I am very grateful to Luisito BERTINELLI for working out the indicators of spatial autocorrelation, as well as Claire DUJARDIN, Philippe MONFORT, Henri R. SNEESSENS and Jacques F. THISSE for their advice and comments. My thanks also go to Françoise WAGNER for her meticulous proofreading of this article. All remaining errors, of course, are my own responsibility.

In the economic domain, various studies stress the importance of the location of enterprises that decide to invest in R&D. Proximity to other enterprises engaged in R&D, especially in the same field, or to university research centres is not to insignificant. Authors, such as ANSELIN *et al.* (1997), emphasise precisely the importance of the spatial interaction between the location of enterprises and that of universities. In their contributions, these authors point out that this interaction generates economic spin-offs from the university research via the *spillover* effect. Indeed, *spillovers* appear to play an important role, especially when they support the creation and development of productive activities around university centres. Moreover, in their analyses, they even ascertain a more distinct tendency of small firms to engage in R&D projects, especially in sectors where the competition is not very strong. The results of this study are very much in line with the contents of the contribution offered by Almeida and KOGUT (1997), that focuses on the study of conditions enabling business *start-ups* to achieve rather remarkable results[2]. In fact, these enterprises make the largest profits from their innovative activities when they are located in areas where there are strong interactions with other agents facilitating stable links and generating positive feedback. The patent data used by these authors show that the *start-ups* reveal a greater tendency to join to industrial *networks* compared with bigger firms. The authors give reasons for this behaviour by referring to the lack of resources, which is one of the main features of small firms compared with their larger counterparts. This condition causes them to rely increasingly on external sources of *knowledge*. In their study, they survey an important number of *start-ups* in the Silicon Valley.

On the basis of an econometric analysis of patent data, *start-ups* actually do show a greater tendency to integrate into regional networks. In particular, the positive externalities deriving from their R&D activity are more localized compared with other enterprises. This characteristic is more pronounced among Silicon Valley entrepreneurs, where the setting up of networks is also aimed at including university research centres and even representatives of the organisations or institutions financing the projects. It is thus the diversity of the participants and their flexibility in the performance of their activities that allows them to interact in the best way. This result is in line with the conclusions of SAXENIAN (1994). In the Silicon Valley, it is the flexibility in the management of resources and interaction of the activities undertaken by the different partners of a network that has enabled the creation of new *start-ups*. Moreover, in order to ensure the success of these initiatives, the author points out that the dissemination of a *culture* of communication, collaboration and interaction among all the members of these networks remains essential. Nevertheless, the spatial dimension still plays a very important role in establishing the effects that the interaction among the agents of the same group, pole or agglomeration can engender on the R&D activity of the firms within the selected area.

For this reason, the present study will try to draw a map of the location of Belgian firms (multinational or local) expending funds on R&D on the basis of a spatial approach.

[2] In this respect, the contribution of Henderson *et al.* (1995) on the development of the role of the universities as promoters of research activity (via the analysis of patent data) should be borne in mind. This contribution provides important indications concerning the practical application of the contents of theoretical research itself.

To this end, we make use of the information contained in the *R&D Survey (1998)* database. This will enable us to point out the geographical and sectorial distribution of the firms that invest in R&D in Belgium. This setting will allow us to assess (i) the regional differences in terms of sectorial specialisation concerning R&D investments and (ii) the geographical distribution of firms investing in R&D. Relying on the information available, we will comment these results with a view to assess how the geographical dimension of R&D could help in understanding and detecting the path to ensure a regional development process.

This study is structured as follows. Section 2 briefly examines the innovation system in Belgium, while Section 3 introduces elements helpful in understanding the topics to be dealt with. Section 4 presents the spatial analysis of R&D data with the aim of determining the interaction between the location of firms, the distribution of R&D investments and the regional development. Section 5 inserts the results obtained previously in a European context. We will comment the importance of developing R&D projects at local level on the basis of the last cohesion report drawn up by the European Union. Finally, Section 6 contains a number of remarks and comments from a more general point of view.

2. Innovation in Belgium

In the Belgian economic panorama, the topic of research and development (R&D) assumes a leading role for different reasons. Belgium is well known as a small country with an open economy, i.e. a country that has intense international exchanges. This condition also influences the structure of the national industrial system. The extensive opening-up of international markets coincides with a high intensity of incoming direct investment flows. If we focus on the structure of the Belgian industrial system, we notice a remarkable presence of multinational subsidiaries (Cincera (2000), Veugelers-Cassiman (1999a, 1999b)). Nevertheless, such a huge presence of foreign subsidiaries does have considerable effects on the country. Among the various components affected by this massive presence of multinational companies in Belgium, investments in research and development, as well as innovation (in a broad sense) are the most involved. Although the massive presence of foreign companies may ensure stable links, contacts or collaboration with other foreign partners (or even other subsidiaries of the same corporation), investment in R&D does not always generate spin-offs in the local economies.

Multinational companies dominate a great quota of the innovations carried out in Belgium. As the study of Veugelers-Cassiman (1999a, 1999b) argues, the fact that multinational subsidiaries belong to international industrial groups gives them access to extraterritorial technological sources and strengthens the technological transfer and dissemination process in the local market. However, these authors prove that such companies are less inclined to transfer technology on the local market compared to other local firms with access to international technologies, such as the exporting firms. Although multinationals represent an important means of technological transfer, their mere presence is not sufficient to justify the territorial disparities that exist in Belgium concerning innovation and R&D activities and, in particular, the impact they have at level of regional development.

The Belgian innovation system is widely acknowledged as being a complex one. The authorities concerned share the range of the most relevant competence by way of broad decision-making autonomy. The institutional structure extends over three levels, including the Federal State, the Regions and the Communities. According to the study proposed by Capron *et al.* (2000), the Federal State's areas of competence have gradually been reduced following the *regionalisation* of research and development policies. Most of the funds intended for financing research projects are managed by independent institutions that have been regionalised. In addition, it is the duty of Federal Government officials to define strategic plans on research, which the Local Authorities must refer to on each occasion when drawing up their programmes. The autonomy granted to the Regions and Communities by the Federal State can be easily perceived in the various objectives pursued by the former. While the French-speaking Community mainly concerns itself with funding basic research at the universities, the Flemish Community's principal interest is directed towards the development and dissemination of new technologies (especially biotechnologies). To this end, for instance, the Flemish Community's regional R&D policy aims at forging stable co-operation links between firms. To assist in this endeavour, it supports policies for the creation of firms, with the objective of promoting the dissemination and application of new technologies. Conversely, the Walloon Region, places emphasis on supporting R&D - covering both pure and applied research - that can generate interesting applications in the industrial domain. For example: the Walloon Region assists enterprises (especially SMEs) wishing to develop R&D, principally in co-operation with other European companies. The Brussels-Capital Region, on the other hand, seeks to finance the development of R&D projects that facilitate both pure research and applications. It has also a particular interest in supporting any initiative enabling the setting-up of joint projects that co-ordinate the activities of enterprises and institutes, thus encouraging participation in European programs.

The different orientation of the regional policies has a considerable influence on the different indicators of innovation or research and development. According to the study proposed by Capron and Cincera (1999), in Flanders, greater amounts of funds invested in R&D for new products also generate a higher number of patent applications compared with the other two Belgian regions. Flanders allocates 60% of R&D funds to the research of new products, while the corresponding figure for the Walloon Region is 50%. We can deduce the direction of research funded by each region from the number of patents applied for and according to the sectors concerned. Based on the data available, Flanders appears to specialise more in the manufacture of instruments while the Walloon Region and the Brussels-Capital Region are mainly concerned with the chemical and pharmaceutical industries.

Belgium is not a unique case at European level. The study proposed by Dohse (2000) shows, in the case of Germany, how the regionalisation of R&D policies can lead to interesting results. Relying on direct experience, he succeeds in proving how the joint action of Local Authorities and the Federal Government can produce promising results. The Dohse's study concentrates on the German BIOREGIO project, designed to strengthen the position of German industry in the field of biotechnology, where national firms were lagging a long way behind their main international competitors. The action aimed at making up this ground was carried out jointly by the Federal Government and a group of regions selected to host specialised centres form the development of biotechnologies. Beyond the critical evaluations of the method applied [3], this experience remains important, for it shows how co-ordination between federal and regional policies can facilitate the pursuance of quite high-profile objectives and not be confined to merely managing very general programs.

This project has supported the creation of local agglomerations of firms in the selected regions of the project and it stimulated also the intra-regional co-operation as well as inter-regional competition. Thus, regions become places where new knowledge is developed and local companies can benefit from the level of competencies developed and cumulated in each regional area. This concept of localised appropriation leads to the more general degree of competition among regions and among firms, but also between governments and institutions[4]. Nevertheless, competition among regions, which appears to be at the root of this programme's success such to ensures the incentives to pursue the pre-defined objectives, is connected with the idea of inter-regional immobility of the production factors. If capital or labour force cannot leave from their regions, competition among regions may as well arise with regard to the distribution of available funds that aims at enhancing their marginal productivity and their revenues.

However, facing this evidence, we can also wonder whether the regional size is the optimal spatial dimension to be accounted when planning policies for local development in a country, for instance, like Belgium.

3. Research and development in Belgium: the *R&D survey*

The method of the analysis we apply in this study refers to the approach followed by Wallsten (2001) in analysing the importance of spatial proximity for the firms participating in the SBIR (Small Business Innovation Research) programme in the United States. The results of this contribution show that spatial proximity to other enterprises already participating in the SBIR facilitates the joining of new firms to the same program.

The idea that allows accounting for the spatial dimension in the economic field stems from the awareness that the distribution of firms (inside a pre-defined spatial unit) is not always random in relation to space. There are studies (e.g. Ellison and Glaeser (1997)) which show that the tendency of the firms to concentrate in particular areas is fairly pronounced, even more than it can be expected if considering the geographical distribution of firms as random. Thus, there are strong reasons to believe that the choice of location for a firm is not entirely random. In another contribution that recalls the historical development of the approaches proposed for analysing the relationship between regional disparities and technological choices, Canniëls (1996) underlines the importance of the analysis of spatial units when considering the effects of technological *spillovers* among firms, especially in the case of firms forming *clusters* or networks.

[3] The main criticism addressed at this program is that it only supports development in certain regions and therefore it prevents the same in others.

[4] When allocating public funds, for example, real competitions among regions are organised such to share the available funds as much efficiently as possible.

Starting from the contributions we referred to, it is clear that the spatial dimension is meaningful when we focus on the phenomena of *clusters*. However, one of the biggest problems that frequently has to be addressed is the lack of adequately detailed information for taking into spatial units smaller than the regional or even the national level[5]. To elaborate the statistics of this study, however, we do have enough detailed information at hand that will allow us to go down as far as the *arrondissement* (district) level. The sample of firms available to us displays a clear tendency of the Belgian firms that invest in R&D to polarise, as shown in appendix B. We can therefore state that the distribution of R&D activity in Belgium is not random and, thus, continue our study by considering the spatial dimension as the central element of the analysis. The data that we will use for this study are taken from the results of the *R&D Survey (1998)*. This survey was conducted on a selected sample of Belgian enterprises that invest in R&D on a regular basis, i.e. companies permanently developing R&D activities or which did so during the period under review. The criteria applied for selecting the sample of firms allowed the questionnaire to be sent to a stratified group of Belgian enterprises belonging to the three regions and representing all the categories and types of enterprises that exist in Belgium.

The database at our disposal includes 1,637 Belgian companies and covers the years 1996 and 1997. For each firm, we know the sector of activity (on the basis of the NACE-BEL classification), its location through the postal code[6], its total sales, its size (according to the number of employees) and the amounts of capital invested in R&D. Due to the fact that this information comes from a survey and that the companies were not compelled to answer, the database is not balanced. The information contained in this database does not allow us to conclude whether R&D expenditure undertaken in Belgium leads to innovations in Belgium or abroad.

The concentration of enterprises involved in R&D projects during the years 1996 and 1997 is not evenly spread across Belgium. Breaking down the enterprises included in the database according to district (*arrondissement*) shows that those engaging in R&D are principally located in the east of the country and around the Brussels Region.

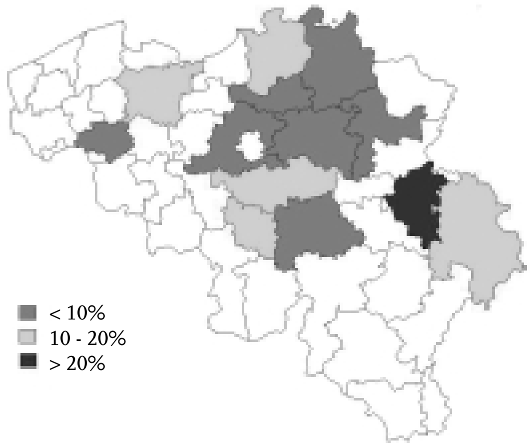
The map we present in *Figure 1* helps to better visualise the spatial distribution of the districts (*arrondissements*) with a high concentration of firms[7].

[5] In the conclusion, we will also tackle the problem of determining a meaningful reference spatial unit, knowing that the spatial definition of region or nation is quite frequently a conventional one.

[6] This means that we did not receive any confidential information that could have allowed us to precisely ascertain the identity of the companies themselves.

[7] This map was drawn using the REGIOMAP software application.

FIGURE 1 **Spatial distribution of districts with a high concentration of R&D companies** • 1996 • EUR
Concentration (in %) of firms by district



Source: R&D Survey (1998).

The districts (*arrondissements*) with a higher concentration of firms investing in R&D are located around the Brussels Region and extend very much towards the east of Belgium. The areas bordering on Germany and the Netherlands attract an important number of the companies in our sample, especially the Walloon Region. By contrast, the border with France (with the exception of the Kortrijk district) does not appear to be selected by a large number of firms investing in R&D. Unfortunately, the data at hand do not allow us to verify whether companies also maintain cross-border collaborations, although the large concentration of in the eastern part of Belgium should not exclude this possibility, especially in the German-speaking area.

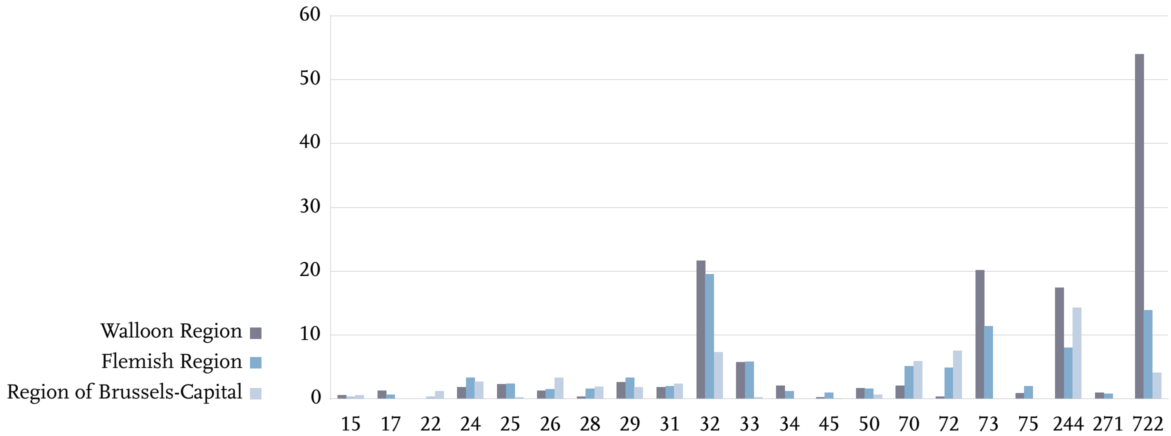
In the Walloon Region, the more dynamic companies are mainly concentrated in five districts (*arrondissements*) (Charleroi, Liege, Namur, Nivelles and Verviers) while in Flanders, the degree of concentration is lower in a limited number of districts. From a strictly spatial point of view, it would appear that the Walloon enterprises developing R&D projects to prefer to be located near universities or French-speaking high or professional schools. In the Walloon Region, most of the selected districts have at least one university centre or para-university, while this feature is less pronounced in Flanders. This helps in showing how universities or, more generally, research centres, are able play the role of technology incubators in the French-speaking area of the country, as it is the case elsewhere in Europe. They seem to act as a considerable magnet for inducing the formation of quite stable collaboration links between the enterprises and such research centres.

Subsequently, we computed a number of general indicators in order to obtain information at sectorial level and comparable across the three Belgian regions. We decided to calculate for each region and each selected sector the average of all the information of all the firms belonging to them. This enabled us to determine the characteristics of a *representative firm* for each sector.

On the basis of the information available to us from the *R&D Survey (1998)*, we can calculate useful indicators representative of each sector, i.e. average R&D expenditure over (average) sales by sector and the average R&D level per employee in each relevant sector. The first statistics allow us to evaluate the importance of R&D expenditure compared with the average profitability of a sector's industrial activity. This indicator also illustrates the role played by the research activity in a given sector of activity. The other indicator concentrates mainly on the intensity of R&D related to each employee and indirectly it reflects the importance that research can have within the productive cycle of each selected sector. Although these two indicators appear similar, they are not totally equivalent. In some sectors, although the sums invested in R&D may not be significant in terms of total sales, they can be quite important when compared with the size of the enterprises themselves. We have calculated these indicators for 1996, taking into account the selected sectors for each Belgian region[8]. The results are presented in the graphics in *Figures 2* and *3* (for the sector legend, see *appendix A*).

On the base of the quota of the R&D expenditure over sales, firms in the Walloon Region invested the most (compared with firms in the other regions) in the communication equipment manufacturing, pharmaceutical and software sectors. In contrast, the investments in Flanders are mainly directed towards traditional sectors.

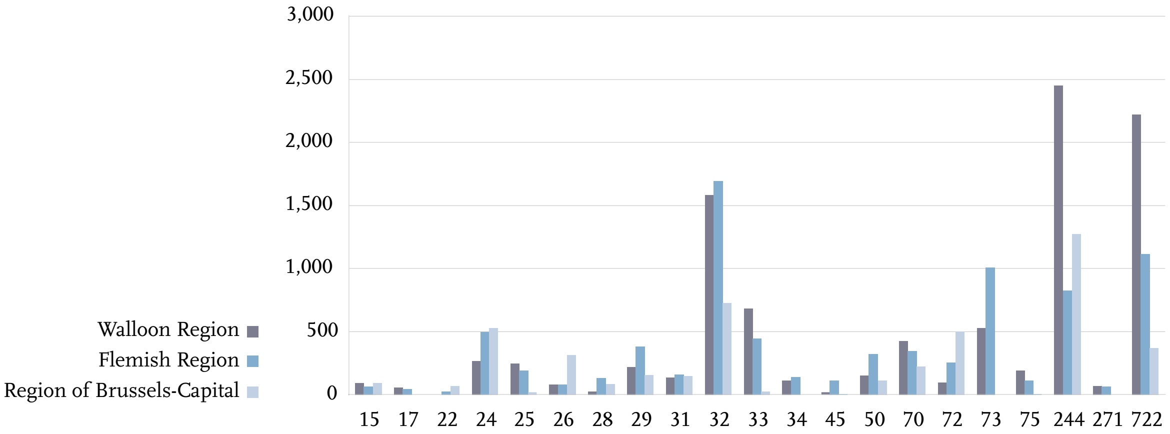
FIGURE 2 **R&D over sales** • 1996 • EUR



Source: R&D Survey (1998), Calculations: Author.

[8] For 1996 we have a more complete range of information on the firms of the sample.

FIGURE 3 **R&D per employee** • 1996 • EUR



Source: R&D Survey (1998), Calculations: Author.

If we consider the level of investment per employee, the difference between the sums invested in the above-mentioned sectors and the other sectors are less striking, though they do remain the same as the differences already pointed out in terms of the rate of investment. The second figure shows that although the sums invested in R&D represent a marginal proportion of sales in the chemical and general manufacturing sectors, the sums invested *per* employee confirms to be substantial. A comparison of the graphics in *Figures 2* and *3* reveals that if we want to point out the most performing regional firms by sector of activity, we then have to look very carefully at the indicator taken into consideration. Indeed, there are sectors for which the gap widens when moving from the level of R&D expenditure in terms of sales to the level of investment per employee, even to the extent of reversing the order of classification. If we concentrate, for instance, on telecommunications and radio equipment manufacturing (32) or even the real estate sector (70), we realise that the amounts of R&D expenditure as a share of sales are greater for the Walloon firms compared with their Flemish counterparts, while the reverse is true when viewed according to the number of employees. In order to give an interpretation of these results, we can hypothesise that the Flemish companies invest in R&D at a level equivalent (or comparable) to that of the Walloon firms (on average and for each of the sectors referred to above). In this context, the results of the first indicator allow us to conclude that, on average, the level of sales of the Flemish companies (for the sectors selected) is substantially higher than that for their Walloon counterparts. Furthermore, if we apply the same hypothesis to the second indicator, we can deduce that the Flemish enterprises (on average and for the selected sectors) are smaller than those in the Walloon Region are[9].

[9] According to the indicators taken into account, the firms located in the Brussels-Capital Region invest more in a small number of industrial sectors (e.g. computer construction and the production of non-metallic mineral products), but they are ahead of the others in the service sector. This Region is particularly involved in R&D for the real estate management sectors.

In any case, there is a clear predominance of R&D expenditure on the part of the Walloon enterprises in the pharmaceutical industry (244) and the development of software (722) when considered in relation to both types of indicators.

Some explanations for this behaviour can be found in the results of the study carried out jointly by the Bureau du Plan, KUL and UCL (2000). This study focuses on the effects of delocalisation in Belgium and above all on the consequences resulting from the movement of the firms. It shows that the most innovative firms score better in relation to employment growth, but the spillovers stemming from these innovations (within Belgium) are limited since these multinationals belong to international networks that enable them to transfer the activities from one country to another. The study also demonstrates the *young and small firms* (national and multinational) experience a higher employment and productivity growth resulting from investments in new technologies or other innovations. By simulating the cycle of life of Belgian firms, they get a reduction in the creation of added value from the 14^{th} year of life onwards for non-innovating achieve the highest level of added value from the 20^{th} year onwards, while those exporting more than 50% of their production reach this level from the 26^{th} year of activity. In order to quantify this effect over the period 1990-1996, the study calculated that the firms that combine innovations of product and process experienced an additional growth rate of 5.1% of added value and 2% of employment.

By applying the results of this study to the regional cases of interest to us, we can map out a more complete picture of the identity of the Walloon companies investing most in R&D. The firms in the sectors concerned (telecommunications, R&D and software development) are probably very young companies and also small (on average), especially in the case of the last two sectors. Their tendency to spend large amounts on R&D aims at accelerating the cumulating process of resources and innovations in order to reach the highest level of added value as quickly as possible.

Furthermore, the analysis referred to above also reveals a positive correlation between the level of training of the labour force and the likelihood of a company realising combined innovation of product and process. Moreover, and still relying on this analysis, the most innovative firms in Belgium are also those that experience substantial employment growth. Within the context of this study, we have also tested this result in order to evaluate if the correlation between the growth rate of the firm's size and R&D expenditure (for the selected periods, i.e. 1996 and 1997) is the same. We calculated the variation of the average number of employees and the variation of R&D expenditure for each sector of activity in each region. The correlations obtained are reproduced in *Table 1* below.

TABLE 1 **Correlation between variation in employment and R&D expenditure**

	Correlation
Region of Brussels-Capital	0.17
Flemish Region	0.45
Walloon Region	-0.23

Source: R&D Survey (1998), Calculations: Author.

The correlations that exist between variation in employment and R&D expenditure are quite weak. However, although the growth in size increases the research effort for enterprises in Flanders and Brussels (above all in Flanders), the reverse is true for the Walloon Region, where investment in R&D is stimulated by a reduction in company size. This would therefore confirm the results of the report drawn up by the Bureau du Plan, KUL and UCL as well as support the interpretation we have put forward regarding the remarkable propensity to invest in R&D in some sectors of the Walloon Region.

These results once again confirm the lack of uniformity in the industrial structure and dynamics of the Belgian regions. Policies that support R&D support as a means of fostering competitiveness must firstly account for the territorial features and the industrial structure of each Belgian region. The regional peculiarities should be emphasised and used to support development projects. Following on from the results obtained, policies supporting the creation and investment in R&D for SMEs could reveal very useful for redressing the Walloon economy. Conversely, policies addressed to large companies appear to be more efficient in the Region of Brussels-Capital.

4. R&D and spatial autocorrelation

For a number of years now, there has been a growing interest in integrating the spatial dimension into economic studies, especially within the context of international and regional economic research. Since the early 90s, this spatial dimension has become more and more important for economists. The application of a few ideas stemming from the spatial dimension makes it possible to propose new kinds of approach for tackling problems in economics that have already been identified but which were difficult to formalise. For instance, there has been an open debate on the reasons behind the location choices at firm level and, in particular, on the selection of location sites in order to explain the uneven development of territorial entities (Wallsten, 2001).

Since the 90s, the economic literature contains a number of contributions aimed at measuring the geographic concentration of independent production units in a satisfactory manner. Interacting with other firms and taking advantage of spillovers are the main arguments put forward to explain the tendency of firms to agglomerate. Spatial econometrics, which is a tool intended to provide spatial dependence with an empirical content, plays the major role in this respect. Indeed, it enables the development of procedures that, in turn, make it possible to quantify the clustering phenomenon. Thus, the *spatial autocorrelation* concept facilitates the carrying out of empirical studies for testing the independence (or not) of territorially based observations. We speak of *positive spatial autocorrelation* when we witness a geographical regrouping of similar observations or, in other words, when neighbouring sites appear more similar than remote ones.

Without getting lost in technical details, we can state that spatial autocorrelation measures the degree to which an attribute in a given location depends on the attributes of neighbouring locations (Le Gallo, 2000 and Le Gallo *et al.*, 2000). One of the sources of this interdependence is the *interaction* between two places which takes place by the circulation of goods and people, by communication or by externalities by which an economic agent reacts to the actions of other agents.

4.1 MORAN index

A certain number of indicators have been developed to measure spatial autocorrelation. They differ from each other depending on whether they aim at analysing the existence of spatial autocorrelation from a general point of view or more locally. Among the various indicators put forward, we focus on the *Moran index* (MORAN, 1950) for analysing the spatial autocorrelation of R&D expenditure per sector at the Belgian level, while the same analysis is carried out at the regional level with the help of *LISA*, i.e. local indicators derived from the Moran global index.

The Moran index compares the value of a selected variable (in a predetermined geographical place) with that of all the other variables for all the other sites[10]. It is similar to the standard correlation coefficient since it compares (two by two) the reciprocal product of two values (of the examined variable) for two different locations. Usually, the closer the values for these two sites, the higher their product will be. We observe the presence of positive spatial autocorrelation when the Moran index is greater than the expected value of the Moran statistic that is inversely proportional to the dimension of the sample.

However, the computation of this indicator needs to choose the way to account for the spatial distance between the observations (via the definition of a weighting matrix, which is included in the formula of the index) and the functional form of the statistical distribution of errors. Concerning the weighting matrix, we have chosen two definitions of weighting for the distance (d): the inverse of the geodesic distance[11] and the squared inverse of the same. Although this choice is, in effect, arbitrary, these two measures are at the same time the most intuitive and the most commonly used.
For the function of distribution of observations, we consider two possible specifications. The first consists in not imposing any predetermined functions but, rather, evaluating a functional form generated by the software itself by permuting all the available observations for all the locations taken into account and by calculating the average and the variance as the *moments* of this distribution[12]. The second functional specification entails transforming the Moran statistic into a centred and reduced form that asymptotically follows a Gaussian function.

Table 2 below is taken from the BERTINELLI-NICOLINI (2001) study and adopts a number of Moran indicators for the sampling of selected Belgian companies.

In elaborating these indicators, we wanted to avoid the distortions due to the differences in *size* of the observations and districts. In this regard, we replaced the raw R&D expenditure data per sector and district with the *density* variable of R&D expenditure, i.e. the ratio between the amount of expenditure of all the companies in one sector and one district (arrondissement) and the area of the district itself.

[10] In this study, we will consider, for each sector of activity, the R&D expenditure of a company with those of all the other firms in the same sector of activity in the 43 selected districts.

[11] The geodesic distance is the shortest distance between two points when these points are measured in a system of spherical coordinates (latitude, longitude). It is equivalent to the Euclidean distance if we measure it on a plane, while if we measure it on a sphere, it is a large circular arc.

[12] This distribution was calculated by considering 10000 possible permutations of the observations.

TABLE 2 **MORAN index**

NACE -BEL		Moran statistic: random distribution				Moran statistic: normal distribution			
		Weight: (1/d)		Weight: $(1/d^2)$		Weight: (1/d)		Weight: $(1/d^2)$	
		R&D96	R&D97	R&D96	R&D97	R&D96	R&D97	R&D96	R&D97
15	Manufacture of foodstuffs, alcohol and tobacco	-0.029	-0.027	-0.041**	-0.040*	-0.029	-0.027	-0.041	-0.040
17	Production of textiles, clothing, leathers and shoes	0.028**	0.005**	0.075**	0.014	0.028**	0.005	0.075*	0.014
22	Paper and paper board industry, publishing	-0.016**	-0.030**	0.013***	-0.039**	-0.016	-0.030	0.013	-0.039
24	Chemical industry	-0.022	-0.012	-0.028	-0.010	-0.022	-0.012	-0.028	-0.010
25	Manufacturing of rubber and plastic products	-0.033	-0.018	-0.035	-0.029	-0.033	-0.018	-0.035	-0.029
26	Production of other non-metallic mineral products	-0.026	-0.026	-0.023	-0.022	-0.026	-0.026	-0.023	-0.022
28	Metallurgy and manufacture of metal products	0.021***	-0.028	0.143***	-0.031	0.021*	-0.028	0.143***	-0.031
29	Manufacture of machines and equipment tools	-0.040	-0.035	-0.091*	-0.060	-0.040	-0.035	-0.091	-0.060
31	Manufacture of electrical and electronic equipment	-0.025	-0.025	-0.033	-0.035	-0.025	-0.025	-0.033	-0.035
32	Manufacture of radio, television and communication tools	-0.027	-0.029	-0.047	-0.047	-0.027	-0.029	-0.047	-0.047
33	Manufacture of medical, precision, optical, clock and watch instruments	-0.021	-0.020	-0.014	-0.012	-0.021	-0.020	-0.014	-0.012
34	Manufacture of means of transport	-0.017	-0.030	-0.007	-0.039	-0.017	-0.030	-0.007	-0.039
45	Construction	0.043**	0.023**	0.187***	0.111**	0.043***	0.023*	0.187***	0.111**
50	Commerce of means of transport	-0.022	-0.028	-0.023	-0.037	-0.022	-0.028	-0.023	-0.037
70	Real estate industry	-0.018*	-0.020	0.007***	-0.0003***	-0.018	-0.020	0.007	-0.0002
72	Computer and data processing industry	-0.004***	-0.027	0.056***	-0.037*	-0.004	-0.028	0.056	-0.037
73	Research and development (services)	-0.030*	-0.028	-0.038**	-0.035*	-0.030	-0.028	-0.038	-0.035
75	Public administration and Social services	-0.028	-0.027	-0.044	-0.038	-0.028	-0.027	-0.044	-0.038
244	Pharmaceutical industry	-0.009	-0.012	0.006	0.0005	-0.009	-0.012	0.006	0.0005
271	Iron industry (CECA)	-0.045***	-0.024	-0.067**	-0.033	-0.045	-0.024	-0.067	-0.033
722	Software industry	-0.040	-0.033	-0.055	-0.041	-0.040	-0.033	-0.055	-0.041

NOTE: Statistical significance: *** 1%, ** 5%, * 10%.
Legend: (d): Geodesic distance between two districts.
Source: BERTINELLI and NICOLINI, 2001.

Generally, the rules for evaluating whether the indicators included in the table are statistically significant demands that the value displayed for each of them (per sector and analysis class) exceeds the average of the Moran statistic (*E (I)*)[13].

Based on these results, R&D expenditure appears to be spatially autocorrelated for the textile, paper and printing sectors, the manufacture of metallic products, building, real-estate activities and computing activities. The spatial autocorrelation result is quite strong for the sectors referred to above since it results to be independent of the chosen specification. Autocorrelation may exist for other sectors (e.g. the paper and printing sector, i.e. sector 22) though it is heavily dependent on the hypothesis concerning the extent of the distance taken in consideration in the weight matrix of the index.

Although the degree of statistical significance is rather variable, the hypothesis that spatial proximity to other companies investing in R&D plays an important role in the investment decision for each company is valid for the selected sectors.

In Belgium, it is the service sector that is the most affected by these dynamics, above all the computer industry.

The tendency towards concentration that we have just established relates to the whole of Belgium. However, it could also be ascertained that, at the regional level, other companies or other sectors also show a propensity to aggregate locally.

In order to develop this second track of the analysis, we have recourse to other indicators of spatial autocorrelation that evaluate the phenomenon more precisely from a local point of view. These are the LISA indicators, which are described briefly in the following section.

4.2 LISA indicators

The LISA (*Local Indicators of Spatial Association)* are spatial indicators that concentrate on the analysis of local spatial autocorrelation. They were developed by Anselin (1995)[14] and their objective is to detect the tendency towards spatial concentration at local level. The statistical structure of the LISA indicators is quite similar to that of the Moran indicator. Proceeding from the hypothesis of a random distribution of observations, the LISA aim at testing the existence of a local concentration of activities through the comparison of the value of a spatially localised observation with the values of the other observations around it. For this reason, the LISA indicators provide information on the degree of local spatial concentration and the sum total of all the LISA indicators (for all the observations) is proportional to the value of the corresponding Moran index. From this point of view, the LISA may also provide information other than the tendency towards local spatial concentration. In the case where differences in the extent of spatial autocorrelation arise, the LISA may indicate cases of local instability, i.e. the LISA may detect the existence of abnormal observations ("*outliers*") compared with the global extent of spatial autocorrelation.

[13] For the cases we have dealt with, this average corresponds, approximately, to *E (I)=-0.024.*

[14] We refer to this contribution for all technical information concerning the LISA.

However, on the one hand if the LISA make it possible to detect the existence of spatial concentrations of statistically significant observations, on the other hand, these indicators are not able to provide more information about the configuration of these concentrations, i.e. about the type of spatial relation that exists between an observation and those around it.

In order to obtain this second kind of information, which is important for analysing the spatial distribution of R&D activity in Belgium at the local level, we must have recourse to another type of indicator, i.e. the *Moran Scatterplot*. Although this indicator does not provide any information about the statistical value of the spatial association, it does makes it possible to draw, graphically, the distribution in space of the relation between a vector of observations (in this case, concerning R&D expenditure) and the spatially weighted mean of all the other observations. By referring to the four quadrants of the Cartesian space, this procedure makes it possible to detect four different configurations of spatial associations between an observation in a region (or a spatially localised spot) and its neighbourhood.

In the context of this analysis, the observations taken into account are the firms' amounts of R&D expenditure. When we face a region that has a strong concentration of R&D activity and other regions showing the same feature surround it, we find in the first Cartesian quadrant. This configuration is indicated as HH, while the symmetrical case (i.e. the case of a region with low R&D activity surrounded by other regions with equally low R&D activity) is defined as LL. There are also two other cases that identify an asymmetry between the region we examine and those around it. In the case of a region with strong R&D activity, which is not the case for the surrounding regions, this region places itself in the 4th quadrant and the configuration is identified as HL. Conversely, when we consider a region with a low level of R&D activity surrounded by regions with strong R&D activity, we are in the 2nd quadrant of the Cartesian space (configuration LH).

In the statistical study of the spatial distribution of R&D in Belgium at regional level (and, therefore, the analysis of local concentration of R&D activities for each selected sector), the definition method of LISA was applied to detect the statistically significant R&D spatial agglomerations (by sector). We evaluated the R&D expenditure per sector and district and then subsequently aggregated per region the results obtained per district.

For technical reasons, we evaluated the LISA using the centred and reduced Moran statistic, alternatively considering the inverse of the distance and the inverse of the squared distance as weight (for the weight matrix). These two different measures of distance enabled us to test (at the local level) how the spatial configuration of R&D distribution can change by giving a lower weight to more distant districts (where we considered the inverse of the squared distance). Once these concentrations were detected, we evaluated them in comparison with the configurations proposed by the Moran Scatterplot indicators and obtained the results set out in the following table (for the sector legend, see appendix A)[15]:

[15] Even in this case, we rely on the *density* variable of R&D expenditure for establishing the indicators.

TABLE 3 **Local spatial concentration of R&D activity in Belgium**

Weight: (1/d)						Weight: ($1/d^2$)								
HL			HH			HL			HH			LH		
B	F	W	B	F	W	B	F	W	B	F	W	B	F	W
15	244	25	**45**	**17**		**15**	244	25	**45**	**17**	244		31	
22	722	33				26	722	33		**45**			**73**	
24		34				31		34						
26						32								
31						50								
32														
50														
72														
73														

Note: B: Brussels-Capital Region; F: Flemish Region; W: Walloon Region.
Legend: (d): Geodesic distance between two districts.
Source: Bertinelli and Nicolini, 2001.

In the Belgian case, we have only three statistically significant configurations. The data at hand allow us to completely exclude the case of one (or more) districts with low R&D activity (within a sector) surrounded by other sectors with a low level of involvement in R&D activity.

When we assign the same weight to the districts closest to the district under examination and those furthest away, we detect only two possible configurations: HL and HH[16].

In the first case (HL), we are in front of sectors – for districts of the same region – in relation to which the externalities that may result from R&D activity are very localised. This means that we obtain a more uneven structure of R&D concentration at the sectorial level, while in the case of a HH structure, externalities circulate better through space, thus resulting in a more uniform structure.

The results given in *Table 3* show a strong regional specialisation in R&D activity, especially in the Brussels-Capital Region. Nonetheless, we can deduce from this that the productive specialisation of the industrial structure differs from one region to another. In fact, the concentration of R&D activity is only one of the possible results emerging from the dynamism of firms set in each region. The results presented in *Table 3* show that the statistical indicators of local spatial autocorrelation are very sensitive to the weight that is applied. The less significance of the districts more distant from that we take into consideration makes it possible to isolate a more diversified number of R&D poles per sector of activity and region. This result allows us to conclude that by lessening the influence of the most distant localities, we can focus better on

[16] According to the local concentration indices, it could be observed that the same sector may appear, for a single region, in more than one configuration. This can be explained by the fact that these indicators were developed from data collected at the district level. This means, therefore, that there may be districts within the same region with a greater concentration of R&D activity than others as well as other districts characterised by a more uniform distribution of R&D activity.

the local territorial reality and thus detect concentrations of companies that invest in R&D with a strictly local orientation and importance[17].

A comparison of the results of the two sections of *Table 3* reveals that the regional specialisations we detected are quite strong. Almost all the concentrations of firms that invest in R&D in the Belgian regions and display an HL type of spatial structure maintain this structure regardless of the weight used, especially in the case of the Walloon and Flemish Regions. The orientations are clear. The Brussels-Capital Region contains poles of investors in R&D in the traditional sectors of the economy as well as in the services. In contrast, the Walloon Region has poles of enterprises that invest in R&D only in the traditional sectors. Furthermore, if we consider the commerce of means of transports (for Brussels-Capital) and the computer and data processing sector (for Flanders), the configuration we detected is highly concentrated, even when using a weight more oriented towards the local dimension of the agglomerations.

Finally, if we compare the results obtained with the global Moran index and the local indicators, we can establish to what extent each region contributes in a more incisive way to the formation of the global spatial autocorrelation indicator for each of the sectors under examination. In *Table 3*, we have pointed out (in bold type) the sectors for which the global Moran index is statistically significant. This result is in keeping with the previous comments. Flanders reveals a relatively substantial concentration, both at local and national level, of enterprises engaging in R&D in the textile and construction sectors[18], while Brussels-Capital shows a strong concentration of companies investing in R&D in the printing and publishing industries, though also in computer and data processing industry and even R&D itself. On the other hand, the sectorial poles of R&D activity in the Walloon area do not seem to produce any great impact on a national scale.

The results of this second analysis confirm the ideas put forward in the previous sections of the study. There is a regional fragmentation of R&D activity in Belgium, which is reflected by the dynamism of enterprises differing from one region to another. The policies adopted to support R&D should, above all else, respect the local reality and the environment at which they are addressed.

5. R&D expenditure within the European Union

In the "Second cohesion report" (2001) by the European Commission, R&D is regarded as one of the fundamental elements at the root of regional economic growth. According to this report, (average) R&D expenditure in Europe over the past few years represents only 1.8% of GDP, while the corresponding figure for the United States and Japan is 2.8% and 2.9% respectively. Based on the sums currently spent on R&D by the central regions of the European Union (which are also the best performing regions in economic terms), we can develop some very useful indicators. The central regions of Europe

[17] This method of analysis does not allow us to give indications of the *border effects*. In order to analyse this issue, the same type of analysis should be applied to the foreign regions that share at least one border with the Belgian regions, and the results collected combined with those for the Belgian regions.

[18] See the right-hand section of *Table 3*, in the HH configuration.

(comprising the triangle *North Yorkshire* - United Kingdom -, *Franche-Comté* - France -, and *Hamburg* - Germany) account for 14% of EU territory, 30% of the population and contribute 47% of the European Union's GDP. Furthermore, R&D expenditure in 1997 represented 2.1% of GDP in these regions compared with 0.9 in the peripheral regions. According to the cohesion report, research and development deserve particular attention, because:

> *(...) The structure of production costs of enterprises has developed a great deal over the past years: the proportion of fixed research and development costs is rising constantly while transport cost continues to fall. As R&D tends, like other strategic activities with a high level of value added, to be concentrated in central regions (...) this development could accelerate the metropolisation of the European economy and the concentration of activities with low added value in the peripheral regions.*
> (extract from the Second cohesion report, 2001, page 30).

The challenges raised by R&D expenditure are substantial, entailing consequences that not only concern the competitiveness of a sector in any region, but which could also have an impact on the formulation of regional development strategies.

Growth can therefore stem not only from an increase in fixed capital stock, but also from the technical progress that enhances the efficiency with which the capital is used. In addition, the revolution of information systems means that the investments made in technological progress will become more and more significant.

Although competitive and less competitive firms do coexist in each region, all of them are subject to the effects of common factors, such as material and immaterial infrastructures, the qualification of labour force as well as an institutional and cultural atmosphere favourable to innovation[19]. In particular, the presence of highly competitive firms in a region tends to stimulate other firms and encourage them to invest more. One of the reasons for the significant delay in economic development in the less prosperous regions of the European Union is the concentration of activities with low added value or of companies with a level of productivity inferior to the European average, generated by a weak dynamics in the search for opportunities to test and adopt new technologies. However, the capacity of regional economies to face competition and adapt to the technical progress is linked with their innovative capacity.

Based on the conclusions of the European summit in Lisbon, numerous measures for promoting R&D at regional level have been implemented, aimed in particular at supporting the needs of companies and the environment. A new way of tackling the problem has been conceived: innovation is no longer merely a linear process proceeding from pure research to commercialisation. Innovation is the result of the active interaction of several players, including companies (especially SMEs) and the environment to which they belong. Furthermore, given that SMEs must frequently have recourse to external

[19] A study on the ratio between competitiveness, labour qualification and investment in R&D was carried out for Belgium (Sneessens *et al.* (1999)). On the basis of econometric estimations for the Belgian regions, the level of R&D expenditure over production appears to be an important and statistically significant component for explaining the extent of international competitiveness of a sample of regional sectors.

collaboration in the R&D process (by virtue of the constraints of the resources at their disposal), the management of enterprise networks or other forms of concentration must be linked to the innovation process. Innovation is no longer strictly linked to traditional institutional players such as universities, research centres or the competent authorities, but rather also to the way SME networks are managed. In this new perspective, it is important to promote an entrepreneurial culture of collaboration, communication and co-ordination at different levels like that developed at Silicon Valley, for instance. This new form of partnership between companies and institutions could also help in creating a sense of mutual trust and belonging to a group of local activity or even regional activity among the economic players (e.g. entrepreneurs).

Based on the data available in the *Second cohesion report,* the distribution of innovation capacity between the regions within the European Union reflects the structure of the national scientific and technological systems and other differences at national level may widen the gap (e.g. staff training levels, and even the rate of qualified personnel in relation to non-qualified workers). A high level of R&D intensity at the regional level stems from good interaction between the scientific sector and the firms with the help of a strong institutional environment. When we look at the less privileged regions, we see that this environment does not exist. The absence of a sector providing services to companies, the lack of a developed financial system, and a weak public sector that does not support R&D or innovation do nothing to stimulate dynamism on the part of the companies concerned.

In view of these interactions, the European Union intends to develop a series of policies over the coming years aimed at supporting the creation of knowledge networks at both local and regional level. Furthermore, based on the results of current bilateral or multilateral collaboration at regional level (e.g. that linked to initiatives organised by the Association of the Regions “Four motors for Europe”), the European union plans to set up more co-operation programs to strengthen regional R&D capacities by also facilitating specialisation in direct actions or complementary projects. This action should also encourage the creation of a *European research space* with the participation of large number of regions. There are five major areas that should be targeted by the Community interventions associated with the creation of this research space, i.e. the development of research activity, innovation and SMEs, as well as infrastructures, human resources and the relationship between science, society and citizens. These goals should not be pursued to the detriment of the general coherence of European co-operation in science and technology, of the international dimension of the on-going projects and of the regional aspects. Compared with the previous programmes, this one is not only aimed at strengthening the fields of science and technology, it also encourages the dissemination of *knowledge* and the capacity for absorption through more selective transmission of information to the participants. This means paying considerable attention to communication between partners and the training of human resources. The aim of this is to support research activity in the European Union as well as provide a positive contribution towards reducing regional disparities.

Although innovation, research and development do help to support competitiveness, these activities are also seen as instruments to be applied in the context of cohesion policies. A recent study (Clarysse-Muldur, 2001) proposes to investigate on the relation between regional technology systems and regional development levels within the

European Union with the help of empirical methods. The data concerning the European regions reveal a tendency of the regions themselves to group in *clusters* in which all regions (belonging to one of them) display the same level of economic and technological development. Based on the development of their R&D and innovation policies and the results stemming from these policies, each region may move from one group to another. Furthermore, the authors show that a process of economic and technological convergence also exists for these clusters or clubs[20]. In the long term, we can see all the present groups progressively converging[21] towards three large clusters (*leading club*, *middle club* and *lagging club*), that will form a structure with a stable equilibrium at three different levels of development.

In this context, the policies sustained by the European Union result to be twofold. They should help to stimulate the development and application of new technologies in each region (especially those lagging behind the European average) as well as promote the dissemination of technology among the regions in an attempt to reduce existing disparities and encourage the convergence of the technology clubs referred to above.

However, the analysis presented for Belgium in the preceding sections reveals the existence of agglomerations of firms engaging in R&D at a more local than regional level. Thus, there are poles of activities that exist within the regions themselves and which also concern several sectors. The territorial reality therefore demands that a great deal of attention is paid to the manner in which policies for encouraging R&D are managed. Furthermore, we have to be on our guard to ensure the validity and efficiency of the implementation of these policies, which are often conceived on a regional scale, for example. The case we have been dealing with here demands very considerable caution. We have established that substantial structural differences (concerning R&D activity) may exist within a single region. We should, however, consider the optimum dimension of the spatial entities that should be the target of different policies aimed at supporting R&D. The *regional* space often corresponds more to an *artificial* distribution of the territory, which does not always take account the economic structure of the territory itself. It often the case that quite similar industrial structures are detected in cross-border or even trans-regional zones. In this context, it could be useful to consider policies or implementing programs that do not necessarily apply to a single region (seen as a geopolitical territorial entity) but, rather, to territorial entities displaying homogeneous economic structures. There are already a number of examples of this at the level of the European regions, such as the actions carried out by the Communauté de Travail des Alpes Occidentales, which brings together a number of French and Italian regions and Swiss cantons on the basis of territorial similarity and a cross-border geographical location[22], or the URBAN program of the European Union for the sustained development of towns and districts in critical situations. This would inevitably lead to the conception of intervention programs not only for a

[20] The authors have defined six main clusters to which the European regions belong by combining the possible different values of the economic and technologic indicators. The categories of selected clusters are as follows (classified in descending order in relation to the values of the established indicators): the *industrial leaders, clampers-on, low growers, economic catchers-up, technological catchers-up and lagged behind.*

[21] By following the development of a number of indicators of the economic and technology level on a regional basis.

[22] It is important to remind also that the main objective of the *Interreg III* program (supported by the FEDER of the European Union) is to strengthen economic and social cohesion by promoting both inter-regional and cross-border co-operation.

specific *region*, but also for territorial entities displaying the same type of economic specialisation (and structure). The inevitable consequence of this approach would demand a review of the role as well as the distribution of powers and competencies relating to economic intervention shared by the different authorities at national, regional or local level. From this point of view, it is, of course essential to define the criteria for ensuring the coherence and compatibility of the policies implemented at the decentralised level.

Conclusions

The results we obtained from the information included in the *R&D Survey (1998)* indicate to what extent the spatial dimension is essential for a complete analysis of the phenomena concerning decisions to invest in R&D. In the case of Belgium, there is a strict correlation at firm level between the tendency to concentrate territorially and the amounts these companies invest in R&D. This behaviour is observed principally in those sectors with a higher technological content, but also in services and new technologies.

It has already been noted in other studies (Sneessens *et al.* (1999), Capron (2000)) that the phenomenon of spatial agglomeration must not be neglected and, in particular, that it must be pointed out as a means of stimulating the dynamism of enterprises.

One of the factors that could rather easily support companies in this process is the creation of networks of firms in which each member can benefit from the positive externalities resulting from direct and permanent interaction with the other companies in the same group. However, the efficient functioning and meaningful performance of company networks go hand in hand with the role played by local institutions, as well as the infrastructures, the environment and all the other players concerned. As argued by Capron (2000), there are different elements that have to be taken into consideration when evaluating the effects of the co-ordination of any activity performed by firms, such as, for instance, R&D. Rules must be established for the correct transmission of information, with the principal purpose to sharing knowledge and other forms of interaction for learning. In this context, the natural role of the institutions and Local Authorities (at regional level in the case of Belgium, for example) should be to fill up the deficiencies that arise due to the decentralisation of a market system. Furthermore, in an approach that would consider more selective forms of intervention and be directed towards territorial entities with economically homogeneous characteristics (as proposed at the end of the previous section), the task of the national or Federal Authorities should assume an even more significant dimension. In fact, in the case of policies comprising a pronounced local component, the efficiency of the interventions is linked to the capacity for detecting the optimum size of the territorial entities, often ignoring the regional dimension itself. Under these hypotheses, there is a tangible risk of creating power gaps or conflicts due to the institutional distribution of competencies among the Local Authorities. The most natural solution for escaping from such situations would be to charge the Central Authorities to fill these gaps by making them responsible for the management and co-ordination of such interventions.

Solving these structural deficiencies in the organisation of productive activity could also be envisaged through a more efficient management of the available resources not only at regional level but also at a more local level. The experience of other European regions (e.g. a number of Italian regions, the Comunidad Valenciana, Wales) (Cooke and Morgan, 1998) could provide examples on on how local enterprise networks can assist in new local start-ups and support a sustainable development process. The Flanders initiative to support the agglomeration process of firms in networks with the creation of technological innovation cells on a provincial basis (to help the companies develop their innovation strategies) is a policy that is consistent with the considerations previously expressed. The same view could be expressed with regard to the latest policies approved by the Walloon Region to foster innovation, the only regret being that these policies were not started sooner. That is particularly the case with the "Prométhée"[23] project, which is intended to improve recognition of innovation potential in the Walloon Region. Based on an analysis of the resources available in the region (technologies, scientific and industrial structures), the aim of this project is to encourage synergies between companies in order to organise networks suitable to solve the needs of firms so as to stimulate their innovation capacities. Its efficiency will be all the more important if the main priorities of intervention are targeted towards those sectors with greater regional development potential, such as the biotechnology and the testing for new materials.

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[23] According to information displayed on the website http://mrw.wallonie.be/dgtre/.

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Appendix A

The selected companies belong are following sectors classified according to the NACE-BEL nomenclature, whose codes are specified in the following table.

TABLE 4 **NACE-BEL nomenclature of activities**

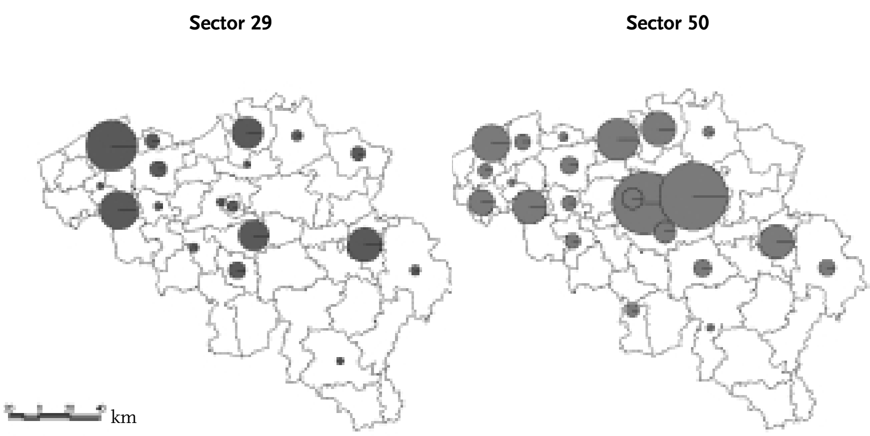
NACE BEL Classification	
2-digits	
15	Manufacture of foodstuff, alcohol, tobacco
17	Production of textile, clothing, leathers and shoes
22	Paper and paper board industry, publishing and printing house
24	Chemical industry
25	Manufacturing of rubber and plastic industry
26	Production of other non-metallic mineral products
28	Metallurgy and manufacture of metal products
29	Manufacture of machinery and equipment tools
31	Manufacture of electrical and electronic equipment and instruments
32	Manufacture of radio, television and communication tools
33	Manufacture of medical, precision, optical, clock and watch instruments
34	Manufacture of means of transport
45	Construction
50	Commerce of means of transports
70	Real estate industry
72	Computer and data processing industry
73	Research and development (services)
75	Public administration and Social services
3-digits	
244	Pharmaceutical industry
271	Iron industry (CECA)
722	Software industry

Appendix B

The phenomenon of spatial autocorrelation is crucial in the analysis of R&D in Belgium. The data included in the *R&D Survey (1998)* make it possible to evaluate whether the spatial dimension influences the investment decisions. In particular, the possible existence of positive spatial autocorrelation for R&D expenditure (selected according to sector and considering the spatial entities at district level) could mean that a firm may have a tendency to invest capital in R&D according to the R&D investment of the companies around it. Furthermore, if we focus on the analysis of spatial concentration according to region, the existence of spatial autocorrelation could help in understanding whether and how location in a district can affect the R&D investment decisions of the companies that base themselves there. The *regional* variable therefore becomes an essential factor in defining the choice of companies' investments.

The analysis of the distribution and intensity of R&D expenditure shows that spatial autocorrelation is significant for a few sectors, but not for all. The two examples presented in *Figure 4* provide a better understanding of this phenomenon. R&D expenditure in the machinery and instrument manufacturing sector (29) in 1997 shows a level of concentration lower than that for the commerce of means of transport (50) in the same year. Consequently, the latter sector should present a positive degree of spatial autocorrelation compared to the former.

FIGURE 4 **R&D distribution In Belgium: a few sectorial examples** • 1997



Source: R&D Survey (1998), Calculations: Bertinelli and Nicolini (2001).

The regional structure of R&D expenditure in the Belgian enterprise sector*

André Spithoven and Peter Teirlinck[1]

1. Introduction

Volume I of this report, presented the Belgian performance relating to innovation, science and technology in a European context. A European context, however, does not imply that one should neglect the impact of regional or even local factors that come into play when considering the development of R&D activities.

In this empirical contribution we intend to describe regional R&D expenditure in the business sector in a more systematic way. It was pointed out in *volume I* of the report that responsibility for R&D in Belgium is confined to the Flemish Region, the Walloon Region and the Brussels Capital Region. In the case of R&D, we find important differences between these three Belgian regions when comparing the ratio of business R&D expenditure to gross regional product (for 1998: Brussels Capital Region: 0.99%, Flanders: 1.52% and Wallonia: 1.23%)[2]. At the end of this contribution, it should be clear to the reader that the differences between these three Belgian regions do not give a complete indication of the real potential of each region. In contrast with most (inter)national empirical literature, we will focus on a lower spatial level. This more detailed approach will make it clear that, in looking for regional components that affect the R&D decisions of enterprises, it is useful to analyse a lower spatial level to understand the regional and local presence and development of R&D expenditure.

The key idea behind our investigation is that the locality or the district has some useful social (e.g. universities, incubation centres, highly skilled labour market, etc.) and physical (e.g. airport, good accessibility, adequately equipped sites, etc.) infrastructures that exert some positive effects on R&D expenditure. However, the historical and political components should not be neglected in this regard. We illustrate this with a number of examples in these different areas. The recent development of the Flanders Language

* Original version.

To get in touch with the authors, see pages 4 and 5.

[1] We would like to thank Michele Cincera and Bart Clarysse for their valuable comments on earlier drafts of this contribution. Of course we remain responsible for the omissions and errors in the text.

[2] The figures were compiled by the Federal Co-operation Commission, Concertation Group CFS/STAT; OSTC calculations.

Valley in Ieper, the plans for business location around the High Speed Train location in Schaarbeek (Brussels) and the fact that universities have a juridical right to develop science parks are just a few examples of the social and physical environment. In this last case, it can be noted that the universities apparently do not always develop these parks in the proximity of the university itself (see the recent decision of the University of Gent to develop a research park in Oostende some 50 km away)[3]. An excellent example of the importance of political decisions on the economic development in a specific district was the decision after the Second World War to launch the petrochemical industry with the building of a petroleum port in the area of Antwerp and the important public support to attract multinational petroleum companies. Capron (2000) clearly describes the different regional growth stages that our country has experienced. The prosperity of Belgium at the end of the 19th century was unequally spread around the country. Lebrun, Bruwier *et al.* (1979) point to the regional specialisation: cotton and linen mills in Gent, wool in Verviers, coal, metallurgy and zinc in Liège, coal in Mons, and coal, metallurgy and glass in Charleroi. The combination of a well-developed rural industry with a good stock of skills, a high degree of openness to foreign innovations, a good transport infrastructure (roads, railways, and canals), an abundant work force, and high agricultural productivity in a context of significant private and public entrepreneurship formed the pillar of this prosperity (Capron, 2000).

In a next stage, the Walloon districts continued to polarise Belgian growth with the development of the steel industry and the building materials, chemicals and engineering sectors.In that period, industrial development was supplemented by the development of “tertiary” activities at Brussels (as the capital of the Kingdom), which quickly became the financial and administrative centre of the country, and of Antwerpen (because of its location advantage) whose port served as the gateway to international trade for the Walloon metal, steel, glass, and cement industries. The other Belgian regions specialised mainly in agricultural products.

At the end of the 19th and the beginning of the 20th century, new industrial structures were emerging in the Flemish region: the photography industry (Gevaert), assembly plants for motor vehicles (Ford, Renault and General Motors), the chemical and petroleum industry (Petrofina). The coal and steel industry continued to sustain the economic expansion of Wallonia.

During the 1950s, the decline of the Walloon economy set in: the development in alternative energy sources and the exhaustion of the coal pits caused the coal mines to be gradually closed down, and although the steel industry improved its production processes and increased productivity, it specialised mainly in products with low added value. The boom in the industry and the availability of energy stimulated the creation of new plants for which the coastal areas in the Flemish region were chosen. Multinationals preferred to build new plants in new industrial areas near the port of Antwerp and in other Flemish areas rather than in Wallonia, where the demography as well as the environment was less favourable (Capron, 2000).

[3] Newspaper article in ‘De Morgen’ of August 8th 2001.

Making an analysis of the regional distribution of R&D activities without taking into account the above mentioned factors would be misleading as all these elements can be assumed to have an impact on the spatial embedding of R&D expenditure. Following simultaneous causal growth models between R&D and economic activity (see Aghion and Howitt (1998) for an overview of endogenous growth theories, and Caniëls (1999) for an overview of the importance of the regional factor for R&D), this can, in turn, lead to the further development of economic poles, local/regional production systems and industrial districts. An appropriate specialisation and industrial mix can aid regional economic development by attracting the production of more (sophisticated) goods and services. In such a way, a veritable local social network could develop. The aim of this contribution is to investigate in the first place whether the R&D activities of Belgian firms are locally concentrated and, if so, what the critical success factors and hindering factors are in relation to a district attracting R&D activities. In doing so, it is our intention to make some observations that can contribute towards understanding the development path of a specific district.

This contribution represents an initial attempt to explain R&D expenditure in Belgium at the NUTS3-level, henceforth referred to as "districts", in greater detail. We are fully aware of a number of shortcomings in the analysis presented here. First of all, the component of human capital is neglected. In addition, the other players in R&D activity in Belgium (universities, authorities, research centres) are not taken into account in a formalised way. Finally, it should be mentioned that refining R&D expenditure could also be very interesting. Drawing a distinction between research and development could produce a more relevant picture. It is, however, an arduous task to obtain reliable data for such an entire range of activities. At this stage of our work, we therefore prefer to stress the reliability of the source of the data and would rather concentrate only on the business sector, because - in relative terms - it is the most prominent in relation to R&D expenditure.

This contribution is divided into different sections. In the next section, we present a methodical clarification of the concepts used. Firstly, there are several data sets available to investigate the questions referred to above: R&D output data such as patent indicators or bibliometric indicators could be used. However, in this contribution we use the R&D input variables such as R&D expenditure. We also indicate what is meant by "regions" or "districts"? What can be gained by using lower spatial levels than those employed in the bulk of the existing literature in Belgium?

In section three, we search for spatial patterns of R&D expenditure in Belgium, placing a degree of emphasis on the spatial advantage concerning R&D expenditure and the spatial concentration of such expenditure. Section four places R&D expenditure in a dynamic context. Here we use a traditional shift and share analysis to obtain an insight into these dynamics. In both sections - three and four - we give ample examples to clarify our statements. We conclude with some tentative policy implications.

2. Data description

As already mentioned in the introduction, R&D data are used as a proxy for innovation. The data used in this analysis are provided by the OSTC (Office for Scientific, Technical and Cultural Affairs), which gathers this information on the basis of the biannual OECD R&D national survey. In this analysis, R&D data for 1992 are provided by the survey of 1994 covering the period 1992-1993, while the data for 1999 are provided by the 2000 survey covering the period 1998-1999 (and 2000 forecast).

The estimation of the total intra-mural R&D budget of the private sector in Belgium is based on the results of a repertory of permanent R&D spenders and a random sample of the remaining population of Belgian firms not known as permanent R&D spenders. This is used to make an estimation of non-permanent R&D expenditure. It goes without saying that the repertory is regularly updated over a period of time.

This analysis focuses only on the permanent R&D spenders during the period 1992-1999. It should be noted that these firms represent by far the largest part of total business R&D activity in Belgium. Of the total R&D budget in Belgium in 1992 estimated at 2,088 million EUR, nearly 91% was undertaken by permanent R&D spenders. For the year 1999, more than 87% of total R&D expenditure (3,300 million EUR) is covered in the repertory. The fact that the coverage in 1999 was somewhat less than that in 1992 can be explained by a more thoroughly funded questioning of the firms outside the repertory, which resulted in a higher amount of R&D expenditure found on the part of not-permanent R&D spenders. An advantage of working only with the permanent R&D spenders is that the impact of methodological changes in the sample of non-repertory R&D spending firms is filtered out (for an overview, see CAPRON *et al.* (2000)).

The concept of "regions" covers many fields. A region might be a "natural region" when considered by geographers, e.g. the "Condroz" or the "Borinage" in the South of Belgium or the "Polders" in the Coastal area or the "Kempen" in the North East. Here the physical characteristics play a decisive role. However, a host of other types and definitions do exist. To name just a few examples (MINISTÈRE DE LA RÉGION WALLONNE, 2001): the Walloon region distinguishes between "employment zones" (bassins d'emploi) which are formed on the basis of the mobility between municipalities; "functional regions" which show a multifunctional character; or "supramunicipal co-operation zones" based on a voluntary membership between several adjacent territories or even exterior territories like Brussels, Lille, Luxembourg or Aix-la-Chapelle-Maastricht. In frequent cases, however, the administrative borders define a region. Eurostat has published a "Regional Manual" to investigate the regional dimension of the R&D more closely (EUROSTAT, 1996).

In order to make them meaningful, Eurostat, in its Regional Manual, advised the Member States to compile the R&D statistics in as detailed a manner as possible, viz. NUTS3 level[4] in the case of Belgium. In Belgium, there are 43 such regions or "arrondissements" (see *appendix 1* for a map of the 43 regions and their names). This contribution refers to these NUTS3 regions as "districts". In using these territories as our regional

[4] This corresponds to the Belgian "arrondissements" ("counties" in the UK; "Kreis" in Germany: "arrondissement" in France).

level, we differ from other studies on R&D in Belgium which, when taking into account a regional split-up, are limited at the NUTS 1 level (the Flemish Region, the Walloon Region and the Brussels-Capital Region).

It should be clear that the lower the NUTS level at which one can perform a regional analysis, the more valuable the analysis is by virtue of increasing the possibilities to analyse the impact of certain geographical, structural or other factors that can be important for undertaking R&D activities. On the other hand, an important disadvantage of adopting more detailed NUTS levels is the more limited number of R&D active firms per district, which makes a comparison between districts more difficult and/or less reliable.

As statistics gathered by official agents through administrative channels are organised according to VAT numbers and as such correspond to the zip-codes (corresponding to NUTS5) of the place of performance, the administrative borders would appear the most suitable for our spatial analysis. Taking into account the location where R&D is actually performed rather than the address of the head office enabled us to consider the amounts of R&D expenditure actually realised in a district (doing otherwise would have meant counting all R&D expenditure of a firm active in different districts in the district where it has its head office). In this way, the R&D activities of 21 firms were reclassified under another region. This also enabled us to obtain a more precise sectoral classification for firms with multiple activity lines distributed over different performance sites.

In total, 1,734 firms are included in our analysis for the period 1992-1999. Where individual data are missing, they were calculated by the OSTC (missing values are interpolated on the base of the individual development of each firm's global personnel, taking into account its legal situation and checking the annual accounts for important changes). In 1992, 1,377 firms were considered to be permanent R&D spenders. In 1999, this total increased to 1,536. We found that 282 firms started permanent R&D activities during this period between 1992 and 1999. We note a far more important increase in the number of permanent R&D spenders in Belgium (+11.6%) in comparison with the development of the total number of firms in Belgium (+5.7%) (National Office for Social Security, 1999). R&D expenditure in the business enterprise sector also rose as a percentage of gross domestic product (GDP) during the period 1992-1999 (from 1.05% to 1.18%)[5].

3. Regional pattern of R&D expenditure in the enterprise sector

3.1 Regional (in)equality of R&D expenditure

Commenting on R&D expenditure in the different Belgian NUTS3 regions or districts without embedding them into the economic activity in the different districts negates the contextuality that plays a part in the entrepreneurial decision to engage in R&D.

[5] Federal Co-operation Commission, 2001.

Although this contribution is primarily concerned with R&D expenditure undertaken by the enterprise sector, it is instructive to see how they relate to other regionalised variables such as the regional share of the gross product. The regional share of the employment in the private sector is taken into account in order to correct the fact that only the private enterprise sector is covered in this contribution, whereas GRP covers the public sector as well. An examination of the first 10 districts for each of these variables produces *Table 1*.

TABLE 1 **Key figures for the 10 most prominent economic districts** • 1998

District	R&D (%)	District	GRP (%)	District	Empl. (%)
Antwerpen	14.5	Brussels	19.3	Brussels	15.3
Turnhout	13.5	Antwerpen	11.9	Antwerpen	11.8
Brussels	12.2	Halle-Vilvoorde	6.2	Halle-Vilvoorde	6.7
Nivelles	10.0	Gent	5.5	Gent	5.6
Halle-Vilvoorde	7.1	Liège	4.8	Hasselt	4.8
Leuven	4.7	Hasselt	3.9	Liège	4.6
Charleroi	4.6	Turnhout	3.7	Turnhout	4.3
Hasselt	4.6	Leuven	3.7	Kortrijk	3.7
Gent	4.0	Charleroi	3.2	Leuven	3.4
Liège	3.4	Nivelles	3.2	Charleroi	3.5
Total	78.6	**Total**	65.3	**Total**	63.5

Sources: National Bank of Belgium; National Office for Social Security (RSZ / ONSS); Federal Co-operation Commission (CFS/STAT). Own calculations.

All the percentages cited are given for the year 1998 by virtue of these being the most recent available for the gross regional product (GRP). It is clear that a strong rank correlation (calculated for the 43 districts) exists between the variables such as GRP and R&D (Spearman = 87%) as well as private employment according to district and R&D (Spearman = 88%) respectively. Nevertheless, inspection of the table leads to the inference that the overall concentration of the R&D expenditure of enterprises is higher than that of the regional product and private employment. We take a closer look at this observation in section 3.3.

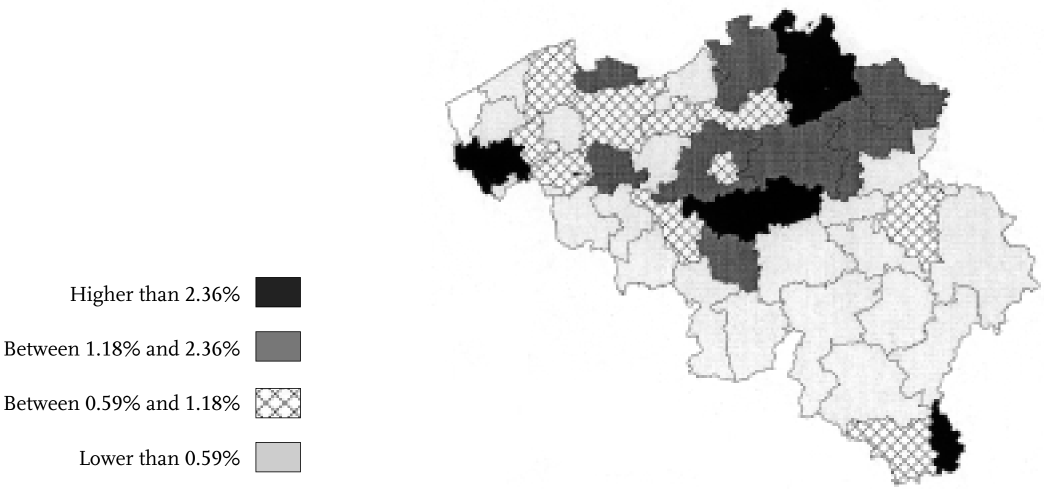
As could be expected, the gross regional product is highest for the Brussels district. First and foremost, its international orientation acts as an important attraction pole to a host of multinational corporations. Also, the fact that the Brussels district serves as the "capital" of Europe, of Belgium and even of the Flemish region implies that Brussels is an important administrative centre. As such, many international organisations have their European headquarters in the Brussels district (e.g. NATO). However, Brussels clearly forms an attraction pole to companies of almost every sector, and for services in particular - especially considering the function of Brussels as a financial centre. The concentration of services rather than manufacturing activities has to be seen in the context of a lack of industrial sites within the Brussels territory, which covers an area of 161 km^2. This tight market for industrial sites can be cited as the main reason for the high costs associated with accommodating manufacturing activities. Nonetheless, the central urban function of the Brussels district is not without its difficulties.

To name just one, daily commuting to and from Brussels poses one of the biggest road congestion problems in the country. As noted in the *table above*, R&D expenditure in the enterprise sector for the Brussels district is below the share in the other economic indicators. In this context, we should also take into account the districts adjacent to Brussels when talking about the Brussels district. Important economic areas in the vicinity of Brussels include Halle-Vilvoorde (e.g. Diegem, Zaventem, Dilbeek) and Nivelles (e.g. Waterloo, Braine l'Alleud, Wavre, Louvain-La-Neuve).
These are districts with strong R&D activity.

R&D expenditure in the business sector is thus more concentrated in the most important economic districts than in the other districts. In Turnhout and Nivelles, in particular, we find a relatively strong concentration of R&D activity. Within the ten most important districts, only the districts of Brussels, Gent and Liège display lower R&D shares than their share in GRP or private employment.

In *Map 1*, we present the R&D expenditures as a fraction of GRP (= R&D intensity) for the 43 districts in Belgium. The latest available gross regional product figure is for the year 1998. For Belgium, average R&D intensity amounts to 1.18%[6].

MAP 1 **R&D expenditures as a % of GRP**



Sources: Federal Co-operation Commission - CFS/STAT (2001), National Bank of Belgium (2001).
Own calculations.

If the regional pattern of the gross regional product and R&D expenditure were identical, we would expect a homogeneously coloured map. However, as can be seen from the map above, the spatial pattern of R&D intensity is rather unequal[7]. This implies that the spatial pattern of economic activity deviates from the spatial pattern of R&D expenditure.

[6] Please note that this percentage only relates to enterprises undertaking permanent R&D expenditure.

[7] This could also be inferred by calculating the variation coefficient - defined as a measure of relative dispersion and shows the variation of R&D expenditure over the 43 districts relative to the mean - which is 63%.

The centre of gravity of R&D intensity is located around the capital (Halle-Vilvoorde, Nivelles and Leuven) and appears to extend towards the Kempen in the north-east. This high R&D intensity is correlated with important physical infrastructure networks. More precisely, we note important R&D intensity along the “Canal de Charleroi” and the E19 between Brussels (Halle-Vilvoorde – Nivelles) and Charleroi, as well as the area between the “Albertkanaal” and the Dutch frontier (Antwerpen, Turnhout, Maaseik), including important traffic routes such as the E34 Antwerpen-Eindhoven, the E313 Antwerpen-Hasselt and the E19 Antwerpen-Breda. The presence of railroad infrastructures also plays a significant part in attracting R&D- intensive companies.

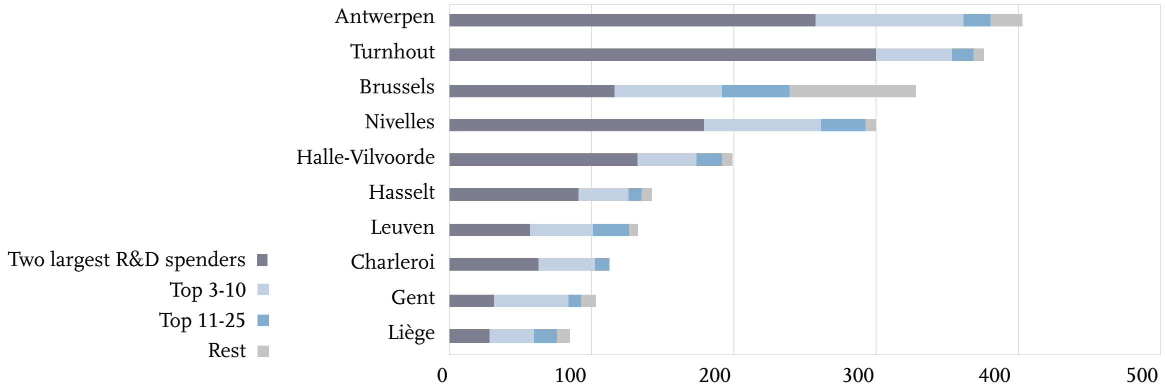
Apart from this concentration, we also observe some of the more “peripheral” districts (e.g. Arlon, Ieper) with a score much higher then the average. In total, half of the R&D intensive districts with above-average scores are located at the Belgian frontier, i.e. in the proximity of important industrial foreign sites such as Eindhoven, Lille and Luxembourg. In overall terms however, the south-south-east of Belgium (the Ardennes) does not appear to attract a high share of R&D because of the low level of economic activity in those districts. The geophysical system, coupled with the reduced accessibility that follows in its wake, is probably one of the most salient factors behind this phenomenon.

When detecting districts with more or less successful R&D, the data have to be interpreted with great caution. In 1999, for instance, more than half of R&D expenditure in Belgium was realised within 24 enterprises. The R&D activities in a district can therefore be influenced to a very considerable extent by the presence (or absence) of one or a few large spenders in that district. Needless to say, the dependence of a districts’ R&D activity on a few R&D champions is a very vulnerable situation. In order to take this argument into account, we present in *Figure 1* the share of R&D within a district realised among its most important and less important R&D spenders.

In Turnhout, Halle-Vilvoorde and Hasselt, total R&D expenditure is for more than half related to the largest R&D spender in each district. The relatively low position of Liège and Gent observed earlier can at least partly be explained by the absence of a very large R&D spender. However, the mix of R&D activities is far better than in most other districts. Here, too, Brussels seems to be a special case. No less than 30% of its R&D activity is realised outside its 25 most important R&D spenders.

This more descriptive section makes it clear that there are differences in R&D expenditure between the different Belgian districts. In the next section, we look at regional specialisation in a more formalised and detailed manner.

FIGURE 1 **R&D expenditure according to company size by district** • 1999 • Million EUR



Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

3.2 Regional specialisation

The index of R&D advantage (an index of relative specialisation in R&D) for each district looks at the presence of R&D expenditure within a manufacturing or service sector and compares it to the share of this sector at the national level of R&D expenditure[8]. As such, we find districts that are - in relative terms – "specialised" or "despecialised" (even though the weighting of the sector can be rather minor or even insignificant). In this contribution, we use the index of R&D advantage (also known as "location coefficient") to identify which industries are "over-represented" in which districts, and which are "under-represented". This approach, provides an initial indication of which industries form the specialisation of the districts' R&D expenditure.

For the sake of clarity, we have aggregated the different economic sectors into five main sectorgroups, where the "level" of technology served as a categorising principle: high, medium and low technology in the manufacturing industry and high and medium & low technology in the service sector[9]. This aggregation results in a loss of information for some of the sectors within the groups themselves as it is perfectly possible for the sub-sector to fall under an entirely different category - e.g. over-represented - from the direction of the total for the sector (which might be under-represented). Nonetheless, we adhere to the classical divide between manufacturing and services, and even complement it with a division according to high, medium

[8] Expressed in algebraic form as follows:

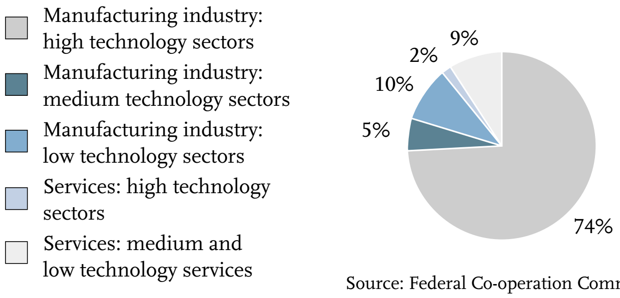
$$S_{ir} = \left[\frac{\dfrac{R_{ir}}{\sum_{i=1}^{n} R_{ir}}}{\dfrac{\sum_{r=1}^{f} R_{ir}}{\sum_{i=1}^{n} \sum_{r=1}^{f} R_{ir}}} \right]$$

where S stands for the index of R&D advantage (or specialisation coefficient); R is the R&D expenditure in the business enterprise sector; i is the i-th sector, n is the total number of sectors (here 5), r is the r-th district, and f is the total number of districts (here 43).

[9] See *appendix* 2 for an extensive list of activities. The classification is founded on Eurostat proposals for sector classification. Sectors not classified by Eurostat are classified according to our own judgement.

or low technology. For reasons of confidentiality and significance, we have opted to merge the medium and low technology sectors in the service sector[10]. *Figure 2* shows the impact of each sector in total R&D activity in Belgium.

FIGURE 2 **Research and development expenditure in Belgium** • 1999



Source: Federal Co-operation Commission, CFS/STAT (2001). Own calculations.

The high technology sectors in the manufacturing industry represent by far the largest share of R&D activity in Belgium. Not surprisingly, the largest R&D spenders can be found in the pharmaceutical industry, the chemical industry and the electrical and electronics industry. Because of the large differences between R&D amounts spent in the different categories, care should be taken when analysing the R&D strength of a district. A district can be highly R&D intensive in absolute terms, but display relatively low intensity in comparison with other (national or foreign) districts in the field in which it specialises. On the other hand, a district that specialises in R&D activities in sectors in which the R&D amounts are lower can be more competitive in the domain of R&D in those sectors in which it specialises.

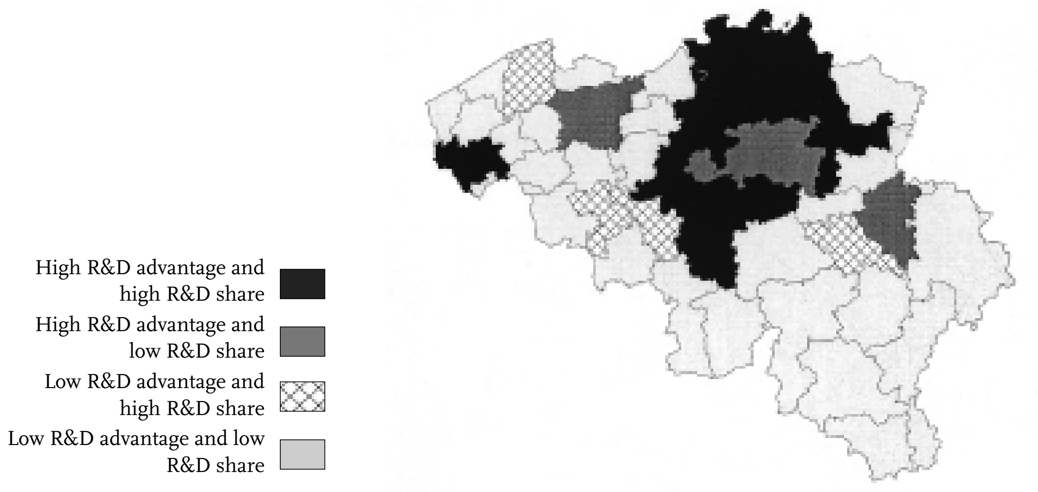
From the definition of the index of R&D advantage, it is clear that each district is either specialised or despecialised for a particular technological sector. To draw a distinction between the more important and less important districts, we have taken the share of the R&D expenditure in the total of that particular sector into account. In this way we identify four categories: a sector in a district either has a high share of R&D in the totality of that sector in Belgium and is specialised; or it has a high share but is despecialised; or it has a low share and is specialised; or it has a low share and is despecialised.

Map 2 shows the R&D advantage in the high technology sectors of the manufacturing industry. A classification is made between a high R&D advantage if the share of R&D activity in that sector surpasses the national average in terms of the total R&D activity in that district. The opposite results in despecialisation or under-representation. The R&D share is high if the absolute part of R&D in that sector in terms of the total R&D in that sector is higher than the regional average of 2.3%.

MAP 2 **Regional R&D advantage and regional R&D share in the high-tech manufacturing sector**

[10] Following Scherer (1982), we are fully aware of the excessively broad definition of the sector classification used here. Optimally, the relations between different players in different industries should be taken into account in this analysis. This is not done here because of the unavailability of data.

Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

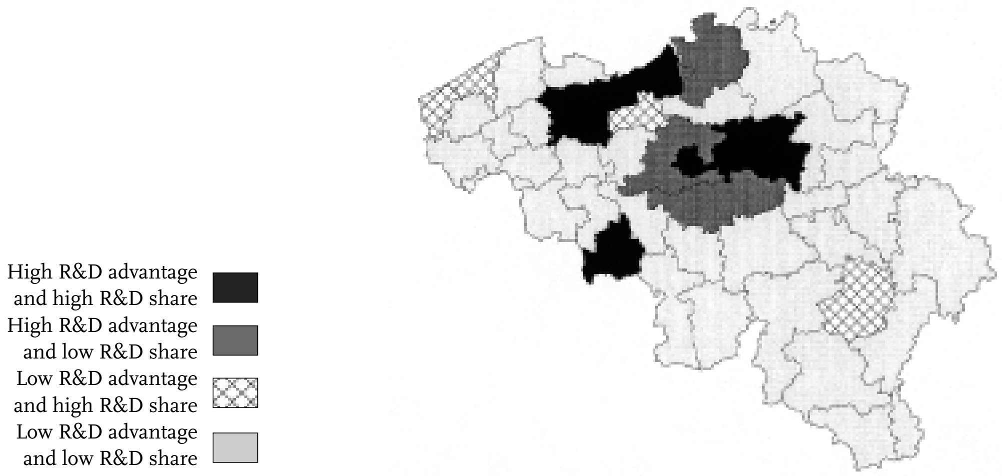


If we compare the results in *Map 2* to those of *Map 1* (the ratio of R&D expenditure to the GRP for that district), we note that all ten of the large economic districts have a high R&D advantage in high-tech manufacturing R&D activities.

Brussels, Gent, Leuven and Liège, however, display an absolute R&D share in these activities which is below the national average. In view of the dominance of high-tech R&D in the total R&D budget, it is not surprising that the districts performing well in this domain also show an above average value for their R&D/GRP ratio. In this context, the situation of Leuven draws our attention because it could be expected that high-tech firms in manufacturing industries, in particular, would be localised in the district with one of the largest universities in Belgium and a high research output.

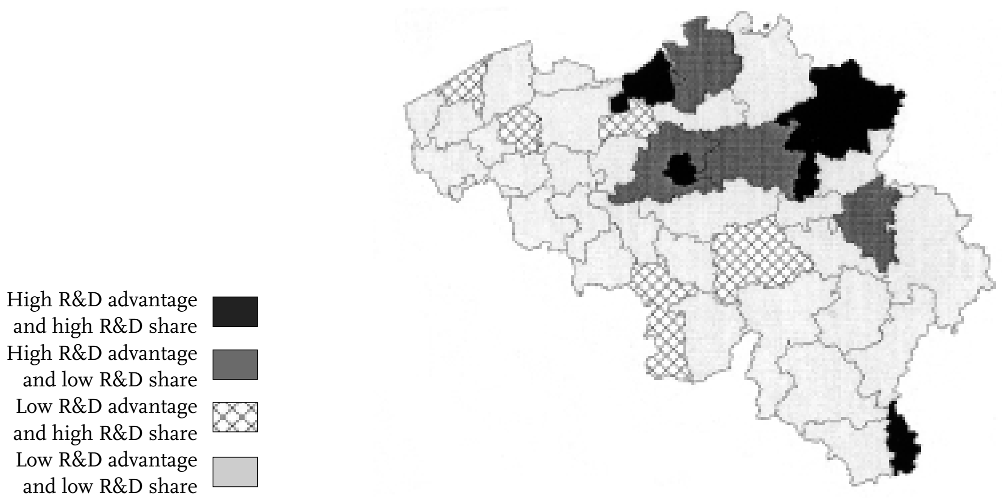
Map 3 below, which represents the situation of R&D expenditure in the high technology service sectors, reveals a possible explanation for this phenomenon. Leuven has a strong R&D advantage in high-tech services and has a R&D share in this sector that is far above the national average, i.e. nearly 7% of all R&D in Leuven is realised in the high-tech services (especially computer and related services). This is more than three times the national average of about 2% (see above). A similar phenomenon can be observed in Brussels and Gent. Of the ten most important Belgian districts in economic terms, only six (Brussels, Halle-Vilvoorde, Leuven, Nivelles, Antwerpen and Gent) have a high R&D advantage in both R&D in high-tech manufacturing industries as well as in R&D in high-tech service sectors.

MAP 3 **Regional R&D advantage and regional R&D share in the high-tech service sector**



Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

MAP 4 **Regional R&D advantage and regional R&D share in the medium and low-tech service sector**

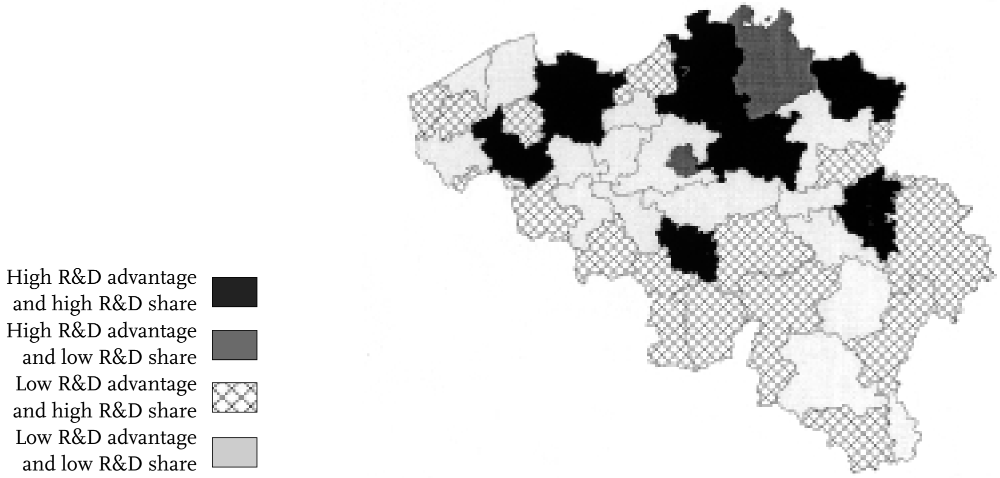


Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

In contrast to the R&D in high-tech services, low and medium tech services R&D (*Map 4*) is rather scarce in Gent. Services, in global terms, are characterised by a relatively large concentration in a minority of Belgian districts (low R&D advantage and low R&D share can be found in most districts). This clearly contrasts with the relatively more equal distribution of R&D activities in the manufacturing industries (especially in low and medium tech sectors: see further).

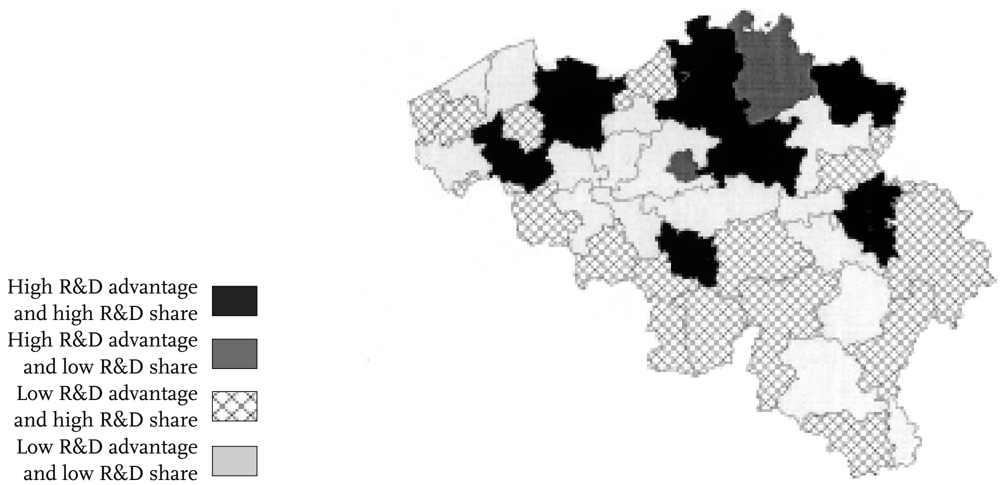
If we look at the R&D activities in the medium-tech (*Map 5* below) and low-tech (*Map 6* below) manufacturing industries, we note that R&D activities do not display a clear spatial pattern for the medium-tech manufacturing industry. With regard to R&D in low-technology manufacturing industries, we do, however, see a concentration in the area around the Gent-Leuven axis. The most prominent sectors in low-tech manufacturing sector R&D in this area are food and beverages (56% of total R&D budget of low-tech manufacturing industry in the area), textile and clothing (17%) and the agro-industry (7%). Sixty-four per cent of the total R&D amount in the agro-industry in Belgium is located in Leuven. Textile and clothing are prominent in the Kortrijk-Tielt-Oudenaarde regions. Food and beverages cluster around Halle-Vilvoorde–Leuven– Turnhout (50% of the total R&D budgets in that sector). Although it cannot be said that there is a high R&D advantage in the low-tech and medium-tech manufacturing industry in the south-south-east of Belgium, we see (in contrast to the absence of high-tech manufacturing and services R&D) high R&D shares in that part of Belgium. This implies that, within these districts, the medium and low-tech manufacturing sectors do have an important position in R&D expenditure undertaken by the enterprise sector.

MAP 5 **Regional R&D advantage and regional R&D share in the medium-tech manufacturing sector**



Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

MAP 6 **Regional R&D advantage and regional R&D share in the low-tech manufacturing sector**



Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

In the next section, we further refine the analysis by studying concentration at two distinct levels. First of all, we verify whether the R&D activities of enterprises tend to be concentrated according to industry (at a lower aggregated industrial level then the five sector groups we have used up to now), i.e. which industry experiences a concentration of R&D expenditure, and to what degree. Subsequently, we reverse the analysis to investigate the concentration of R&D expenditure according to district. These are very distinct types, with the first looking at whether the industry itself is concentrated (i.e. whether R&D is performed in a small or large number of companies in this sector); and the second ascertaining whether the companies are concentrated in one district or dispersed over several districts.

3.3 Regional concentration

It is a standard procedure to capture a regional pattern by calculating the well-known Herfindahl index (Scherer and Ross, 1990). In the course of time, the economics profession has composed many other coefficients that are less prone to the criticisms ventilated in the case of the Herfindahl index, such as sensitivity where there are only a few observations[11]. Economists commonly use the Herfindahl index for the measurment of industrial concentration.

It can be calculated in the following way:

$$H_i = \sum_{i=1}^{n} \left[\frac{R_{ir}}{\sum_{r=1}^{f} R_{ir}} \right]^2 \text{ or, alternatively, as, } H_r = \sum_{r=1}^{f} \left[\frac{R_{ir}}{\sum_{i=1}^{n} R_{ir}} \right]^2$$

where R is the R&D expenditure; i is the economic activity; n is the number of activities (36 sectors); r is the district; and f is the total number of districts (43 districts).

The first index (H-industry) gives an indication of the industrial concentration in each sector. The maximum score is one if the R&D expenditure is concentrated in only one economic activity; the minimum score is when all R&D expenditure is considered to be equally dispersed across the activities.

[11] We also calculated a similar measurement, the entropy coefficient, defined as:

$$E = \sum_{i=1}^{n} \left[\frac{R_{ir}}{\sum_{r=1}^{f} R_{ir}} \right] \log_2 \left[1 * \left[\frac{R_{ir}}{\sum_{r=1}^{f} R_{ir}} \right] \right]$$

with the same ingredients as the Herfindahl index. When market shares are equal, its value reduces to $\log_2 N$, being zero under pure monopoly and rising non-linearly as the number of firms increases. Because we found very similar results to those of the Herfindhal-index when using this index, we do not present them here.

TABLE 2 **Industrial concentration of R&D expenditure for the business enterprise sector**

Economic activity	Herfindahl	Economic activity	Herfindahl
Business services	0.97	Electronics-communications	0.25
Mining	0.92	Electronic parts	0.23
Financial institutions	0.84	Scientific instruments	0.22
Telecommunication	0.65	Printing	0.21
Rail & tramway material	0.65	Recycling	0.21
Cokes, nuclear	0.65	Non-metallic mineral products	0.20
Transport	0.64	Computer & related activities	0.20
Office & computing	0.54	Furniture	0.19
Non-ferrous production	0.53	Construction	0.18
Leather and shoes	0.50	Textile	0.16
Shipbuilding & repair	0.50	Various n.e.c.	0.15
Tobacco	0.48	Real estate & renting	0.14
Aircrafts & space industry	0.46	Paper	0.14
Agriculture	0.43	Software	0.14
Clothing	0.42	Chemicals	0.14
Wood	0.38	Rubber & plastics	0.14
Pharmaceuticals	0.37	Food & beverages	0.13
Research & development	0.35	Motor vehicles (assembly)	0.12
Electricity, gas & water	0.31	Electrical machinery	0.09
Basic metals	0.30	Non-electrical machinery	0.08
Games & toys	0.28	Metal products	0.07

Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

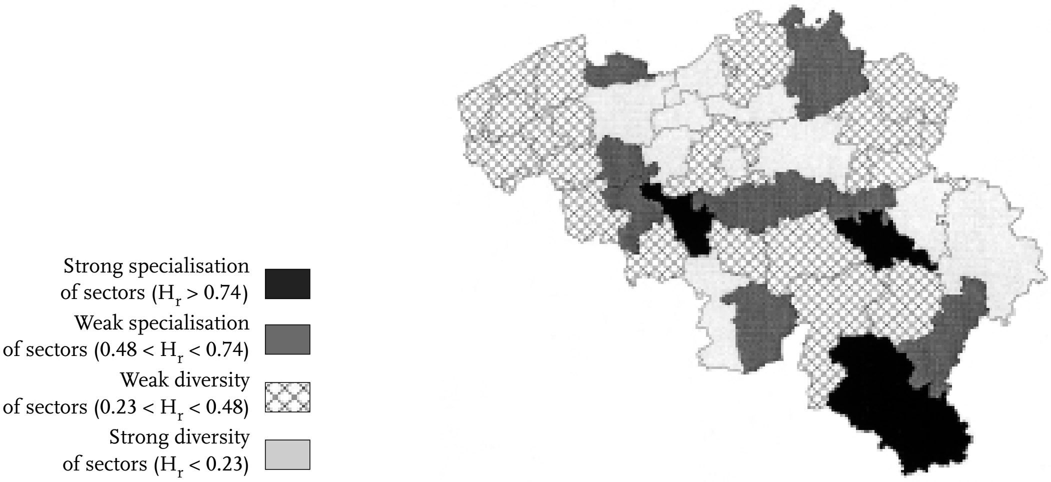
Table 2 reveals that there are marked differences in the concentration between industries according to the OSTC database of permanent R&D performers. The R&D expenditure in enterprises is most concentrated in the business services sector, where we found a strong R&D advantage in Brussels, Leuven and Gent.

The fact that some economic activities are not unconstrained because of the specificity of their production process (e.g. mining, nuclear plants, transport) also results in the R&D expenditure undertaken by these enterprises being locally concentrated.

We can also use the index by calculating the share of R&D expenditure of sector i in the r-th district in terms of the total of district r. (H-district). By squaring this proportion and summing over all the districts, this index gives a summary measurement of spatial concentration. The higher the value of the Herfindahl index, the more spatially concentrated the economic sector tends to be. Again, the maximum score is one if all of the R&D expenditure is concentrated in only one region. The minimum value is 0.02 (0.023256) if all R&D is spread equally across the 43 districts.

In order to produce a chart that summarises the information, we take the theoretical value possible for the Herfindahl index between the maximum and the minimum and divide it into a first group of districts displaying concentration of only some economic activities (Herfindahl larger than 0.486; where this threshold is merely the median between the maximum and minimum values of the Herfindahl score); and a group of districts in which the economic activities are diversified. The division is repeated in the same way within these groups themselves in order to attain further distinction. This yields four distinct types of districts (see *Map 7*).

MAP 7 **Regional concentration of R&D expenditure in all economic activities**



Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

In some districts there appears to be greater concentration of R&D expenditure in certain economic activities than in other districts. Perhaps these districts do not find it possible or necessary to diversify their activities. If all R&D expenditure in a district were to be undertaken in one industry, this would result in a score of 1, whereas if all R&D were equally divided between the 36 economic activities, we would obtain a minimum score of 0.028. In fact, all districts fall between these two extremes. In Nivelles, for example, we find that 80% of all R&D expenditure is in the pharmaceutical sector (a manufacturing sector with high technology). In Brussels, on the contrary, there are no sectors accounting for more than 30% of all R&D outlays. As could be expected, the districts that have large attraction poles such as airports, universities, seaports, good accessibility, adequate infrastructure, good accommodation, etc., have much less concentration of one or several economic activities (and thus are less dependent on it).

The development of the Herfindal index shows that the overall concentration of aggregated economic sectors tends to diminish slightly over time. This exercise is carried out in *Table 3*.

TABLE 3 **Concentration of R&D expenditure according to sector and technological content over time**

	Herfindahl 1999	Herfindahl 1992
Aggregated economic sectors		
Manufacturing high tech sectors	0.095	0.099
Manufacturing medium tech sectors	0.087	0.102
Manufacturing low tech sectors	0.067	0.070
Services high tech sectors	0.217	0.179
Services medium and low tech sectors	0.259	0.311
Total for all sectors	0.081	0.091

Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

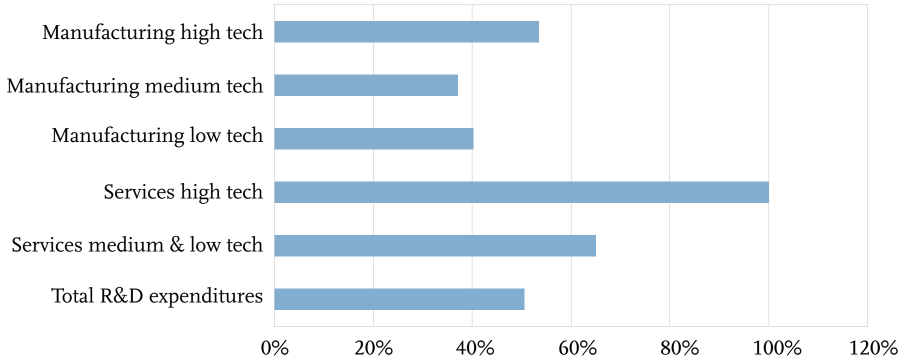
This implies that the concentration of R&D expenditure in these sectors is being reduced. One possible causal element associated with this phenomenon could be that globalisation has had the effect of increasing competition between enterprises. There are simply more firms to begin with, resulting in a reduction of sectoral concentration. More of them then engage in new R&D expenditure. We have already noted that 282 enterprises started their permanent R&D activities during the period considered. The trend towards lesser industrial concentration is even starker for the services in medium and low-tech sectors than for the manufacturing sectors. A notable exception is the case of high-tech services where concentration increased substantially during the 1992-99 period, as explained earlier in outlining the performance of this sector in Brussels, Leuven and Gent.

4. Regional dynamics in R&D expenditure

4.1 Regional R&D evolution

The nominal growth in Belgian R&D expenditure between 1992 and 1999 was considerable with a rise of 53%. This growth performance differs among the sectors making up the Belgian economy, as can be seen in *Figure 3*.

FIGURE 3 **Sectoral growth (in %) performance of R&D expenditure in the private sector between 1992 and 1999**

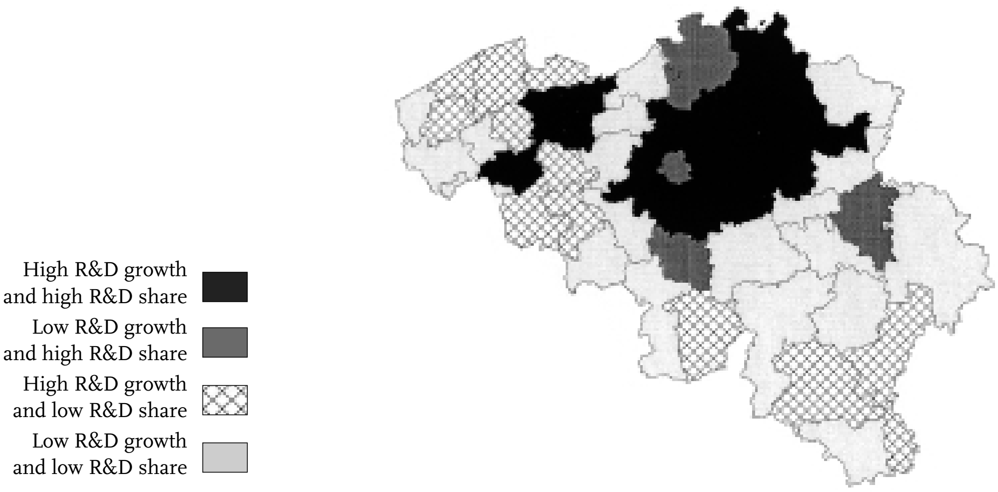


Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

The fact that Belgium is gradually transforming more and more into a service economy is vindicated by the dynamics of R&D expenditure. The growth rates of the service sectors, regardless of their technical content, are above the Belgian average. Due to the weighting of the manufacturing high-tech sectors, which was around three quarters of all R&D expenditure in the private enterprise sector, it could be expected that growth performance would not differ from the average performance to any great extent. The growth rates of the remaining sectors in the manufacturing sectors score below average, indicating their relative unattractiveness for R&D spenders. If we look at the firms in the manufacturing industry, it should be noted that the classification in, for example, the high-tech industries does not reveal any important differences between the underlying sectors. For the four most important sectors (when defined as covering more than 5% of total R&D budget in 1999), we note relatively high growth rates of R&D expenditure in the pharmaceutical (+201% between 1992 and 1999) and motor vehicle industries (+92%). The electrical machinery (+34%) and chemical industries (+17%), on the other hand, lagged behind the mean national growth rate of R&D expenditure between 1992 and 1999.

As growth performance also differs by virtue of the weighting of the district in total R&D expenditure, we found it useful to couple the growth performance ("high" is above the average of 53% and "low" falls below it), with the share of the district in R&D expenditure ("high" being above the average of 2.3% and "low" beneath this average). The result of this, as can be seen from *Map 8* below, is that there appear to be notable spatial disparities in growth performance.

MAP 8 **Growth performance of R&D expenditure according to district between 1992 and 1999**



Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

In the South of Belgium we find districts with negative growth (Namur being the most important in economic terms), alongside districts that more than doubled their R&D expenditure (e.g. Arlon, Tournai, Bastogne, etc.). This can be partially ascribed to their relatively low shares of R&D expenditure (see further). Although the growth pattern is less volatile in the remainder of Belgium, it, too, remains unequal.

The districts with high growth rates and high shares are excellent districts for R&D expenditure. Two axes running from North to South are distinguished, i.e. the main territory of Turnhout-Hasselt-Mechelen-Leuven-Halle-Vilvoorde-Nivelles and a smaller axis formed by Gent-Kortrijk. A reason for Kortrijk (and - to a lesser extent -Tournai-Ath) could be found in the presence of the growth pole of Lille (with its high-speed rail connection and flourishing location for many companies) just across the border.

Another observation is that some districts with a high share have low growth rates: Antwerpen, Brussels, Liège and Charleroi. As we indicated in *Table 1*, these are among the most important districts of the country in economic terms, though their growth rates indicate some difficulties in attracting firms that are active R&D spenders. This could undermine their position as innovation environments in the longer term.

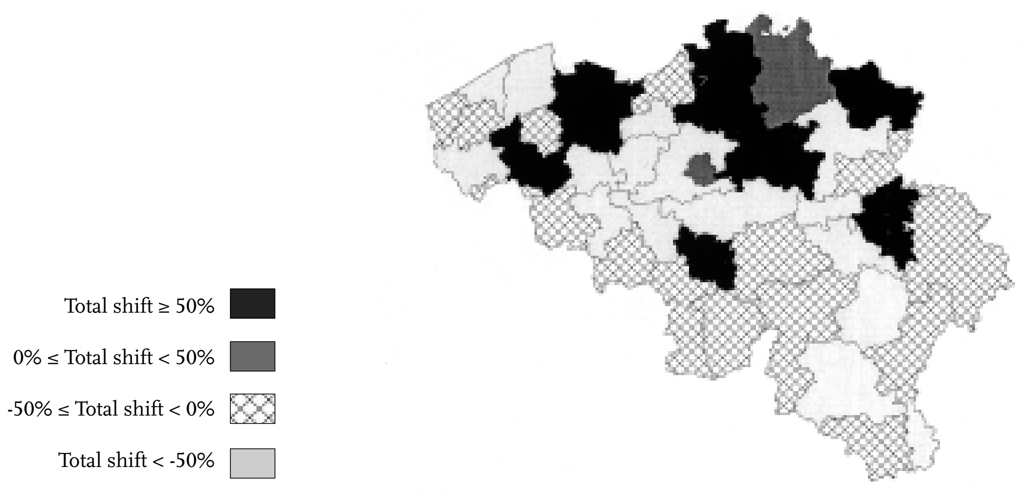
Based on the evolutionary perspective in the R&D literature, it is presumed that regional dynamics in R&D expenditure experience a relatively slow pace because of the time-consuming nature of organisational and institutional changes (NELSON and WINTER, 1982; NELSON, 1993). However, this feature could not be brought out by virtue of the relatively short period under consideration (1992-1999). The shift from one district to another is, moreover, conditioned by the existing regional dispersion of R&D expenditure, especially since the shares of R&D expenditure according to district for 1992 and 1999 do not differ to any great extent between the two periods. The positive influence of existing firms, usually indicated by the phrase “agglomeration advantages”, can be expected to form an excellent regional production environment for existing firms to augment their R&D efforts. Whether this environment is also a breeding place for spin-off activities does, however, require additional empirical investigation. This topic is especially important at the policy level, since many of the efforts of the national and regional governments are directed at stimulating spin-off activities. Additional and unambiguous empirical “evidence” can help decision-makers to direct their efforts in a more efficient way given the knowledge that R&D activities are spatially disparate over their territories.

4.2 Shift and share

The shift and share technique enables growth to be described more accurately (e.g. SPITHOVEN and MEURIS (1997); VAN GEUNS (1990); DE BRABANDER (1983); FOTHERGILL and GUDGIN (1982); MASSEY and MEEGAN (1982); FOTHERGILL and GUDGIN (1979) and RICHARDSON (1978)). In this paragraph, we concentrate on the growth performance of the five aggregated sectors in which the technological content is used as the categorising principle (see *appendix 2*).

The shift and share technique disaggregates the overall change in R&D expenditure into several (fictional) components. First of all, the “federal” or “national” component (also termed “standard growth” is the change that would have occurred if the total R&D expenditure in a district had grown at the same rate as that for Belgium as a whole, i.e. 53%. The difference between this component and the actual growth rate then represents the so-called “total” shift. This shift is depicted in *Map 9*.

MAP 9 **Differences in growth performance between the actual growth rate according to district and the standard growth rate ("total shift")**



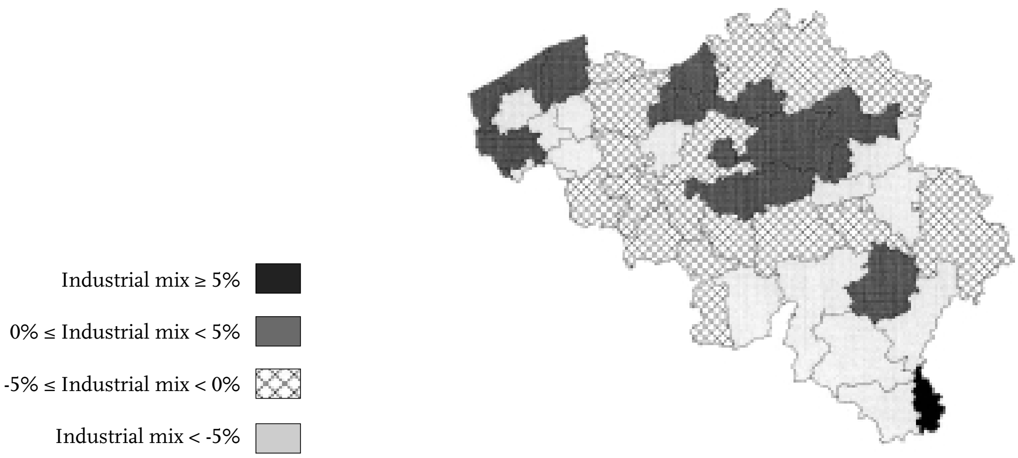
Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

The total shift gives an indication of whether or not the district performs better (positive) or worse (negative) than the federal level. The map resembles – but does not duplicate – that presented earlier which outlined the growth/share relation of R&D expenditure. The positive total shift is most pronounced along two north-south axes, i.e. Turnhout-Hasselt-Mechelen-Vlaams-Brabant-Nivelles and Eeklo-Gent-Kortrijk-Oudenaarde-Tournai. Due to their explosive actual growth, some of the peripheral districts display positive total shifts, e.g. Oostende-Diksmuide, Neufchâteau-Bastogne-Arlon and Philippeville.

The total shift is negative in some important economic districts: Brussels, Antwerpen, Liège, Charleroi and Namur, indicating below average growth and, therefore, "stagnating" R&D expenditure.

This total shift is, in fact, "composed" of two parts. First a "structural" component, or an "industrial" mix, which is the change relative to the federal state that can be attributed to a district's particular mix of industries. This is calculated as the change that would have occurred if each industry in the district had grown at the federal rate for that particular industry, minus the federal component or standard growth. The resulting growth rates are far smaller in magnitude than those referred to in the total shift. For this reason, the percentages used to categorise the districts in order to map these growth rates are 10 times smaller then in the case of the total shift. A positive score indicates that the district, on average, specialises in sectors with a high growth rate in R&D expenditure; a negative score implies that the district is populated, on average, with sectors experiencing a below average growth rate in R&D expenditure in the private enterprise sector.

MAP 10 **Industrial mix of the Belgian districts**



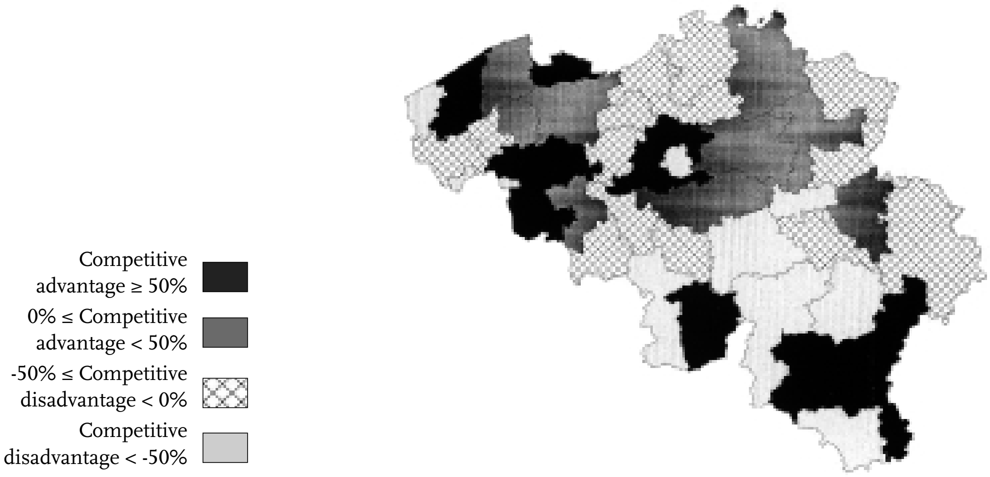
Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

The industrial mix is calculated by summing together the growth performance of the economic sectors constituting each district. The results for each separate sector are quite instructive and can be found in *appendix 3*. On the whole, three sectors score positively, i.e. those with high technical content in both manufacturing and services and the medium-low technology in the services. The two remaining manufacturing sectors with medium and low technology display a negative impact. As shown in *appendix 3*, districts specialising in these sectors tend to undergo this negative influence: e.g. Virton, Diksmuide, Mouscron, Bastogne, etc. For other districts - with greater diversification or specialisation in another sector - this negative impact is overcome by the positive impact of the other sectors: e.g. Arlon (especially medium-low tech services sector); Brussels and Sint-Niklaas (medium-low services); Nivelles, Ieper and Mechelen (high-tech manufacturing sectors).

All in all, a quarter of the districts are more or less specialised in economic activities showing good growth performance. One third of the districts can be categorised as possessing a relatively bad industrial mix (i.e. lower than -5%).

Secondly, the total shift has a "regional" or "differential" component, which is a residual by virtue of its being calculated as the difference between the expected change (federal and structural components) and the actual change in that district. Although calculated as a residual, this regional component is of specific analytical interest as it indicates that there are (perhaps numerous) factors present that can influence the decision to engage in R&D expenditure other than the industrial mix or due to institutional factors which are the same for every firm in a particular territory. The Walloon region and the Flemish region have, for example, taken action to stimulate R&D within their boundaries. The tax rate - a responsibility of the federal government - is the same for each enterprise regardless of where it is located. Thus, the regional component represents an initial indication of these specific effects. Its economic significance has been ascertained by interpreting this component as an index of a district's competitive (dis)advantage.

MAP 11 **Competitive (dis)advantage of a district**



Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations

Investigating this interesting and important component in a thorough analytical way is beyond the scope of this contribution. However, some “common sense” observations do follow from *Map 11*.

First of all, we see that the map resembles - with some notable differences such as Liège and Mechelen - that depicting the total shift. This comes as no surprise by virtue of the weighting of competitive advantage in comparison to the industrial mix. Of the Belgian districts relevant in economic terms, only Liège and Gent appear to achieve a positive score, whereas Brussels has a negative competitive advantage (or disadvantage).

Some of the districts around Brussels attain very high scores, especially the adjacent district of Halle-Vilvoorde. This could well be due to the presence of the airport at Zaventem and/or the availability of industrial sites in the adjacent local authority areas (for the most part in the north-east and north-west) to the Brussels district. Leuven and Nivelles also display a high score, which may be attributed to the existence of the largest universities in the country.

Liège has a high score for competitive advantage, although its total shift was negative. Possible reasons for this is the presence of attraction poles such as the university, the regional airport of Bierset (which is growing in importance because of the night flights) the presence of the high speed train guaranteeing accessibility, the renewal of the city centre, etc., all factors that contribute towards the attraction of the Liège district as a location to conduct business.

Mechelen, on the other hand, displays a rather different development with a negative competitive advantage score.

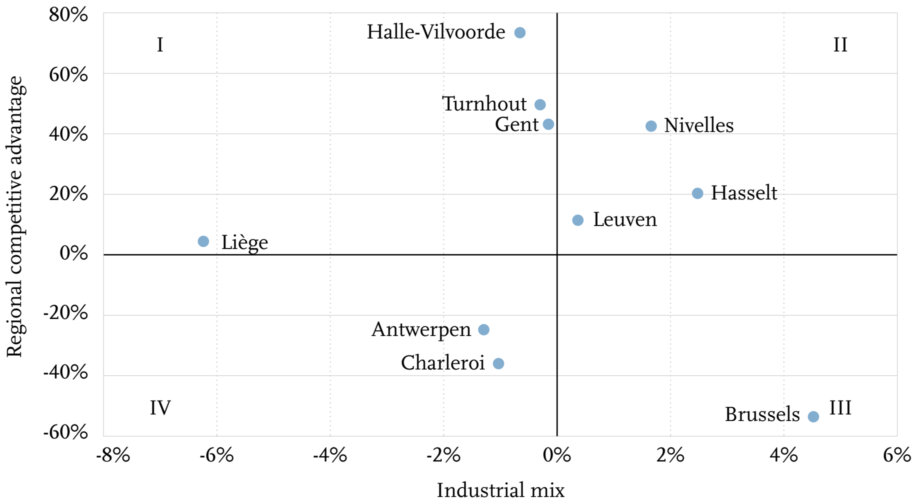
The "peripheral" district that deserves special attention is Turnhout. Here it was found that, when the share of R&D expenditure is considered, the district scores high compared with its economic weighting (whether in terms of production, GRP, or in terms of employment (RSZ/ONSS)). The district has excellent accessibility and some of the most important public research centres are located there: e.g. VITO (Vlaamse Instelling voor Technologisch Onderzoek - Flemish institute for technological research) and the SCK (Studiecentrum voor kernenergie - Research centre for nuclear power). The district of Turnhout has also been able to rely on financial support from the European funds to "catch up" with the other European regions.

The competitive advantage in the South of the province of West-Flanders and the West of the province of Hainaut should not be examined without taking into account the upsurge of economic activity in Lille (France). Lille not only has a well-known university, it is also connected at an extremely important junction through the high-speed rail link (thus ensuring good connections with Brussels, Paris, and London). Furthermore, a host of international companies have opted for Lille, causing the city to grow into the most prominent business site in Nord-Pas-de-Calais, with good accessibility from and to France, Belgium, and the United Kingdom.

A comparison of the two components of the total shift reveals that growth performance in R&D expenditure does not depend on the industrial mix of the districts to any important extent. It can also be inferred that the "regional" factors are especially important for explaining R&D expenditure on a district-by-district basis.

As a corollary of the shift and share technique, we can deduce a typology for the Belgian districts by looking at the co-occurrence of the industrial mix and competitive advantage. This helps us to deduce districts where a different policy emphasis might be needed. This is done in *Figure 4a* for the ten most important economic districts (in terms of their gross regional product); and in *Figure 4b* for the other districts.

FIGURE 4a **A typology for the "key" Belgian districts**



Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

To illustrate *Figure 4a*, we explain the situation of the district of Antwerpen, where R&D expenditure actually grew by 26% between 1992 and 1999. Given the fact that the national growth level is 53%, there was a negative total shift of 27%, of which 1% was due to the choice of sectors where R&D expenditure was undertaken and the remainder (26%) due to some regional or local factor.

In the first quadrant we find those districts with a strong appeal to firms engaging in R&D expenditure between 1992 and 1999, though the industrial mix in these districts is rather weak. Thus, these districts are, relatively speaking, specialised in stagnating sectors, while also displaying a competitive advantage in those sectors. As such, we can describe these districts as “intermediary” districts. They have to be careful that their specialisation in sectors with weak growth potential does not become excessive so as to avert problems in the future.

For the districts that belong to quadrant II, we can say that they have a favourable industrial mix and attract firms engaging in R&D between 1992 and 1999. These potential “growth districts” have a bright future ahead of them.

Quadrant III has a favourable industrial mix but a weak competitive advantage. All “prosperous” activities seem to be represented, though growth performance is rather weak due to regional or competitive factors. A more selective policy could be in order here so as to stimulate R&D expenditure undertaken by the firms active in these districts. But it could also be an indication that these districts (and the localities within them) are not as attractive for R&D spenders as other districts. In the case of Brussels, we have already addressed the congestion problems and the high real estate prices as the most salient regional or local dangers.

Lastly, the most negative dynamics can be found in quadrant IV. These are districts “lagging behind” as far as R&D expenditure is concerned by virtue of the industrial mix being unfavourable and the district not being attractive for growth in R&D expenditure. We must bear in mind that these growth rates are based on arithmetically computation and are in a figure of speech “fictional” rates.

The map setting out the R&D situation of the ten most important districts reveals some interesting points. First of all, although Brussels has a very favourable industrial mix for R&D, it is evidently not that attractive for firms wishing to develop R&D activities (negative competitive advantage). Looking at the Brussels situation in greater detail, it can be said that the positive industrial mix in Brussels is due to the relatively high number of firms performing R&D in the low and medium-tech services (a sector that is growing faster than the national average). In Brussels, more than 55% of total R&D spending in this sector is related to the banking sector. In Brussels, R&D in this sector grew – in absolute figures – 10% less than the national average. The second and third important service sectors performing R&D (business activities and other services) grew over 40% and 50% less than the national average respectively. The slower pace of R&D expenditure in the low and medium tech services compared with national growth in Brussels is, as such, not the result of one particular sub-sector/firm. It is, however, beyond the scope of this contribution to explain this phenomenon. Possible reasons could be that road traffic problems are interpreted as being more severe on the part of highly skilled R&D personnel, or the development of

R&D activities can be more space consuming and possibilities for growth are limited by the scarcity of space available, etc.

The situation in the district of Liège, on the other hand, shows a quite neutral regional competitive R&D advantage, but a negative industrial mix. Apparently, this district (like many other districts in the Walloon Region) has experienced problems in reconverting its economy (leader up to mid-way through the last century) towards fast growing high-tech industries. During the period 1992-1999, R&D activities in this district were oriented towards the chemical and plastics industry. R&D in the metallurgic industry in this district declined mainly due to the problems at Cockerill Sambre.

The industrial mix in the other eight important economic districts in Belgium is fairly equal. The very high regional advantage in Halle-Vilvoorde should be interpreted with great caution. In fact – as mentioned earlier – R&D in this district is dominated by its largest R&D spender. This firm more than tripled its R&D efforts between 1992 and 1999, thus explaining the high regional advantage[12]. Without this firm, the average growth rate of R&D activities between 1992 and 1999 was 47%, i.e. more than 5% less than the national average. A similar situation can be found in the districts Turnhout and Hasselt, where the local R&D champion more than doubled its R&D efforts. The remaining firms, however, displayed a growth rate of only 32% and 27% respectively, i.e. far less than the national average.

The favourable industrial mix in Nivelles is hardly surprising as the four largest R&D spending firms in that district are to be found in the pharmaceutical industry, which was the sector with the most rapid R&D growth between 1992 and 1999. The good score for the competitive advantage can be related to the fact that these firms managed to grow stronger than the average companies in that industry. The strong concentration and growth of these activities can perhaps be related to the strong input of two important universities in this district. First of all, UCL developed a science and research park in this area in 1969, gearing its technologies towards chemicals and biotechnology. On the other hand, ULB, which focuses on industrial research, also has a science park in this district (Capron, Cincera, Dumont, 2000, p.59). This could be an argument in favour of the support of basic research developed at universities (or developed in collaboration between universities and R&D active firms) and the development of local activities.

The districts of Leuven and Gent are characterised by a strong diversity of R&D activities between the top 10 of their R&D spending firms. All the firms in Leuven and eight of the ten in Gent belong to a different activity code. The stronger regional advantage in Gent can at least partly be explained by the intensified research of Innogenetics and Barco during the period 1992-1999. In contrast with Cockerill in Liège, Sidmar in Gent successfully intensified its research and development activities in the metallurgy sector.

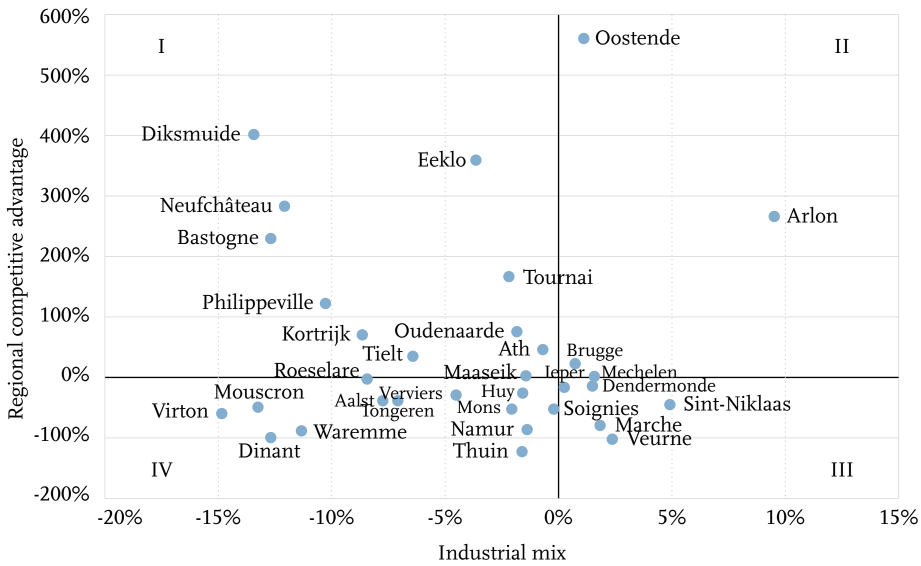
In the district of Charleroi, six out of ten leading R&D firms are to be found in the chemical industry. These firms represent nearly 60% of all R&D performed in that district. This explains the negative score for the industrial mix. It would be interesting to study the interactions (if there are any) between these firms and this phenomenon in the light of recent theories of the creation of a competitive edge for firms that cluster together.

[12] Due to confidentiality, we cannot disclose the name of the firm.

The negative competitive advantage of Antwerpen is rather surprising because it cannot be directly explained by the development of a particular sector. Antwerpen is oriented towards medium and high technology manufacturing industries. As was the case for Brussels in the low and medium service sectors, the development of medium and high technology in the district of Antwerpen has apparently experienced a global evolution that is below the national average development of R&D activities in those sectors.

The same exercise can be carried out for the other districts. Great care should, however, be taken when analysing the results shown in *Figure 4b* as a large number of districts do not perform very much R&D. In these cases, it is likely that the R&D profile of the district can be even more dominated by one or a small number of firms spending money on R&D.

FIGURE 4b **A typology for the other Belgian districts**



Source: Federal Co-operation Commission - CFS/STAT (2001). Own calculations.

We look at the outlayers in the figure above. The districts centralised around the intersection of the two axes are not discussed in detail.

If we consider those districts with a competitive advantage of more than 200% and an industrial mix of more than 10% as outlayers in *Figure 4b*, we note the following outlayers in the first quadrant: Diksmuide, Neufchâteau, Bastogne, Philippeville and Eeklo. In the second quadrant we have Oostende and Arlon. In the third quadrant we find no outlayers. Virton, Mouscron, Dinant and Waremme are the outlayers in the “lagging behind” districts of quadrant four.

As mentioned above, the outlayer position of these districts should be interpreted with great care. Only 3.8% of all Belgian firms active in R&D are located in those 11 districts (i.e. more than 25% of the total of 43 districts). These firms account for only 2.1% of the total R&D expenditure of Belgian firms permanently spending money on R&D.

With the exception of Virton (where only two R&D spending firms were found, one of which (Mobil Plastics Europe, now known as Exxonmobil chemical films Europe, Inc, see www.exxonmobil.com) with important R&D activity), the districts of Dinant, Mouscron, Waremme, Philippeville, Bastogne, Neufchâteau and Diksmuide are characterised by the absence of important R&D spenders. In these districts, the classification according to the regional R&D component is very sensitive. A minor error in our database or a slight change in R&D behaviour of one or a few firms in those districts could completely change the position for these districts. The fact that Virton is the most negatively positioned with an important R&D player is due to the fact that the industry in which this firm specialises is declining, and the company displays relatively poor development at the level of R&D performance compared with its competitors in this sector. This does not mean that the firm is in a bad economic position: a positive (negative) relation between R&D (the absence of R&D) and prosperity at the individual firm level is not proven. The situation of Waremme looks rather arkward at a first sight by virtue of being located between the high performance district of Nivelles and the large economic districts of Leuven and Liège. The small area of this district and the orientation of the local economy towards agricultural activities can be an explanation for the absence of important R&D activities.

The situation in Eeklo is dominated by the presence of the "Onderzoekscentrum voor de aanwending van Staal (OCAS)", the research centre of Sidmar (see website www.sidmar.be) located in Zelzate. The research centre is situated very near to Sidmar, but is located in the district of Eeklo instead of Gent (where Sidmar is based). This case is an excellent example for illustrating the problem, mentioned in the introduction, of the use of administrative frontiers between districts. Although the two entities are very close in terms of physical distance, they are located in different administrative districts.

In the very favourable quadrant II, the R&D situation of Oostende is dominated by the presence of Daikin Europe, which orientates its R&D activities towards innovation, eco-design and environment (see website www.daikin.com), performs relatively very well in R&D activities and is located in a growing business. The recent decision of Gent University to develop R&D activities in the Oostende district could have an important influence on the district's R&D profile in the future. The situation in Arlon is dominated by a large research centre in the growing field of biology and software. Most of the research performed in this firm is undertaken for other countries (especially Luxembourg).

We prefer not to go into further detail for the other – non-outlaying - districts. We conclude this chapter with an interesting typology of three more important geographical areas with a different R&D profile. The results of the figure show a clustering of districts with the same R&D profile in three large areas. Primarily, we can characterise the area of Eeklo-(Gent-)Oudenaarde-Ath-Tournai-Kortrijk-Tielt as an area with a rather weak industrial mix but a favourable competitive advantage. The area of Mons-Soignies-(Charleroi)-Namur, on the other hand, displays a rather unfavourable competitive advantage and an industrial mix that is slightly negative. The third large area that can be detected is the area between the large economic districts of Gent, Brussels and Antwerpen, i.e. the area of Sint-Niklaas-Dendermonde-Mechelen. In this area, the industrial mix is more positive and the competitive advantage quite neutral (to slightly negative). This could be seen as an indication of the existence of regional interdependency between R&D activities.

5. Conclusion and some policy implications

In this contribution, we have concentrated on research and development expenditure undertaken by the business enterprise sector in Belgium. It should be noted that research and development activities are an input indicator of the innovation process. As such, this indicator is not a measure of the efficiency in translating this research and development into economically useful products and/or processes.

Performing R&D activities is considered a key factor for firms to build on or maintain a competitive advantage. Theories about national innovation systems have been developed during the last decade (for an overview of the Belgian innovation system, see Capron and Meeusen (2000)). More recently, however, the attention in economic literature has been drawn towards the competitive advantage in R&D activities (see e.g. Caniëls, 1999). When discussing regional R&D in Belgium, a distinction is made between the Flemish, the Walloon and the Brussels regions. In this contribution, we have gone beyond that level and present Belgian R&D data at the NUTS3 level; i.e. district level.

Apparently, R&D activities in the business sector in Belgium are - compared with economic activity as measured by GRP - more concentrated in the more important economic districts than in the other districts. The high R&D intensity in these districts is correlated with important physical infrastructure networks. This increases the importance of historical/political decisions not only in the field of economic activity, but all the more so for the development of R&D.

The Ardennes (in the South-Southeast of Belgium) do not seem to attract a high R&D share because not many firms are located there. The geophysical system, coupled with the reduced accessibility that follows in its wake, is probably one of the most salient factors behind this phenomenon.

When looking at the concentration of R&D activities within firms in a particular district, it can be noted that by far the largest part of R&D activities in Turnhout, Halle-Vilvoorde and Hasselt are related to the largest R&D spenders in those districts. The low position of Liège and Gent can at least partly be explained by the absence of a very large R&D spender, though the mix of the R&D activities is far better in those districts than in most other districts. Brussels seems to be a special case with no less than 30% of its R&D activity realised outside its 25 most important R&D spenders. These observations are very critical for the dependence and profile of regional R&D activities and should be taken into account when developing policies at local level to stimulate R&D.

The hightechnology sectors in the manufacturing industry represent by far the largest part of R&D activity in Belgium. Not surprisingly, the largest R&D spenders can be found in the pharmaceutical industry, the chemical industry, and the electrical and electronics industry. By virtue of the large differences in R&D amounts spent in the different categories, great care should be taken when analysing the R&D strength of a district. A district can be highly R&D intensive in absolute terms, but display relatively low intensity in comparison with other (national or foreign) districts in the domain in which it specialises. On the other hand, a district whose R&D activities specialise in sectors in which the R&D amounts are lower can - even with a relative low R&D budget - be more competitive in the domain of R&D in those sectors in which it is specialised. As such, it is critical to fully understand the strengths and weaknesses of a district's economy. An international comparison in this aspect is absolutely necessary.

Of the ten most important Belgian districts in economic terms, only six (Brussels, Halle-Vilvoorde, Leuven, Nivelles, Antwerpen and Gent) have a high R&D advantage in R&D in high-tech manufacturing industries as well as in R&D in high-tech service sectors. Services in global terms are characterised by a relatively large concentration in a minority of Belgian districts (low R&D advantage and low R&D can be found in most districts). This clearly contrasts with the relatively more equally spread R&D activities in the manufacturing industries. As such, it would be interesting to investigate further why R&D is spatially concentrated in service sectors.

The sectoral concentration of R&D expenditure in economic activities also varies between districts. We found a strong concentration of R&D activities in the pharmaceutical sector in the district of Nivelles and in the chemical industry in Charleroi. In Brussels, on the other hand, there are no sectors that account for more than 30% of all R&D outlay. Concentration can have the advantage of developing regional clusters of firms active in R&D in a specific sector. LAMBOOY (1988) stipulates that the location of R&D is influenced by the type of network to which it belongs. The concept of "economic space" refers to the (market) relations the firm has with the network of suppliers and customers. This implies that the distance between these economic activities must be rather small, e.g. this is important in the automobile assembly sector or the steel sector.

Seen in this light, the social network is also of importance, with smaller SME's, in particular, locating their activities according to the location of relatives and friends. Even political influences can play a part in a firm's decision on where to locate. An anecdotal case is the location of the Toyota headquarters in Europe, where the French city of Valenciennes was finally chosen and even the quality of the fish in the local market was taken into consideration!

On the other hand, there can also be disadvantages associated with strong concentration of R&D activities in specific sectors. First of all, in these cases there is a strong dependence of a district on a particular R&D activity. Additionally, if location really does matter, the absence of diversity can be a hampering factor for cross-fertilisation between firms in different industries. In view of this, it is noted that the districts that have large attraction poles such as airports, universities, seaports, good accessibility, adequate infrastructure, good accommodation, etc., have a much lower degree of concentration of one or several economic activities (and are therefore less dependent on it).

Nominal growth in Belgian R&D expenditure was considerable between 1992 and 1999, displaying a rise of 53%. However, growth performance also differs by virtue of the weighting of the district in total R&D expenditure. The total shift was divided up into, firstly, a "structural" component, or an "industrial" mix, which signifies the change relating to the federal state that can be attributed to a district's particular mix of industries. Secondly, the total shift has a "regional" component or competitive advantage, which is a residual by virtue of its being calculated as the difference between the expected change (federal and structural components) and the actual change in that district. Although calculated as a residual, this competitive advantage is of specific analytical interest as it indicates that there are (perhaps numerous) factors present that can influence the decision to engage in R&D expenditure other than the industrial mix or due to institutional factors that are the same for every firm in a particular territory. Its economic significance has been ascertained by interpreting this component as an index of a district's competitive (dis)advantage. We find the most striking result to be the competitive disadvantages of the large districts of Brussels and Antwerpen. In contrast to some other districts, this phenomenon could not be related to one or a small number of firms in those districts. In Brussels, R&D in the low and medium tech sector, in particular, evidently grows at a rate far below the national figure. In Antwerpen, the same phenomenon is found for R&D activities in the high and medium tech industry.

When looking at the political landscape for R&D policy in Belgium, we should note that the Belgian innovation system is well known for its complexity. There are different (regional) authorities at NUTS1 level, which are responsible for research and development matters on their territory. This territorially bound structure is further supplemented by the Federal state, which still has some say in particular and/or strategic domains. Besides the regional authorities, there are the Flemish and French Communities, which are responsible for higher education, among other things. Following the recent work of Capron and Meeusen (2000), the tasks of the Federal state concerning R&D-related matters continues to diminish in favour of the "lower" level authorities.

Since spatial differences in R&D expenditure do exist, measures could be in order to reduce the technology gap. In our analysis, we indeed found indications of differences between the R&D expenditure of private firms in different districts. However, these differences only occur at the NUTS3 level, and are not visible at the NUTS1 level. Our contribution revealed important differences in R&D activity even within the Flemish, Walloon and Brussels Capital Region itself. On the other hand, some districts at the NUTS3 level show quite similar R&D characteristics even though they do not belong to the same region at NUTS1 level. These institutionally defined regions (NUTS1) thus do not reflect the real differences in R&D systems/patterns. Uniform policy measures pertaining to the entire territory of that region (for an overview of the different initiatives taken at the regional levels, see BRISTI, volume 1, part 2) consequently run the risk of being less than optimum. The development of an appropriate R&D strategy has to be carried out with extreme caution in order to exploit the full potential of each NUTS3 region (or district). Scientific policy measures should support the highly active R&D districts and - at the same time - actions should be undertaken in the less R&D active districts to enhance characteristics favourable to R&D (material and immaterial infrastructure, qualification of the labour force, institutional and cultural environment, etc.). The presence of infrastructure networks (industrial sites, roads, railways, and waterways to improve accessibility) seems crucial to the location of (economic and) R&D activities. The findings in this contribution do not subscribe to the idea of "trickle down" economics, i.e. that the benefits from one district are diffused by market mechanisms to also benefit other (adjacent) districts.

In this context, policy makers should also be aware that the R&D expenditure of Belgian firms tends to be influenced by the extreme openness of the Belgian economy. We are not indifferent to the fact that the regional structure and sectoral composition of R&D expenditure is affected by the dependency relating to actions taken abroad. A look at the presence of multinational or transnational firms in the Belgian economy makes it clear that their influence should be taken into account. These influences extend from links with the mother company to international collaboration. Multinational firms also have far better access to the technology at their home base, which implies better diffusion of the technology within the individual multinational and thus forms a competitive advantage vis-à-vis other enterprises within the same industry. This is not to say that the R&D performed in Belgium would be scattered in a homogeneous way if we do not consider the influence exerted by the multinational companies. The regional dispersion of R&D expenditure would persist. This is partly due to the fact that even the multinational companies perform (some of) their R&D in Belgium, too. One of the reasons for this is the excellent knowledge base provided for by the educational system (and the universities in particular) in forming the stock of human capital. All in all, we have to realise that the policy measures initiated by the governments responsible are partly dependent on the actions taken abroad.

Taking all these factors into account, we could summarise with the political conclusion that we dare to venture that the Belgian regions (at NUTS1 level) - the Flemish Region, Brussels-Capital Region and Walloon Region - are important at a policy level, establishing an institutional environment for businesses to operate in. Our finding that there appear to be differences within regions at the NUTS1 level and similarities between regions belonging to a different NUTS1 region implies that an important co-operative task in the domain of R&D lies ahead of the policy makers.

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Appendix 1

The 43 districts in Belgium

Appendix 2

Technological content of the economic sectors

Manufacturing
High technology
• Aerospace
• Computers, office machinery
• Electronics-communications
• Pharmaceuticals
• Scientific instruments
• Motor vehicles
• Electrical machinery
• Chemicals
• Other transport equipment
• Non-electrical machinery
Medium technology
• Rubber and plastic products
• Shipbuilding
• Other manufacturing
• Non-ferrous metals
• Non-metallic mineral products
• Fabricated metal products
• Petroleum refining
• Ferrous metals
• Gas, water, electricity
Low technology
• Paper, printing
• Textile and clothing
• Food, beverages and tobacco
• Wood and furniture
• Recycling
• Other activities not classified elsewhere

Services
High technology
• Computer and related activities
• Research and development
• Telecommunications
Medium and low technology
• Business activities
• Financial intermediation
• Postes
• Transport
• Other services

Appendix 3

Composition of the industrial mix

	Manufacturing sectors			Service sectors		Total
	High technology	Medium technology	Low technology	High technology	Medium and low technology	
Districts						
Antwerpen	1.2%	-2.2%	-0.2%	0.0%	0.4%	-0.8%
Mechelen	1.2%	-0.8%	-0.4%	0.1%	0.9%	1.0%
Turnhout	1.2%	-1.4%	-0.3%	0.1%	0.3%	-0.1%
Brussel	0.9%	-0.5%	-0.3%	0.1%	4.2%	4.3%
Halle-Vilvoorde	0.9%	-0.4%	-2.7%	0.1%	1.6%	-0.5%
Leuven	1.0%	-1.4%	-1.0%	0.5%	0.3%	-0.7%
Nivelles	1.3%	-0.1%	-0.3%	0.1%	0.5%	1.6%
Brugge	1.3%	-0.1%	-0.7%	0.0%	0.2%	0.8%
Diksmuide	0.0%	-14.2%	0.0%	0.0%	1.2%	-13.1%
Ieper	1.1%	-0.6%	0.0%	0.5%	0.0%	1.1%
Kortrijk	0.4%	-6.5%	-2.9%	0.2%	0.0%	-8.8%
Oostende	0.0%	-1.1%	-4.9%	0.0%	7.2%	1.2%
Roeselare	0.5%	-5.3%	-3.3%	0.0%	0.1%	-8.0%
Tielt	0.0%	-1.8%	-7.9%	0.0%	3.1%	-6.6%
Veurne	0.8%	-4.5%	-0.5%	0.4%	0.0%	-3.8%
Aalst	0.4%	-1.9%	-6.4%	0.1%	0.2%	-7.6%
Dendermonde	1.0%	-0.2%	-1.8%	0.1%	1.7%	0.8%
Eeklo	0.5%	0.0%	-5.5%	0.3%	1.6%	-3.1%
Gent	1.0%	-2.3%	-0.7%	0.3%	0.3%	-1.4%
Oudenaarde	1.3%	-0.6%	-0.9%	0.0%	0.0%	-0.2%
Sint-Niklaas	0.7%	-0.7%	-0.9%	0.4%	3.4%	3.0%
Ath	1.3%	0.0%	-1.4%	0.0%	0.0%	-0.2%
Charleroi	1.2%	-2.1%	0.0%	0.0%	0.2%	-0.7%
Mons	1.0%	-4.6%	0.0%	0.1%	0.0%	-3.5%
Mouscron	0.1%	-6.9%	-6.2%	0.0%	0.0%	-13.0%
Soignies	1.3%	-0.7%	-0.6%	0.0%	0.0%	0.0%
Thuin	1.1%	-2.3%	-0.1%	0.3%	0.0%	-1.1%
Tournai	0.7%	-5.7%	-0.6%	0.2%	0.1%	-5.3%
Huy	1.2%	-0.1%	-2.0%	0.0%	0.0%	-0.8%
Liege	0.6%	-7.1%	-0.1%	0.2%	0.7%	-5.8%
Verviers	0.8%	-2.1%	-3.2%	0.0%	0.5%	-4.0%
Waremme	0.0%	0.0%	-11.9%	0.0%	0.5%	-11.4%
Hasselt	1.0%	-1.6%	-0.7%	0.2%	1.1%	0.0%
Maaseik	1.2%	-2.0%	-0.4%	0.0%	0.1%	-1.0%
Tongeren	0.8%	-7.0%	-0.2%	0.0%	0.1%	-6.3%
Arlon	0.0%	-1.4%	-0.7%	0.0%	11.6%	9.6%
Bastogne	0.0%	0.0%	-12.3%	0.0%	0.0%	-12.3%
Marche-en-Famenne	0.0%	0.0%	-4.2%	2.1%	0.0%	-2.1%
Neufchâteau	0.0%	0.0%	-12.0%	0.0%	0.0%	-11.9%
Virton	0.0%	-15.0%	0.0%	0.0%	0.0%	-15.0%
Dinant	0.0%	-0.2%	-12.2%	0.0%	0.0%	-12.4%
Namur	0.2%	-2.3%	-0.5%	1.9%	0.7%	0.0%
Philippeville	0.0%	-12.8%	0.0%	0.0%	2.5%	-10.3%

Transition towards the knowledge-based economy: growth potential and learning regions*

Henri Capron

Introduction

The systemic approach has imposed itself over the past ten years as a framework for analysing innovation processes and as a new basis of reflecting on the development of science and technology policies (S&T) (OECD, 1999b). Initially focusing on national innovation systems (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Metcalfe, 1995; Edquist, 1997), it has also proven to be a powerful analysis tool at regional level (Massard, 1998; Braczyck and Cooke, 1998). The concept of innovation system is closely linked to the one of innovation clusters (OECD, 1999a). With this concept, emphasis is placed on the links and interdependences between institutional players for greater control of value added networks and the valorization of positive externalities associated with sharing and exchanging knowledge. By virtue of that, the regional level, or even the local level, appears to be adequate because of its direct link with the proximity concept. Nevertheless, the territorial anchoring of an innovation system requires multiple proximity, i.e. non-exclusively geographical.

The application of this approach to the Belgian case has shown some institutional mismatches within the innovation system at the federal level as well as at regional level (Capron and Meeusen, 1999; Capron and Cincera, 1999, 2000). The federalisation of the country has materialized through the implementation of S&T policies that are noticeably different between the three regions. If the interregional differences in terms of economic structures constitute an important part of the explanation, institutional factors have equally played a large part in increasing the differentiation of the regional innovation systems in Belgium. Three innovation systems that are relatively independent now dominate the Belgian technological arena although the universities come under the control, not of the regions, but of their respective community. The Federal State prerogatives are restricted to matters transcending regional areas. It has thus become reductionist and even incorrect to talk about a Belgian innovation system while ignoring federated entities.

* Original text in French.

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After highlighting the relevance of a territorial approach of innovation systems and the necessity of a new mode of institutional governance in order to fully grasp the opportunities offered by the transition of an industrial economy to a knowledge-based economy, attention will be focused on the capacity of the regions to install a mode of governance suited to the imperatives of the new economy. The European framework will be used as a point of reference to put into perspective the position and characteristics of the Belgian regions with regard to their innovation potential. Firstly, the regions will be positioned globally within the European arena according to the key elements of the innovation systems. What is the position of the regions in the European spatial hierarchy as regards their scientific and technological potential? In the light of this positioning, the main structural components of the innovation regional systems will be analysed at both the spatial and sectorial level in a second phase. The innovation potential is not evenly distributed over the territory as a whole, rather it is concentrated in a limited number of districts. This potential is, moreover, highly conditioned by the technological intensity of the specialised sectors in the regions. How is the Belgian landscape made up of from this twofold point of view? Finally, another aspect at least as important as those mentioned above but of a more qualitative nature entails determining where the regions currently find themselves along the curve of their learning process. In other words, to what extent do the institutional and organisational components underlying their innovation systems make them into learning regions with sufficient assets to integrate favourably into the new knowledge society? The analysis is concluded with an overall assessment of the issues confronting the regions.

1. Innovation systems: from the nation to the region and from the region to the territory

Spatial dynamics play a key role in the functioning of innovation systems. Space is neither economically nor technologically neutral. According to Arcangeli (1993), a national innovation system would only constitute the network of networks structuring the regional innovation settings, with the latter requiring effective coordination of the organisation and communication infrastructures. The regional innovation settings are characterised by the extent of local synergies existing between cooperation networks, information exchange networks, work mobility networks and other flows interconnecting private and public institutions involved at the various stages of the innovation process representative of regional activity poles.

The heart of the innovation system is based on the whole of sectorial interactions between the different categories of players: the stronger the interactions between the system components in terms of the generation, transmission and utilisation of knowledge, the greater its achievements. The orientation and priorities of S&T policies, the regulatory and normative framework determining the knowledge regime, the official structures ensuring knowledge transmission and the financing arrangements for the innovation process are all factors that condition the extent, the course and the effects of interactions between different categories of institutions playing a decisive part in the innovation system.

As emphasised by David and Foray (1995), the channels and means through which the knowledge distribution and utilisation are achieved have become a crucial element of innovation systems and are at least as important as the capacity to generate new knowledge. In this respect, public policies should pay greater attention to the processes linked with the accessibility and distribution of knowledge by implementing tools that improve the characteristics of the knowledge regime, i.e. which support and reinforce the transfer and absorption capacity of the latter. With market forces being insufficient on their own to ensure the effective distribution and utilisation of knowledge, this requires the setting up of appropriate bridging institutions to provide for its dissemination, stimulate cooperation, make access to the existing stock of knowledge easier and improve the capacity of users to research relevant scientific and technological information.

Four kinds of institutions play a decisive part in the effectiveness of the innovation system. First of all, private enterprises and research centres are the main vehicles carrying out the commercial valorization of the fruit borne by the innovation process. Secondly, the research and technology centres made up of public research centres, joint research centres and research institutes are essential for the development of infratechnologies, generic technologies and cost-sharing research. Thirdly, there are the university and inter-university research centres as well as research communities, whose main objective is to disseminate and develop knowledge. Finally, bridging institutions, such as S&T diffusion and assimilation centres, resource centres, technological consultants, university interfaces, professional associations whose essential role is to stimulate interactions between players, distribute new knowledge and make sure the research system functions effectively.

The quality of the industrial and technological clusters formed, of the official and informal networks established, of scientific, technological and economic specialisations and of the specific links that form the basis of the system's institutional dynamics depends on the degree of connectivity between these different types of institutions. These various elements make up the root of knowledge potential and its achievements as well as the global performance of the innovation system. To sum up, the performance of an innovation system is nothing other than the reflection of the quality of the system of institutional governance that animates it.

Up to recently, the government's key role was to find remedies to compensate for the deficiencies of the market system. The observation of systemic deficiencies within innovation systems calls for corrective governmental actions to reinforce coordination between policies associated with knowledge management and economic and social needs. This implies that policies benefiting innovation and technology are becoming an integral part of global economic policy. Such integration calls for a radical change in the way of thinking on the part of public Authorities, which often give priority to a vertical approach that is scarcely propitious to efficient and effective management of the innovation system.

As underlined by COOKE (1998), a regional innovation system is characterised by microconstitutional regulation based on trust, reliability, exchange and cooperative interaction. It is the institutional capacity to attract and stimulate competitive advantage, often through the promotion of cooperative practices between economic and social players, that gives the region a strong conceptual and actual identity (DE VET, 1993). At regional level, the institutional component plays a predominant part, as the potential cost of institutional rigidity is enormous. The need for a region to benefit from an efficient institutional system is therefore a major factor for a successful innovation system.

Given that the region does not constitute a uniform whole, but being more usually characterised by a diversified territory, there is a need to take account of the territorial anchoring of innovation dynamics. The relation between innovation and territory relates back to interactions between learning, innovation and space, which are principally based on multiple proximity relations (not only geographic but also temporal, technological, organisational and relational) between the institutional players involved in the process of producing, transmitting and disseminating knowledge. Territorialized innovation systems are defined as collective learning areas where new knowledge emerges through interactions according to a twofold process of problem solving and institutional learning (BOUABDALLAH and *al.*, 1996). More fundamentally, the emergence of a territorial system depends on the existence and effectiveness of institutional animation and intermediation structures guaranteeing interrelations between the players.

For a number of years now, empirical studies have gathered showing that the distance between players has a significant role in the dynamics of the innovation process. The work of JAFFE (1989), ACS and *al.* (1992) and JAFFE and *al.* (1993), for example, demonstrate that the knowledge spillovers from university research to private enterprises are facilitated by geographic proximity. In their analysis of the distance effect on the dissemination of knowledge, FELDMAN (1994), AUDRETSCH and FELDMAN (1996), AUDRETSCH (1998) and FELDMAN and AUDRETSCH (1999) have likewise shown that innovations have a strong tendency to be concentrated geographically. According to ANSELIN and *al.* (1997b), the contribution of university institutions to the creation of new technological knowledge depends heavily on the development level of the local innovation systems. Agglomeration factors, such as the concentration of high-tech enterprises, the availability of business service activities and a dense SME network contribute substantially to the intensity of technology transfers originating from local universities (VARGA, 1998). The critical mass for benefiting from agglomeration economies in metropolitan regions corresponds to a population of about one million inhabitants and the existence of a high local university potential. In those regions that do not have the sufficient critical mass in agglomeration terms, research support must be accompanied by measures facilitating the development of jobs in high-tech operations and services to enterprises. ANSELIN and *al.* (1997a) show that relations between industry and universities at local level are very sensitive to distance and that the bulk of university spill-over effects are globally limited to a radius of 80 km.

2. Regional governance systems

The two last decades have been marked by the growing role played by the regions in economic and social development. Ohmae (1993) questions the relevance of nation-states in a globalised economy. Region-states are establishing themselves more and more as natural economic areas and must, in this respect, possess the essential ingredients in order to be established in the New World economy. In contrast, according to Porter (1990), the intensification of global competitiveness makes the role of nations-states more rather than less important, although he also acknowledges that the region, and even the local level, constitutes the geographical unit that determines growth (Porter, 1998).

The transition from an industrial economy to a knowledge-based economy is not without any bearing on this evolution. The former is based on a mode of organisation founded on hierarchic structures and the notion that the world is relatively sure and predictable. In an economy where knowledge has become a critical resource that supersedes capital as the main production factor, what prevails is a hierarchic type of organisation mode conscious of the complexity of its environment, i.e. structured in the form of networks. In the same ways as enterprises, administrations must become organisations undergoing a continuous learning process and having faith in the capacity of decentralised and autonomous networks to create wealth (Schwartz and *al.*, 1999).

The growing focus on the region in terms of a “strategic site” in the forming of public policies is manifested by particular attention being paid to the forms of regional governance that accompany this process. As crucial elements within these governance systems, regional development agencies play an essential role in facilitating consensus between players, as well as institutional change and social learning. As such, they are at the same time an animator and intermediary in the process of creating networks and institutions (Morgan, 1997).

In a dynamic world that is becoming increasingly complex and diversified, governance has become composite and governability is not assured (Paquet, 1998). In knowledge economy in which the effectiveness of the network structures on a partnership basis has become a crucial element for competitiveness, centralised and hierarchic governance structures have become less and less efficient and operational. An ever-closer link is established between the concepts of networks, partnerships, agglomerations, institutions, and systemic and regional governance. As the networks are the vital liaison channels between groups of agents for information and service exchange, the partnership implies a commitment on the part of the agents to fully collaborate with special concern for absolute quality and adaptation of internal operational structures in order to improve the global efficiency of the system.

Regional governance relates to the institutional structures and methods of organization, formal and informal, underlying and influencing the strategic decisions and actions of players and groups within a specific area. In this regard, it goes beyond the mere framework of regional government, also encompassing the public and private institutions such as chambers of commerce, professional associations, training centres, development agencies, and universities. It is characterised by the institutional capacity to operate structural adjustments needed by the system in the general interest. Qualifying a regional governance system increasingly requires referring to the concepts of 'institutional thickness' and social capital. The institutional thickness as defined by Amin and Thrift (1995) is characterised by the players' capacity to come together to develop, consolidate and disseminate appropriate patterns of collective representation, the structuring of interactions and of active innovation support. In more generic terms, social capital is defined as the relational infrastructure linked with collective action, which requires trust, adhesion, reciprocity and a predisposition to collaborate to mutually beneficial ends (Henderson and Morgan, 2002). The latter two concepts constitute the ferment of success of industrial districts and innovative environments. In the knowledge economy, social capital acquires a very particular connotation given it is naturally highly interactive. If the economy of networks is based on technology, it can only be built on human relations: starting with electronic chips and ending with trust (Kelly, 1998).

From the point of view of governance analysis, only the concept of collective learning can provide the mental tools useful for the study of governance (Paquet, 1998). While, in the prevailing industrial system, governance has been carried out by a centralised and hierarchic guidance structure, in the emerging knowledge economy the wealth of interactions, the density of networks and the acceleration of change are increasingly transforming organisation into a game whose prevailing logic escapes the situation "definers". In such a context, organisations seem to be increasingly disconcerted, with governance as a piloting activity becoming more and more complex to the extent it consists in a series of ad hoc reactions to systems constantly generating unpredictable results. In fact, the quality of a governance system is evaluated according to the capacity of the institutions to evolve from a programmatic type of functioning mode to one of a partnership type. In a programmatic governance system, the emphasis is placed on managing separate projects and defensive and confrontational management modes. The realisation of a need for interfacing between projects and operators to enable greater coherence and effectiveness actions calls for a partnership management system based on the integration of projects, as well as a territorial development logic and a cooperative approach.

In such a context, the agglomerations or clustering policy has imposed itself as an operational means of stimulating horizontal and vertical relations between firms and institutions in order to instil a cooperative culture generating synergy effects between different categories of players with a decisive role in regional development. Being part of an agglomeration or network is likely to improve productivity, the tempo of innovation as well as the competitive performance of enterprises (OECD, 2000). The agglomeration policy offers a framework that is propitious for dialogue and cooperation between enterprises, public institutions and non-governmental organisations. By triggering cooperation between enterprises and greater proximity between enterprises and institutions, it enables the efficiency of enterprises to grow and improve the quality of public actions in the field of training, dissemination of information and the provision of infrastructures. This implies a fair distribution of competences on a partnership basis and non-hierarchical relations between local players who have a profound knowledge of local situations and regional Authorities representing the only entity likely to have the global vision needed for harmonious territorial development. Close collaboration with the private sector is also essential to ensure that the planned actions meet an actual need and put matters in perspective between institutional mismatches and the shortcomings of the market economy in order for the agglomeration initiatives and institutions to complement each other efficiently according to their respective competencies.

As quite rightly emphasised by FLORIDA (2000), the role of the regions in the new age of the global knowledge-intensive capitalism continues to be greatly misunderstood although they are a key element of this. The regions are gradually becoming points of reference for knowledge creation and learning. Insofar as they are able to develop the characteristics of learning regions, they act as collectors and guardians of knowledge, providing the infrastructures and environment needed for knowledge flows, the emergence of new ideas and the learning process: they become, in reality, vehicles of globalisation. The regions have set up governance mechanisms that, although they proved to be suitable for the industrial system that ruled the economy of the 20th century, are not very effective for integration in the knowledge-based economy. While the regions with an old industrial tradition are characterised by top-down type relations, a vertical hierarchy and regulation modes based on command and control, learning regions develop bottom-up governance structures reflecting those of knowledge-intensive firms: mutual dependency relations, a network organization, decentralised decision-making processes, flexibility and a constant concern to meet the needs of consumers-citizens.

TABLE 1 **From industrial regions to learning regions**

	Industrial regions	Learning regions
Competitiveness bases	Comparative advantage based on: • Natural resources • Physical labour	Sustainable advantage based on: • Knowledge creation • Continuous improvements
Production system	Mass production • Physical labour as source of value • Separation of production and innovation	Knowledge-based production • Continuous creativity • Knowledge as a source of value • Integration of production and innovation
Industrial infrastructure	Arm's length supplier relations	Enterprises networks and close relations with suppliers as a source of innovation
Human infrastructure	• Low-cost and low-skill labour • Taylorist workforce • Taylorist education and training system	• "Intelligent" work • Continuous improvement of the quality of human resources • Continuous education and training
Physical and communication infrastructure	Physical infrastructure conceived on a national basis	• Infrastructure considered on a global basis • Electronic exchange of information between customers, end-users and suppliers
Industrial governance system	• Conflicting relations • Hierarchic organization • Regulatory framework based on command and control	• Mutual dependence partnership relations • Network organisation • Flexible regulatory framework
Institutional governance system	Centralized, hierarchic and reactive functional logic • Division of competencies • Intervention based on market deficiencies • Centralised decision-making • Administrative management	Bottom-up, partnership-based and proactive territorial logic • Integration of competencies • Intervention based on systemic deficiencies • Decentralised decision-making • Public-private partnership

Source: adapted and extended from FLORIDA (2000).

Table 1 compares the main characteristics of learning regions with industrial regions. While the latter have based their development on their capacity to valorize their comparative advantages associated with the exploitation of natural resources, the former mainly bank on their capacity to mobilize and valorize learning and new knowledge. The contrast is very evident between the functional logic that prevails in industrial regions and the territorial logic that makes learning regions successful. Transition from one model to the other cannot be achieved without a regional strategy providing the impetus essential to mobilise the process of change. If this implies a radical break with traditional development policies, it also entails profound institutional adjustments in order to create a framework suitable for the emergence of an interactive system facilitating innovation and learning. We can only claim to set up an interaction and learning process if the institutional framework itself reflects the culture of learning that it wishes to promote.

3. Belgium within the European innovation system

The efficient national innovation systems only reflect the effectiveness of the innovation systems in a few regions. This is relatively clear when referring to the concept of innovation archipelagos for singling out the European regions that concentrate a significant amount of expenditure on R&D (European Commission, 1997). Of a total of 136 European regions (Capron and Cincera, 1999, 2000), ten account for more than half of European R&D expenditure and registered European patents. Conversely, forty regions located at the opposite end of the scale make up less than 1% of European R&D and record less than 1% of European patents.

A typology of the European regions (except last new adherent countries, Austria, Finland and Sweden) has been suggested by Clarysse and Muldur (2001), who classify the regions in six groups on the basis of technological and economic indicators. While Brussels-Capital belongs to the top group, i.e. the industrial leaders, made up of eight regions, Flanders and the Walloon Region are ranked in the third group, i.e. weak-growth regions[1]. The authors' aim was to classify the regions according to their twin dynamics of technological and economic development. This gives to Brussels a leading position and suggests a close proximity between Flanders and the Walloon Region in spite of substantial gaps in terms of technological and economic achievements.

Three key elements play an essential part in the effectiveness of innovation systems: absorption capacity, transfer capacity and creative capacity. Although the study by Clarysse and Muldur provides a relevant vision of the European economic and technological spatial landscape, it remains silent on the links between proposed regional types and the basic components of innovation systems. To what extent do the Belgian regions differ from each other and from their European partners with regard to the key functions that must be fulfilled by an efficient innovation system in a knowledge-based economy? In other words, what is their absorption capacity, their transfer capacity and their creative capacity? If interactions between these functions are essential to the

[1] The six groups of regions formed by the authors are respectively: the “industrial leaders”, the “clampers-on”, the “slow growers”, the “economic catchers-up”, the “technological catchers-up” and the “laggers behind”.

efficiency of the innovation system, an analysis of the basic quantitative indicators relating to science and technology does nevertheless enable to draw up some observations. Consequently, it is by focusing on the three basic components of an innovation system, i.e. the capacity of production, transfer and transmission of knowledge, that a partitioning of the European regions putting the position of the Belgian ones into perspective has been achieved.

This analysis of the positioning of the European regions was founded on indicators based on five groups of variables[2] representing the technological and economic achievements of the regions:

- R&D activities: in the analysis of innovation systems highlighting the specific roles played by government institutions, universities and the industrial sector, a distinction is drawn between these three categories of players, with these indicators providing an assessment of the regions' capacity to carry out the technological adjustments needed to maintain their economic achievements;
- patents: the most commonly-used measure to evaluate the innovation capacity of a region in spite of its weaknesses, it gives an indication of a region's propensity to elaborate new products and methods likely to modernise the production structures;
- labour productivity as measured by the ratio between GDP and the working population active in the region: it represents an indication of the region's capacity to grasp the opportunities offered by the new products and processes;
- wealth level per inhabitant (in purchasing power standards): it is representative of the capacity of a region to create competitive advantages and valorize them in order to improve the well-being of its population;
- educational attainment[3] of the population aged 25 to 59 years, which gives an idea of the capacity to assimilate new technologies: regions enjoying a higher than average proportion of qualified workers show a comparatively greater capacity to adjust more easily to technological evolution.

Two complementary categories of indexes have been calculated for both R&D and patents: a measure of the technological base on the basis of R&D expenditure and patents per inhabitant plus an measure of technological intensity based on R&D expenditure and the number of patents per unit of GDP. The aim of the R&D-based indexes is to evaluate to what extent a region invests sufficiently in this field in order to ensure its economic development (absorption and transfer capacity). The patent-based index evaluates the region's creative capacity. The distinction between the R&D realized by the different categories of institutions makes it possible to estimate the extent of the "institutional pluralism" of R&D activities. The second category of indicators helps to assess the technological positioning of the regions in relative terms according to their level of wealth.

[2] All the data used in this section are provided by EUROSTAT.

[3] The ISCED (International Standard Classification of Educational Diplomas) enables a comparison of the education and qualification levels of the population. The ISCED levels 1 and 2 correspond to primary and lower secondary education (low educational attainment), ISCED 3 to upper secondary education (medium educational attainment) and ISCED levels 5 and 6 to higher education (high educational attainment) (ISCED 4 is no more in use).

Combining the different European indexes enables a preliminary assessment of the three essential components of the innovation system[4] :

- absorption capacity: based on a composite index taking account of training and productivity levels;
- transfer capacity: resulting from the combination of the absorption capacity, GDP per inhabitant, R&D per active worker and R&D intensity of the different types of institutions;
- creative capacity: resulting from the absorption and transfer capacity, R&D per inhabitant of the different categories of institutions, the number of patents and R&D productivity in terms of patents.

The classification of the regions based on the indexes calculated in this way was carried out in relation to the European average. The combining of different indexes makes it possible to divide the regions into different groups according to their position and evolution within the European innovation system. In order to estimate the regions' capacity to adjust, the analysis was completed by evaluating the evolution of the main technological indicators during the 1994-1998 period. This results in a twofold typology of the regions: based on their technological potential on one hand, and on the evolution of this potential on the other hand. The main points emerging from the classification of the European regions as shown in *Table 2* can be summarised as follows:

- The first group of regions displays the best technological achievements. Among these are the regions dominating the European technological space and which can, in this respect, be classified as the European technological leaders. Here, we again come across the innovation archipelagos already pointed out in the first European report on scientific and technological indicators (EUROPEAN COMMISSION, 1994). This group can be broken down into two subsets: the technological leaders that dominate the European technological space given their high level of absorption, transfer and creative capacity (indexes above 125) and the technology challengers, comprising those regions able to join the leading group very quickly without any particular problem (indexes above 100). Flanders and Brussels belong to this subset. With a growth rate for technological indicators higher than the European average, Flanders is on the way to moving towards the first subset. The federalisation of the country has

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[4] All the variables were calculated in an indexed manner compared with the European average; the composite indexes used are the following:

IA = (P+IN/7 +2* MO/7 + 4*SU/7)/2

IT = (2*IA + 0,55*IND + 0,15*GOV + 0,30*EDU + INP + RDP + PIB)/6

IC = (1,5*IA + 2*IT + 0,55*IPO + 0,15*GPO + 0,30*EPO + BRP + BPO + BRE + BPR + BPT)/10,5

Where IC = creative capacity index, IT = transfer capacity index, IA = absorption capacity index, P = labour productivity, IN = low educational attainment, MO = medium educational attainment, SU = high educational attainment, IND = industrial R&D intensity, GOV = government R&D intensity, EDU = higher education R&D intensity, INP = industrial R&D per active employee, RDP = total R&D per active employee, PIB = GDP per inhabitant in SPA, IPO = industrial R&D per inhabitant, GPO = government R&D per inhabitant, EPO = higher education R&D per inhabitant, BRP = patents per inhabitant, BPO = patents per GDP unit, BRE = patents per active employee, BPR = industrial R&D patents, BPT = total R&D patents.

The fact of taking into account several types of weighting for a same variable aims at smoothing the indicators and grasping the phenomenon studied in the best possible way. The inclusion of absorption capacity in the transfer capacity index and of absorption and transfer capacity in the creative capacity index is explained by the fact that a good transfer capacity implies a good absorption capacity and a good creative capacity requires good absorption and transfer capacity. These conditions are met for the majority of regions. Furthermore, slight modifications of the mix of indicators taken to form the three major indexes have little implication on the regional typology obtained.

strongly influenced the spatial distribution of R&D activities in Belgium, thus affecting the polarising role of Brussels. Although Brussels accounted 40% of R&D potential in 1963, the region now represents only 20% of the total number of researchers (CAPRON, 2000). Without an intensive science and technology policy, it is rather unlikely that the region will catch up with the leading pack. This is confirmed by the growth rate of the technology indicators for the overall European average.

TABLE 2 **Technology classification of the European regions**

	Creative capacity		Transfer capacity		Absorption capacity	
	Technology leaders	Technology challengers	Technology transition	Technology followers	Technology assimilation	Technology backwardness
Technological growth dynamics						
High	Stockholm Bavaria Sydsverige Västsverige Östra Mellansverige Övre Norrland Hamburg Berlin Suomi/Finland		Norra Mellansverige North Vejle, Ringkobing, Viborg Haute-Normandy	Baleares Fyns Nordjyllands Mellersta Norrland Pais Vasco	Navarra Castilla-la Mancha Andalucia	
Strong	Baden-Wuerttemberg Hessen East Anglia Copenhagen Frederiksberg Roskilde North Rhine-Westfalia Rhone-Alpes Aarhus	**Vlaams Gewest** Netherlands Lower Saxony Midi-Pyrénées Bremen	Saarland Tyrol Schleswig-Holstein South West (UK) Provence-Alpes-Côte d'Azur Franche-Comté **Walloon Region** Centre Scotland Lorraine Languedoc-Roussillon	Vorarlberg Lower Austria Smaland Med Oarna Kärnten Upper Austria Veneto Trentino-Alto Adige Poitou-Charentes Auvergne Ireland Saxony Madrid	Basse-Normandie Sonderjyllands, Ribe Pays de la Loire Cataluna Limousin Vestsjaellands Storstroms Bornholms Comunidad valenciana Aragon Asturias Attiki Dytiki Ellada Lisboa e Vale do Tejo Murcia Rioja Kriti Norte Notio Aigaio Thessalia Dytiki Makedonia	Acores Galicia Centro (P) Voreio Aigaio Ipeiros Madeira

	Creative capacity		Transfer capacity		Absorption capacity	
	Technology leaders	Technology challengers	Technology transition	Technology followers	Technology assimilation	Technology backwardness
Technological growth dynamics						
Medium	Rhineland-Pfalz Ile de France Vienna	Alsace Brussels Lombardy	Steiermark Emilia-Romagna Bourgogne East Midlands West Midlands Friuli-Venezia Giulia Picardie Liguria Brittany	Salzburg Yorkshire and Humberside Marche Lazio Aquitaine Brandenburg Saxony-Anhalt	Champagne-Ardenne Canaries Toscana Umbria Nord-Pas de Calais Sicilia Kentriki Makedonia Abruzzi Castilla-Leon Extremadura Northern Ireland Sardegna Puglia Cantabria Corse Molise Sterea Ellada	Anatoliki Makedonia, Thraki Burgenland Alentejo Calabria Ionia Nisia Peloponnisos
Poor		North West (UK) South East (UK)	Piemonte	Wales Thuringia	Valle d'Aosta Mecklenburg Campania	Basilicata Algarve

• The second group covers regions characterised by a transfer or creative and absorption capacity higher than the European average. In global terms, these regions have sufficient resources to exploit new products and processes developed in the most innovative regions and are sometimes quite innovative without necessarily having substantial R&D infrastructures (e.g. Vorarlberg). They could also, with a more voluntaristic technology policy, improve their creative or transfer capacity to a substantial extent. The technology transition regions are those with enough potential to catch up with the first group of regions, provided they implement an efficient valorization policy in their research infrastructure. The group of technology followers is made of regions suffering from greater handicaps with regard to research structures: either R&D investment is clearly inadequate or the propensity to patent is very limited. The Walloon area belongs to the group of regions undergoing technology transition. Although its absorption and transfer capacity level is distinctly higher than the European average, there is a lack of R&D investment and its productivity in terms of patents is definitely not sufficient. An improvement in industrial R&D and greater valorization of its research potential would help the region to substantially increase its technological achievements, and through this, its economic performance. In strictly quantitative terms, the recent evolution is favourable to the region, the growth rate of its technological indicators being higher than the European average.

• The last group, also made of two sub-sets of regions, suffers from numerous deficiencies in research structures. The first sub-set covers those regions benefiting from an assimilation capacity for new technologies but which experience difficulty in valorizing this learning capacity. Substantial efforts must be made by these regions to ensure that they master the initial stage of the research processes. The second sub-set includes those regions with a marked technological backwardness: not one single indicator favours them and much still needs to be done in the area of research policy.

If we have a look at the evolution of technological indicators, we observe that the leading European regions tend to maintain their predominance, with the growth rate of their indicators at least in line with the European average. On the other hand, the regions positioned in the lower right-hand corner of the table are those with problems, not only because most of the indicators are unfavourable for them, but also with regard to their development.

Although some regions such as Champagne-Ardenne and Valle d'Aosta display good economic performance in spite of weak technological potential, their development often depends on specific local aspects that are difficult to reproduce elsewhere. Moreover, any crumbling away of these specific features could ultimately cause a problem for these regions due to the lack of a stable technology base.

The main point emerging from this table shows that there is an evident need to improve, at the spatial level, the balance with regard to the distribution of competencies concerning S&T activities. The policies to be implemented in order to reach this goal must however be suited to the regional environments and be part of global strategic development. The European regions that do not enjoy an adequate critical mass of R&D potential in order to adapt and diversify their production structure are large in number[5]. In these regions, emphasis must be placed on infrastructure development to benefit higher education and on improving training programmes, both necessary conditions for enabling the assimilation of technological knowledge.

Wallonia belongs to a group of regions facing reconversion and restructuring problems. These regions, in spite of high R&D indexes in higher education, are not only characterised by industrial R&D indexes that are lower than the European average but also by a strong specialisation of industrial activities in sectors with weak or moderately intensive technology intensity. These regions would have everything to gain from policies aimed at developing diversification of R&D activities according to their specificities, as well as triggering collaboration between industry and universities, as well as within industries. In this context, more qualitative actions promoting the development of transfer and absorption capacities would be more beneficial than those nurturing the creative capacity through sheer support funding, especially where these actions are strongly oriented towards the upstream side of the research process. It is quite plausible that a substantial strengthening of absorption and transfer capacities would give rise to a considerable improvement of the creative capacity with the significant advantage that the latter would be of an endogenous nature, and not exogenous as is currently the case.

[5] The low level of R&D expenditure is such that these regions often do not have the capacity to develop defensive strategies.

4. Economic bases of the innovation system

An essential characteristic of the Belgian economy is its uneven spatial development. On the one hand, the Walloon Region was a pioneer of the industrial revolution while Flanders remained, for its part, very distant from the industrial transformations of the 18th century. Wallonia is now facing the same problems of industrial restructuring as the old English industrial regions. In this respect, the Walloon problem is scarcely different from that confronting the old European regions with an industrial tradition, such as Nord-Pas de Calais, Lorraine, Merseyside or Sarre. After World War II, economic growth in Belgium was essentially a result of accelerated development in Flanders, strongly supported by the central government. Its benefits in terms of localisation, the absence of any stigma from the industrial revolution and the availability of an abundant supply of labour were to be advantageous for the region taking off economically. The decline of the coal-mining activity in the Walloon area and the concentration of foreign investment in Flanders have exacerbated the development of the regional disparities. In the mid-70s, the crisis in the steel industry served to accelerate Wallonia's decline as well as radically change the path of regional growth. The consolidation of the international status of Brussels allowed it to preserve its predominance in Belgium despite the federalisation of the country, federalisation that presented the regions with the means to implement policies suited to their own specific features.

The three Belgian regions now display radically different socio-economic profiles. Brussels is a metropolitan region characterised by a large concentration of administrative centres and limited industrial activity, while Flanders is a strongly industrialised region with undeniable localisation advantages and an effective service infrastructure, and the Walloon area is a de-industrialised region confronted with an economy weakened by successive crises and numerous deficiencies in the field of high-level services. Nevertheless, the three regions do have one common characteristic: a high scientific potential.

Belgium's current prosperity has its source in a long tradition of openness to innovations and new ideas. This process can be explained by the long cycles of economic activity and technological development (Capron, 2000). One of the main secrets of Belgium's prosperity lies in its capacity to adapt its industrial structure in the light of technological advances. Over the long cycles of economic evolution, Belgium has succeeded in grasping the opportunities offered by the emergence of innovative industry clusters even if, over the past few decades, this has essentially been the result of its capacity to take advantage of foreign multinational investments (Borschum, 1999). Notwithstanding its territorial exiguity, Belgium is characterised by a strong cultural diversity and regional growth trajectories which make a global approach far less relevant when it comes to explaining why and how the country has been one of the world's most dynamic regions for more than two centuries.

Table 3 shows some main characteristics of Belgium, its regions as well as its subregional entities. Although Belgium holds a favourable position at European level in terms of GDP per inhabitant, patents per inhabitant and labour productivity, this is not the case for entrepreneurial potential as measured according to the number of self-employed per inhabitant. Western Flanders alone distinguishes itself through a high degree of entrepreneurial potential. It is a region whose development is essentially of an endogenous nature while the rest of the country is heavily dependent on multinational enterprises whose decision-making centres are located abroad. In the Walloon area, the Walloon Brabant and a section of Luxemburg are also characterised by a high degree of entrepreneurial dynamism. The lack of entrepreneurial dynamism constitutes a major handicap in the Walloon area. Liege and Charleroi have, together with Mons and Arlon, the lowest indexes in the country.

There is a strong polarisation of the creation of wealth along the Walloon Brabant-Antwerpen axis, a region accounting for nearly 40% of the population, but representing more than 50% of the wealth created in Belgium. The Ghent-Kortrijk region is also a growth-polarising zone. In contrast, the economic difficulties of Wallonia are manifestly obvious if we look at the wealth level indicator, not one district surpasses the European average, with the exception of Walloon Brabant. In global terms, it is also the wealthiest districts that are the most innovative, with Brussels and the Walloon and Flemish Brabant the most dominant, followed by the Antwerpen region. Apart from these groups of regions, a few innovation archipelagos also stand out: Maaseik, Brugge and Ieper in Flanders and Verviers in the Walloon area. The most striking aspect is certainly the poor performance of Wallonia, particularly in its two large metropolitan areas, Charleroi and Liege, which do not appear able to exercise their polarising role within the Walloon arena.

A comparison of the productivity indexes shows that the interregional gaps are sensitively less pronounced than the ones observed for the GDP per capita despite high discrepancies between districts. While Brussels, Antwerpen, Hal-Vilvoorde, Walloon Brabant and Virton attain the highest values, the other districts have indexes that are, for the most part, higher than the European average. The Walloon problem is associated not so much with a lack of efficiency on the part of existing enterprises as with insufficient economic activity on its territory and less than optimum valorization of its economic and technological potential.

TABLE 3 **Basic indicators** • EUR15 = 100

Entities	GDP per inhabitant 1998	Patents per inhabitant (97-98)	Labour productivity 1998	Entrepreneurship 1998
BELGIUM	112	100	116	84
Brussels	231	107	141	79
Vlaams Gewest	109	116	113	89
• Antwerpen	129	146	126	80
Antwerpen	145	174	132	80
Mechelen	107	67	120	78
Turnhout	106	142	113	82
• Limburg	94	71	100	79
Hasselt	116	55	103	76
Maaseik	80	103	98	78
Tongeren	66	67	95	85

Entities	GDP per inhabitant 1998	Patents per inhabitant (97-98)	Labour productivity 1998	Entrepreneur-ship 1998
• East Flanders	97	84	109	91
Aalst	72	54	100	84
Dendermonde	78	87	104	90
Eeklo	72	98	95	103
Gent	126	98	115	94
Oudenaarde	88	55	102	93
St-Niklaas	92	96	108	87
• Vlaams Brabant	112	175	123	86
Hal-Vilvoorde	128	139	130	90
Leuven	93	220	112	82
• West Vlaanderen	102	87	102	110
Brugge	101	107	99	107
Diksmuide	73	81	94	136
Ieper	85	107	93	116
Kortrijk	119	96	108	102
Oostende	80	37	100	95
Roeselare	112	91	99	116
Tielt	113	75	108	132
Veurne	96	40	102	125
Walloon Region	82	68	105	76
• Walloon Brabant	104	170	129	103
• Hainaut	73	40	101	65
Ath	60	51	101	81
Charleroi	87	46	110	56
Mons	73	40	102	59
Mouscron	85	1	96	72
Soignies	63	60	93	67
Thuin	47	38	93	76
Tournai	76	11	93	79
• Liège	87	83	104	75
Huy	77	71	112	82
Liège	92	77	104	66
Verviers	85	101	100	88
Waremme	59	91	107	84
• Luxembourg	82	43	101	89
Arlon	100	99	102	54
Bastogne	67	88	88	114
Marche-en-Famenne	86	16	100	105
Neufchâteau	78	0	94	103
Virton	73	25	126	71
• Namur	80	50	103	81
Dinant	66	0	97	97
Namur	88	69	106	74
Philippeville	60	41	99	86

These interregional differences are essentially explained by the differences in the regions' economic structure. Without going down to the district level, this can be illustrated by calculating the regional economic bases in relation to the European average. These bases are measured by considering the index of the proportion of sectorial employment in the population compared with what is observed for the European average. For the manufacturing industry, this employment has been divided into the four groups of industries singled out by the OECD in order to take account of the technology intensity of the different sectors of industrial activity. It becomes immediately clear from *Table 4* that the Belgian economic base is not only lower than the European average, it also focuses in global terms on the sectors with low and medium technology intensity. Nevertheless, as the previous table shows, the high labour productivity level largely compensates for this lesser dimension of the economic base. It is clear, however, that the profile of the regions differs quite sensitively.

Owing to the concentration of economic activity on its territory, the Brussels-Capital Region enjoys a very high base. Four sectors display an index higher than the average, i.e. pharmaceuticals, the automobile industry, diverse industries and printing. Although one of these strategic poles adopted by the region is well represented, this contrasts with the health pole, by way of the pharmaceutical sector, the food-processing poles, and the precision and communication industries, which have relatively weak bases. With regard to the latter, this finding needs to be qualified in view of the fact that a substantial part of the activity is classified under services and not industry. However, what characterises this region to the greatest extent is its strong specialisation in services.

Given its industrial base is larger than that of the two other regions, Flanders holds a favourable position in a greater number of sectors than the other regions. Although it is particularly specialised in industries with low and medium technology intensity, two sectors described as being of medium--high technology intensity dominate, i.e. chemicals and the automobile industry. Among the sectors with high technological intensity, although no single one obtains an index higher than the average, there is considerable potential in the pharmaceutical and electronic sectors. The strong polarisation of the Flemish development strategy towards activities performed at the IMEC (Interuniversity MicroElectronics Center) and the VIB (Flemish Institute for Biotechnology) means that a strengthening of the region's position can be expected over the next few years.

For the Walloon Region, *Table 4* highlights two sectors in which it has a competitive advantage and on which it can base its industrial redeployment by relying on its technological potential and strong economic specialisation, i.e. the pharmaceutical sector, where the emergence of biotechnologies offers significant development prospects, and the other transports sector, in which the Walloon specialisation focuses mainly on the construction of railway equipment. In other transport sectors such as aeronautics and the automobile industry, which would not appear to be a confirmed Walloon specialisation, the research potential of the Walloon Region remains limited, mainly upstream from the production level, given its specialisation in the field of new materials.

Two traditional sectors emerge equally as being specific to Wallonia, i.e. steel and non-ferrous metals, and non-metallic minerals. In these sectors, the main vehicle for development is represented by the opportunities offered by new materials. The major issue in these low-growth sectors is to valorise the acquired experience and the technological potential by focusing on the market niches displaying the highest growth rates.

In the other sectors, the region's industrial position is such that it would be relatively illusory to claim that it holds a significant position, except in some market niches targeted according to their technological potential and better commercial valorization of the existing scientific base. This is particularly the case for sectors such as aeronautics, information technology and chemistry.

To what extent have the regions set up structures enabling an improvement of their innovation potential? Various initiatives have been implemented, such as Brussels-Technopol in the Brussels-Capital Region, the Prometheus project in the Walloon Region, and the innovation decree in the Flemish Region. In each of these regions, the cluster policy now plays a central role, not only with regard to science and technology policy but also in terms of economic development[6]. It is an undeniable fact that Flanders has the greater experience in this respect, dating back to the nineties. The objective here is not to carry out an analysis of these regional policies but, rather, to assess regional potential and the regions' capacity to adjust their governance systems to enable them to enter the knowledge-based economy. For this reason, we shall confine ourselves to drawing up an inventory of the scientific and industrial parks integrating the university antennas currently functioning in Belgium. The number of spin-offs from Belgian University institutions is also mentioned for information purposes.

The policy in favour of creating science parks has, effectively, been a response to the growing dependence of the productive systems vis-à-vis innovation activities. Added to this is the need for universities to be more involved in economic development, particularly for budgetary and policy reasons. The goal pursued is to stimulate cross-fertilisation in order to shorten the commercial valorization periods for research results, to facilitate the springing up of new ideas, new products and processes, and to support enterprises in their approach to innovation. Belgium has not remained apart from this new trend, as *Table 5* shows. To what extent are these science parks likely to provide new momentum for the country's economic development?

According to the findings of Clarysse and *al.* (2001), 56.5% of the 154 university spin-offs are Flemish, 32.5% Walloon and 11.0% from Brussels. Although these figures are comparatively low compared with those presented by Twente university (300 spin-offs) for the Netherlands and Linköping and Goteborg for Sweden (160 and 400 spin-offs respectively), this level is quite high in comparison to the United Kingdom and Canada, where the number is approximately 300 (one hundred for Quebec)[7]. The total number of Belgian spin-offs corresponds in reality the only average annual number of spin-offs established by MIT (Bank of Boston, 1997). Although the Cambridge region is often described as the typical example of the innovative region, the number of spin-offs originating from the university is limited to a mere 5% of the 1,200 high-tech enterprises located in the region[8].

[6] Even if, in the Brussels Region, they are described more as strategic poles and technological competence poles.

[7] See, among others, Lindholm (1999) and Howells, J. Nedeva M. and *al.* (1998).

[8] The Economist, 1999, *Britain: Ancient and modern*, January 1.

TABLE 4 **Regional industrial bases** • 1997

	EUR15 = 100			
	Brussels	Flanders	Wallonia	Belgium
Sectors				
Global economy	149	89	73	90
Agriculture	3	57	38	46
Mining	5	11	79	33
Manufacturing industry	57	96	56	80
• High technology intensity industries	71	84	65	77
Electronics	27	96	22	65
Aeronautics	75	31	69	48
Pharmaceuticals	158	97	153	121
Computers and office equipment	0	9	5	7
• Medium high technology intensity industries	54	81	39	65
Chemicals	54	111	45	84
Instruments	43	36	34	36
Electrical machinery	30	49	35	43
Automobile industry	118	138	12	95
Non-electrical machinery	31	50	46	47
Other transports	48	99	155	113
• Medium low technology intensity industries	42	100	85	90
Rubber & plastics	11	83	46	65
Shipbuilding	0	40	10	27
Metallic production	58	108	74	93
Steel & nonferrous metals	12	98	117	97
Non-metallic minerals	32	84	121	92
Petroleum industry	16	166	2	99
Diverse industries	192	179	109	157
• Low technology intensity industries	66	108	51	86
Paper & printing	130	88	54	81
Textiles	33	105	25	72
Food & tobacco	74	127	73	105
Wood & by-products	36	107	52	83
Construction	90	93	81	89
Utilities	169	70	87	85
Services	208	96	86	104
Commerce	146	102	77	98
Finance, insurance	382	110	78	126
Transport	186	100	72	100
Other services	221	97	110	114

Source: Capron (2000).

TABLE 5 **Science parks or assimilated**[9]

Name	Date of creation	Localisation	Area (ha)	# firms	Main technological fields	Universities (spin-off**)	Incubator research centres
Walloon area (50)							
• Louvain-la-Neuve	1969	Louvain-la-Neuve	227	100	Chemistry, biotechnology	UCL* (21)	
• Sart Tilman	1981	Liège	50	60	Aeronautics, health, optics	ULg* (26)	CSL, CRM, CRIF Incubator
• Nivelles	1980	Nivelles	n.a.	100	Industrial research	ULB	CRIA, CTGA
• CREALYS	1990	Gembloux	50	12	Biotechnologyies, Food-processing	FUNDP (1) FUSAGx (1)	CRA
• Aéropôle	1996	Charleroi	n.a.	n.a.	Biotechnology, information technology	UCL-ULB-FUNDP	IBMM CETIC Incubator
• Initialis	1998	Mons	43	12	Information technology and new materials	FPMs (1), UMH	Materia Nova Multitel Incubator
• Seneffe	1998	Seneffe	4	n.a.	Chemistry	UCL	CERTECH Incubator
Flanders (87)							
• Research Park	1980s	Neder-Over-Heembeek	17	14	Software, mechanics, hydraulics	VUB (6)	-
• Haasrode Research Park	1972	Haasrode	120	45	Information technology, materials, software	KUL* (42)	IMEC (16) Incubator
• Research Park	1980s	Zellik	19	14	Measure instruments, software	VUB	-
• Science Park	1986	Zwijnaarde	13.6	8	Biotechnology	RUG (21)	VIB (2) Bioincubator
• Wetenschapspark Limburg	1989	Diepenbeek	16 (3)	17	Multimedia, telematics	LUC* (5)	IMO, EDM Incubator
• UBCA (Antwerp Incubation Centre)	1992	Antwerp	n.a.	8	Software, medical and pharmaceutical technology	UA (1)	-
• Research Park Kortrijk	1996	Kortrijk	10	n.a.	Materials, electronics, information technology, biotechnology	KULAK	-
Brussels (17)							
• Erasmus Science Park	1981	Anderlecht	20	7	Health	ULB (11)	EBC, EEBIC
• Vesalius Science Park	1985	Woluwé	68	14	Broadcasting technology, biotechnology, pharmacy	UCL*	Incubator
• Da Vinci Park	1974	Evère	36	46	Information technology	ULB	-

Notes: *Contiguity between park and university. **ULB and VUB are also active in the Walloon Region for the first case and in the Flemish Region for the second, the spin-offs attributed to the Brussels-Capital Region are over-estimated.

[9] Definition of acronyms: 1) Universities: UCL: Université Catholique de Louvain, ULg: Université de Liège, ULB: Université Libre de Bruxelles, FUNDP: Facultés Notre-Dame de la Paix à Namur, FUSAGx: Faculté des Sciences Agronomiques de Gembloux, FPMs: Faculté Polytechnique de Mons, UMH: Université de Mons-Hainaut, RUG:Universiteit Gent, KUL: Katholieke Universiteit Leuven, LUC: Limburgs Universitair Centrum, UA: Universteit Antwerpen, VUB: Vrije Universiteit Brussel, KULAK: Katholieke Universiteit Leuven te Kortrijk.
2) Research centres: CSL: Centre Spatial de Liège, CRM: Centre de Recherches Métallurgiques, CRIF: Centre de Recherches scientifiques et techniques de l'Industrie des Fabrications métalliques, CRIA: Centre de Recherche Industrielle et Agricole, CGTA: Centre de Techniques de Gestion Appliquée, CRA: Centre de Recherches Agronomiques, IBMM: Institut de Biologie Médicale et Moléculaire, CETIC: Centre des Technologies de l'Information et de la Communication, CERTECH: Centre d'Expertise et de Recherche Techniques en Chimie du Hainaut, IMEC: Interuniversitair micro-electronica centrum, VIB: Vlaamse instelling voor biotechnologie, IMO: Instituut voor MateriaalOnderzoek, EDM: Expertisecentrum voor Digitale Media, EBC: Enterprise Business Center, EEBIC: European Enterprise and Business Incubation Center.

However, as emphasised by Keeble and *al.* (1999), the indirect spin-offs, i.e. stimulated by university spin-offs, are equally important. The favourable attitude of the university towards research collaborations, knowledge sharing and cross-fertilisation has played a decisive role in the development of the region. What has made Cambridge successful is the capacity of local enterprises to generate interlinked competence networks and integrate national and international networks. The science park and university spin-offs are, from this point of view, mere components of a vast collective regional learning process.

The analysis of the entrepreneurial climate of a group of European regions conducted by Clarysse and *al.* (2001) highlights the different profiles of the Flanders and Walloon Regions. Flanders distances itself from the Walloon Region both in terms of risk capital as well as incubation structures and networking despite the favourable developments observed in Wallonia over the past few years. The recent focus of the Walloon government on the clustering policy and implementation of the Prometheus project, which is aimed at "creating new dynamics to bring together all players, public and private, to reflect how to best use the available resources for the benefit of innovation"[10] could, if the intentions are materialized, the initiatives coordinated and the efforts pursued, provide an impetus for the regional collective learning process that is currently so desperately lacking.

5. Belgian regional innovation systems

Although the quantitative indicators offer an initial synthetic view of the positioning of the regions, they do not facilitate an evaluation of the degree of interactions between the players in the innovation system or of the capacity of the institutions to stimulate dynamism on the part of these players. The three regions have a science and technology base located in the higher section of the distribution of the European regions[11]. To what extent are the governance systems of the regions sufficiently effective at the institutional and organisational levels in order to facilitate their entry into the knowledge-based economy? Have the regions become or are they on the way to become learning regions? Where are they positioned along their learning curve?

During recent years, the number of empirical studies aiming at identifying the intrinsic characteristics of regional and local innovation systems has grown (Acs, 2000; Braczyk and *al.*, 1998; Cooke and *al.* 1998, 2000; de la Mothe and *al.*, 1998). In this regard, the work of Cooke offers a methodological base for assessing the institutional and organisational achievements of these systems and to what extent the existing structures are of a systemic nature. To do this, he suggests making a distinction between the characteristics associated with the infrastructures (institutional bases of the innovation system) and those related to superstructures (relations between players within the innovation system). Depending on the nature of the characteristics observed, a region will or will not display strong systemic potential with regard to its innovation system. *Table 6* gives a summary of the main characteristics taken into account.

[10] Direction générale des technologies de la recherche et de l'énergie, 2000.

[11] The average of the indicators studied places Flanders in 16th position, Brussels-Capital 18th and Wallonia 32nd.

As stated by Cooke and *al*. (2000), the policy challenges with which public decision-makers are confronted in relation to improving their regional innovation policy rely upon their aptitude to promote the following elements:

- *learning capacity (policy learning)* through recognition by the regional Authorities of their own strengths and weaknesses and of the best practices developed in other regions;
- *cooperation capacity (policy networks)* through the setting up of dense regional institutional networks to improve the coordination of innovation support policies;
- *intermediation capacity (policy bridges)* through the implementation of suitable technology policy instruments suitable for directing the structural adjustment of traditional enterprises towards activities displaying growth perspectives;
- *consensus capacity (policy consensus)* through the systematic search for policy consensus on lines of action accepted by the different categories of players regarding the innovation strategy pursued.

TABLE 6 **Potential of regional innovation systems**

	High potential	Low potential
Infrastructural level	• Budgetary autonomy • Existence of a regional capital market • Regional infrastructure competencies • Regional industry-university strategy	• Decentralised expenditure • National financial organisations • Limited influence on the choice of infrastructures • Fragmented innovation projects
Superstructural level		
• Institutional organisation	• Cooperation culture • Interactive learning • Associative consensus	• Competition culture • Individualism • Institutional dissensions
• Industrial organisation	• Harmonious work relations • Structuring of workers' training • Externalisation of activities • Interactive innovation process via exchanges of knowledge	• Antagonistic labour relations • Self-acquired skills • Internalisation of commercial functions • Stand alone R&D and limited propensity to innovate
• Governance organisation	• Inclusive • Proactive • Consultative • Heterarchic	• Exclusive • Reactive • Authoritarian • Hierarchic

Source: adapted from Cooke *and al.*, 2000.

In a comparative analysis of some regional innovation systems representative of several categories of regions, Cooke and *al.* (2000) provide us with a set of interesting elements. *Figure 1* summarises the position achieved by the different regions studied, to which Flanders and Brussels have been added. The first and fourth quadrants compare regions according to their institutional and infrastructure capacity and the organisation of their industrial and political system. While Baden-Württemberg, Steiermark, Wales and the Basque Country distinguish themselves through the quality of their innovation systems, the Walloon area and the Portuguese Centre display huge deficiencies in their innovation systems, with only the regions of two countries in transition attaining a more unfavourable position, i.e. Lower Silesia in Poland and Féjer in Hungary. Its innovation dynamism and pro-active policy, especially in the fields of clustering and networking, leads to position Flanders in the first quadrant, at an intermediary level between Baden-Württemberg and Wales, while Brussels is halfway between Flanders and the Walloon area, its innovation policy being limited to actions supported through Brussels-Technopol.

The second quadrant, which positions the regions according to their degree of regional autonomy and the efficiency of their innovation policy, shows that the Belgian regions, together with Baden-Württemberg, are those with a higher degree of regional autonomy. Nevertheless, their innovation policy achievements vary quite substantially. The Walloon innovation policy is fragmented, without any clear vision of the technological niches deserving priority and of the links that need to be established with the economic instruments. Although some kind of structuring does exist in the Brussels Region thanks to Brussels-Technopol, the approach remains vague and not very pro-active. Of the three regions, Flanders is the one that has adopted the most pro-active approach by implementing a clustering policy at a very early stage and concentrating its resources on a number of structuring poles.

To complete this diagnosis of the regions studied, the regions have been positioned according to two essential components of innovation systems. These components are, on one hand, links with the bridging institutions and, on the other hand, inter-firms links. In relation to these two components, the Walloon Region displays an obvious weakness for the two kinds of links, while, at the other extreme, Baden-Württemberg sets itself apart through a strong propensity of firms to cooperate amongst themselves and establish links with the bridging institutions. Flanders shows a greater propensity to collaborate and enter strategic alliances (VEUGELERS and DEBACKERE, 1999). Brussels, for its part, holds a position somewhere between the other two, which is mainly explained by its metropolitan status.

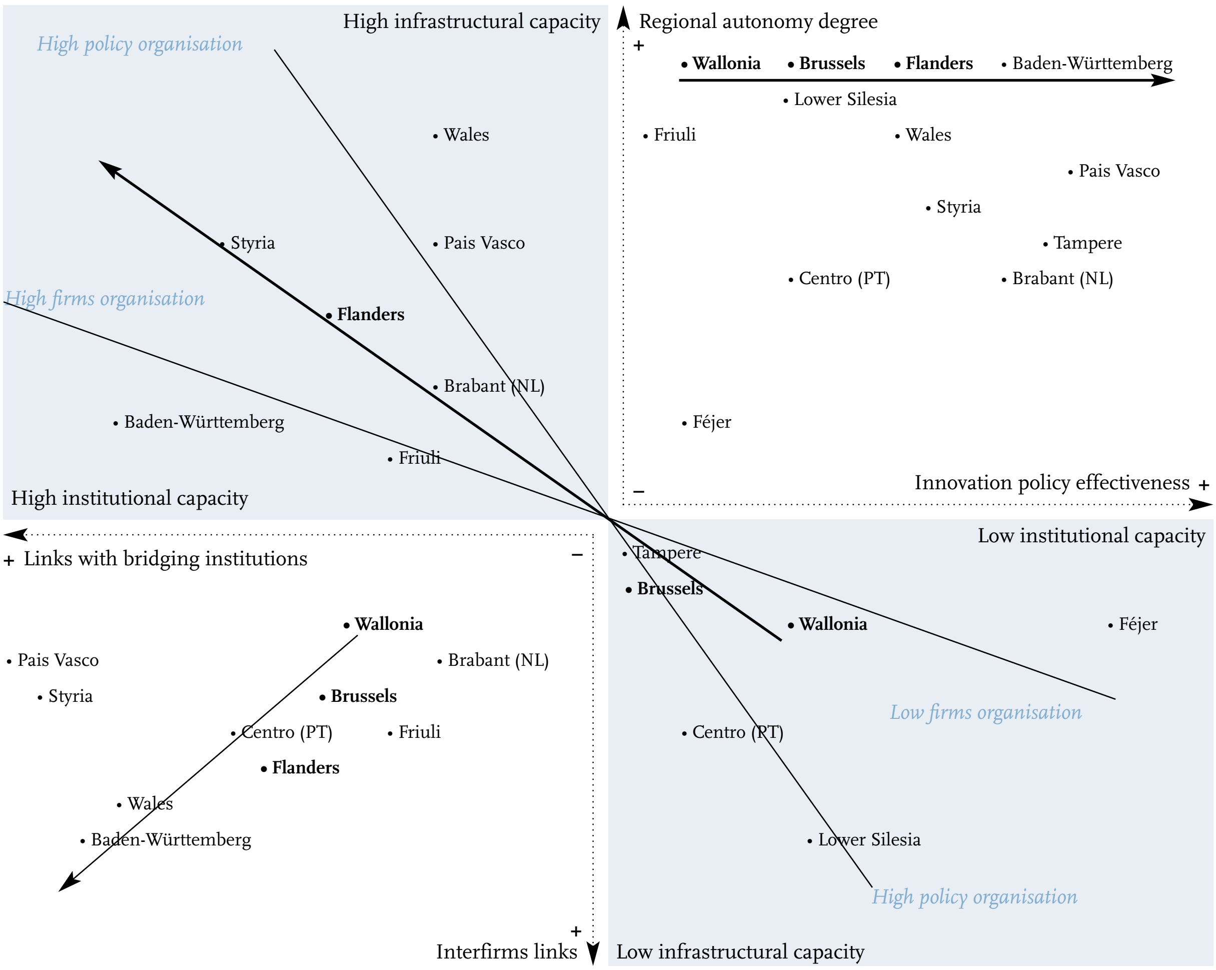
TABLE 7 **Collaboration per 10^9 inhabitant in the EUREKA projects and the European framework programmes***

	Framework Programmes					EUREKA			
	Liens	Total	RTO	Enterprises	Universities	Total	RTO	Enterprises	Universities
Brussels	11,929	1,509	312	440	757	37	23	3	11
Flanders	3,428	491	94	122	276	27	18	3	6
Wallonia	2,985	500	77	83	340	11	8	1	2
Belgium	4,059	566	123	268	245	22	15	2	5

*Only the three categories of players referred to are considered. The IMEC collaborations were included under the heading of Universities and not RTO.
Source of data: CAPRON and CINCERA, 1999.

Table 7 shows that it is important to qualify the diagnosis in terms of collaborations. Although the Walloon area suffers from a lack of participation in the EUREKA programme, the number of its collaborations in the European framework programmes is equivalent to that of Flanders. In contrast, although the French-speaking universities are known for their dynamism, the same cannot be said for the enterprises. It is therefore due to its technology policy alone, and not because of its lack of a scientific base, that the deficiencies of the Walloon innovation system are the most striking. In other words, the Walloon area enjoys a favourable position in the field of pre-competitive research but lags behind in relative terms for near-market research. The number of links indicates that the networks to which Flanders and Brussels belong are, in global terms, on a larger scale than for the Walloon area. However, in relative terms, it is Brussels that largely dominates Belgian collaborations with the framework programmes and the EUREKA programme. This dominance is, however, less pronounced in the EUREKA programme, where Flanders appears to be particularly active.

FIGURE 1 **Potential of regional innovation systems**



Source: Adapted from Cooke *et al.*, 2000.

To sum up, the bold lines in *Figure 1* show how far the regions still have to go in order to improve their innovation system, i.e. in strengthening their institutional capacity by replacing hierarchic innovation policy practices with cooperative and associative approaches and developing their infrastructure capacities on the basis of a strategic approach focused on the real needs of enterprises with regard to innovation. The weakness of links between enterprises, the lack of adequately structured bridging institutions, the absence of interactions between economic, science and technology policies, and the fragmentation of the innovation system at institutional level are all elements that explain Wallonia's poor technological achievements compared with Flanders, while Brussels holds a position somewhere between the other two in this respect.

There is certainly a link between the shortcomings observed at the regional-policy level and the increase in the number of initiatives taken by the local players with regard to promoting innovation. Although there continue to be questions about their actual competences in this field and the effectiveness of their means of operating, the approach initiated by the local players does bear witness to a will to promote their systemic innovation potential. Nevertheless, the question arises concerning the territorial structuring of such initiatives which, in the absence of a coherent regional policy, run the risk of ending up in a situation of infra-regional competition with the pernicious effects that this implies (e.g. spatial fragmentation of the innovation system, redundancy of local choices, insufficient critical masses, etc.) rather than in valorizing the infra-regional complementarities (territorial specialisations and collaborations and sharing competencies).

In this regard, Baden-Württemberg is often singled out as a model region at European level for the efficiency of its governance system (Cooke and Morgan, 1998). A limited number of regional governmental administrations are charged with channelling decisions taken by different regional ministries and ensure the distribution of implementation responsibilities between the different categories of local and regional Authorities and intermediaries. The region benefits from a dense innovation infrastructure network that has close links with the industrial sectors. The main players include, in particular, about a hundred independent research institutes, with 14 Max Planck Institutes and 14 Fraunhofer Institutes, as well as 220 Steinbeis Foundation technology transfer centres. The chambers of commerce play also an important role in promoting support programmes and supervise professional training programmes.

6. Conclusions

The challenge for Belgium, and thus for its regions, over the coming years will be to move a significant way along their learning curve in order to maintain their historic position among the most prosperous regions of Europe. The three regions display very contrasting profiles that can only partly be explained by historical reasons. Endowed with its European capital status and its central position within the Belgian arena, the Brussels-Capital Region benefits from agglomeration forces associated with these factors without it having to implement its own voluntaristic technology policy. With the federalisation of the country, its role in the national R&D system has been noticeably reduced. This region therefore needs to engage in deep reflection in order to harmonise its metropolitan status with the technopolitan-type activities inherent in any large European metropolis. Of the three regions, Flanders is certainly the one that is best positioned along the learning curve. Wallonia, for its part, still has a long way to cover because it still is tightly trapped in its old industrial system and the political initiatives likely to provide the impetus necessary for accelerating the process of change being very diffident.

Although the three regions do display solid technological and economic potential that allows them to be optimistic in terms of fitting into the knowledge society, the main challenge lies in their capacity to become learning regions. In this regard, Flanders is the region that has undergone the most significant evolution during the past twenty years. It has already become a learning region even though the challenges to be addressed remain substantial. Its focus on generic technologies and its integration policy with regard to international networks exudes an image of dynamism hardly noticeable in the other two regions. The Brussels-Capital Region projects the image of a region that relies on its metropolitan assets without really pondering on its technopolitan future. The recent decision to reappraise the actions of Brussels-Technopol with a view to refocusing activities on the technological and organisational innovation of enterprises established in the capital as well as on greater coordination of the public and private services offered could breathe a new innovation dynamism into the region. The Walloon Region, on the other hand, is vacillating between the nostalgia of a prestigious industrial past that urgently requires transition and the will to prepare for its entry into the knowledge society. The projects currently implemented in the Walloon Region could generate a change of direction towards greater interactivity between development players as well as a climate more propitious to innovation. An innovation potential does exist. This will only be able to manifest itself if the region adopts a systemic and strategic vision of its economic development.

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The participation of Belgium in European R&D Programmes*

Henri Capron and Michele Cincera

Introduction

The analysis of national systems of innovation has highlighted the central role played by the interactions between actors in the dynamics of innovation (DAVID and FORAY, 1995; LUNDVALL, 1992; EDQUIST, 1997; METCALFE, 1995). The setting in network of the actors and the promotion of collaborations and technological partnerships are now in the heart of science and technology policies (OECD, 1999). Faced with the fragmentation of the European system of science and technology, the European Commission has privileged such an approach with for instance the launching of the first Framework Programmes.

Thanks to the launch of several successive Framework Programmes, the European Union has become an essential player in technology policy. However, the measure of the real impact of European collaborative programmes on economic performance remains a question under scrutiny. Some argue that subsidising exclusively European collaborations may not constitute an effective use of European resources and that despite the creation of an impressive array of links between players, the political spillovers have been minimal (PETERSON and SHARP, 1998). The sheer complexity of many EU collaborative research programmes is also questioned in the sense that it may have reduced the effectiveness of collaborations (MOWERY, 1994). If the collaboration requirement ensures the development of some type of networking, it may not necessarily be the most cost-effective means of supporting technological diffusion to SMEs or regions faced with economic restructuring or development problems (SOETE and ARUNDEL, 1993). It is, however, recognised that although the European collaborative programmes may not have improved competitiveness, they have stimulated the acquisition of new competencies and sharpened research skills. It is with these different points in mind that the role of Belgian participation in the Framework Programmes must be assessed. As shown in several studies (EUROPEAN COMMISSION, 1997, GEUNA, 1998), the successive European framework programmes represent a main channel of S&T collaboration, especially between universities and public research and technology organisations. The lower costs of developing new technologies by reducing duplication of research efforts, sharing the risks of undertaking R&D, obtaining

* Original version.

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immediate access to new technologies and economical production sources, and enhancing the feasibility of large and complex research projects are among the main benefits of R&D collaboration suggested in the literature (Kumar and Magun, 1998).

If the European Framework Programmes play a capital role in the formation of European networks, they are conditioned by the choices operated by the Commission with regard to the technological fields. Moreover, one cannot neglect the fact that the European funds represent only one small share of the European total R&D so that they cannot really influence the rate and the direction of technological change (Pavitt, 1998). Lastly, according to Georghiou (1998), insofar as the European programs have achieved their goal in building a European scientific Community, a progressive opening of the Framework Programmes in favour of the non-European countries would bring a new blood to the existing networks of collaboration.

The Belgian participation in the European R&D programs is an important component of the Belgian innovation system given the high degree of opening of the country. As Capron and Meeusen (2000) have shown, the Belgian innovation system suffers from certain systemic mismatches. Nevertheless, a distinction has to be made between the performances reached by the three regions (Capron and Cincera, 1999). However, in a general way, the existence of an articulated and well established analytical framework is missing for the analysis of innovation systems (Nelson, 1993). To mitigate this drawback, an analytical scheme for the analysis of institutional systems linked to the existing S&T indicators has been proposed by Capron and Cincera (2001). The process pursued in this paper constitutes a first application to one of the components of the Belgian innovation system.

In order to appreciate to what extent Belgian organisations are highly involved in world-wide research networking and transfer, three types of information are used: the pre-competitive collaborations as they can be identified in the CORDIS database, the near-market co-operation coming from the EUREKA database and strategic alliances formed on a private basis and founded on data presented in the European reports on S&T indicators (European Commission, 1994 and 1997).

1. Pre-competitive Research Cooperation

In order to appreciate the degree of commitment of Belgian research teams to shared-cost actions financed under the Framework Programmes (FPs), six types of indexes have been calculated (See *Appendix 1*):

- the *per capita participation index,* which gives a measure of the degree of participation of a country relative to the European average independently of the technological base;
- the *per-researcher participation index,* which gives a measure of the degree of participation of a country relative to the European average by taking the technological base into account;
- the *distribution index, w*hich gives a measure of the degree of participation of the different categories of players (large enterprises, SMEs, research centres, higher education and others) of a country relative to the European average, all other things otherwise being equal;

• the *per-capita collaborative links index*, which gives a measure of the collaborative links of a country relative to the European average independently of the technological base;
• the *per-researcher collaborative links index*, which gives a measure of the collaborative links of a country relative to the European average by taking into account the technological base;
• the *mutual collaboration spatial specialisation index*, which is a measure of the geographical orientation of mutual collaborations of a country relative to the European average.

The Belgian level of participation in European R&D programmes is very high, as can be seen in *Table 1*. However, the per-capita and per-researcher participation indexes obtained for the other European countries show that some other small countries perform better than Belgium. The favourable positions held by Greece, Ireland and Portugal are explained by the fact that the FPs include a number of specific actions to stimulate technology cohesion. The index obtained for Greece is in fact very impressive given its weak technological base. The weak value of indexes obtained by large Member States results from the limited number of projects in which they can participate given their large technological base. Globally, these indexes show that small countries are, in relative terms, the main beneficiaries of the research networks created under the impulse of the EU technology policy. Yet, in absolute terms, the five largest Member States account for two-thirds of participation. Thus, despite their low per-capita indexes, large countries dominate the trans-European research networks and form the nucleus of the network (European Commission, 1997). In fact, they hold a strategic position within the community collaboration network given their large technological base.

TABLE 1 **Participation Index of Countries Participating in the Shared-cost**

Third Framework Programme				Fourth Framework Programme			
Per-capita Index		Per-researcher Index		Per-capita Index		Per-researcher Index	
DK	251	GR	450	LU	259	GR	450
IR	234	IR	219	IR	242	LU	266
NL	171	PO	200	DK	222	IR	215
BE	**170**	DK	183	FI	207	PO	187
GR	157	NL	172	SW	178	**BE**	**164**
UK	110	**BE**	**166**	**BE**	**177**	NL	163
PO	106	IT	109	NL	171	DK	153
FR	104	SP	102	GR	166	AU	139
SW	102	UK	96	UK	106	FI	131
DE	99	FR	88	AU	106	SP	127
LU	78	LU	85	PO	105	SW	113
FI	75	DE	69	FR	96	IT	108
IT	65	SW	68	SP	73	UK	88
SP	55	FI	50	DE	71	FR	78
AU	29	AU	40	IT	68	DE	61

Source: European Commission (1997, 2000), DULBEA-CERT calculations.

Another main observation is that the collaborations engaged in by countries are largely influenced by geographic and/or cultural proximities. Among the main geographic clusters of collaboration that can be identified in *Table 2*, we can cite the Scandinavian countries, the German-speaking countries and the Latin language countries. In the case of Belgium, it appears that the weighting of collaborations with neighbouring countries is particularly important. Another interesting observation concerns the propensity of countries to develop intra-national collaborations. The teams of large countries appear to have relatively less intra-national collaborative links than the smaller countries. Just behind the four largest European countries we find the Netherlands and Belgium, whose intra-national collaboration links are less pronounced than those observed in other small countries as Austria and the Scandinavian countries. A comparison of the Belgian intra-national collaborative links indexes from the 3rd to the 4th FP shows that the value obtained decreases from 129 to 99[1]. As a consequence, the Belgian teams do not seem to exploit their complementarities and specialisation patterns in order to improve their positioning in the European networks. In general, small countries do not have sufficient resources to cover a large spectrum of technological fields and teams often specialise in technological niches in contrast to large countries, in which the large-scale research centres of multinational companies are mainly concentrated and university research teams frequently have the critical mass necessary to cover large technological fields. With regard to the policy issue, it will be useful to deepen the analysis in order to appreciate to what extent this observation is due to the regionalisation of a large part of the S&T policy or whether it is independent of the federalisation process of the country.

TABLE 2 **Mutual collaboration spatial specialisation between countries participating in the shared-cost research actions under the Fourth Framework Programme**

	BE	DK	DE	GR	SP	FR	IR	IT	LU	NL	AU	PO	FI	SW	UK
BE	133	98	116	83	82	125	92	104	164	126	99	85	99	102	96
DK		178	111	89	73	80	88	91	230	134	125	89	128	182	113
DE			87	79	88	120	64	116	99	117	147	73	110	142	112
GR				161	107	91	100	124	164	91	108	107	124	112	104
SP					126	115	84	140	99	84	103	64	85	112	102
FR						87	72	130	99	94	90	85	85	110	111
IR							203	83	328	108	86	122	142	127	142
IT								103	66	85	112	92	99	107	102
LU									1938	46	203	110	294	90	79
NL										117	86	70	131	132	121
AU											271	55	128	112	85
PO												201	117	102	110
FI													248	209	103
SW														177	113
UK															83

Source: European Commission (1997, 2000), DULBEA-CERT calculations.

1 In fact, it is the country registering the highest decrease in the number of intra-national collaborations.

Table 3 provides further information on the evolution of Belgian participation in FPs. The participation and collaborative links indexes for Belgium show a downward trend. This a priori negative observation is explained by the fact that the participations as well as the collaborations have become more diversified over time as a consequence of both the increasing participation of outside countries[2] and EU enlargement.

In relation to the value obtained for the distribution indexes, we mainly focus our attention on the R&D projects in the 4th FP. All things otherwise being equal, the distribution index shows to what extent the distribution of participation among the different categories of players is similar to that observed at European level. With a value of 33% above the European average, the higher-education sector appears to play a prominent role in the explanation of both the high participation and collaborative links indexes.

Conversely, the value obtained for large enterprises is 22% below the European average. In fact, the combination of the three indexes makes it possible to appreciate the real position of the different Belgian categories of players within the European networks. Indeed, the participation index for Belgium, as measured by the number of participations per capita relative to the European average, shows that Belgian participation is 58% above the European average. Consequently, although the distribution index for large enterprises is below the European average and weaker compared with other types of organisation, we cannot conclude that their degree of participation is below the European average. It is the combination of both the participation and the distribution indexes that produces the participation index of large enterprises in European Programmes. In the 4th FP, their index of participation is equal to 123, largely above the European average. However, universities are the most committed in networking with an index equal to 210 for the same programme.

TABLE 3 **Belgian Participation in European Programmes**

	Financing						Participation					
Programmes	Second		Third		Fourth		Second		Third		Fourth	
	%	Index	%	Index	%	Index	%	Index	%	Index	%	Index
Collaborative links	-	-	-	-	-	-	-	-	5.0	174	5.0	173
Participation	-	-	-	-	-	-	5.5	193	4.5	170	4.9	177
Distribution:												
- Large Enterprises	20.1	49	20.3	59	16.9	63	13.0	59	13.7	64	13.8	78
- SMEs	16.4	88	17.6	107	14.9	93	18.0	99	16.9	117	19.9	100
- Research Centres	28.4	137	20.2	86	17.9	75	24.7	84	22.6	76	15.9	71
- Higher Education	34.5	183	35.3	157	41.3	151	42.6	146	41.5	132	36.5	132
- Others	0.7	117	6.6	194	9.0	153	1.6	133	5.3	183	13.8	112

Note: The indexes reported are the per-capita ones.
Source: European Commission (1994, 1997, 2000), DULBEA-CERT calculations.

[2] Mainly EFTA countries that are not EU Members and countries of Central and Eastern Europe.

The SMEs also exhibit a noteworthy index for their participation in the FP with a value equal to 169. The category of players least committed to the FPs seems to be the research organisations whose index value is 'only' equal to 104. This can be explained by historical factors, including the choice of the Belgian government to sustain collective research centres[3]. However the Belgian institutional map is changing with the federalisation of S&T policy, with one of the principal factors being the decision of the Flemish government to promote inter-university research centres such as the Interuniversity Micro Electronic Center (IMEC), the Flemish Technology and Research Institute (VITO) and the Flemish Biotechnology Institute (VIB), which is not the case in the other two regions.

Globally, both the participation and collaborative links indexes do not change substantially from the 2nd to the 4th FP, which means that the integration of the different categories of organisations in the European R&D networks remains very high over a period of time. The high value of both the collaborative links and participation indexes provides evidence of the Belgium's active role in European networking. It appears that the Belgian S&T system is well integrated into the European S&T network. Its position could certainly be improved given that its score remains relatively inferior to what can be observed in a number of other highly industrialised countries. A question remains with respect to what extent this phenomenon at the pre-competitive level is translated into an equally favourable position in near-market research and strategic alliances.

At the regional level, the French-speaking universities (53% of Belgian university participations) appear to be more integrated into the European networks than their Flemish counterparts (47%). Conversely, Flemish firms and research centres have a higher propensity to collaborate at European level than their Walloon counterparts.

The distribution of Belgian collaborative links with other EU countries reported in *Table 4* does not emphasise any major differences between regions. Brussels and Wallonia exhibit a higher propensity to collaborate with French and Italian teams with 25.5% and 27.8% of collaborations respectively, compared with 21.3% for Flanders. On its own, Flanders is, in relative terms, more closely linked to German and Dutch teams with 25% of collaboration, as opposed to 20.2% and 19.9% for Brussels and Wallonia respectively. Furthermore, Flemish teams play a more central role in intra-national networking than their Walloon and Brussels counterparts. As the intra-national research networks can be split into intra-regional and inter-regional ones, further studies should highlight to what extent the intra-national network is principally structured on an intra-regional or inter-regional basis.

The community intervention system in S&T is based on a selection of scientific and technological priorities to be financed. The distribution of participations among technological fields covered by community RTD actions reveals which type of activities the collaborations developed by a region focus on. In order to position Belgium and its regions in this regard, the technological revealed comparative advantage indexes (TRCAs) have been calculated. We can also measure technological revealed comparative base indexes (TRCBs) in order to appreciate if, given its size, the country or the regions have a sufficient number of participations in the major fields of specialisation.

[3] From an analysis of European collaborations, Feldman and Lichtenberg (1998) conclude that there is a complementarity between public and private organisations and that the technological activities of the private sector are more receptive to the technological activities of the public non-academic sector than of those of the universities.

TABLE 4 **Distribution of collaborative links**

Belgium		Brussels		Flanders		Wallonia	
	42,616		11,333		20,227		9,850
FR	15.9	FR	16.9	DE	15.5	FR	19.9
DE	14.3	UK	13.1	FR	13.6	DE	13.4
UK	13.2	DE	13.1	UK	13.5	UK	12.7
BE	10.0	BE	8.8	BE	10.2	BE	9.2
NL	8.0	IT	8.7	NL	9.5	IT	7.9
IT	8.0	NL	7.1	IT	7.7	SP	6.5
SP	6.0	SP	6.2	SP	5.8	NL	5.9
DK	3.2	GR	3.3	DK	3.2	GR	3.2
GR	3.0	DK	3.2	SE	2.9	DK	2.9
SE	2.9	SE	3.1	PT	2.8	PT	2.8
PT	2.8	PT	2.9	GR	2.8	SE	2.6
IE	2.2	IE	2.2	IE	2.2	IE	2.4
FI	1.5	FI	1.6	FI	1.5	FI	1.3
AT	1.1	AT	1.1	AT	1.1	AT	1.0
LU	0.4	LU	0.4	LU	0.2	LU	0.5
Others	7.7	Others	8.4	Others	7.6	Others	7.6

Source: CORDIS database, DULBEA-CERT calculations.

The values reported in *Table 5* show that Belgium has high TRCB indexes for the majority of technological fields. Its main weakness in European networks is to be found in the energy sector and, to a lesser degree, in the environment and health sectors. The Belgian position is very favourable in high-tech sectors such as electronics, telecommunications, aerospace, information technologies and biotechnology. These observations must, however, be qualified, the participation in community programmes being largely adjusted according to the structure of budget appropriations. For example, 12% of Belgian participations are located in information technologies, a sector that accounts for around 18% of the community budget to the four FPs. In the biotechnology sector, we observe Belgian participation equal to 4% while the share of this specific programme in the total budget appropriation amounts to 3%.

At the regional level, two TRCA indexes are reported. The first, TRCA-BEL, has been calculated with respect to the Belgian participations whereas the second, TRCA-EUR, represents a comparison with the European average. Given the formulation of the TRCA-BEL index, the specialisation fields will be distributed between regions whatever their degree of participation in networks. The TRCA-EUR indexes take all European participations into account, making it possible to relativise regional specialisation fields. For instance, the Belgian specialisation acquired by Brussels and Wallonia in the energy sector at Belgian level is not confirmed at European level.

TABLE 5 **TRCA and TRCB Indices according to Technological Fields based on CORDIS Participations.**
1987-1998

Flanders	TRCA-BEL	TRCB-BEL	Brussels	TRCA-BEL	TRCB-BEL
Resources of the Sea, Fisheries	105	178	Telecommunications	180	224
Measurement Methods	116	166	Standards	109	156
Electronics, Microelectronics	121	154	Information Processing, Information Systems	128	154
Aerospace Technology	122	148	Safety	143	144
Standards	103	147	Electronics, Microelectronics	109	139
Radiation Protection	127	134	Biotechnology	128	137
Agriculture	100	128	Resources of the Sea, Fisheries	72	122
Information Processing	103	124	Measurement Methods	77	111
Telecommunications	82	101	Environmental Protection	129	109
Industrial Manufacture	102	94	Medicine, Health	130	98
Biotechnology	86	92	Agriculture	71	92
Materials Technology	98	84	Radiation Protection	82	86
Safety	80	80	Aerospace Technology	63	76
Medicine, Health	103	78	Renewable Sources of Energy	118	66
Environmental Protection	72	61	Fossil Fuels	118	65
Fossil Fuels	87	48	Materials Technology	63	54
Renewable Sources of Energy	85	47	Industrial Manufacture	58	53
Coordination, Cooperation	95	120	Coordination, Cooperation	109	138
Education, Training	87	97	Education, Training	104	116

Note: % = percentage with respect to the total number of participations,

$$TRCA_{ij} = \left[\frac{n_{ij}}{\sum_i n_{ij}} \right] \Big/ \left[\frac{\sum_j n_{ij}}{\sum_{i,j} n_{ij}} \right]$$

, where i = technological field and j = region, the sum on j refers to the Belgian (BEL) and the European (EUR) areas respectively,

$$TRCB_{ij} = \left[\frac{n_{ij}}{pop_j} \right] \Big/ \left[\frac{\sum_j n_{ij}}{\sum_j pop_j} \right]$$

, where pop_j = population of country j.

Data source: CORDIS database, DULBEA-CERT calculations.

Wallonia	TRCA -BEL	TRCB -BEL	Belgium	%	TRCA -BEL	TRCB -BEL
Resources of the Sea, Fisheries	119	202	Resources of the Sea, Fisheries	4	170	188
Agriculture	134	171	Standards	4	143	158
Industrial Manufacture	144	133	Measurement Methods	3	143	158
Materials Technology	144	123	Agriculture	6	128	142
Aerospace Technology	96	116	Electronics, Microelectronics	8	127	141
Environmental Protection	135	115	Telecommunications	4	124	137
Biotechnology	107	114	Aerospace Technology	8	122	134
Safety	107	108	Information Processing	12	121	133
Measurement Methods	60	86	Biotechnology	4	107	118
Standards	57	82	Radiation Protection	2	106	117
Radiation Protection	72	76	Safety	6	101	112
Electronics, Microelectronics	54	69	Industrial Manufacture	10	93	102
Information Processing	56	68	Materials Technology	11	85	94
Fossil Fuels	117	64	Environmental Protection	6	85	94
Renewable Sources of Energy	116	64	Medicine, Health	4	76	84
Medicine, Health	71	54	Renewable Sources of Energy	5	56	61
Telecommunications	42	52	Fossil Fuels	3	55	61
Coordination, Cooperation	105	133	Coordination, Cooperation		126	141
Education, Training	123	137	Education, Training		111	124

Electronics and information technologies appear to be two main strengths of the Flemish S&T system at both Belgian and European level. Brussels also obtains good scores for these fields, which it is not the case for Wallonia. Industrial and material technologies emerge as a strong Walloon specialisation. Biotechnology appears to be a common specialisation field of both Brussels and Wallonia. Finally, these specialisation patterns are in line with the regional S&T policy choices made during the period under review.

With regard to the technological proximities between organisations, the HEIs of the three regions are active in the same fields and are a complement rather than a substitute for industrial participation (see *Appendix 2*). The other types of organisation draw a more mixed profile with specialisation patterns in the same technological fields as industry and HEIs to some extent. To sum up, *Figure 1* draws the map of Belgian participation in the European network. Of 43 districts, 5 account for three-quarters of all participations: Brussels, Leuven, Ghent, Nivelles and Liege. At a second level, Antwerp, Turnhout and Namur emerge with a total of 15%. Given the strong implication of large universities, participation in pre-competitive research is highly concentrated in the university regions.

FIGURE 1 **Number of CORDIS participations**

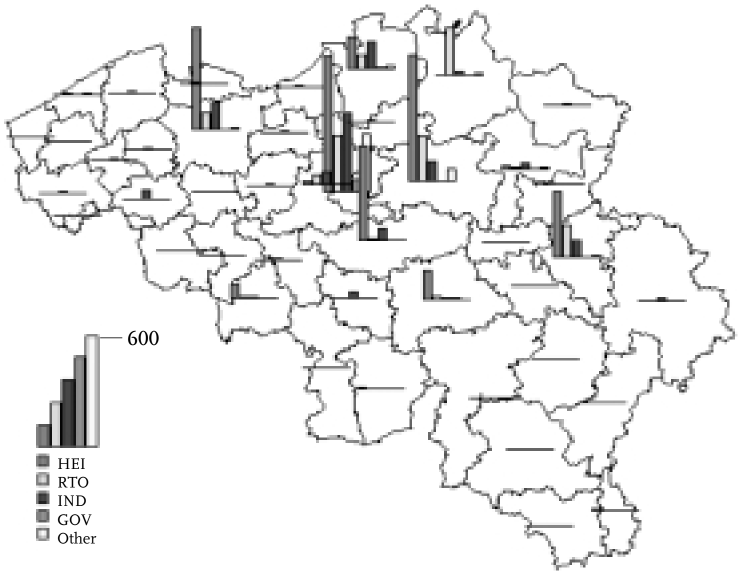
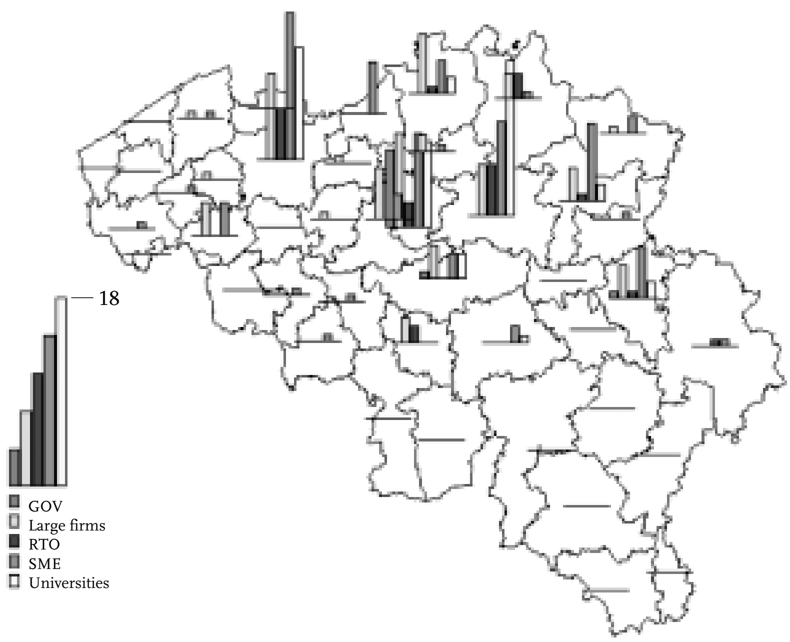


FIGURE 2 **Number of EUREKA participations**



2. Near-market Research Cooperation

EUREKA's focus on near-market research aims at complementing the pre-competitive community programmes. As pointed out by PETERSON AND SHARP (1998 p.93), "EUREKA is a strange and amorphous initiative about which it is difficult to generalise. However, it has become an important tool in Europe's technology-policy arsenal". It should be recognised that there is, in fact, some rivalry between the EUREKA initiative and the European framework programmes and that some projects cover pre-competitive research more than near-market research.

The main findings of the annual evaluation conducted in 2000 (EUREKA, 2000) on the projects completed during the five last years confirm to a large extent the results of past studies, which show that:

- industrial participants are highly satisfied with their achievements at the end of the R&D phase. 88% of industrial participants consider their technological achievements to be "excellent" or "good" and only 11% view these as "weak".
- technical difficulties are the major obstacles encountered: 40% of the industrial participants have encountered technical difficulties during their project. About 15% of the industrial participants report having experienced a "lack of public funding" and 9% a 'lack of private funding'.
- industrialists have been highly successful in developing new products and processes. 67% of industrial participants have developed new products and/or processes. 39% have only developed new products, 24% have only developed new processes and another 38% have developed both new products and new processes.
- public funding is a main prerequisite for R&D and commercial success. 65% of the industrialists that have developed new products and processes have stated that they received public funding compared with 45% of those who did not realise any new products or processes. Public funding during the R&D phase increases the likelihood of receiving private funding. However, private funding should be viewed as complementary rather than as a substitute for public funding.
- Improved or new knowledge and skills are among the most important results at the end of EUREKA projects. 61% of industrial participants in EUREKA have reported that they acquired new knowledge or improved their existing knowledge. This lends support to the argument that new knowledge/skills are not a substitute for products and processes but rather complementary to these.

Although Belgium is involved in 12.6% of the total number of projects, the Belgian teams represent only 4.1% of the number of participating EU organisations and, last but not least, its financial contribution is limited to 3.6% of total EU funds. In order to appreciate the importance of Belgian participation compared with other European countries, a number of indexes calculated as the ratio of the Belgian participation divided by the population ratio are reported in *Table 6*. As shown in this table, all the Belgian indexes are above the European average. However, other small countries are more active in European networks but with financial participation generally lower than for Belgian. Only two small countries perform better than Belgium, i.e. the Netherlands and Finland. Among large countries, France and, at a second level, Germany[4] are the two large countries most active in the European networks. Both countries globalise more than 50% of their funds. In relative terms, the UK appears to be the country least engaged in European networks.

TABLE 6 **EUREKA projects**

	Projects		Participations		Organisations		Budgets		Indexes		
	#	%	#	%	SME	RTO's & HEI's	Total budget	% country	Projects	Partici-pations	Budgets
DE	452	14.4	921	16.1	264	288	14,739	25.8	66	73	94
UK	307	9.8	619	10.8	195	148	8,764	7.9	62	69	24
FR	431	13.7	981	17.2	350	248	17,446	32.9	87	109	197
IT	211	6.7	405	7.1	78	131	14,928	18.1	44	46	95
SP	287	9.1	448	7.8	179	106	8,599	8.5	87	75	37
NL	349	11.1	524	9.2	228	91	13,469	15.5	266	219	269
GR	39	1.2	54	0.9	13	24	541	5.0	44	34	5
BE	166	5.3	233	4.1	87	61	12,195	5.4	194	150	130
PT	131	4.2	208	3.6	76	58	869	13.1	158	138	23
SE	230	7.3	288	5.0	110	61	9,002	2.6	307	212	53
AT	164	5.2	237	4.1	86	67	8,825	2.6	242	192	57
DK	159	5.1	198	3.5	73	45	5,855	4.8	359	245	107
FI	147	4.7	254	4.4	85	47	10,259	4.8	341	323	192
IE	34	1.1	333	5.8	13	9	4,690	1.1	110	591	28
LU	11	0.4	14	0.2	4	0	800	1.6	308	215	62
Eur. Comm.	23	0.7	0	0.0	0	0	4,049	17.3	-	-	-
EU15	1,366	100	5,717	100	1,841	1,384	18,518	90.5	100	100	100
Others	-	-	1,121		403	418	708.1	-	-	-	-

Source: EUREKA, DULBEA-CERT calculations.

Given the general positioning of Belgium, what can be said about the participation of the regions? *Figure 2* indicates that Belgian participation is highly concentrated in a few districts, mainly located in the Flemish Region. It appears immediately that most participations are not located in districts with higher economic activity, except for Brussels.

An important initial observation is that the Flemish Region is, to a large extent, the main Belgian player in the EUREKA network as it can be seen in *Table 7*. Of a total of 244 active Belgian participations, 161 are located in the Flemish Region. The Walloon Region does not appear to be very involved in the EUREKA network, with the index for the number of participants equal to 180 for the Flemish Region as opposed to 80 for Wallonia. In contrast, the index for Brussels-Capital is 300.

These data mean that Walloon participation is 20% below, Flemish participation 80% above and that for the Brussels Region three times above the European average. The Brussels index is, in fact, largely overestimated, given that 20% of participations are attributed to the Federal Government which, at a second level, selects the regional teams whose research is to be financed by the Federal Office for Scientific, Technical and Cultural Affairs (OSTC). As no correction has been implemented for this bias, the Flemish index must be interpreted as a value by default.

[4] The population taken into account includes the new Länder.

If we now look at the types of organisations participating in networks, we observe that SMEs are present to a greater extent than large enterprises. The Ghent and Leuven universities are also major players. In relative terms, no significant regional differences can be observed among the three regions. In the Walloon Region, only the two industrial urban districts are concerned with EUREKA projects: the Walloon Brabant, Charleroi and Liege.

With regard to the technological fields, the regional differences are very limited. Three technological fields account for a large part of collaborations: information technology, environment, as well as the medical area and biotechnology. In the Flemish Region, the research projects are mainly concentrated in new materials and telecommunications. In the Walloon Region, the environment issue constitutes a significant percentage of participations.

Turning to the number of European participants in projects, it appears that Flemish teams are more engaged in large-scale and/or large-team projects (mainly JESSI and EUROTRAC) than Brussels. Nonetheless, the large number of participants observed for Brussels is once more explained in terms of the relay role played by the OSTC in some large-scale projects. In the Walloon Region, the average number of network members per project is similar to that observed for Flanders.

If we compare the distribution of Belgian participants among organisations with the distribution observed at European level, it emerges that the European universities and RTOs are more involved than their Belgian counterparts, with the reverse true for SMEs. However, if such an observation is correct in relative terms, we must bear in mind that it is not the case in absolute terms, given Belgium' high rate of participation. A major difference between Flanders and Wallonia is the very weak level of participation of enterprises in the latter region.

TABLE 7 **Distribution of Belgian EUREKA projects**

	Brussels	Flanders	Wallonia	Belgium
# of participations	44	161	38	244
% of main contractors	20.5	29.2	15.8	25.4
Distribution of organisations (%)				
• Government/national administration	20.5	0.0	5.3	4.5
• Large firms	25.0	29.2	28.9	28.7
• RTOs	6.8	10.6	10.5	9.8
• SMEs	25.0	38.5	39.5	36.1
• Universities	22.7	21.7	15.8	20.9
Distribution of technological area (%)				
• Communications	11.4	6.2	0.0	6.1
• Energy technology	0.0	4.3	5.3	3.7
• Environment	31.8	14.9	23.7	19.3
• Information technology	20.5	24.2	26.3	23.8
• Medical and biotechnology	4.5	18.0	15.8	15.2
• New materials	9.1	12.4	15.8	12.3
• Robotics/production automation/lasers	13.6	13.0	10.5	12.7
• Transport	9.1	6.8	2.6	7.0
Network members				
• # of participants	1,185	2,052	492	3,965
• % of Belgian	9.5	18.0	16.1	14.2
• Average number of participants	26.9	12.7	12.9	16.3
European organisations (%)				
• Government/national administration	9.8	4.1	5.3	5.9
• Large companies	21.0	30.8	12.6	25.8
• Research institute	28.4	23.6	32.2	26.1
• SMEs	7.5	16.2	11.7	12.6
Universities	33.3	25.1	38.3	29.6
European participants (%)				
• Brussels	2.1	1.9	2.2	1.9
• Flanders	3.1	8.6	2.4	5.6
• Wallonia	0.9	0.6	4.4	1.1
• EUR14	80.8	78.5	78.0	80.4
• Others	15.3	12.3	15.2	12.9

Source: EUREKA database, DULBEA-CERT calculations.

Finally, regarding the spatial distribution of European partnerships, infra-regional links are stronger in Flanders than in other regions in addition to the higher participation of Flanders in European networks. A question mark is certainly the lesser propensity of both Flemish and Walloon teams to collaborate together. With the exception of Brussels, intra-regional collaborations are more important than the inter-regional variety within the framework of international co-operation agreements, which could provide evidence of a spreading-out process of regional innovation systems. This observation leads to the suggestion that there are certainly some grounds for actions being taken by both the Federal and Regional Authorities to stimulate joint inter-regional near-market research consortia.

In a nutshell, the diagnosis concerning the participation of Belgian research teams in EUREKA projects is a very positive one. When we examine Belgian participation in EUREKA projects, both Flemish universities and enterprises are more involved in collaborations than their French-speaking counterparts, i.e. around 70% for Dutch-speaking institutions compared with 30% for French-speaking ones. The Flemish teams are thus very active in near-market research. These observations seem to indicate that the Walloon research system is less business-oriented than the Flemish system. An important question certainly centres on the economic return of these collaborations. Despite the high level of its university research, the Walloon Region faces numerous difficulties in valorizing its R&D potential, e.g. by promoting near-market research. Consequently, we can conclude that there is an important spatial mismatch in the Belgian innovation system, within as well as between regions, i.e. the Walloon valorization mismatch and the inter-regional collaboration mismatch.

3. Technology-based alliances

The globalisation of markets and the acceleration of technological change are both elements that explain the present trend towards the formation of strategic partnerships. Besides the Framework Programmes and the EUREKA projects, enterprises decide to enter into alliances on a private basis in order to expand their market, reduce risks and share technological competencies. A major drawback of FP and EUREKA data is that the collaborations reported are mainly forged at European level, with the result that they are not relevant in terms of analysing the extent of collaborations between major trading blocs. In line with the conclusion reached by a number of studies (European Commission, 1997), strategic alliances are closely related to the core technology of partners. One third of technology-based alliances contained in the IFO database (European Commission, 1997) are concentrated in the pharmaceuticals sector, 15% in the electronics sector and around 10% each in the computer and office machinery and instruments sectors.

If we consider the data published in the *Second European Report on S&T Indicators* (European Commission, 1997) on technological co-operation between enterprises throughout the world, the very high degree of internationalisation of the Belgian R&D system as exemplified by its participation in European R&D programmes needs to be substantially qualified. Of a total of approximately 5000 international technology alliances between EU Members, the US and Japan, Belgian enterprises are recorded in only 57 of these collaborations. If we only consider strategic alliances including at least one EU partner, we observe that the Belgian share in the total is equal to 3.0%. As shown in *Table 8*, the participation indexes are equal to 106 for the per-capita and 103 for the per-researcher index respectively. The scores obtained by some other small countries like the Netherlands, Sweden and Ireland show that Belgium could improve its performance[5]. However, this very average position could be explained by the country's high degree of multinationalisation. Indeed, in a country whose economic

[5] It should be emphasised that the Belgian position in the European average is largely dependent on the very low scores obtained by technological stragglers. When the indexes are calculated excluding the four countries with the lower scores, the new indexes obtained for Belgium are equal to 90 for the per-capita and 97 for the researcher index respectively.

structure is largely dominated by foreign companies, participation in international strategic alliances could be hampered by the worldwide strategies pursued by groups' head offices. This aspect will be more significant if the multinational does not have R&D teams in the country, which is unfortunately the case for the majority of subsidiaries of foreign firms.

These additional results show that although Belgium has largely developed its European collaborations thanks to the EU programmes and the EUREKA initiative, there is a question mark concerning its position as a partner in strategic alliances. In the present era of the globalisation of markets, further endeavours should be undertaken by the Belgian Public Authorities to promote more strategic partnerships involving Belgian firms at global level. So far, its good performance in pre-competitive and near-market research does not seem to have stimulated its participation in strategic alliances to any great extent. Despite the lack of regional distribution of strategic alliances, it can be expected that the Walloon Region is less committed in these alliances than the other Belgian regional partners. Within the context of a benchmark approach, Belgium should almost double its number of participations in order to be at the top of the rankings in relative terms.

TABLE 8 **International technology alliances of EU countries** • 1984-1995

Distribution (%)		Per-capita Participation Index		Per-researcher Participation Index	
UK	28.2	SW	193	NL	192
DE	23.2	NL	191	UK	148
FR	17.7	UK	169	SW	129
NL	8.4	DE	134	IR	117
IT	7.5	IR	125	**BE**	**103**
SW	4.9	FR	107	DE	93
BE	**3.0**	**BE**	**106**	FR	91
ES	2.2	FI	103	IT	77
FI	1.5	DK	86	FI	69
IR	1.3	IT	46	DK	62
DK	1.3	ES	20	ES	37
PO	0.4	PO	15	PO	29
GR	0.3	GR	9	GR	26
LU	-	LU	0	LU	0

Note: The alliances taken into account refer to the major trading blocs: the EU, the US and Japan.
Source: European Commission (1997), DULBEA-CERT calculations.

4. Conclusions

The level of Belgian participation in European R&D programmes is very high and largely influenced by geographic and cultural proximities. However, the weakness of intra-national collaboration links shows that Belgian teams do not sufficiently exploit their complementarities. The regions display a high degree of participation in the majority of technological fields, with electronics and information technologies appearing to be two major strengths of the Flemish Region. Brussels also obtains good scores for these fields. The industrial and material technologies and biotechnology sectors emerge as a strong Walloon specialisation.

With regard to EUREKA projects, the Flemish Region is the main Belgian player in the networks, while regional differences are very limited in the technological fields. A major difference between Flanders and Wallonia is the very weak level of participation of enterprises in the latter region. Furthermore, intra-regional links are stronger in Flanders than in the other regions, with evidence of a lesser propensity on the part of both Flemish and Walloon teams to collaborate together. The weakness of inter-regional collaborations could be an indication of a spreading-out process relating to regional innovation systems. In this field, there are certainly some grounds for Federal Authorities to implement a policy aimed at reducing the spatial collaboration gap.

Looking at strategic alliances forged on a private basis, the very high degree of internationalisation of the Belgian R&D system as exemplified by its participation in European R&D programmes needs to be substantially qualified. Indeed, the low level of participation of Belgian R&D private companies in international strategic alliances compared with pre-competitive R&D collaborations contrasts with the dynamism of Belgian research teams in European S&T networks. In order to better valorize the S&T potential of these pre-competitive and near-market joint research projects in economic terms, new policies could be implemented in the S&T field, e.g. programmes aimed at consolidating and enhancing acquired knowledge through special emphasis on downstream capabilities, such as manufacturing and commercialisation capabilities.

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Appendix 1

Measure of Indexes

- *Per-capita participation index:* $100^*(P_i/pop_i)/(P_E/pop_E)$
- *Per-researcher participation index:* $100^*(P_i/res_i)/(P_E/res_E)$
- *Distribution index:* $100^*(P_{ij}/P_i)/(P_{Ej}/P_E)$
- *Per-capita collaborative links indexes:* $100^*(L_i/pop_i)/(L_E/pop_E)$
- *Per-researcher collaborative links indexes:* $100^*(L_i/res_i)/(L_E/res_E)$
- *Mutual collaboration spatial specialisation:* $100^*(L_{il}/L_i)/(L_l/L_E)$

where:
P_i = number of participations of country i
pop_i = population of country i
res_i = number of researchers of country i
P_{ij} = number of participations of the category of players j in country i
L_i = number of collaborative links of country i
L_{il} = number of collaborative links between country i and country l
E = subscript for Europe (EUR15)

Appendix 2

CORDIS projects: Technological proximities

		GOV			HEI			IND			Other			RTO		
		B	F	W	B	F	W	B	F	W	B	F	W	B	F	W
GOV	Brussels	1														
	Flanders	0.4	1													
	Wallonia	0.6	0.7	1												
HEI	Brussels	0.7	0.3	0.4	1											
	Flanders	0.7	0.3	0.5	1	1										
	Wallonia	0.7	0.4	0.5	1	1	1									
IND	Brussels	0.5	0.4	0.3	0.3	0.4	0.4	1								
	Flanders	0.4	0.3	0.2	0.3	0.3	0.3	0.9	1							
	Wallonia	0.4	0.3	0.4	0.3	0.4	0.4	0.8	0.9	1						
Others	Brussels	0.6	0.3	0.4	0.8	0.8	0.8	0.5	0.4	0.3	1					
	Flanders	0.7	0.3	0.6	0.8	0.8	0.8	0.6	0.4	0.4	0.7	1				
	Wallonia	0.6	0.4	0.5	0.7	0.7	0.7	0.6	0.5	0.4	0.7	0.8	1			
RTO	Brussels	0.7	0.4	0.5	0.8	0.8	0.8	0.5	0.5	0.6	0.7	0.7	0.6	1		
	Flanders	0.6	0.3	0.4	0.5	0.6	0.6	0.8	0.8	0.7	0.6	0.6	0.6	0.7	1	
	Wallonia	0.2	0.1	0.2	0.2	0.3	0.3	0.4	0.6	0.8	0.1	0.2	0.2	0.4	0.4	1

Legend: B = Brussels, F = Flanders, W = Wallonia.
Source: CORDIS, DULBEA-CERT estimations.
Note: proximity index performed as the angular separation between the vectors of participation distribution across technological key words of projects.

A Study of Knowledge Spillovers from the Compatible EPO and USPTO Patent Datasets for Belgian Companies*

Ruslan Lukach and Joseph Plasmans[1]

Abstract

This paper conducts a comprehensive study of patent citations indicated in patents granted to Belgian corporate applicants by the United States and European patent offices during the period between 1996 and 2000. It employs a qualitative response variable analysis relating to patent citations in different industries.

The modelling results conclude that there are different patterns of citation behaviour in patents belonging to different industrial classes. Although patents in some industries are more likely to have inter-firm or inter-industry spillovers, there are industries with more intra-firm or intra-industry patent citation patterns. With regard to the relationship between the probability of a citation occurring in a particular industry and the relative time lag between the citing and cited patents, the picture also varies depending on the industry of the citing patent.

1. Introduction

> Knowledge flows, by contrast, are invisible; they leave no paper trail by which they may be measured and tracked, and there is nothing to prevent the theorist from assuming anything about them that she likes.
> KRUGMAN (1991, p. 53)

The presented research aims at tracking down knowledge spillovers in Belgium by following some of their "trails". There is no doubt about the importance of knowledge spillovers for economic growth. In a contemporary knowledge and technology-driven economy the role of knowledge exchange and dissemination is sometimes as significant as, for example, the role of direct investment. Firstly, such spillovers allow better penetration and diffusion of innovation among economic agents, thus increasing their competitiveness (through lower costs of new technologies). Secondly, they stimulate cooperation in R&D by creating additional incentives for innovators to try to internalise knowledge flows and pool resources in joint research efforts. Both of these

* Original version.

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types of effect eventually result in faster technological progress and economic growth in the country.

1.1 Knowledge, Spillovers, Competition and Economic Growth: the Theory

There is one important aspect worth mentioning, i.e. the difference between information and knowledge. Information can be obtained and disseminated freely (almost) without any cost. On the other hand, knowledge is something that is very difficult to enumerate or codify. Knowledge is precisely that intangible asset that can have a certain economic value if properly used and commercialised.

Although a knowledge spillover is a phenomenon that is quite easy to imagine, it is much more difficult to actually come up with an effective measure of it. According to the definition given by De Bondt (1996), the concept of a "knowledge spillover" is specified as "an involuntary leakage or voluntary exchange of useful technological information". Another definition, presented in Nieuwenhuijsen and van Stel (2000), describes knowledge spillovers as the situation in which one economic agent benefits from the R&D efforts of another economic agent without any tangible remuneration.

Bernstein and Nadiri (1988) classify knowledge spillovers as vertical or horizontal. Horizontal spillovers occur between competitors, while vertical spillovers flow between firms in different industries. Both these types of spillover are directly linked to three factors of economic growth (Glaeser *et al.* (1992)): specialisation, competition and diversity. Specialisation is characterised by a higher intensity of intra-industry knowledge spillovers, whereas diversity goes hand in hand with more extensive inter-industry knowledge exchange. Subsequently, the competition factor affects the degree of inter-firm innovation flows.

Extensive literature is already available on the importance of knowledge spillovers as a factor determining firms' optimal R&D strategies. The very basis of this was laid down by the study conducted by d'Aspremont and Jacquemin (A&J (1988)), which showed that the spillover effect influences a firm's willingness to cooperate in R&D. Their main conclusion states that, when knowledge spillovers are relatively strong, economic agents have strong incentives to cooperate with each other.

Gandal and Scotchmer (1991) advocate that it is more efficient to delegate research efforts to the agent with the highest ability by means of a Research Joint Venture (RJV) and that this will lead to better private and social results. Within the framework of A&J (1988), the study by Lukach and Plasmans (2000) investigated the optimal R&D and production strategies of firms with differing capabilities in research and production. It concludes that in RJVs the firm with a lower marginal per unit cost of R&D conducts by far the larger part of joint R&D. This finding provides the additional evidence of delegation described by Gandal and Scotchmer. Moreover, under conditions of greater knowledge spillovers, creation of RJV leads to an improved social welfare position.

In his famous "Learning by Doing" model, ARROW (1962) points out that the competitive behaviour of firms in the economy yields a lower amount of aggregate investment compared to what is socially desirable. By stimulating firms to cooperate in R&D, the social planner shifts the mode of their R&D and production behaviour from a competitive to a less competitive position with a higher welfare-function value. In order to stimulate R&D cooperation among innovative firms, the regulator has a number of tools with which to achieve the desired effect. Such tools can be direct or tax subsidies, government R&D investment, as well as expenditure policies.

In the described theoretical framework, for example, the firms maximising profits in industries with weak knowledge spillovers tend to compete in R&D rather than cooperate. Thus, if the regulator wishes to induce R&D cooperation, it should come up with some tangible way to stimulate cooperation on the part of such firms. On the other hand, where there are substantial knowledge spillovers, market forces provide a certain stimulus for companies to cooperate in research and, thus, enabling the regulator to save resources by letting "nature do its job". If we therefore consider the regulator's task as stimulating economic growth by inducing R&D cooperation, it becomes clear that correct assessment of the environment of knowledge spillovers can be one of the important elements for the success of such regulatory policy.

1.2 Knowledge Spillovers: the Patent "Trail"

Our research relies heavily on the observation that the decision to patent a certain innovation is a "strategic decision" (JAFFE *et al.* (1993)). If the firm decides to apply for a patent, it recognises the potential value of the invention. This does not mean, of course, that not-patented knowledge is worthless, though we should advocate that patented knowledge is the variety most likely to be commercialised. There have been a number of historical developments that have created greater incentives for firms to protect their innovation by means of a patent. Firstly, the main purpose of a patent is to protect an "individual" act of invention and grant the inventor temporary rights to exclusively benefit from his/her innovative idea. However, with the increase in the volume of "invention by investment" (KINGSTON, 2001) over time, patents had to evolve to also accommodate the rights of the investor employing the inventor and/or providing him/her with the means to conduct the research concerned. Gradually, patents became protectors not only of the individual act of creativity, but also of the result of directed and managed investment in research and development.

The patent thus developed from a mere legal document into a tool of strategic competitive behaviour. Firms build up their intellectual property portfolios, trade patents, sell licenses, and create patent pools with other firms. In some industries, patents have crucial strategic importance. In the pharmaceutical industry, for example, it is not enough to patent just one molecular structure for efficient protection of the invention - a small molecular variation of the same active component must also be patented. Thus, firms in chemical and pharmaceutical industries have to apply for numerous patents to protect their innovative effort and investment. Firms in other industries are also becoming more active in the area of patenting.

Plasmans *et al.* (1999) advocate that entrepreneurial innovative behaviour can be gauged reasonably well by the entrepreneur's patent behaviour. They take the average propensity to patent (the number of patents per million constant PPP dollars of R&D expenditure) as a crude measure for the absence of knowledge spillovers and apply it to panel data for core EU countries and different industries (over the sample period 1989-1995).

In their contribution to the publication of The National Innovation System of Belgium, Capron and Cincera (2000) studied the technological performance of Belgian companies using patent and scientific-publication information as output indicators of technological and innovation activity from 1980 to 1996. The aim of this study was to determine the areas of comparative technological advantage and the regional distribution of innovative efforts in Belgium.

As we conclude that patents encapsulate an important part of commercially valuable knowledge, it is rational to consider the advantages of utilising the patent data in analysing firms' strategic R&D behaviour. As already mentioned, a patent is, technically speaking, a legal document. Its content comprises the information subsequently verified and submitted to a controlling body. Thus, the patent citation represents certified evidence of previous knowledge used by the inventor(s) obtaining a given patent. This previous knowledge may come from the same patented domain. Hence, we conclude that the patent citation shows the spillover of one protected knowledge pool (i.e. recognised as potentially valuable) to another.

The study of patent citations has its own limitations. The advantages and disadvantages of using patent citation data are extensively discussed by Griliches (1990) and Jaffe *et al.* (1993). As patent citations are linked to the patenting procedure itself, they capture only the knowledge flows, occurring between patented "pieces" of innovation. Other means of knowledge transfer are not captured by patent citations, i.e. purchase of capital goods with embodied technologies, employment of engineers and other creative staff from other firms and institutions, voluntary knowledge exchange at conferences and in scientific publications, etc. Though we should admit the importance of other non-patent-citation means of knowledge exchange, it is necessary to point out that only the patent citation is, to a large extent, finalised as a representation of such exchange. The knowledge acquired is likely, informally or indirectly, to become the subject of a dispute with other economic agents. Such disputes are common in business practice and they add a substantial amount of disturbance to data when they are used to analyse innovative information exchange. Patent information is better protected from such disruption because it clearly indicates the ownership of a particular piece of knowledge that is protected by law. Although patent disputes are also possible, these are usually resolved quickly by the relevant institutions.

Patent citation data have one further shortcoming, in that the patent examiner has the right to add other citations he/she finds applicable in a given case, even though the inventor may not be aware of the inventions added. The addition of new citations by the patent examiners is widely practiced in the USPTO (United States Patent and Trademark Office), and the EPO (European Patent Office) examiners are able to do that as well. We have interviewed one of the USPTO examiners, who informed us that it is not possible to effectively distinguish between the "original" citation and a citation added by the examiner for the majority of US patents (as they are published in the published databases). We can actually consider such added records as an indication of knowledge spillovers that are not officially recognised by the inventors, but from which he or she could also have benefited. However, all the other advantages, including a vast pool of available data and, most of all, the explicitness of patent claims make the patent citation a good object for knowledge transfer analysis (Jaffe *et al.* (1993) and Verspagen (1997)).

An extensive study of Verspagen (1997) analyses patent citation data in relation to the productivity growth analysis for a cross-country, cross-sectional sample. He advocates that patent citations provide a measure of knowledge spillovers, different from other conventional measuring methods. Furthermore, Verspagen investigated the impact of large Dutch companies on domestic knowledge diffusion in the Netherlands in 1999 by studying patent-to-patent citation data provided by the EPO. This study employed a network analysis to analyse the position of Dutch multinationals in the domestic technology infrastructure.

Another Dutch study investigated the citations of granted USPTO patents relating to Dutch-authored research papers (Tijssen (2001)) in order to ascertain the impact of Dutch-authored innovations on other patented knowledge.

Our study derives from the previous investigation of knowledge spillovers in Belgium (see Plasmans and Lukach (2001)). This study presented a "snap-shot" picture of knowledge flows through the mechanism of patent citations for all patent applications submitted to the EPO by Belgian firms, as well as the applications granted and submitted to the USPTO in 1997. We conducted a comparative analysis of the data and tested the methodology for qualitative response variable analysis (probit and logit modelling), based on the recent research by Jaffe and Trajtenberg (1998), who constructed a "probit-type" model of knowledge flows using patent citations. They established a likelihood measure for the citation probability of any given patent pair. This allows a numerical evaluation of the "citation frequency"[2] between different industries as well as between different geographical areas. Jaffe & Trajtenberg's study was based solely on data provided by the USPTO and concentrated on industrial and national levels. We apply a similar technique to estimate the impact of knowledge spillovers (domestic and international) among different industries in Belgium, though we employ two sources, i.e. the USPTO and EPO databases, thus widening the scope of our data by building two compatible datasets.

In the current study, we were able to achieve several important improvements and extensions for such analysis. Firstly, we managed to obtain two compatible datasets from the EPO and the USPTO. Our fundamental data units are represented by all patents granted to Belgian firms by the EPO and the USPTO during the period between 1996 and 2000 inclusive. We consider not only the citations between the patents issued by the same office, but also those citations in which one patent was issued by the EPO and another by the USPTO (cross-patent-office citation). We ascertain all Belgian firms that had patents granted during the period observed and aggregate them in industries. Together with the industrial structure of spillovers, we are also able to form a geographic pattern of Belgian patent citations.

[2] According to the definition given by Jaffe and Trajtenberg (1998), a "citation frequency" is a likelihood measure for the probability that any particular patent h granted in year t will cite some particular patent k granted in year $\tau \le t$.

2. Overview of the data

In this paper, we analyse patenting data from two major sources: the EPO and the USPTO. The main purpose of this research is to create a picture of "patent-driven" knowledge spillovers in Belgium. In particular, we study the set of patents obtained by Belgian firms during the five years from 1996 to 2000.

As our interest focuses on a firm-level analysis of the data, we intend to adjust the list of firms considered by using the shareholding and subsidiary relationship information collected by the National Bank of Belgium (NBB) and provided by the Bureau van Dijk (BVD's BelFirst database). The dataset currently available to us describes the firms' corporate governance structure as presented in their 1998 annual reports. Since 1998 is a median year in the period observed, we assume that it provides a good approximation of the typical firms' corporate governance structure for the period 1996 - 2000.

The raw dataset is presented by the patent citations indicated in the patents granted to Belgian corporate applicants by the EPO or the USPTO. Among these, we select all citations corresponding to the applicants which are identifiable in the BelFirst database. This allows us to adjust the ownership of patents belonging to the firms involved in shareholder-subsidiary relationships. Thus, the primary object of our analysis is the patenting behaviour of the Belgian firms.

Our primary source of information lies in "patent citation pairs". This kind of data provides a good opportunity to study knowledge flows indicated by the citation references in the patent application. JAFFE and TRAJTENBERG (1998) and VERSPAGEN (1999), for example, conducted analyses of different patent citation datasets using different methodologies, i.e. econometric probit(logit)-type models, technological proximity matrices, and network analysis.

The dataset we use provides data on all the applications that resulted in patents being granted and already contains the citations indicated by the patent office investigators. We have derived additional advantage by using the data from two different patent offices simultaneously. In the vast majority of previous studies, only one source was used and only one particular part of citations was studied. Where the data were derived from the EPO database, the sole citations studied were (mainly) the citations where one EPO patent cites another EPO patent (similarly with the USPTO). In our case, we use not only citations between patents issued by one patent office, but also those citations where the patent issued by the EPO cites the patent issued by the USPTO and vice versa. This is a very important new development, which significantly expands the sample and improves its representativeness.

In our primary dataset, each line represents a single patent citation accompanied by several descriptive characteristics, i.e. the patent number, the applicant's name, the applicant's country, the year in which the patent was granted, and the patent's class according to the International Patent Classification (IPC). In addition, we use the IPC-ISIC (ISIC – the International Standard Industrial Classification of All Economic Activities of the United Nations) concordance table compiled by Verspagen *et al.* (1994) to transform somewhat ambiguous IPC classes into more business-oriented groups indicated in the ISIC (compatible with the familiar NACE classification).

The patent citation pool is used to build another interesting dataset. We aggregate the citation data and summarise them in a firm-oriented sample, where the basic observation is the firm that is "identifiable" and can be linked to the NBB's information. Thus, there is a number of variables attributed to each firm: the total number of citations from patents applied for (both at the EPO and the USPTO), the number of citations from patents applied for at the EPO, the number of citations from patents applied for at the USPTO, the total number of citing patents applied for (both at the EPO and the USPTO), the number of citing patents applied for at the EPO, plus the number of citing patents applied for at the USPTO.

3. Preliminary data analysis

After processing data initially, we are able to make certain preliminary observations and conclusions. In this way, we plan to establish a basis for the further model analysis. These results are obtained from a basic aggregation of the data on the number of patents and citations corresponding to different firms, industries, and countries. The source dataset is a pooled sample of all patents granted by the EPO and the USPTO to Belgian firms during the period between 1996 and 2000. Our conclusions and observations are grouped into several sections:

- geographic distribution of citations;
- firm-oriented distribution of patents and citations;
- structure of the "citation time lag" between citing and cited patents;
- distribution of citations among different industries.

3.1 Geographic distribution of citations

First, we consider the basic geographic distribution of citations made by Belgian applicants. In *Table 1* we list ten countries producing the largest number of citations (i.e. the countries of origin of cited patents' owners) together with the number of citations coming from other countries and the overall number of analysed citations. The list of "top ten performers" consists of countries with more than 1% of total citations and covers the vast majority of these citations (96.2%).

According to the data from both patent offices, the USA patents are cited most. The second and third places are held by Japan and Belgium respectively, although Belgium ranks third in the USPTO sample, and second in the EPO sample. Rationally, we would have expected Belgian patents to be the most cited (i.e. in first position), driven by the argument that intra-firm and intra-country citations are more likely to occur (Jaffe & Trajtenberg (1998), pp. 6-7) than the more distant ones. Patents from the United States are most frequently cited by Belgian companies, which allows us to assume the existence of a very strong "transatlantic" knowledge flow. The "Japanese" knowledge spillover channel is also quite strong. The other positions are occupied by the countries of the European Union (EU) and the Czech Republic, which now holds candidate status. Thus, we conclude that the "geographic proximity" assumption is not strongly supported by the information collected as domestic patents are not the most frequently cited. However, citing domestically cannot be rejected out of hand by virtue of the fact that we observe Belgian patents in the group of the top three.

Table 1 also shows that the citations of American patents account for more or less comparable proportions of the USPTO and the EPO samples. Thus, if we assume that the citations added by the examiners at the USPTO do have a certain bias towards adding more citations to the American patents, this disturbance is not substantial.

TABLE 1 **Geographic distribution of patent citations in Belgian firms' patents granted by the EPO and USPTO** • 1996-2000

	Country	USPTO	EPO	Total
1	United States of America	42.15%	35.98%	40.62%
2	Japan	18.64%	17.11%	18.26%
3	Belgium	17.18%	20.42%	17.98%
4	Germany	6.07%	7.36%	6.39%
5	France	3.17%	4.15%	3.41%
6	Great Britain	3.19%	3.88%	3.36%
7	Italy	1.63%	2.15%	1.76%
8	Czech Republic	1.93%	0.85%	1.65%
9	Switzerland	1.55%	1.60%	1.56%
10	The Netherlands	0.90%	1.95%	1.16%
	Other	3.59%	4.55%	3.84%

3.2 Firm-oriented distribution of patents and citations

The second block of preliminary results deals with the "top 20 performers" among the firms surveyed. *Table 2* contains the percentages of patents granted to these companies. *Table 3* presents the list of firms with the highest number of patent citations indicated in patents granted by the EPO and the USPTO during the period from 1996 to 2000. In this table, we see that the top 20 companies (or 9.6% of all firms in our dataset) account for more than four fifths of the patent citations.

TABLE 2 **Percentage of patents granted to selected Belgian firms by the EPO and the USPTO** • 1996-2000

	Belgian firms	USPTO	EPO	Total
1	Agfa-Gevaert	38.86%	34.71%	37.14%
2	Solvay	9.30%	10.93%	9.97%
3	Janssen Pharmaceutica	7.86%	3.17%	5.92%
4	Esselte	2.62%	2.64%	2.63%
5	Raychem	2.74%	2.82%	2.78%
6	Dow Corning	1.87%	1.06%	1.53%
7	Xeikon	1.75%	1.06%	1.46%
8	Fina Research	2.43%	3.00%	2.67%
9	Glaverbel	1.62%	0.26%	1.06%
10	Heraeus Electro-Nite International	2.06%	1.85%	1.97%
11	Bekaert	2.18%	2.03%	2.12%
12	Plant Genetic Systems	2.74%	0.35%	1.75%
13	Innogenetics	1.75%	0.79%	1.35%
14	Smithkline Beecham Biologicals	0.94%	0.97%	0.95%
15	U.C.B.	1.00%	1.32%	1.13%
16	Michel Van De Wiele	1.62%	0.97%	1.35%
17	Picanol	1.06%	1.67%	1.31%
18	Owens-Corning	0.50%	0.09%	0.33%
19	Bayer Antwerpen	0.56%	0.88%	0.69%
20	Lernout & Hauspie Speech Products	0.87%	0.00%	0.51%
	Other	15.66%	29.43%	21.37%

These results are closely related to the findings already presented by Plasmans *et al.* (1999), which were based on a study of patenting behaviour in 22 major industrial sectors of EU core countries during the period 1989 – 1995. This study indicates that a very limited number of companies actually accounts for the significantly larger part of patents granted by the EPO. Our data show a similar picture: the three companies at the top of the list own 56.02% of all patents issued between 1996 and 2000 (inclusive) by the USPTO and 48.81% of the patents issued by the EPO during the same period. The results obtained by Capron and Cincera ((2000), p. 178) indicate that there was a tendency towards a growing concentration of patenting among the limited number of bigger players. Our findings show that such concentration has intensified still further over the past five years. Capron and Cincera ((2000), p.179), for example, indicate that the top 20 Belgian patenting firms accounted for 49.8% of EPO patents and 65.7% of USPTO patents during the period 1980-1996. Since 1996, however, we see that the top 20 players are now responsible for 70.57% and 84.34% of patents respectively.

TABLE 3 **Percentage of patent citations generated in the patents granted to selected Belgian firms by the EPO and the USPTO** • 1996-2000

	Belgian firms	USPTO	EPO	Total
1	Agfa-Gevaert	34.19%	36.01%	34.58%
2	Solvay	9.37%	9.99%	9.50%
3	Janssen Pharmaceutica	5.46%	3.66%	5.08%
4	Esselte	4.71%	3.50%	4.45%
5	Raychem	4.17%	3.26%	3.98%
6	Dow Corning	3.20%	1.35%	2.80%
7	Xeikon	2.89%	1.51%	2.60%
8	Fina Research	2.04%	3.10%	2.26%
9	Glaverbel	2.52%	0.24%	2.04%
10	Heraeus Electro-Nite International	2.10%	1.79%	2.04%
11	Bekaert	2.14%	1.59%	2.03%
12	Plant Genetic Systems	2.29%	0.36%	1.88%
13	Innogenetics	1.66%	1.11%	1.55%
14	Smithkline Beecham Biologicals	1.27%	1.19%	1.25%
15	U.C.B.	1.23%	1.11%	1.21%
16	Michel Van De Wiele	1.30%	0.76%	1.18%
17	Picanol	0.89%	1.35%	0.99%
18	Owens-Corning	1.21%	0.04%	0.96%
19	Bayer Antwerpen	1.00%	0.72%	0.94%
20	Lernout & Hauspie Speech Products	1.14%	0.00%	0.90%
	Other	15.22%	27.34%	17.80%

Table 4 shows the “aggregated size” characteristics of the companies mentioned above. We have obtained weighted consolidated turnover figures for each firm as the sum of the firms’ own turnover plus the turnover of their subsidiaries weighted by the total participation share. A similar procedure was also applied to average annual employment. These variables serve as proxy measures for the firms’ relative size characteristic.

Of these companies, some are quite big and well-known (Agfa-Gevaert, Solvay, Janssen Pharmaceutica, Glaverbel, Bekaert), while others are much smaller (Esselte, Xeikon, Sofitech, Owens-Corning). This indicates that although the biggest firms occupy the top three positions, there are also small companies engaging in the active patenting process. Thus, the large size of a company does not necessarily indicate that it will be more active in patenting than its smaller counterparts.

TABLE 4 **Profiles of selected Belgian firms** • based on 1998 annual financial reports

	Name	Weighted Consolidated Turnover[3] (million EUR)	Weighted Consolidated Average Employment (employees)
1	Agfa-Gevaert	1,638.6	5,701.62
2	Solvay	2,055.0	3,629.04
3	Janssen Pharmaceutica	1,194.8	3,864.98
4	Esselte	133.9	571.98
5	Raychem	292.5	849.07
6	Dow Corning	49.6	394.00
7	Xeikon	119.0	274.00
8	Fina Research	64.5	474.00
9	Glaverbel	894.9	4,278.78
10	Heraeus Electro-Nite International	76.8	471.00
11	Bekaert	833.2	4,965.00
12	Plant Genetic Systems	27.3	167.00
13	Innogenetics	17.4	379.80
14	Smithkline Beecham Biologicals	654.4	1,442.00
15	U.C.B.	904.8	3,692.74
16	Michel Van De Wiele	171.0	583.89
17	Picanol	342.1	1,764.98
18	Owens-Corning	396.6	906.00
19	Bayer Antwerpen	969.3	2,575.00
20	Lernout & Hauspie Speech Products	106.6	297.61

Source: Bureau van Dijk

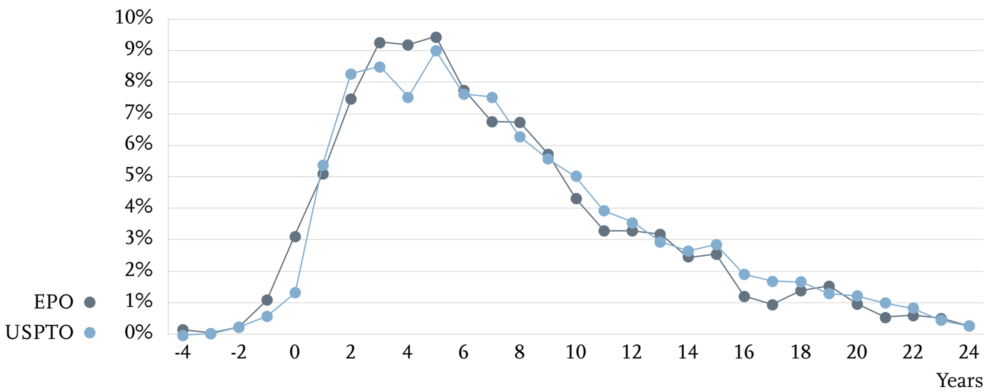
3.3 The structure of the "citation time lag" between citing and cited patents

We can derive implications regarding the time structure of knowledge spillovers based on the data concerning the time lag between citing and cited patents. *Figure 1* illustrates the distribution of cited patents among the different years. The basic shape of the distribution is very similar to the shape of the estimated citation frequency functions obtained by Jaffe and Trajtenberg (1998). The figure shows that recent patents (relative to the date of the citing patent) are more likely to be cited than older ones. The specifics of the patent examination process actually allow the (small) negative citation lag values to occur as one patent can cite a published application for another patent granted later than the citing patent itself, or when the cited patent is reissued.

[3] We obtained weighted consolidated turnover figures for each firm as the sum of the firms' own turnover plus the turnover of their Belgian subsidiaries weighted by the total participation share. A similar procedure was also applied to average annual employment. These variables serve as proxy measures for the firms' relative size characteristic.

Another fact worth noting is that the time structure of the citation lag is more or less the same in both the USPTO and the EPO sample. This can serve as additional evidence of compatibility of the data in these two samples and that pooling these two samples is feasible.

FIGURE 1 **Time Lag Structure based on the Belgian patents granted by two different patent offices** • 1996-2000

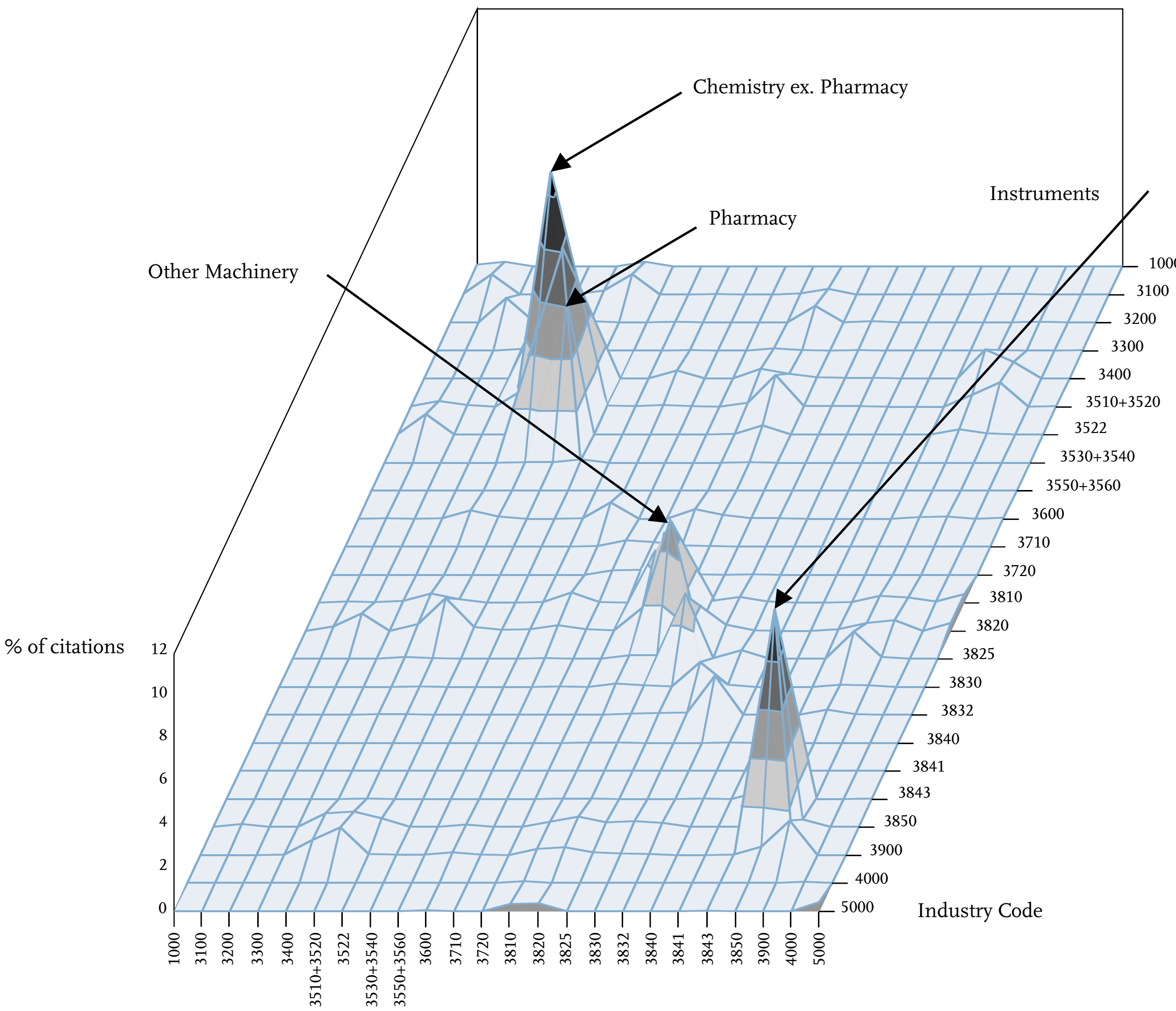


3.4 Intra-industry citations in different industries

Let us consider the industrial structure of patent citations indicated in a pooled sample (the USPTO and EPO samples together). *Figure 2* presents the "surface" of intra- and inter-industry citations. Each point on the surface represents the percentage of citations between two industry codes in the overall sample. The industries presented in the figure were determined from the patent's main IPC, transformed using the IPC-ISIC concordance table (Verspagen *et al.* (1994)). To determine the category of a patent indicating several categories in the application, we used the first category listed. *Table 5* lists all the industries indicated in the ISIC, accompanied by the corresponding percentages of citations calculated in the pooled sample.

The figure is actually a graphical representation of the cross-industry citation matrix, calculated over the entire citation sample. This matrix closely resembles the widely used "Yale matrix" (see e.g. Verspagen (1997)). As we expected, these diagonal elements are quite "high" (see the "Main Diagonal Ridge" on *Figure 2*), i.e. there is evidence that intra-industry citations are more numerous than the citations between different industries.

FIGURE 2 **Relative frequencies of citations among industries surface** • 1996-2000
• for industry codes see Table 5



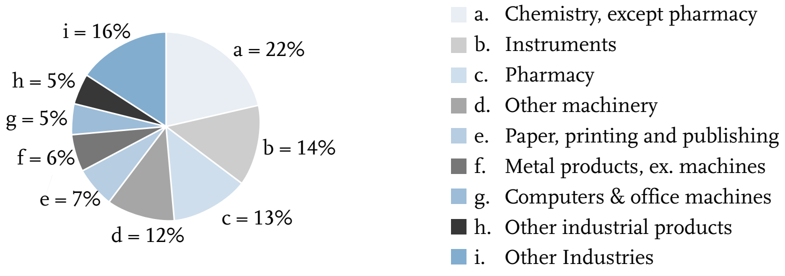
The highest peaks correspond to intra-industry citations in the "Chemistry excluding Pharmacy" (10.9% of all citations), "Instruments" (10.1%), "Pharmacy" (6.28%), and "Other Machinery" (5.17%) industries. There is also a number of peaks outside the main diagonal, indicating active streams of knowledge flow between certain industries. Although these flows are primarily symmetric (relatively strong in both directions between two industries), there are several asymmetric peaks corresponding to one-directional spillovers, such as between "Paper, Printing and Publishing" and "Instruments" (1.34%). Of the symmetric cross-industry knowledge flows, the strongest occur between "Chemistry excluding Pharmacy" and "Pharmacy" industries (5.6% of citations one way and 5.25% in the opposite direction), and between "Chemistry excl. Pharmacy" and "Other Machinery" (1.48% one way and 1.51% in the opposite direction).

TABLE 5 **Citation Percentages (as a fraction of all citations)** • 1996-2000

ISIC code	Industry	% of citations
3510+3520	Chemistry, except pharmacy	21.29%
3850	Instruments	14.04%
3522	Pharmacy	13.41%
3820	Other machinery	11.55%
3400	Paper, printing and publishing	6.94%
3810	Metal products, excl. machines	6.38%
3825	Computers & office machines	5.38%
3900	Other industrial products	5.22%
3100	Food, beverages, tobacco	2.56%
3832	Electronics	2.50%
3600	Stone, clay and glass products	2.23%
3200	Textiles, clothes, etc.	2.22%
3830	Electric mach., excl. electronics	1.79%
5000	Building and construction	1.23%
3710	Ferrous basic metals	0.70%
3720	Non ferrous basic metals	0.58%
1000	Agriculture	0.56%
3843	Motor vehicles	0.45%
3300	Wood and furniture	0.33%
3530+3540	Oil refining	0.22%
4000	Utilities	0.19%
3550+3560	Rubber and plastic products	0.15%
3840	Other transport	0.09%
3841	Shipbuilding	0.01%

There are eight major industries that account for the largest part (84%) of all citations considered: 3510+3520 (Chemistry excluding Pharmacy), 3850 (Instruments), 3522 (Pharmacy), 3820 (Other Machinery), 3400 (Paper, Printing and Publishing), 3810 (Metal Products, excluding Machinery), 3825 (Computers and Office Machines), and 3900 (Other Industrial Products). The individual shares of these industrial sectors are presented in *Figure 3*.

FIGURE 3 **Percentages of citations by industries** • 1996-2000



4. Models and estimation

4.1 Citation pairs modelling

We now intend to employ an econometric methodology to try to gain a deeper insight into the knowledge spillovers pattern, "encoded" into patent citation data. Previous researchers" experience (JAFFE and TRAJTENBERG (1998)) shows that patent citation data are best analysed using a binary choice (qualitative response) probit-type (or logit-type) model. The occurrence of a citation with particular attributes represents a binary event (occurrence or not), from which it is possible to estimate the probability of occurrence.

We focus our attention on one particular kind of event that takes place as the patent citation occurs. The event is "the citation occurs in the citing patent belonging to the particular industry class". We study the estimated probability of this event and its relationship with a set of independent variables in order to derive analytical implications concerning the inter- and intra-industry/firm structure of knowledge spillovers. Our dependent variable is an indicator with the value 1 if the citation occurs in the patent of a given particular industry, and 0 otherwise. We have chosen patents from eight major industries (mentioned above) to be analysed by the model. We consider the following list of explanatory variables:
- an indicator that the patent citation has occurred between patents owned by the same firm or institution (equals 1 if both citing and cited patents belong to the same firm, and 0 otherwise), represented by the variable *SameFirm*;
- a "concordance weighted" indicator that the citation has occurred between patents belonging to the same ISIC-industry class (real number between 0 and 1 inclusive), represented by the variable *SameIndustry*;
- the year in which the citing patent was issued, represented by the variable *Year*;
- the value of a citation lag (i.e. the time difference between citing and cited patents, expressed in years), represented by the variable *CitationLag*.

We use the concordance percentage from the MERIT Concordance Table (the share of patents in each IPC class assigned to the corresponding ISIC category; see VERSPAGEN *et al.* (1994)) to weight the indicator variable for the citation occurred. For example, if two patents belong to the same industry, we calculate the product of their concordance percentages, thus obtaining the measure of "citation occurrence" in this particular industry. The concordance percentage is the relative frequency of patents in the particular IPC class falling into a given ISIC category, which means that their product in the citation pair represents a certain likelihood measure of the patent citation itself to fall into this ISIC category. Moreover, the use of concordance percentages leads to expansion of the modelled sample due to the fact that one IPC class may fall into several industries with different weightings.

It is possible to estimate our equations using two different specifications of the binary choice model, i.e. probit and logit. We compared these two specifications in a preliminary estimation. The goodness of fit criteria showed that the probit model was better at predicting the probability of citation in our sample. We ran another series of preliminary computations to determine the best way of obtaining general implications regarding knowledge spillovers. In this step, we conducted an estimation of a probit model in two different sub-samples, i.e. the sample consisting of citations indicated in EPO data and the sample consisting of citations indicated in USPTO data. We came to the conclusion that it is reasonable to use the pooled sample to study the knowledge spillovers generated by the patent citation behaviour of Belgian companies. There are three arguments in support of this decision. Firstly, following estimation of the probit model in two different samples, we observed that 25 of 32 (8 industry equations with 4 slopes each) estimated slope coefficients[4] have the same sign with mostly adequate statistical significance. Secondly, because we are primarily interested in the overall picture of patent-citation-induced knowledge spillovers generated by the Belgian companies, it is preferable to consider these patent citations in a pooled sample. And thirdly, the close similarity of the time lag structure plus the firms' patent and citation percentages provides additional arguments for the compatibility of these two datasets.

Estimation results

There are several aspects to be noted with regard to interpreting the results. Among the explanatory variables in our model, we have one binary variable, two integer variables, and one emerging from the real numbers set. The corresponding slopes are presented in the output tables (*Tables 6 – 13*). In these tables, we marked the variables yielding different signs in separate USPTO and EPO samples with a star superscript. Below, we refer to some of the results of estimations conducted in different samples. Because of lack of space, only results from the pooled sample estimation are presented in the tables.

TABLE 6 **Probit regression results in the "Chemistry, excluding Pharmacy" industry**

	Coefficient	Slope	Std. Err.	Chi-Square	Prob.
3510+3520					
Intercept	-40.6092		13.0865	9.6294	0.0019
SameFirm	-0.2068	-0.0590	0.0236	76.6574	0.0001
SameIndustry	0.4959	0.1415	0.0217	521.4676	0.0001
Year	0.0207	0.0059	0.0066	9.9599	0.0016
TimeLag*	-0.0014	-0.0004	0.0017	0.7104	0.3993

Chemistry, excluding Pharmacy (*Table 6*)

The results for the Chemistry, excl. Pharmacy industry indicate that there is evidence of a negative relationship between the *SameFirm* dummy and the probability of citation. This fact was also indicated in both the individual USPTO and EPO samples. It allows us to conclude that a "chemical" patent is more likely to cite a patent belonging to a different firm rather than its own, i.e. this industry is more oriented towards using the other firms' patented knowledge.

The coefficient for the *SameIndustry* variable points at a higher likelihood of a citation occurring in the same industrial class. This is quite reasonable given the special

[4] In this model the slope coefficient is the product of the corresponding equation coefficient and the value of the standard normal density (in the probit model) function calculated at the means of the regressors (see Appendix).

nature of the chemical industry. As chemical patents usually protect either molecular structures or technological sequences for their synthesis, this knowledge does not extend far beyond the scope of the industry.

The positive coefficient for the variable *Year* indicates that the citation is more likely to occur in the relatively newer chemical patents. With regard to the time difference between the citing and cited patents, it is difficult to arrive at a definitive conclusion about the relationship between the time lag and the likelihood of a citation due to the (entirely) inadequate statistical significance of the estimator. Moreover, different sub-samples yielded different conclusions for this coefficient (positive in the EPO and negative in the USPTO).

To summarise the results, we may state that in the "Chemistry, excluding Pharmacy" industry the "citation-induced" knowledge spillovers tend to be inter-firm, but intra-industry. The question of how the "age" of a cited patent affects the probability of citation in this industry requires additional inquiry. As for citing patents, there is a clear indication that the newer patents tend to generate more citations.

TABLE 7 **Probit regression results in the "Instruments" industry**

	Coefficient	Slope	Std. Err.	Chi-Square	Prob.
3850					
Intercept	48.9020		15.4857	9.9723	0.0016
SameFirm	0.0388	0.0074	0.0296	1.7161	0.1902
SameIndustry	-1.1434	-0.2170	0.0225	2574.0460	0.0001
Year*	-0.0237	-0.0045	0.0078	9.3510	0.0022
TimeLag*	0.0069	0.0013	0.0020	11.6520	0.0006

Instruments (*Table 7*)

Our data for this industry failed to provide an acceptable conclusion regarding the relationship between the likelihood of patent citation and the fact that the citing and cited patents both belong to the same firm. The coefficient is positive (indicating likely intra-firm citation), though not significant enough. However, there is very strong evidence that the probability of citation is much lower in the "Instruments" industry when citing and cited patents belong to the same industry class.

Although mixed signals emerge from two samples concerning the estimated slope coefficient for the *Year* and *TimeLag* variables, the pooled sample delivers these coefficients with quite high statistical significance. It shows that the more recent citing patents indicate a smaller number of citations, and that the older patents are more likely to be cited by the patents in this industry.

The final "verdict" for the Instruments industry states that it is likely to favour inter-industry knowledge spillovers, but has an undetermined attitude towards intra-firm patent citation. Knowledge in this industry does not appear to "depreciate" rapidly, something that is supported by the evidence of a significant positive relationship between the time lag between the patents and the probability of citation.

TABLE 8 **Probit regression results in the "Pharmacy" industry**

	Coefficient	Slope	Std. Err.	Chi-Square	Prob.
3522					
Intercept	28.4484		14.6002	3.7966	0.0514
SameFirm	-0.2921	-0.0621	0.0252	134.4540	0.0001
SameIndustry*	0.2449	0.0521	0.0247	98.1231	0.0001
Year*	-0.0137	-0.0029	0.0073	3.5224	0.0605
TimeLag	0.0059	0.0012	0.0020	8.9331	0.0028

Pharmacy (*Table 8*)

The "Pharmacy" industry shows a lower likelihood of intra-firm citation and a higher probability for knowledge spillovers in the same industry (though we do get different signs in the sub-samples). Thus, in general terms, we expect a knowledge exchange that is more intensive among different firms but within the limits of the same industry.

It appears that the more recent pharmaceutical patents indicate fewer citations, although the coefficient is moderately significant and varies in sign in the two sub-samples. The coefficient for the *TimeLag* variable is positive and significant, and points to slower knowledge "depreciation" in this industry.

TABLE 9 **Probit regression results in the "Other Machinery" industry**

	Coefficient	Slope	Std. Err.	Chi-Square	Prob.
3820					
Intercept	-63.6286		15.2102	17.4998	0.0001
SameFirm	0.2019	0.0384	0.0311	42.2220	0.0001
SameIndustry	0.1180	0.0225	0.0244	23.3507	0.0001
Year*	0.0325	0.0062	0.0076	18.2367	0.0001
TimeLag	-0.0252	-0.0048	0.0019	172.3057	0.0001

Other Machinery (*Table 9*)

The title for this industry is quite ambiguous and makes it difficult to extract particular policy implications, although it does cover a significant number of patent citations. The results show that in this industry the time difference between two patents has a negative effect on the probability of the citation, and that newer patents employ a larger number of external citations. With regard to the existence of intra-firm spillovers, we find strong support for this in the pooled data as well as in both individual sub-samples. It also provides evidence of a stronger intra-industry knowledge exchange.

TABLE 10 **Probit regression results in the "Paper, Printing and Publishing" industry**

	Coefficient	Slope	Std. Err.	Chi-Square	Prob.
3400					
Intercept	66.0388		17.5350	14.1836	0.0002
SameFirm	-0.2203	-0.0282	0.0303	52.8596	0.0001
SameIndustry	0.3054	0.0391	0.0298	105.0528	0.0001
Year	-0.0324	-0.0042	0.0088	13.6252	0.0002
TimeLag	0.0179	0.0023	0.0024	55.4245	0.0001

Paper, Printing and Publishing (*Table 10*)

As the estimations in both sub-samples "agree" in terms of the signs of the coefficients and given the fact that we have already provided a number of explanations for the coefficients, we will be brief here. This industry exhibits a more inter-firm, but intra-industry pattern of patent citations. Newer patents cite less and older patents are more likely to be cited.

TABLE 11 **Probit regression results in the "Metal Products, excluding Machines" industry**

	Coefficient	Slope	Std. Err.	Chi-Square	Prob.
3810					
Intercept	4.5727		18.3708	0.0620	0.8034
SameFirm	0.3553	0.0406	0.0418	72.2049	0.0001
SameIndustry	0.4019	0.0460	0.0318	159.4133	0.0001
Year*	-0.0015	-0.0002	0.0092	0.0263	0.8711
TimeLag	-0.0270	-0.0031	0.0023	140.4771	0.0001

Metal Products, excluding Machines (*Table 11*)

This industry is more "turned towards itself". The probability of the patent citation's occurrence is higher when two patents belong to the same firm and come from the same industry. Thus, the external knowledge spillovers in the Metal Products industry are weak and some R&D cooperation-inducing measures may be advisable.

There is strong evidence of a negative relationship between the time lag and the likelihood of citation, with newer patents cited more, indicating more rapid knowledge depreciation in this industry. The effect of the patent's issue year on citation remains undetermined by virtue of an extremely low statistical significance (plus the disagreement of the two sub-samples).

TABLE 12 **Probit regression results in the "Computers and Office Machines" industry**

	Coefficient	Slope	Std. Err.	Chi-Square	Prob.
3825					
Intercept	132.9340		20.0005	44.1766	0.0001
SameFirm	0.3392	0.0327	0.0422	64.7092	0.0001
SameIndustry	-0.4940	-0.0477	0.0285	301.2988	0.0001
Year	-0.0657	-0.0063	0.0100	43.1414	0.0001
TimeLag	0.0303	0.0029	0.0028	114.1186	0.0001

Computers and Office Machines (*Table 12*)

This industry merits special attention due to its importance in the current technology-driven age. The model was able to produce statistically significant coefficients with full concordance of the two sub-samples. The data strongly indicate more intra-firm rather than inter-firm knowledge usage. As far as inter-industry knowledge spillovers are concerned, there is strong support for this, meaning a higher likelihood of knowledge being used from other industries.

The model provides support for the positive dependence of the probability of citation on the time difference between patents, thus indicating a relatively higher rate of older knowledge utilisation. We also see that newer patents are less likely to cite knowledge from other patent documents.

TABLE 13 **Probit regression results in the "Other Industrial Products" industry**

	Coefficient	Slope	Std. Err.	Chi-Square	Prob.
3900					
Intercept	-153.2531		19.2663	63.2735	0.0001
SameFirm	0.0369	0.0036	0.0359	1.0586	0.3035
SameIndustry	0.4740	0.0466	0.0349	184.4413	0.0001
Year	0.0774	0.0076	0.0096	64.3892	0.0001
TimeLag	0.0164	0.0016	0.0027	37.6794	0.0001

Other Industrial Products (*Table 13*)

The coefficient for the *SameFirm* dummy is not significant enough for a conclusion to be reached. The indication of mainly intra-industry patent citing behaviour is very strong. The more recent citing patents cite more, and older patents have a higher likelihood of being cited.

4.2 Intra-firm/intra-industry positioning of industries

To obtain a better overview of the general results of modelling knowledge spillovers, we present a map of relative positions for particular industries with relation to the likelihood of intra-firm and intra-industry citation. *Figure 4* is a two-dimensional graph, in which we plot the slope coefficient for the *SameFirm* dummy on the horizontal axis and the slope coefficient for the *SameIndustry* variable on the vertical axis. Such an arrangement is based on interpretation of the slope coefficients obtained. A slope coefficient in our model describes the change in the probability of a patent citation at the means of the regressors (Greene (2000), p. 879).

Thus, a pair of such coefficients for a particular industry indicates its unique position on the map relative to other industries and their origin, which can be interpreted in the following manner. The bottom-left quadrant of the map contains industries that are more inclined towards inter-firm and inter-industry knowledge spillovers (the probability of citation decreases for patents belonging to the same firm and industry class). We can call such industries “open”. In contrast, the top-right quadrant of the map contains more “closed” industries favouring intra-firm and intra-industry citation (citation is more likely if the patent pair comes from the same industry and is owned by the same owner). The bottom-right quadrant combines a higher likelihood of inter-industry, but intra-firm spillovers (which can be the case in complex technologies), while the top-left quadrant combines intra-industry and inter-firm spillovers accordingly.

FIGURE 4 **Positioning of Industries in Relation to Intra-firm and Intra-industry Knowledge Spillovers**

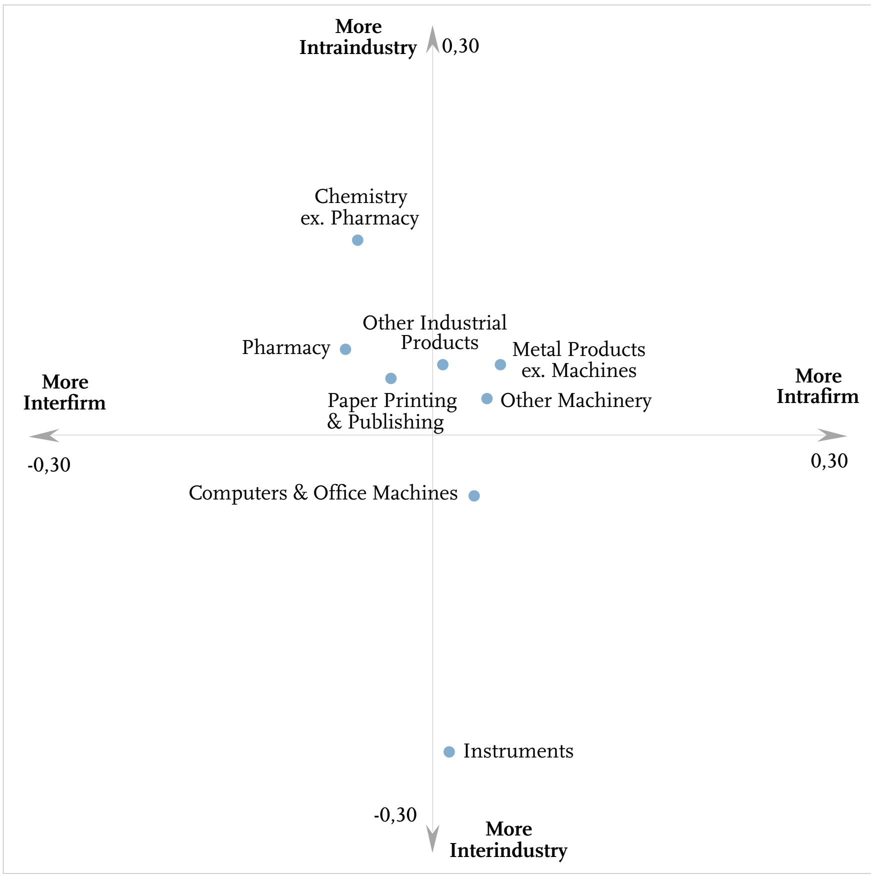


Figure 4 shows that there are no truly "open" industrial sectors considered in our pooled sample. A group of "closed" industries consists of "Metal Products, excl. Machines", "Other Machinery", and "Other Industrial Products" classes. The "Metal Products, excl. Machines" industry is the most "internally-oriented" of them all. The "Instruments" industry is in an interesting position in that it is almost indifferent towards intra- or inter-firm citation, but is strongly on the side of inter-industry knowledge utilisation. The "Computers and Office Machines" industry is open to inter-industry knowledge spillovers, though less inclined towards using the knowledge of other firms. The "Chemistry, excluding Pharmacy" and the "Pharmacy" industry itself exhibit greater openness to inter-firm knowledge spillovers that preferably do not extend far beyond the scope of the same industry. Similar behaviour can be observed for the "Paper, Printing and Publishing" industry.

In considering the political implications of such an analysis, we should turn our attention to the main conclusions reached by D'ASPREMONT and JACQUEMIN (1988) and LUKACH and PLASMANS (2000). They state that, under conditions of substantial knowledge spillovers, symmetric and asymmetric innovative firms have greater incentives for engaging in R&D cooperation, which results in greater R&D investment and innovative product output. For a regulator whose goal is to induce R&D cooperation, it is important to balance the market incentives, created by stronger knowledge spillovers, and the regulatory incentives.

The general guidelines for the regulator, as derived from our study, can be summarised by observing the relative positioning map along the horizontal axis. The industries in the right-side quadrants appear to be more oriented towards intra-firm knowledge spillovers, indicating that there are rationales for stimulating R&D cooperation among firms in these industries. On the other hand, the industries situated in the left-side quadrants operate under conditions of greater knowledge spillovers, with market incentives to urge the companies towards greater cooperation. In this case, the regulator can adopt a less intrusive position, observing the "natural" tendencies towards cooperation and possibly stimulating only the most interesting joint R&D projects and/or alliances.

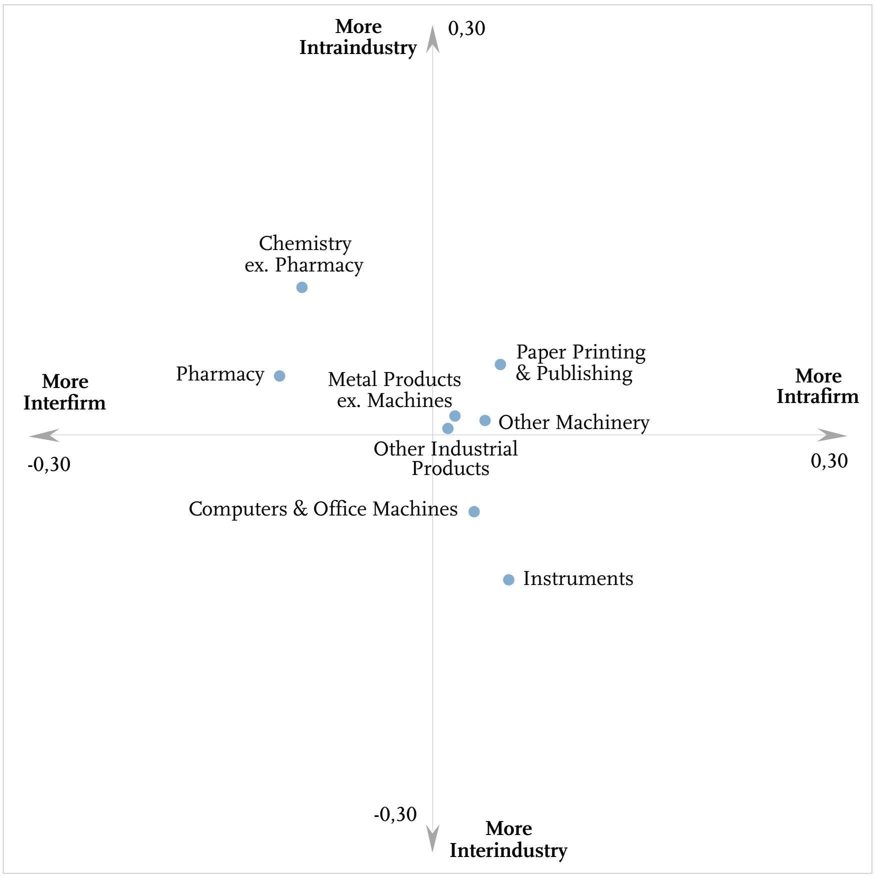
4.3 Agfa-Gevaert: an outlier problem

Looking back at the data presented in *Table 3*, it is very evident that one firm towers high above the others. Patent citations from the patents owned by Agfa-Gevaert account for 34.58% of the pooled sample. The runner-up, Solvay, displays a substantially lower share (9.5%) of citations. Thus, it is reasonable to assume that Agfa-Gevaert generates a strong outlier effect in our data. As an experiment, we deleted all the citations coming from the Agfa-Gevaert's patents from our sample, re-estimated the probit model and built another intra-firm/intra-industry positioning map on the basis of the new results. This new map is presented in *Figure 5*. If we compare the newly obtained map with the previous one, we can make the following observations:

- only one industry ("Paper, Printing and Publishing") out of seven changed its quadrant as a result of the outlier's deletion. The "Paper, Printing and Publishing" industry "took off" from the moderately inter-firm and intra-industry inclined position and "landed" at the point of strong inclination towards intra-firm and inter-industry knowledge spillovers;

- the "Chemistry (excl. Pharmacy)" and "Pharmacy" industries shifted within the limits of the same quadrant;
- the "Other Industrial Products" and "Metal Products excl. Machines" industries moved to neighbouring positions in the same intra-industry intra-firm quadrant;
- "Computers & Office Machines" moved to the position with slightly stronger inter-industry spillovers;
- "Instruments" now clearly favour intra-firm and inter-industry knowledge utilisation;
- the "Other Machinery" industry displayed little change in its position.

FIGURE 5 **Positioning of Industries in Relation to Intra-firm and Intra-industry Knowledge Spillovers (excluding Agfa-Gevaert)**



Thus, comparing *Figure 4* and *Figure 5* shows that deletion of Agfa-Gevaert's citations from the sample lead to certain, though not very dramatic, changes in the estimation results. The majority of industries shifted around somewhat, but stayed in the same quadrants as before. From the size of the industry's shift, we can judge the extent of the outlier's influence in the sample. The jump by the "Paper, Printing & Publishing" industry from one quadrant to another illustrates Agfa-Gevaert's very active position in this industry. Without Agfa-Gevaert this industry seems to be more closed, while appearing more open in the full sample. We also conclude that Agfa-Gevaert has a critical mass in the "Instruments" industry, if we consider the latter's relatively long leap from the moderate to very strong inter-industry spillover position. The other industries did not, however, exhibit strong qualitative change, which is understandable. The experiment conducted showed that Agfa-Gevaert creates a quite perceptible disturbance as an outlier in the observed sample, though only in the industries of its own specialisation.

5. Conclusions

The objective of this study was to investigate the patenting and patent citation behaviour of private Belgian firms using the 1996-2000 patent citation data from the EPO and the USPTO. The attention of this study focused on the patent citation behaviour of Belgian firms using the binary response variable model (probit/logit). We conducted an extensive preliminary analysis of the data and built empirical models. The results can be summarised as follows:

1. Firstly, the study of the patent citation data proved to be useful in analysing the innovation behaviour of Belgian firms. A preliminary analysis indicated that the majority of patenting is conducted by a small number of firms differing in size (represented by consolidated weighted turnover and consolidated weighted average annual employment).
2. The estimated probability of a patent citation, calculated according to a particular set of factors (*SameFirm* and *SameIndustry* dummies, time lag between the citing and the cited patents, the year in which the citing patent was issued), can be used as an efficient measure of the size of knowledge spillovers in a certain industry, and can be applied to various competitive behavioural models. Once the special feature of the industry is determined (such as the likelihood of inter- or intra-firm spillovers and the likelihood of inter-industry knowledge exchange), we obtain an understanding of the intensity of knowledge spillovers. Furthermore, the relationship between the likelihood of citation and the size of a time lag between the citing and cited patents indicates the speed of "citable" knowledge depreciation.
3. In particular, analysing the relative positioning of different industries depending on their attitude towards inter-firm knowledge spillovers allows us to infer implications concerning the necessity of measures to stimulate R&D cooperation. For example, it is preferable for the regulator to propose a policy aimed at stimulating greater R&D cooperation on the part of those industries with less intensive knowledge spillovers, and use less regulation in those industries where such spillovers are stronger.
4. We conclude that Agfa-Gevaert introduces substantial outlier disturbances in the pooled sample. Deletion of this firm's patents from the dataset leads to a noticeable change in the positions of those industries in which Agfa-Gevaert displays a high

degree of specialisation, i.e. the "Paper, Printing & Publishing" and "Instruments" industries. Such disturbances were much weaker in other industries.

5. The occurrences of patent citations in Belgian patents in eight major industries were studied. As a result of this study, it is possible to determine the "level of openness" of different industries toward inter-industry and inter-firm knowledge exchanges through patent citation. Industries with more complex technologies (such as "Computers & Office Machines" and "Instruments") are more open to inter-industry knowledge flows. On the other hand, the industries with "uniform" technological orientation (such as "Chemistry", "Pharmacy", "Metal Products", and "Paper, Printing & Publishing") remain more oriented towards intra-industry knowledge utilisation. In the "Chemistry" and "Pharmacy" sectors, we conclude a higher intensity of inter-firm knowledge exchange, which would indicate a better environment for R&D cooperation. Firms in other industries favour more internal knowledge flows and have less incentives to cooperate in R&D.

Summarising these findings, we come to a general conclusion that public authorities should use differentiated measures to regulate R&D activities (and especially R&D cooperation) by firms in different industries.

The existing knowledge spillovers create certain market-driven incentives inducing firms to cooperate. It is possible for a regulator to use these incentives in combination with particular regulatory measures to achieve the desired effects, be it higher R&D investment or improved diffusion of knowledge in the economy.

In the industries operating under conditions of stronger knowledge spillovers, the regulator can adopt a less intrusive policy (which is usually a "cheaper" one as well), observing the "natural" tendencies towards cooperation and possibly stimulating only the most interesting joint R&D projects and/or alliances. More regulator's attention must be paid to the firms in the industries with weaker knowledge spillovers, because these firms tend to invest in R&D in a more competitive way. It will require a bigger effort from the regulator to stimulate R&D cooperation by direct subsidies and/or advantageous tax measures in such cases. The major outcome of such a successful policy will eventually surface in faster economic growth.

Appendix

The Citation Pairs Probit-Type Model

The pooled dataset contains a list of citation pairs that have already occurred. Thus, if we consider the probability of a citation occurring in patent pairs from our dataset, this is equal to 1. Within this population, we select several other sub-events, for example "the citation has occurred in the citing patent coming from industry A".

The basic probit model can be specified:

$$P(y_i = 1) = F(\hat{\beta}' x_i) = \int_{-\infty}^{\hat{\beta}' x_i} \phi(t)dt, \text{ with } \phi(t) := \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}t^2}, \; i = 1, 2, \ldots, n,$$

whereby n is the number of observations. In our case we have:

$$\beta' x_i = Const_i + \beta_1 ZelfdeOnderneming_i + \beta_2 ZelfdeSector_i + \beta_3 Jaar_i + \beta_4 CiteringsInterval_i + \varepsilon_i .$$

The dependent variable Y is an indicator that the patent citation occurred in the particular industry (see above).

It is known that the estimated coefficients of a probit (logit) model do not yield the value of the marginal effect of the independent variable. For the probit model, the marginal effect for an independent variable is calculated as the product of the corresponding equation coefficient and the value of the standard normal density function calculated at the regressors' means:

$$\left.\frac{\partial F(x_i' \hat{\beta})}{\partial x_{ij}}\right|_{x_i = \bar{x}_i} = f(\bar{x}_i' \hat{\beta})\hat{\beta}_j, \; i = 1, 2, \ldots, n, \; j = 1, 2, \ldots, k,$$

where $f(\bar{x}_i' \hat{\beta})$ is the standard normal density of the mean of the estimated structural part of the model[5].

As we have one binary variable in the model, another method of calculating the marginal effects should also be mentioned. For a binary independent variable b, the marginal effect (also called *slope*) is calculated as $P\{Y = 1 \mid \bar{x}_*, b = 1\} - P\{Y = 1 \mid \bar{x}_*, b = 0\}$. However, Greene ((2000), p. 878) indicates that "simply taking the derivative with respect to the binary variable as if it were continuous provides an approximation that is often surprisingly accurate". Thus, we calculate the slopes for the binary independent variables in our model in the same way as we do this for non-binary variables.

[5] If the logit model is chosen, then $\phi(t) := \frac{1}{1+e^{\hat{\beta}' x_i}}$, $i = 1, 2, \ldots, n$, and the slope is

$$\left.\frac{\partial F(x_i' \hat{\beta})}{\partial x_{ij}}\right|_{x_i = \bar{x}_i} = \frac{\hat{\beta}_j e^{-\bar{x}_i' \hat{\beta}}}{(1+e^{-\bar{x}_i' \hat{\beta}})^2}, \; j = 1, 2, \ldots, k.$$

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S&T Policies, R&D and Economic Growth: Empirical Evidence and Recent Trends*

Bruno van Pottelsberghe de la Potterie and Carine Peeters

1. Introduction

The recent acceleration of productivity in several industrialised countries is often explained by a surge in the pace of technical change. This is consistent with both economic theory and anecdotal evidence. Economic theory points to technical change as the major source of productivity growth in the long term. Anecdotal evidence suggests that new technology (especially information technology in recent years) has substantially contributed to a recent improvement in the productivity of firms.

The major source of technical change, i.e. innovation, is the main objective underlying research and development (R&D) activities. R&D is performed mainly by business firms (domestic and foreign) and public institutions (such as public laboratories and universities). These various sources of knowledge interact with each other and contribute to economic growth to a differing extent. Several science and technology (S&T) policies, such as R&D procurement, R&D tax credits and public research, affect both private R&D investment and productivity growth. The importance of these policy tools is illustrated by the fact that OECD governments spent around USD 150 billion on R&D in 1998, almost one third of total R&D expenditure in the countries concerned.

Governments can affect the expenses incurred by firms for R&D through the use of three main policy instruments: publicly performed research, government funding of business-performed R&D and fiscal incentives. Besides fulfilling public needs (such as defence), the economic rationale for government involvement in this area is the existence of market failures associated with R&D. These market failures are typically twofold. First, imperfect appropriability, or the diffusion of knowledge beyond control of the inventor, implies that the private rate of return on R&D is lower than its social return. In addition, the high risk of research implies very considerable obstacles, which discourage firms from engaging in such activities. This is especially detrimental to small firms, for which access to funding is more difficult. For both reasons, the amount invested by firms in research activities in a competitive framework is likely to be below the socially optimal level (Arrow, 1962).

* Original version.

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However, the effectiveness of policies aimed at stimulating private R&D expenditure can be challenged on three main grounds. Firstly, government spending may crowd out private spending by increasing the demand for scientists and hence the price of research. When faced with higher research costs, firms will shift their funding to alternative investments. This implies that, even if the total amount of R&D is higher due to government funding, the real amount of R&D (adjusted to cost of research) might be lower. A second argument is that public money may directly displace private funding as firms may simply substitute public support for their own, while undertaking the same amount of research as originally planned. In this case there is no “additionality”, since government supports R&D that would have been performed anyway. It is also possible that a firm starting a project thanks to government funding has the effect of deterring other firms from starting a similar project although they had previously considered doing so. In such a case, this produces “aggregate level non-additionality”. It is a direct form of crowding out that does not work through the price mechanism. Thirdly, governments are less likely to allocate resources efficiently than market forces, which may generate distortions in the allocation of resources between fields of research.

In the present chapter, we address the issue of the effectiveness of S&T policies. More specifically, we are interested in the following questions:
- How do these S&T policies, business R&D and foreign R&D affect economic growth?
- How do S&T policies affect private R&D investment?
- What are the recent trends of these policies?
- What is the position of Belgium compared to its neighbours and other small-industrialised countries?

In order to provide some answers to the first two questions, we summarise the recent empirical findings of Guellec and van Pottelsberghe (1999, 2001 and 2003). In these papers, the authors subsequently analyse the various determinants of business R&D investment and multifactor productivity growth. The following section presents their main empirical findings and briefly underlines the major policy and economic implications. The third section presents recent trends in the various S&T policies and facilitates a comparison of Belgium’s position with the one of other small industrialised countries and its main neighbours. Concluding remarks concerning policy implications and the need for further empirical investigation through more disaggregated analyses are dealt with in the last section.

2. Empirical evidence

Guellec and van Pottelsberghe have estimated two types of equations. The first (equation 1) attempts to evaluate the contribution of various sources of knowledge (R&D capital stocks performed by the business sector, by foreign firms, and by public institutions) to productivity growth, whereas the second (equation 2) concerns the determinants of privately funded and performed R&D.

The first equation is derived from a Cobb-Douglas production function. The dependent variable is the multifactor productivity growth (*MFP*) of the industrial sector (computed under the hypotheses of perfect competition and constant returns to scale).

$$MFP_{it} = exp\,[\phi_i + \varphi_t + \mu_{it}]\;\; SRP_{it-1}^{\beta_{rp}} \cdot SFR_{it-1}^{\beta_{fr}} \cdot SRHEGOV_{it-2}^{\beta_{hegov}} \cdot U_{it}^{\sigma_U} \cdot G^{\sigma_G} \quad (1)$$

The variables (for country *i* and time *t*) are defined as follows: *SRP* is the stock of business-performed R&D, *SFR* is the stock of foreign business-performed R&D, *SRHEGOV* is the stock of publicly performed R&D (higher education and public labs). In addition, a set of control variables is included, i.e. country dummies, time dummies, employment rate (*U*, controlling for business cycle effects), and a dummy for the German unification (*G*).

The second equation comprises an evaluation of an R&D investment model that considers business-funded R&D (RP) as a function of output (proxied by value added, VA) and several policy instruments: government funding of R&D performed by business (RG), tax incentives (proxied by the B-index[1], B), government intramural expenditure on R&D (GOV), research performed by universities (or higher education, HE), time dummies, and country-specific fixed effects.[2]

$$\Delta RP_{i,t} = \lambda \Delta RP_{i,t-1} + \beta_{VA}\Delta VA_{i,t} + \beta_{RG}\Delta RG_{i,t-1} + \beta_B \Delta B_{i,t-1}$$

$$+ \beta_{GOV}\Delta GOV_{i,t-1} + \beta_{HE}\Delta HE_{i,t-1} + \tau_t + e_{i,t} \quad (2)$$

The estimates were conducted over the period 1980-1998 on a panel of 16 and 17 OECD Member countries for *equation 1* and *equation 2* respectively. Both equations were estimated through an error-correction model that allows distinguishing short-term and long-term effects of the right-hand side variables. The econometric process was a three-stage instrumental variable least squares method that takes into account the presence of the lagged dependent variable among the explanatory variables and corrects for contemporaneous correlation of the error term. The basic results are presented in the following tables. These parameters and further empirical investigation presented in the respective papers lead to several observations, which are summarised in the next section.

TABLE 1 **Estimated long-term elasticities of MFP with respect to various types of R&D**

	Business R&D (SRP)	Foreign R&D (SFR)	Public R&D (SRHEGOV)
Long-term elasticities	0.13	0.46	0.17

Sources: Guellec and van Pottelsberghe (2001), 16 OECD countries, 1980-1998.

[1] The B index designed by Warda (1996) gives a synthetic view of tax generosity for R&D. Algebraically, the B index is equal to the after-tax cost of 1 € expenditure on R&D divided by one less the corporate income tax rate. The after-tax cost is the net cost of investing in R&D, taking into account all available tax incentives:

B index = $\frac{(1-A)}{(1-\tau)}$, where τ = statutory corporate income tax rate;

A = the net present discounted value of depreciation allowances, tax credits and special allowances on R&D assets. In a country with full write-off and no other scheme, $A = \tau$ and, consequently, $B = 1$. The more favourable a country's tax treatment of R&D is, the lower its B index.

[2] These should take account of stable country characteristics that may influence the private decision to invest in R&D, especially in the long term, such as culture, tax policies, and institutional differences.

TABLE 2 **Estimated long-term elasticities of business R&D outlay with respect to various explanatory variables**

	Value added (VA)	Subsidies (RG)	Fiscal incentives (B)	Public research (GOV)	University Research (HE)
Long-term elasticities	1.54	0.08	-0.33	-0.08	0

Sources: GUELLEC and VAN POTTELSBERGHE (2003), 17 OECD countries, 1980-1998.

2.1 Contribution of various sources of knowledge to productivity

Business R&D and productivity

Research and development performed by business results in new goods and services, in higher output quality and in new production processes. Its role as a catalyst of productivity growth has been investigated in many empirical studies. All of them tend to reach the conclusion that R&D does matter. The estimates presented in *Table 2* confirm these results most emphatically. The long-term elasticity of MFP with respect to business R&D is 0.13. This means that one percent more in business R&D generates a 0.13% increase in productivity. As this elasticity is much higher than the ratio of business R&D to business GDP (around 2% in the OECD over the 1980s and 1990s), the social return on business R&D is higher than its private return (reflected by the income share of R&D). The authors also find that there has been a growing impact of business R&D on MFP over time (an increase of about 0.005 a year).

Additional estimates also make it possible to identify conditions that enhance or reduce this elasticity. The effect of business R&D on productivity is greater in R&D-intensive countries[3], as a further 1 percentage point in a country's R&D intensity increases its elasticity by 0.003 to 0.004. This is due to a better adaptive capability.

The share of government funding has a negative effect on the elasticity of business R&D, although it is small. However, only the defence-related part of public funding has a significant negative effect on MFP. A potential explanation for this negative impact of defence-related public funding of business R&D is that they most often take the form of procurement: the performer of the research project is not the owner of the technological output. In other words, firms cannot exploit freely their technological competences on the market. There are four or five OECD countries that have a substantial defence R&D budget and might be concerned by this issue. Actually, public funding with a civilian objective has a (weak) positive effect on the elasticity of business R&D. As this elasticity mainly captures spillovers, this might indicate that government funding is fairly successful in enhancing business R&D with higher social return. This is all the more possible as part of government funding of civilian business R&D is related to health or the environment, with no direct impact on measured MFP.

[3] R&D intensity is measured by the ratio of business R&D to business GDP.

Foreign R&D and productivity

Foreign knowledge is a second source of new technology for any national economy. There are many ways for technology to cross borders. Companies can buy patents, licences or know-how from foreign firms, they can observe competition (e.g. reverse engineering), they can hire foreign scientists and engineers, they can interact with foreign competitors investing in their country (foreign direct investment), read the scientific and technological literature, or have direct contacts with foreign engineers at conferences or fairs, etc. The impact of foreign produced knowledge on a country's productivity may depend on the capacity of the recipient country to make efficient use of it, which presupposes in turn that this country has sufficient technological activity of its own. This is traditionally labelled as the "absorptive capacity" of an economy. A number of other studies, such as Coe and Helpman (1995) and van Pottelsberghe and Lichtenberg (2001), have estimated the effect of foreign R&D on productivity.

The long-term elasticity of foreign R&D on productivity is very high: one percent more in foreign R&D generates 0.46% in productivity. This is high not only in absolute terms but also compared to the elasticity of domestic R&D reported above, leading to the conclusion that, for any one country, other countries' R&D matters more than domestic R&D for the purpose of productivity growth. This result is very consistent with the fact that the domestic social return on R&D is higher than the private return. If there are technology spillovers within countries, there is no reason for them to stop at the border, and international spillovers should occur. The impact of foreign R&D on productivity is also greater in R&D-intensive countries, due to a better adaptive capability. Finally, smaller countries benefit more from foreign R&D than larger ones.

Public R&D and productivity

Public R&D includes R&D performed both in government laboratories and universities. A key goal of these bodies is to satisfy public needs and to generate basic knowledge, some of which may eventually be used by firms in their own, applied, research. Government laboratories are primarily concerned with meeting public needs, while universities and similar institutions are more concerned with the generation of basic knowledge. In contrast to what has been said for business R&D, there have been very few studies on the effects of public research on productivity.

The output elasticity of public research is 0.17. This tends to show that overall public R&D is very valuable to the economy. Similar to the R&D capital stock generated by domestic and foreign firms, the elasticity of public research is higher when the business R&D intensity of the economy is higher. This shows the importance of the business sector being able to seize opportunities presented by public research. The effect of public R&D on productivity is also greater in countries where the share of universities (as opposed to government laboratories) in public research is higher. This may point to the fact that much government R&D is aimed at public assignments that do not impact directly on productivity (health, environment), whereas universities provide the basic knowledge used by industry at later stages to perform technological innovation.

A further result is that the impact of public research decreases with the share of industry funding of the higher education sector: The more university research is financed by the business sector, the lower is its impact on growth. This could be due to the fact that partnership between firms and universities involve more applied R&D than usual university research, which has lower potential effect than basic research. If we take together the two previous results, the picture that emerges of the preferable situation for funding of public research is the following: it should be competitive (as opposed to institutional) and should come from government (as opposed to enterprises). More sophisticated estimates might show more complex patterns, including certain types of complementarities between government and business funding, or country specificities.

2.2 Determinants of privately funded and performed R&D

We have just emphasised the importance of various sources of R&D for a country's productivity improvement, making particular mention of the crucial role played by private R&D, which acts both directly and indirectly through an increase in absorptive capacity. Governments can affect the expenditure undertaken by firms on R&D through the use of three main policy instruments: publicly performed research, government funding of business performed R&D and fiscal incentives. We will now assess the impact of these policy tools in determining business R&D investments.

Public funding of business R&D investments

The first policy instrument aimed at stimulating business R&D is direct financial support of research performed by the business sector. These subsidies are targeted to specific goals chosen by the funder. The government may fund technological projects that have a potentially high social return (*e.g.* "generic technologies" or "pre-competitive research") or that are useful to the government's own objectives (*e.g.* health, defence). Government-funded R&D has a positive and significant effect on business R&D as the long-term elasticity of 0.08 shows.

To examine how these estimated elasticities translate into euro terms and analyse the impact of government policies on the amount of R&D spent by firms, it is helpful to translate the elasticities into marginal rates of return. The marginal rate of return is calculated as the product of the elasticity and the ratio of the impacted variable (business R&D) to the impacting one. If two policy instruments have the same elasticity, the one with the largest relative size will have the lowest rate of return. The results indicate that €1 of direct government funding generates a €0.70 marginal increase in business-funded R&D, hence an increase of €1.70 in total R&D performed by the business sector.

An alternative specification of the equation facilitates an approximation of the average optimal subsidisation rate of business R&D. The authors first differentiate the private R&D elasticity of government R&D across four groups of countries. The groups are based on the average subsidisation rate for each country over the entire period: countries with subsidisation rates over 19% (high), those with rates from 11-9% (medium-high), those from 4-11% (medium-low), and those below 4% (low). The greatest elasticities are found for countries belonging to the two "medium" groups, while countries with the highest and the lowest funding rates have non-significant elasticities. This suggests that the effectiveness of government funding increases up to a particular threshold and decreases after that. This can be represented by an inverted U-shaped curve and an optimal subsidisation rate of about 9 to 15%.

Fiscal incentives and business R&D investments

Government can also help firms through tax breaks. Most OECD countries allow for a full write-off of current R&D expenditure, which implies that depreciation allowances are deducted from taxable income. Among the 17 countries included in the analysis of Guellec and van Pottelsberghe (1999, 2003), about one third also provided R&D tax credits in the mid-1990s. These are deducted directly from corporate income tax and are based either on the level of R&D expenditure – flat rate – or on the increase in this expenditure with respect to a given base – incremental rate. In addition, some countries allow for accelerated depreciation of investment in machinery, equipment and buildings devoted to R&D activities. Some countries also provide special R&D tax breaks for small firms.

The long-term elasticity of business R&D with respect to the B-index is negative (-0.33). In this case, this result means a positive effect as a lower B index reflects higher tax breaks. The estimates also suggest that the effect of tax breaks is more rapid than the effect of government funding, as business spending reacts immediately to a change in taxes. This appears to be linked to the fact that tax concessions are not conditional on the type of R&D performed by the recipient. Instead of having to launch new projects conforming to government requirements, the firm will simply spend more on ongoing projects, hence accelerating their completion or improving the quality of the outcome. In contrast, government subsidies and contracts apply to projects that are selected by the government or meet certain conditions imposed by the government. In many cases, the research is of a long-term, if not basic, nature, creating new opportunities that induce firms at a later stage to start further research projects with their own funds.

Another aspect that could affect the impact of these first two policy tools on business R&D is their stability over time. Guellec and van Pottelsberghe find that the more volatile a policy, the less effective it is. R&D investment typically involves a long-term commitment and leads to a considerable lowering of costs. Such investment is therefore likely to be sensitive to uncertainty, including uncertainty that arises from fiscal or government funding. Unstable policies in the past are often taken by firms as a signal that future change is likely to occur.

Finally, estimates show that government funding of business R&D is a substitute for fiscal incentives. In other words, increasing the direct funding (tax incentives) of business research reduces the stimulating effect of tax incentives (direct government funding).

Public research and business R&D investments

The research performed in public laboratories has a negative and significant impact on business-funded R&D, with a long-term elasticity of about –0.08. This negative impact is spread over several years (although there is no contemporaneous impact). The crowding-out effect – which is due either to an induced increase in the cost of R&D or to direct displacement – appears to dominate the stimulating effect. Public laboratories are, however, supposed to meet public goals rather that those of business; spillovers may occur but they are not instantaneous and are not the primary goal. The impact of university research on business-funded R&D is not significant[4].

If we look at the marginal rates of return, we can see that government policy leads to a €0.44 marginal reduction in business-funded R&D when spent on government research. This reduction is less than the initial €1 government expenditure, implying that total R&D (public and business) will rise after government has increased its spending. The crowding-out effect of this instrument is only partial.

Government spending may not only affect the amount spent on R&D by business, but also the price of R&D, i.e. increased demand for the scarce resources used for R&D, e.g. researchers, should increase its price. Part of the effect identified above is indeed due to an increase in price, not in the real amount of resources allocated to research. This is difficult to quantify, and further tests are required in order to isolate this indirect impact of government and university research on business R&D from the direct impact of spillovers.

Defence-oriented public support to business R&D

Defence technologies are less likely to be characterised by spillovers, as they are often specific, with little emphasis on cost and the primary focus on extreme performance in extreme conditions. Secrecy constraints may also imply that the results will only diffuse slowly to civilian applications[5]. Furthermore, because defence contracting is attractive - it generates high rewards at low risk - firms might allocate resources that would otherwise have been used for civilian research. The estimates show that the higher the share of defence, the lower the positive effect of government funding is on business R&D. The effect of government research, which is negative in the main estimates, changes to zero when the defence component is netted out. This implies that non-defence government intramural research, which constitutes the bulk of government intramural R&D in most OECD countries, has no negative effect on business R&D[6].

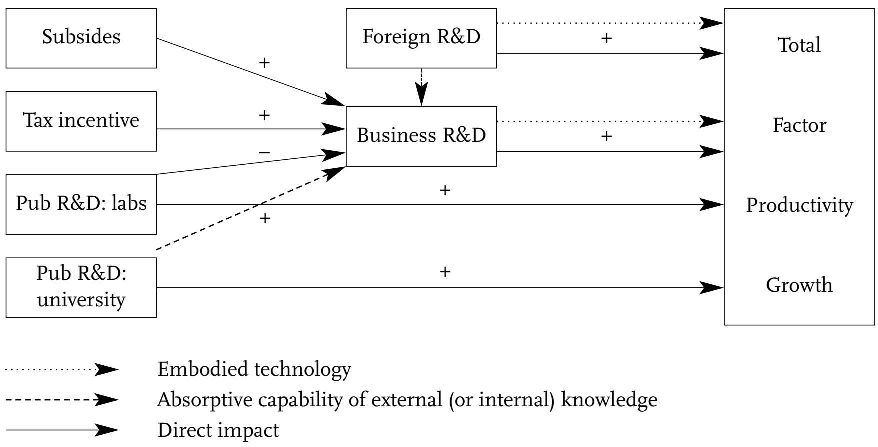
[4] It should be borne in mind, however, that a four-year lag might be too short to capture the longer-term effects of basic research. The effects of basic research can take several decades before reaching the application stage (ADAMS, 1990). Moreover, it is not clear whether positive externalities should translate into increased private R&D expenditures.

[5] Defence-related funding of business R&D typically crystallises into procurements: the results do not necessarily belong to the R&D performer, or might be constrained towards government market. LICHTENBERG (1987) shows that the positive impact of public funding on business R&D disappears when the output is separated into sales to government and other sales.

[6] GUELLEC and VAN POTTELSBERGHE (1999) relied on a different approach to obtain an insight into the effect of defence-related government support. Data on the share of government procurement for defence purposes were collected from five countries. It emerged that the defence component of direct government funding of business R&D had a negative and significant impact for the three countries with very high funding rates.

2.3 Policy implications

The three studies conducted by GUELLEC and VAN POTTELSBERGHE lead to the conclusion that business R&D plays a crucial role in the productivity growth of OECD countries. Its impact follows direct and indirect channels. The direct impact is straightforward, i.e. an increase in private R&D generates a substantial increase in productivity through technical change. The indirect impact translates into absorptive capabilities. Greater investment in R&D by the private sector increases its absorptive capacity of the knowledge generated by both public institutions and foreign firms, hence strengthening the positive effect of foreign and public R&D on productivity. These relationships are illustrated below.



Potential interactions between the policy tools make it difficult to analyse the effectiveness of one instrument independently of the others. Public research, whether performed in government labs or universities, provides basic knowledge that is especially helpful to firms in the most advanced technology areas (close to basic research). Grants help firms in the applied research stage and encourage co-operation as another way of internalising externalities. R&D tax breaks, since they are not - or only to a slight extent - discriminatory, help all R&D performing firms, especially those that do not have access to grants (often small companies) or those conducting research that is not sufficiently "basic" to benefit from other policy instruments. However, there are interactions between the instruments. Those affecting applied research, such as R&D tax credits, may enhance the efficiency of instruments oriented towards basic research as they may strengthen the absorptive capacity of recipient firms. The different tools thus constitute a system and their efficiency can be best captured by analysing the system as a whole.

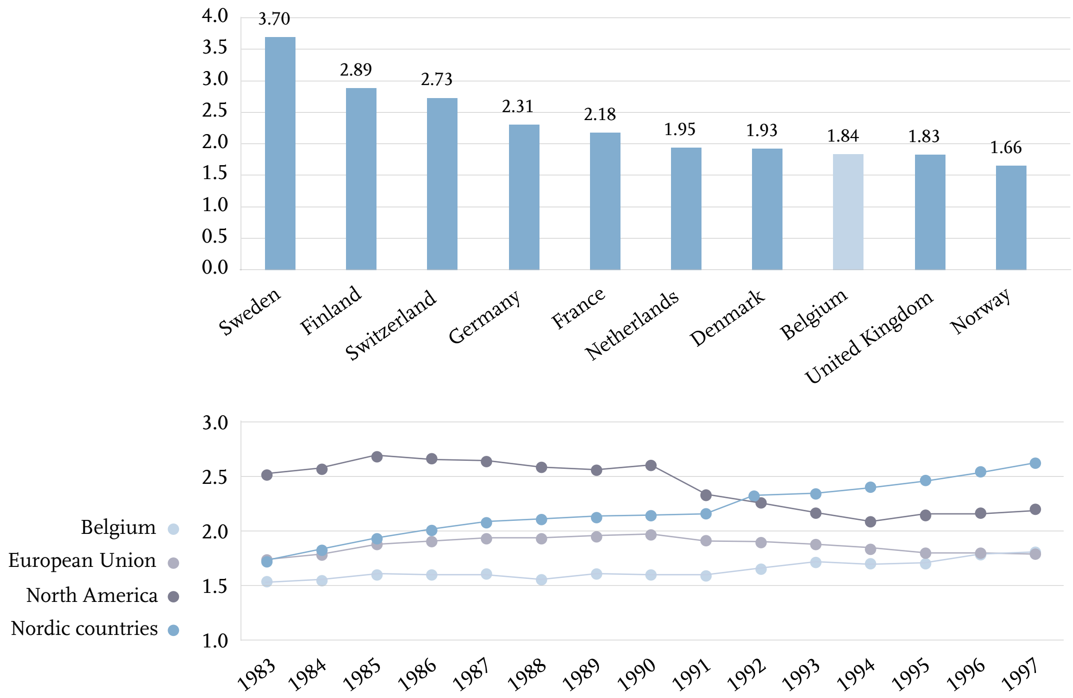
On the other hand, the share of government funding has a negative, albeit negligible, effect in that the impact of business R&D on productivity is lower where the share of government funding is larger. This should not, however, be viewed as lower efficiency of government funded-research. Indeed, it is only the defence-related part of public funding that has a significant (negative) effect on MFP. Only 4 to 5 OECD countries have a substantial defence R&D budget and might be concerned by this problem.

3. Public Policies: recent trends

In this section, several indicators are presented in order to assess the Belgian position and deduce some implications for policy. Seven main indicators are depicted: total R&D intensity, business R&D intensity, the share of public funding in business performed R&D, the generosity of fiscal policies towards business R&D, the share of publicly-performed R&D in total R&D terms, the share of defence oriented R&D in government budget R&D appropriations (GBAORD), and the share of university R&D in public R&D. For each indicator, Belgium is first benchmarked with respect to other industrialised countries. A second figure illustrates the associated development in Belgium over the past 15 years, compared to the trends for the overall European Union, North America and Nordic countries.

Figure 1 illustrates the first indicator: gross domestic expenditure on R&D (GERD) as a percentage of GDP. Here, Belgium is in a relatively bad position compared to its European neighbours. Moreover, the evolution of R&D intensity has been quite stable since the early eighties. This is in radical contrast to the results for the Nordic countries, whose R&D intensity has increased sharply during this period. The results for North America are far better even if its total R&D intensity was weaker in the 90s than in the 80s.

FIGURE 1 **Gross Domestic Expenditure on R&D (GERD)** • as a percentage of GDP • 1998 or more recent

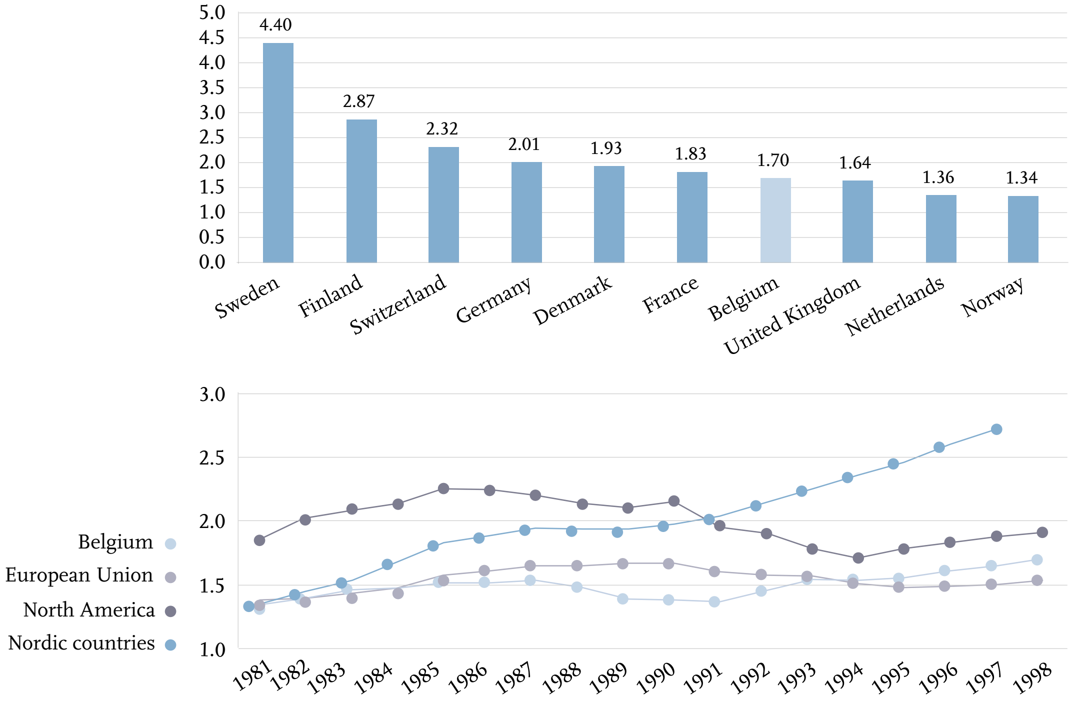


Source: OECD, MSTI.

Business R&D intensity (business enterprise expenditure on R&D - BERD - as a percentage of the domestic product of industry – DPI) reflects the relative efforts of the business sector in research and development activities (*Figure 2*). The previous sections have shown that business R&D contributes to total factor productivity growth in two ways. Firstly, it has a direct effect in that a larger amount of business R&D increases MFP. Secondly, it has also an indirect effect thanks to the better adaptive capability of the knowledge generated by both foreign R&D and public R&D.

Except for Netherlands, Norway and the United Kingdom (which are at about the same level as Belgium), Belgian R&D intensity is weaker than its European neighbours is. Most of the best performing countries (Sweden, Switzerland and Finland) are of similar size to Belgium, which means that significant improvements still need to be achieved. Developments between 1981 and 1997 were quite stable, with a slight upward trend for the last five years. Belgium tends to display an inverse-shaped development compared to the European Union as a whole. The rise in the Nordic countries' level of R&D intensity is again particularly encouraging for them but quite alarming for Belgium, with the gap constantly growing. For North America, business R&D development is in line with that of total R&D intensity.

FIGURE 2 **Business Enterprise Expenditure on R&D (BERD)** • as a percentage of DPI • 1998 or more recent

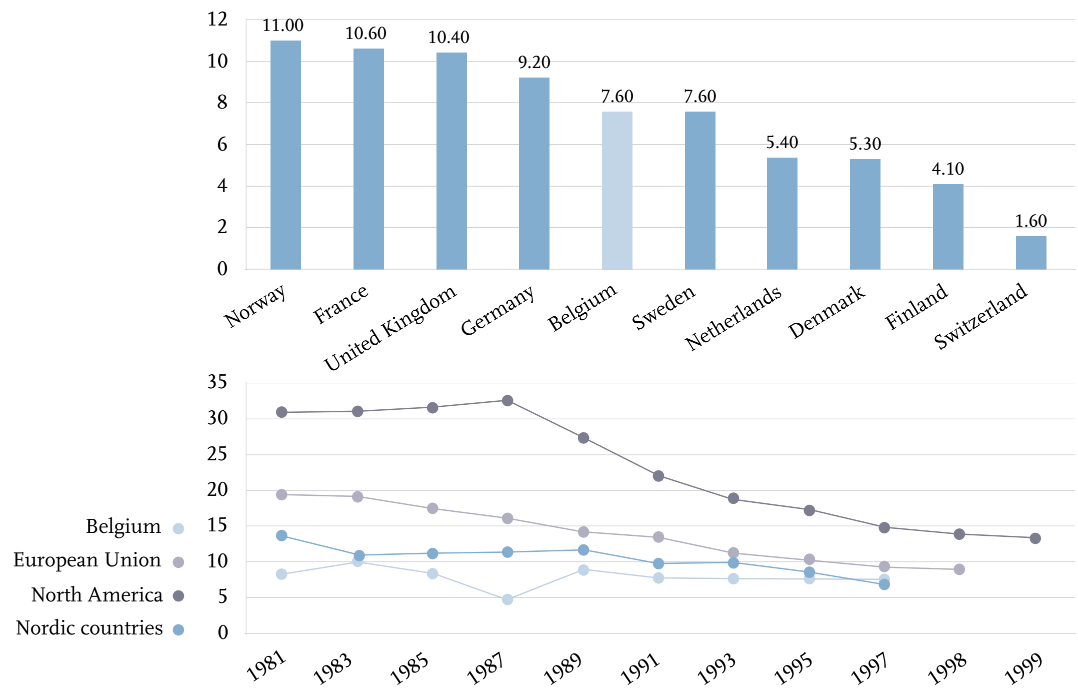


Source: OECD, MSTI.

The next indicator shows to what extent these business R&D performances have been financed by public funding. The subsidisation rate is calculated as the percentage of BERD financed by government. The two graphs presented in *Figure 3* show that Belgium has a relatively weak share of public funding in business R&D, though somewhat greater than for the other small European countries. This relatively weak government support of business R&D cannot be taken as the cause of its poor performances in terms of business R&D intensity since the countries with the highest business R&D intensities have identical or much lower shares of public funding. What should grab our attention is the case of Switzerland, which has the lowest subsidisation rate while its level of R&D intensity is very good (third position). Similarly, Norway and the United Kingdom have very high subsidisation rates and low business R&D intensity. With the same subsidisation rate, Swedish performance in R&D intensity is much better, which underlines that subsidies, although stimulating business R&D expenditure, is far from being the main determinant of business performance in R&D.

Looking at the broader trends, Belgium does not display any significant downward trend in the subsidisation rate. There has been a strong convergence between Europe and North America since the late eighties in this regard. The major trend has been towards a sharp reduction in the share of government support to business R&D, mainly due to the decrease in defence-related government budget appropriations for R&D. Despite this convergence, North America still provides the highest rate of public support to business R&D.

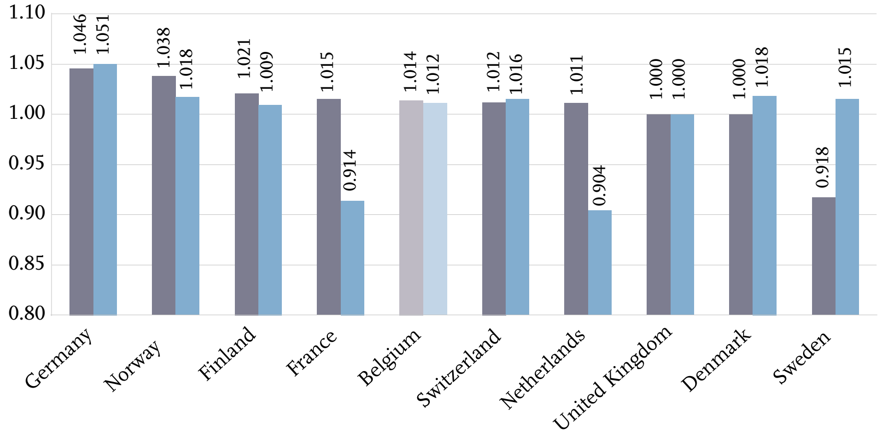
FIGURE 3 **Percentage of BERD financed by government** • 1997 or more recent



Source: OECD, MSTI.

The 1981 and 1998 B index are presented in *Figure 4*. This index illustrates the generosity of fiscal policies towards business R&D. The lower it is, the more generous a fiscal policy is[7].

FIGURE 4 **B index** • 1981 and 1998



Source: OECD.

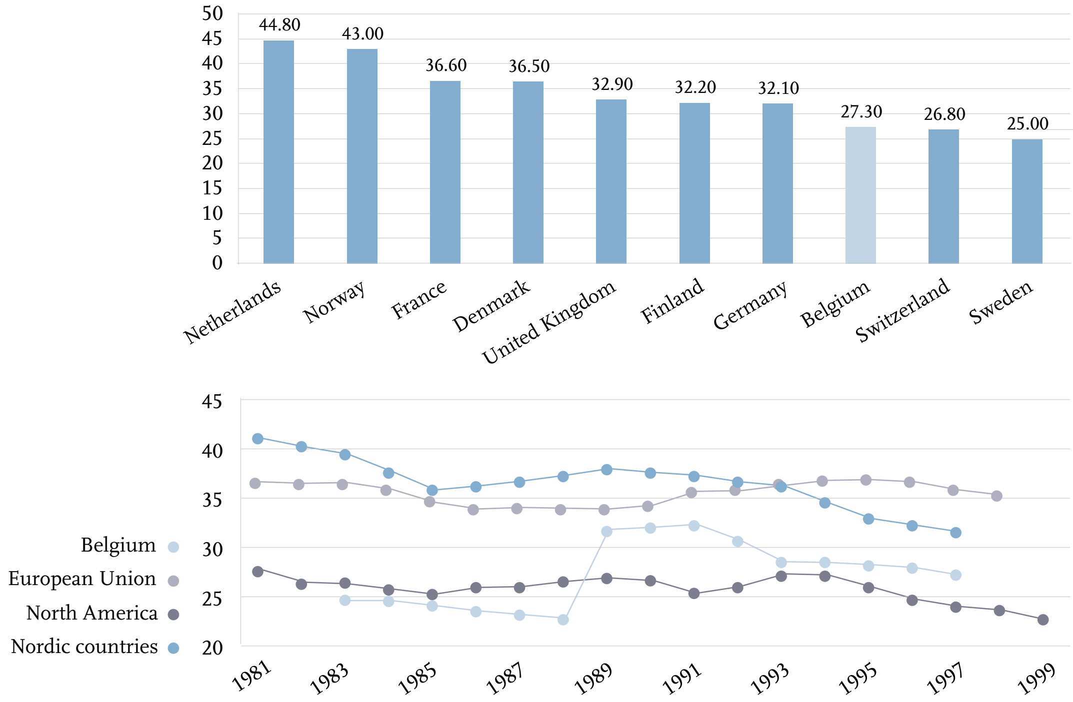
The value of the B index in Belgium is in line with the average for its European neighbours. It displayed quite stable development between 1981 and 1998 as opposed to France and the Netherlands, whose B index has sharply decreased, and in contrast to Sweden, which has substantially reduced its fiscal generosity towards business R&D. It is therefore very hard to highlight a common trend among European countries.

The next indicator is the share of public R&D in total R&D, which is calculated by adding the percentage of GERD (gross domestic expenditure on R&D) performed by the government sector (public laboratories) to the percentage of GERD performed by the higher-education sector. The relatively weak share of publicly performed R&D in Belgium's total R&D activities is a further explanation for Belgium's poor overall R&D intensity. Indeed, the countries associated with relatively low business R&D intensity benefit from an important knowledge base in the public sector. This is particularly the case for the Netherlands, Norway, France, Denmark and the United Kingdom. In these countries, the role of public research appears to be very important, with shares of public research exceeding 30% of total research activities. This intensive involvement of public bodies in research activities seems to compensate for lower business R&D expenditure.

Although the share of public research in total research is relatively low in Belgium, it is important to note that two of the best performers in R&D intensity (Sweden and Switzerland) also display the lowest share of public R&D in terms of total R&D activity. The reason for this may perhaps be found in the distribution of public R&D between universities and public laboratories, as well as in the share of defence R&D. These are the last two indicators presented here. The second graph highlights Belgian development divided into two major periods of stability, with a break in 1990 when the share of public R&D experienced a spectacular increase.

[7] See footnote 1.

FIGURE 5 **Public R&D** • as a percentage of GERD

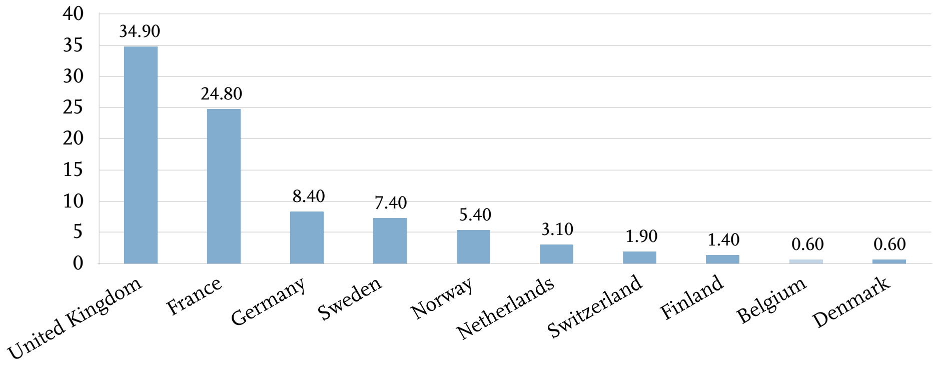


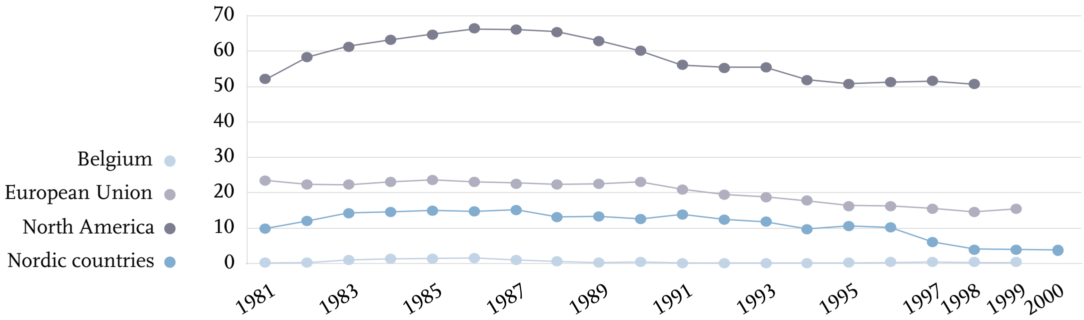
Source: OECD, MSTI.

One of the results of section 2 was that the higher the share of defence-related R&D in total R&D, the weaker the effect of public R&D is on total factor productivity. Thus, even if defence-related R&D funding is not aimed at stimulating private R&D, its crowding-out effect on civilian business R&D should be taken into account. The indicator used here is the defence budget R&D as a percentage of total government budget R&D appropriations (GBAORD).

European countries appear to be very heteroclite in the importance they attach to defence-related R&D, with percentages ranging from 0.60 for Belgium and Denmark to 34.30 for the United Kingdom. This indicator displays a quite stable, although slightly decreasing, development over time, whatever region is considered – be it Belgium, North America, the European Union or the Nordic countries.

FIGURE 6 **Defence budget R&D** • as a percentage of total GBAORD

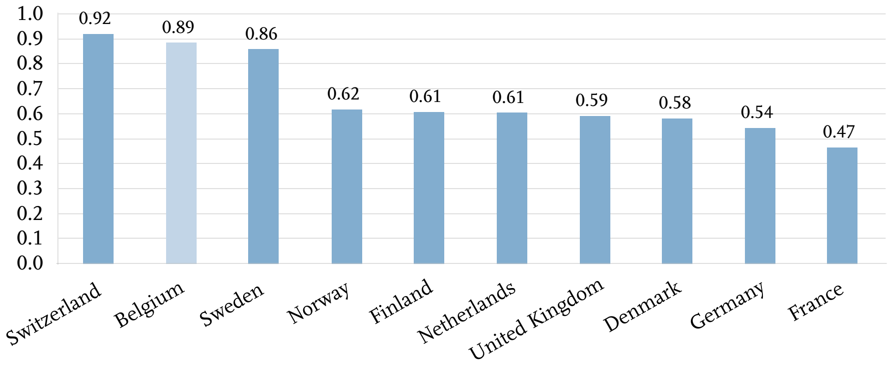


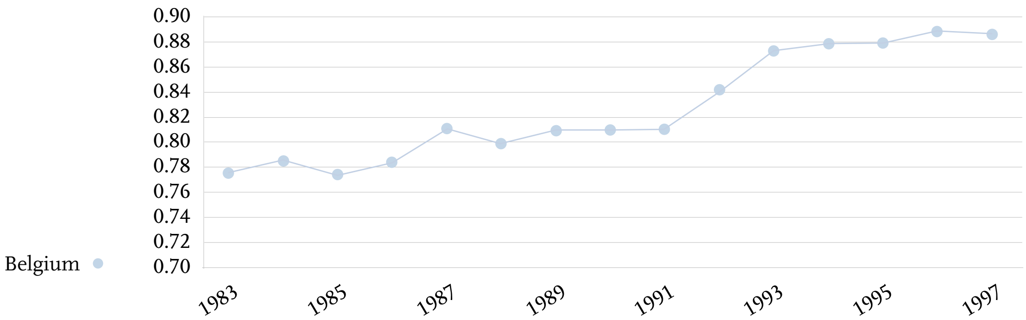


Source: OECD, MSTI.

Another conclusion of section 2 was that the effect of public R&D on productivity is larger in countries where the proportion of universities (as opposed to government labs) is higher. The last indicator illustrated here was constructed by dividing higher education expenditure on R&D – HERD by the sum of government intramural expenditure on R&D – GOVERD, and HERD.

FIGURE 7 **Share of universities in public R&D**





Source: OECD, MSTI.

Belgium ranks very high, coming second just behind Switzerland. The increasing trend evident in the second graph (data for other regions are not available) proves that the Belgian government has taken into account the importance of universities performing research with potential use for business, which has in turn a substantial impact on economic growth in the long term. This is probably the most encouraging conclusion of this indicators analysis for Belgium. On the other hand, however, one striking issue remains unsolved: Why does Belgium have a relatively low R&D intensity, while Sweden, which apparently attaches the same importance as Belgium to subsidisation, public R&D and higher education sector, scores so high?

This last point highlights the limitations of our analysis. The average relationships we studied in this work are useful in themselves, as they provide a reference for individual countries to benchmark their policies. They may, however, conceal differences in the effectiveness of public policies across countries. Furthermore, the changing effect of some variables over time is taken into account only in approximate terms. However, the comprehensive approach taken here facilitates identification of the interactions between various policy tools. Nevertheless, we feel there is a need for microeconomic analyse and case studies that could consolidate some specific issues of the Belgian case regarding business R&D, public policies and productivity growth.

4. Concluding remarks

The first objective of this chapter is to assess how business R&D, foreign R&D and various S&T policies affect economic growth. In global terms, the results point to the increasing importance of technology for economic growth. Business R&D has a positive impact on productivity. Foreign knowledge is also significant, crossing borders through patents, licences, international collaborations, etc, for the purpose of productivity growth. This is consistent with the fact that the social return of business R&D is higher than its private return, thus providing evidence of the existence of technology spill-overs, be they within a specific country or at the international level. Public R&D also has to assume an important role in increasing a country's productivity. The primary goal of government R&D is to fulfil public missions. Nevertheless, R&D performed in the higher-education sector has a substantial impact on economic growth in the long term and governments should therefore ensure adequate funding of this knowledge source.

One element pertaining to all our results is the importance of the business sector in being able to seize opportunities presented by public research, foreign research, or research performed by other firms within the country. Indeed, the impact of all the variables studied was higher in R&D intensive countries, where firms develop an effective adaptive capability.

The second issue we analysed is the way in which various S&T policies affect private R&D investments. Do they enhance or, rather, crowd out private R&D expenditure? How do these tools interact with each other? The first conclusion is that both R&D subsidies and tax breaks have a positive impact on business R&D investments. However, the effect of tax breaks seems to be more rapid and more short-term than that of government funding. The reason for this could be that, in contrast to subsidies, firms do not have to launch news projects that meet government requirements in order to benefit from tax concessions, they can spend more directly on on-going projects. Whatever policy is used, governments should bear in mind that a crucial factor on maximising its impact is stability over time.

In contrast, the crowding-out effect of government research appears to dominate the stimulating effect. One reason for this could be that it takes several years before the knowledge generated in public labs reaches the application stage. Moreover, an increase in public research may raise the demand on resources used for R&D (scientists), and hence their price. This last element can partly explain the negative impact of government R&D on business R&D investments. Nevertheless, this negative effect is reduced when defence-related public outlay is differentiated from the bulk of government expenditure directed toward R&D. Thus, it seems to be only the defence-related part of public R&D expenditure that has a negative impact on business R&D.

Finally, the numerous potential interactions between the policy tools make it more useful to study the system as a whole in order to evaluate the effectiveness of the various S&T policies.

When we look at the various indicators of R&D expenditure in the European Union, the most striking result is the excellent score of the Nordic countries. In contrast, Belgium displays relatively low R&D intensity, due to both low business expenditure on R&D and low proportion of publicly performed R&D. With regard to this last point, it should be noted that Sweden and Switzerland, which have a very good level of R&D intensity, are also those with the smallest share of public R&D in total R&D. The reason for this contradiction between Belgium on the one hand and Sweden and Switzerland on the other hand could possibly have been found in the distribution of public funds amongst defence-related research, governmental labs and university research. This is, however, not the case as Belgium has the lowest percentage of defence R&D and the second highest share of universities in public R&D compared with its European neighbours - a very favourable position. Finally, we highlighted that Swedish performance in R&D intensity - with the same subsidisation rate as Belgium - is much higher, raising the question of what other factors affect business R&D. The macro-economic study we have presented here is useful but not sufficient in order to understand the specific features of the various national innovation systems. There is a clear need for a more in-depth micro-economic analysis of the Belgian innovation system.

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On the effectiveness of R&D subsidies to firms in the Flemish Region*[1]

Wim Meeusen and *Wim Janssens*

1. Introduction

Do government R&D subsidies add to the global amount of private expenditure by private firms or do they, rather, take the place of funds that the firms benefiting from them would have provided themselves anyway? This is the central question on which we focus in this paper. We use extensive survey data on Flemish firms as the basis of an econometric exercise for the period 1992-1997. We supplement the results obtained in this manner by the outcome of a brief personal interview conducted with R&D managers at a number of large Flemish firms active in the R&D scene.

Section 2 reviews the existing literature on the subject, both theoretical and empirical. Section 3 contains the results of the econometric analysis, and in section 4 we present the results of the interview referred to above. Section 5 set out our conclusions.

2. "Additionality" versus "substitution" – a theoretical and empirical look at the effectiveness of R&D subsidies

The concept of "additionality" of R&D subsidies – and therefore also, in a way, the rationale for government intervention in the field of R&D – finds its origin in the phenomenon of market failure: private firms, when left to themselves, will invest in a sub-optimal way in innovative activities as a result, primarily, of their lack of ability to appropriate all the benefits arising from such activities. The low degree of appropriability goes hand in hand with the high risk-content of innovative activities, and thus with high capital costs.

* Original version.

To get in touch with the authors, see pages 4 and 5.

[1] An earlier version of this paper was presented at the "Workshop on Innovation, Technological Change and Growth in Knowledge-based and Service-intense Economies", The Royal Institute of Technology, Stockholm, February 1-2, 2001.

There are two ways in which the authorities can act:
1. they can take over from the private sector directly through public research labs and public enterprises, or through contracting-out directly to private firms; or
2. they can support private R&D activities indirectly through forms of fiscal accommodation or subsidising.

In both cases, however, the economist is confronted with, we cite Klette *et al.* (2000), "an exercise in counterfactual analysis". Neither the firms that are supported, nor those that are not, may be considered as resulting from a random selection procedure. To know "what would have happened if…" is therefore a hazardous enterprise. Determining an adequate set of control-variables in the econometric specification is crucial.

But even if we would succeed in defining a proper set of control-variables, it is not evident that the econometric approach would be the only one possible or valuable. A survey of the literature on this topic indeed shows that case studies and interviews of R&D-managers are often the method chosen (see Mansfield (1996) for a survey of the literature on this topic; see also Link (1996) for a typical study based on cases). The advantage of such an alternative approach is obvious: the interviewer gains a clear qualitative insight into the actual situation of the firm executing the R&D project and is therefore in a position to evaluate the underlying complexity in a way that is inaccessible to the econometrician.

The drawbacks are just as obvious, however, starting with the problem of the interviewee's objectivity, (see for example Luukkonen (1998) for a discussion of this particular problem). Nor is the "what if" problem solved in this way as the R&D manager interviewed will not always be able to answer the question of whether and, if positive, how a specific project would have been executed if government funds had not been supplied. The reason is that often - if not most of the time - successful obtaining of the subsidy for large projects is anticipated in the prior budgeting process. The reply of the manager who did not receive funding and who is asked what he would otherwise have done will probably be even less clear.

The R&D manager, in other words, is probably less able to answer counterfactual questions than the econometrician by virtue of the latter's ability to use control-variables and to call upon the "Law of Large Numbers" and, of course, because he has data on other firms at his disposal. Finally, there is the high financial and time cost of gathering information by means of interviews.

An econometric analysis, the results of which are confronted with insights gained through interviews with a limited set of privileged witnesses in innovative enterprises, would appear to be a reasonable compromise solution.

The impressive amount of econometric research that has become available does not allow a straightforward conclusion with respect to the additionality-substitution issue (see David, Hall and Toole (2000) for an in-depth review), although an "unweighted" summary of the literature would tend towards additionality, rather than in the direction of substitution. In order to sort out the main messages distinctions would, according to David *et al.*, have to be introduced at least in relation to the following aspects:

- fiscal measures versus direct financing;
- within the direct financing category: government contracts versus subsidies;
- short-term versus long-term effects;
- choice of the observation unit.

2.1 Fiscal measures versus direct financing

The main difference between both forms of support is evidently that fiscal measures are, at least in principle, non-discriminatory, while direct financing obviously is: the latter form implies – *ipso facto* – the choice of a specific project. This does not mean, however, that fiscal accommodation will always be neutral, since it will obviously be of greater benefit to projects for which high short-term returns are anticipated than to high-risk projects or projects with returns expected to be earned in the longer term.

Direct financing, on the contrary, will most often be targeted at projects with a high social return, i.e. on projects with a high content in terms of knowledge accumulation and, therefore, the greatest benefits for the society at large in the long term. The greater the positive gap between social and private expected return, the more efficient subsidies can be. In such cases, subsidies will only seldom crowd out private financing.

On the other hand, authors like David *et al.* (2000) suspect a certain tendency on the part of policy-makers and administrators of public funding programmes to select projects that firmly promise high short-term private returns, so as to be able to subsequently reap the political rewards of a successful venture. Crowding-out effects can then be expected to a much greater extent. We would expect the phenomenon referred to by David *et al.* to apply more to the situation in the US rather than that in Europe.

Substitution effects will most likely not occur through fiscal stimuli, although account should be taken of substitution with respect to other (non-R&D) forms of investment where the supply of production factors is sufficiently inflexible.

Hall and Van Reenen (2000) have supplied an extensive survey of econometric studies on the effectiveness of fiscal stimuli for R&D. In view of the subject of this research, we concentrate on direct financing in the following.

2.2 Government contracts versus subsidies

Government contracts mean that financial resources are placed at the disposal of private firms in order to execute a specific research assignment. Defence contracts are the most obvious examples. Subsidies, on the contrary, do not have this direct utilitarian connotation since they involve the financial support of mainly exploratory research and the start-up of new technology lines. The primary aim is knowledge accumulation.

Over the short term, both forms of financing stimulate private R&D through: 1) reducing fixed and variable costs that have to be financed by the firm itself; 2) increasing “absorption capacity”; 3) stimulating future demand (as a result of the signalling function of public contracts and subsidies); and 4) lowering fixed start-up costs for other R&D projects.

We might therefore be inclined to think that government R&D contracts and subsidies have an unambiguous additionality effect. This presumption has to be qualified.

Firstly, specific government contracts can induce a substitution effect if the beneficiary firm would have committed (part of) the necessary funds anyway in the hope of being better placed for landing publicly funded research contracts in the future. Secondly, it cannot be ruled out that other firms – in a larger sectoral context – would be discouraged by the preferential treatment given to the firm landing the contract in the first place (the so-called “first mover” advantage). The same mechanism, perhaps to a somewhat lesser extent, may also apply to subsidies.

Another aspect – that goes in the opposite direction – concerns aggregate demand externalities. In many cases, important contracts generate positive final demand impulses. With subsidies, this externality is only present insofar as the result is longer-term product innovation that would not otherwise have taken place. We may assume that this will be the exception rather than the rule, as subsidies usually relate to R&D of an exploratory nature. Both contracts and subsidies do, of course, create knowledge externalities.

Finally, we should perhaps reiterate that R&D subsidies might entail “adverse selection”. Rather than selecting projects characterised by an important (positive) difference between the expected long-term social and short-term private return, the tendency may exist to aim for the highest visibility, which may mean that projects with minimal risk and immediate returns are favoured.

2.3 Short-term versus long-term effects

The basic idea is simple: in the short term, public and publicly co-financed private R&D expenditure will have a crowding-out effect on privately financed R&D expenditure if the supply of inputs into the R&D process is less than infinitely elastic. The longer the period considered, the higher, however, this elasticity will be, which means that the long-term net (positive) effect of publicly financed R&D may be assumed to be higher in the longer rather than the short term.

Added to the possible long-term beneficial effects are the well-known spillover effects. Firstly, there are the obvious informational spillovers created by the increase in available scientific and technological knowledge resulting from publicly financed R&D. We may indeed assume that publicly financed R&D, because of its bias towards exploratory research and towards research with a higher longer-term social return as opposed to shorter-term private return, will yield additional knowledge that will be characterised by a higher degree of public availability.

Secondly, there is the likely positive influence of publicly financed R&D (foremost, but not exclusively, at universities and research institutes) on the quantity and quality of young scientists and engineers moving into the labour market (cf. the often observed emphasis of government R&D policy on training activities and stimulating university-based applied research). See, for example, LEVIN *et al.* (1987) and PAVITT (1991) for ample evidence on the positive spillover effects created by the increased availability and mobility of scientists and researchers.

It is clear that an adequate econometric specification for testing the effect of publicly financed R&D on overall R&D efforts will have to account for the difference between short and long-term effects.

2.4 Choice of the observation unit

The presence of spillover effects creates a problem in the econometric specification when it comes to choosing the observation unit (production-line, firm, industry or aggregate level). As a result of the inherent characteristics of the phenomenon, spillovers occur *between*, rather than *in* enterprises or industries. We surmise that the spillover effects of publicly financed R&D will, most likely, be positive. At this point, it would seem that there is, therefore, some risk of underestimating the influence of publicly financed R&D on privately funded R&D if the analysis is positioned at production-line or company level. On the other hand, however, it is of course also true that, in an analysis at the global level, R&D by individual firms is implicitly weighted through the process of aggregation, contrary to what happens in company-level analyses. If, because of threshold effects and the existence of longer-term R&D investment plans, large firms would be more inclined to regard R&D subsidies as a welcome, but not crucial source of funds, then there would be a tendency in company-level exercises to overestimate the positive effects of subsidies. It is certainly true that opting for a higher level of integration results in important informational loss. It is the classic dilemma: choosing between a possibly biased estimator with a relatively low variance and a, perhaps, less biased estimator with a high variance.

The econometric analysis of the "additionality-substitution" issue solicits attention in relation to two other technical issues. The first concerns the difficulty created by the underlying identification problem caused by the fact that public financing of R&D, and specifically subsidisation, can induce both shifts in the marginal cost and in the marginal return curve. Rather than trying to solve the issue by adding additional explanatory variables in the equations of the structural form of the model, we opt for the estimation of the reduced form of the model. The reason, of course, is that the aim is to eventually estimate the net effects of public financing on private financing, rather than estimate the precise forms of the curves referred to above.

TABLE 1 **Summary of company-level econometric studies on the "additionality versus substitution" studies**

author(s)	period	country	data type	# obs.
Hamberg (1966)	1960	USA	firms in sectors	8 x (±20)
Howe and McFetridge (1976)	1967-71	Canada	firms in sectors	6 x 44
Shrieves (1978)	1965	USA	firms across sectors	411
Carmichael (1981)	1976-1977	USA	firms in sectors	46 x 2
Higgins and Link (1981)	1977	USA	firms across sectors	174
Link (1982)	1977	USA	firms across sectors	275
Lichtenberg (1984)	1967, 1972, 1977	USA	firms across sectors	991
Lichtenberg (1987)	1979-1984	USA	panel data across sectors	187 x 6
Lichtenberg (1988)	1979-1984	USA	panel data across sectors	167 x 6
Holemans and Sleuwaegen (1988)	1980-1984	Belgium	panel data with sector-dummies	5 x (±47)
Antonelli (1989)	1983	Italy	firms in sectors	86
Toivanen and Niininen (1998)	1989, 1991, 1993	Finland	panel data across sectors	133 x 3
Busom (1999)	1988	Spain	panel data across sectors	147
Wallsten (1999)	1990-1992	USA	panel data across sectors	81

Source: David, Hall and Toole (2000).
(*) the elasticities reported are defined in terms of increases of private in terms of public R&D spending.

The second concern relates to the dangers of reverse causation. Firms will indeed frequently start preparatory R&D in order to be in a better position to attract public funds that might become available in the future. In other words, the marginal returns schedule then shifts in anticipation of possible future public support, with the ensuing difficulty of distinguishing the net reaction of the firm to public financing (Lichtenberg, 1984). A related problem arises as a result of selection bias: firms that are considered to be competent in a specific research field will be in a better position to attract government funds, but will, at the same time, also be more quickly prepared to invest their own funds.

David *et al.* (2000) summarised the empirical results of econometric studies on the "additionality versus substitution" issue of R&D subsidisation. In *Table 1* we concentrate, for our purposes of comparison, on studies using company-level data.

variable explained	explanatory var.	method	result (elasticity) (*)
private R&D employment / tot. employm.	public contracts / turnover	weighted OLS	mixed / additionality
private R&D expenditure	subsidies	weighted OLS	mixed /additionality
log (private R&D employment)	% R&D expend. financed publicly	OLS	substitution
private R&D expenditure	amount of public contracts	pooled OLS	substitution
% research in private R&D	amount of public financing	OLS	substitution (-0.13)
private R&D / turnover	public financing / turnover	OLS	additionality
private R&D / turnover	public financing / turnover	pooled OLS (first differences)	substitution
private R&D expenditure	public financing	"fixed effects" panel	no significance
private R&D expenditure	public financing	"fixed effects" panel (IV)	substitution
log (private R&D)	log (public subsidies)	"fixed effects" panel	additionality (0.25, 0.48)
private R&D; log (private R&D)	% public financing; log (%)	OLS	additionality (0.31, 0.37)
private R&D expenditure	public financing (incl. loans)	IV (first differences)	substitution in large firms (-0.1); no significance in SMEs and for loans
private R&D expenditure	participation in subsidy / loan programmes (dummy)	OLS with correction for selection-bias	additionality (0.20)
private R&D expenditure in 1992	# projects and subsidy	OLS, 3SLS	substitution

Looking at *Table 1*, there seems, at first sight, to be near equality between the number of studies obtaining a substitution and an additionality result. A closer inspection reveals, however, that the picture changes when a distinction is made between US and non-US studies. All the latter yield additionality in one way or another. Probably differences in the institutional environment play a decisive role, with the USA studies mostly concerning contract research rather than subsidisation, predominantly in the defence industry. This is however somewhat surprising as we would expect additionality to appear more readily in relation to contract research rather than subsidies.

We should bear in mind that company-level studies may yield downward biased elasticity results because of the difficulty of incorporating spillover effects into the estimation. This seems to be confirmed by the results of studies at industry and aggregate level. In none of the studies surveyed by David *et al.* – including those relating to the USA – is "substitution" the conclusion: of the 12 studies surveyed by the authors, 10 report additionality, and 2 are inconclusive.

3. Econometric results

The basic data used, on the one hand, are collected in the regular 2-year R&D surveys of all the firms in the Flemish region of Belgium known to be active in R&D and, on the other hand, consist of R&D subsidies granted by IWT to these firms. The period covers 1992-1997. We refer to *Appendix 1* for details on the data used, the econometric methodology chosen and the variables included in the regressions. *Appendix 2* discusses the specification of the model and presents the raw results.

Table 2 summarises the results with respect to the $\hat{\beta}'_L$ coefficient and *e*. The former coefficient represents the long-term impact on *intra muros* expenditure financed with resources other than IWT means in terms of levels; the latter coefficient is the corresponding average point-elasticity (see *Appendix 2*).

A relatively clear picture emerges with regard to the "additionality-substitution" issue. For the sample as a whole and for the separate categories of "large", "medium-sized" and "small" firms[2], the NLS (Non-linear Least Squares) procedure suggests that R&D expenditure, financed with resources other that public funds, increases in response to receiving IWT subsidies. In level terms, the results in the three size-classes are very comparable. For "large" firms, however, the regression – not unexpectedly – yielded an elasticity that is considerably smaller than that obtained for "medium-sized" and "small" enterprises.

TABLE 2 **Net impact of IWT subsidies on private *intra muros* R&D expenditure financed through other means, and the corresponding average point-elasticity**
• Flemish Region • 1992-1997*

	NLS method		
	$\hat{\beta}'_L$ (s.e. $\hat{\beta}'_L$)	P-value	elasticity *e*
all firms	**3.673**		**0.318**
	(0.941)	0.000	
"large" firms	**4.499**		**0.143**
	(0.710)	0.000	
"medium-sized" firms	**5.901**		**0.556**
	(1.711)	0.001	
"small" firms	**5.074**		**0.458**
	(1.006)	0.000	
ICT firms	2.453		0.077
	(1.346)	0.068	

* Bold cells refer to coefficients that are statistically significant at the level of 95% or more.

[2] We explicitly place the adjectives "large", "medium-sized" and "small" between quotation marks. As Belgian industry is dominated by SMEs with only a few, relatively small, Belgian multinational corporations, the size classes used in the analysis have accordingly to be defined in a somewhat unconventional fashion.

The level $\hat{\beta}'_L$ estimates may seem to be surprisingly high, a government input of €1 appearing to induce the recipient firm to add €2.5 to €6 of its own, depending on the case. One should, however, not lose sight of the fact that a selection bias probably applies, the sample consisting only of firms that are known to be active in the R&D scene. The result therefore does not automatically apply to the economy as a whole. Secondly, the IWT subsidies are not given to firms as such, but to specific projects within firms. These projects are, on average, characterised by a greater emphasis on fundamental as opposed to applied issues, by high risks and anticipation of relatively high social as opposed to private return.

The elasticity estimates, for that matter, very much correspond to the results obtained by Holemans and Sleuwaegen (1988) in an earlier study for the whole of Belgium over the period 1980-84. The results are also of roughly the same order of magnitude as those obtained by van Pottelsberghe and Peeters (this volume). They obtained an elasticity estimate of .08 on the basis of an ECM approach using aggregate data for 16 OECD countries (including Belgium) over a period of 16 years. Because of the aggregate nature of the data used, the natural candidate for comparison is our *e*-estimate for "large" firms (i.e. .14)[3] [4].

With respect to the ICT subset, the NLS method resulted in an estimate that is statistically insignificant (albeit in borderline terms). This insignificance may, however, be caused by the (considerably) reduced set of observations that were usable in this procedure.

The estimation results with respect to the other explanatory variables also merit some attention (see *table A2* in *Appendix 2*). It is striking that the coefficient of the size variable almost consistently bears a significant negative sign, concurring with the "anti-Schumpeter" results that prevail in the recent literature and especially those obtained for Belgium (Rayp *et al.*, 1998). The probable reasons for this – apart from the obvious presence of a selection bias as the result of targeting the survey sample at firms that *a priori* are supposed to be active in the R&D field – are well known: advantages of scale for large firms yielding higher R&D productivity, the shelter offered by monopolies, which large firms are more likely to enjoy, and the fact that individuals in large enterprises do not have much scope for being rewarded for the innovative impulses that they would initiate (bureaucracy).

The picture is somewhat blurred with regard to the coefficients for the variable expressing real growth in turnover, and it is therefore hazardous to draw conclusions from them.

[3] Comparisons with results obtained by other methods are hazardous. E.g. Donselaar and Knoester (1999) for the Netherlands obtained a multiplier (level) effect of only 1.04, but they performed their time-series analysis on aggregate data of R&D expenditure and subsidies for the private business sector as a whole, i.e. including firms that were not active on the R&D scene.

[4] Cf. the discussion on the weighting problem (see the discussion on the choice of the observation unit in section 2).

4. A qualitative supplement to the analysis

Although the econometric results do not allow us to conclude that, with respect to the "additionality-substitution" issue, "large" firms in the Flemish Region react, in terms of level effects, significantly differently to R&D subsidies compared to "small" and "medium sized" firms, intuition may suggest otherwise. "Large" firms are indeed often perceived as having crossed a threshold in their R&D activities, inducing them to carry out their long-term R&D plans, irrespective of whether they receive government support for it or not. We repeat, however, that "large" firms in the Belgian context are not large in the usual global sense.

In order to be able to further clarify the results concerning these so-called "large" enterprises as reported above, we conducted a limited number of personal interviews with senior R&D managers in 15 "big R&D spenders" in the Flemish Region, selected on the basis of the size of their intra-mural R&D budget for 1997. They represent 71.6% of the total intra-mural R&D expenditure of the firms present in the data-set for that year, and 62.6% of the R&D subsidies granted to the latter set of firms. The level of coverage of this (reduced) sample is therefore high.

The questions put to them dealt with the company-, market- and policy-driven parameters that determine decisions on R&D, the obstacles with which R&D-active firms are confronted as well as, in particular, the perceived role of subsidies with respect to the "additionality-substitution" issue. We limit ourselves here to the last question and also expand somewhat on the main concern of the interviewees (see JANSSENS *et al.* (2000) for more details of the replies to the other questions).

14 out of the 15 firms surveyed by interview have received support from IWT since 1992:
- 0 firms reported that the planned R&D activities would have taken place "not at all" without the IWT subsidy;
- 11 firms reported that these would have taken place "only partially";
- 3 firms reported that these would have taken place "anyway".

The replies seem to suggest that "substitution" may be present to some extent in the "large" firms that were surveyed. This should, however, be qualified by virtue of the fact that the question related to a particular R&D project and did not refer to what happened with other R&D initiatives of the same firm. In order to gain a better understanding of the latter aspect, we confronted the interviewees with the question of whether or not the subsidy benefited the firm in other than a purely financial manner and, in the case of a positive answer, through which channels (the interviewees could select a maximum of two pre-defined possibilities):
- 7 firms declared that the subsidy allowed them to initiate more risky projects;
- 7 firms declared that they were stimulated by the subsidy to start completely new lines of product- or process-oriented research;
- 5 firms said that the subsidy allowed them to explore existing research lines in greater depth;
- 5 firms declared that they were stimulated to engage in new international research collaboration networks.

Another part of the qualitative analysis was the perception by the interviewees of the procedure underlying the R&D subsidy system applied by IWT. One particular theme cropped up systematically in the interviews: the perceived advantages of evolving towards a system of "framework financing" of R&D. It is obvious that some degree of "wishful thinking" is involved here. Nevertheless, although a system of pure envelope financing is evidently inappropriate, a system of "framework financing", in which companies would receive long-term subsidies if at least a number of necessary conditions are fulfilled might indeed be considered. The "framework" formula reduces a lot of the perceived negative aspects of the present subsidy system focused on well-defined projects (the intellectual property issue[5] and the role of the assessment commission) and could be beneficial in terms of reducing time delays and red tape, without losing the – perceived – positive aspects of the present system (the encouragement of networking and the thematic approach).

A crucial question, of course, is to determine which companies can be considered for framework financing. Although this is a subject that needs thorough analysis, two important conditions immediately spring to mind. Firstly, the firm must have an excellent R&D track record (which means that only sufficiently large and well-established firms can be taken into account) and, secondly, the firm must agree with the concept of an "open project system". This would imply that IWT must be able to perform audits of the progress of the framework programme on a regular basis, making use of so-called "milestone" requirements. This transparency is a minimal requirement as the European authorities will of course regard framework-financing systems with some suspicion. An advantage of this system might be that the in-house expertise of IWT personnel can then be used more efficiently in the sense that more resources become available for scouting activities with small and medium-sized companies.

5. Conclusion

The overall impression created in section 2 by examining the existing literature on the "additionality-substitution" issue with respect to R&D subsidies - as far as European countries are concerned, has been confirmed in the present analysis. The results of the regressions on the aggregate sample of firms in the Flemish Region active in the R&D field in the period 1992-97 suggest that subsidies granted had a positive effect on the amount of other funds earmarked by the firm for R&D financing. This result was corroborated when sub-samples of "small", "medium-sized" and "large" firms were analysed separately. The level effects are of the same order of magnitude across size classes. The results in elasticity terms correspond broadly to other results obtained in the literature.

Although a closer look by means of personal interviews with R&D managers of a small sample of "large" enterprises with high R&D budgets revealed that, to some extent, "substitution" is at play as well, it was also brought to light that R&D subsidies were perceived as bringing other benefits to the firm in terms of the attitude towards

[5] Because of the detailed nature of the subsidy file that has to be introduced by the firm, some firms allegedly refrain from applying for subsidies out of fear of divulging crucial information.

risk, the tendency to initiate new lines of research, and the tendency to engage in additional international R&D co-operation.

But there is, of course, a serious “caveat”. The possible presence of a selection bias, as a consequence of targeting the survey sample on firms that a priori are supposed to be active in the R&D field, does not make it possible to readily generalise the “additionality-substitution” results obtained for the economy as a whole. There are indeed indications in the available literature that, with respect to the average firm in the economy, the multiplier effect of R&D subsidies on intra-muros R&D expenditure, although still positive, is considerably lower than that obtained for our sample of R&D-active firms.

The regression results also confirmed another result that is often cited, i.e. SMEs are characterised by higher R&D intensity than large firms in the set of R&D-active firms.

Appendix 1

The data and the methodology

The data set has a panel structure. The basic data set has been linked to three other company-level databases relating, respectively, to 1) the subsidies granted by IWT[6] to each beneficiary firm; 2) accounting data; and 3) data on R&D co-operation in the context of the Framework Programmes of the EU (the so-called CORDIS database)[7].

With respect to the left-hand side of the reduced form equation that we wish to estimate, a number of decisions have to be made. By virtue of the nature of the question we want to answer, this relates to the *intra muros* R&D expenditure of the firm, though the choice is, on the one hand, between the overall level of this variable, or the part that is financed with funds other than public resources, and on the other hand, between levels or intensities. If we opt for an intensity, there then remains the choice of the reference value that we put in the denominator of the intensity: turnover, employment or value-added.

For a number of practical reasons associated with requirements of stationarity of the series used and the quality of the available data in the databases mentioned above, we have finally opted for a left-hand side variable that consists of the overall amount of *intra muros* R&D expenditure of the firm, expressed as an intensity defined in terms of turnover.

This means that the equation has the following general form:

$$L_r(RDI_{it}) = f\left(L_I\,(IWTSUBI_{it}),\, L_1\,(X^1_{it}),\, L_2\,(X^2_{it}),\, \dots,\, L_K\,(X^K_{it})\right) + u_{it}\,,$$

whereby i and t are indexes of the firm and the year, respectively. RDI is the intensity as defined above, $IWTSUBI$ is the subsidy granted by IWT, also expressed, of course, as an intensity, $X^1, \dots, X^K$ are the other exogenous variables that influence R&D intensity. u is an independently distributed error term. L_r, L_I and $L_1, \dots, L_K$ are lag functions.

We shall now discuss the candidate variables on the right-hand side of the equation.

The lagged value of the endogenous variable RDI is included for two reasons. The first is, of course, inertia. The second relates to the panel structure of the data set. Given that we have to account for the inertia that is obviously present, it is appropriate at the same time to try to absorb company-specific effects with the help of the lagged endogenous variable rather than using a fixed-effects panel specification. With short time-series, the simultaneous use of fixed effects and lagged endogenous variables is indeed hazardous.

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[6] The institution administrating the R&D funds of the Flemish Regional Government destined for the private business sector.

[7] See Janssens *et al.* (2000) for more details on the structure of the database used.

With regard to the *IWTSUBI* variable, we have, in principle, the choice between the subsidy *granted* each year and the amount *actually paid* that year. The latter variable is, of course, directly commensurable to the R&D funding supplied by the firm itself. This is an advantage. On the other hand, it is also true that it is the amount granted that will influence the R&D expenditure behaviour of firms more. The data at our disposal concern subsidies *granted*.

Firm size is a first candidate for controlling the relation between subsidies and R&D efforts. The traditional "Schumpeter hypothesis" is that R&D predominantly takes place in large enterprises[8]. Whether this is presently true is far from certain: Rayp *et al.* (1998), for Belgium – and in accordance with much of the recent empirical literature on this subject – arrive at the opposite conclusion. The probable reasons for this – apart from the obvious presence of a selection bias as the result of targeting the survey sample at firms that *a priori* are supposed to be active in the R&D field – are well known: advantages of scale for large firms, but perhaps also the shelter offered by monopolies, which large firms are more likely to enjoy, and the fact that individuals in large enterprises do not have much scope for being rewarded for the innovative impulses that they would initiate (bureaucracy).

The absence of a size variable certainly gives rise to the risk of producing biased estimates. Since we define R&D intensity in terms of turnover, it is natural to opt for turnover as the measure of firm size.

Growth of turnover is another candidate. Turnover is not only a proxy for firm size, but also for future demand. Brouwer and Kleinknecht (1994), for instance, find some evidence for the well-known hypothesis of Schmookler (1966) in the development of Dutch R&D intensity through the business cycle. In order to avoid the mixing of possibly opposite effects of turnover, and because the demand effect is more of a dynamic nature, we therefore include, besides turnover, the real growth rate of turnover in the equation.

The introduction of the *number of previously subsidised IWT projects* as an explanatory variable in the regression was thought to be interesting because is could give an initial answer to the following question: will the marginal effect of subsidisation increase or decrease respectively with the number of previously subsidised projects by virtue of the fact that the firm has been helped to cross a threshold and thereby to innovate at an accelerated pace, or because a saturation effect has occurred?

The *degree of participation in EU projects* may be another variable worthy of consideration. Brouwer and Kleinknecht (1994) find that firms engaged in international R&D co-operation have a systematically higher share of products in their turnover that are "new" in the sector. The same authors also find that firms co-operating transnationally in the field of R&D are often more inclined than others to combine product- and process-oriented research.

[8] We have to distinguish between the Schumpeter of *Capitalism, Socialism and Democracy* (1942) and that of *The Theory of Economic Development* (1934) in which new firms (and especially SMEs) pre-eminently operate as the vehicles of technological change.

Hall (1990) found that firms that increase their *financial leverage* are often characterised by a declining intensity of R&D, i.e. firms that are heavily indebted may not have much room for new innovative initiatives. However, it is difficult to deny that a problem of "reverse causation" may render the corresponding regression coefficient statistically insignificant: high leverage may be caused by the effort of the firm in the direction of R&D.

Specific *sectoral* and *technological level* effects are captured by the inclusion of sector dummies and by dummies defined on the basis of the OECD categories "high-tech", "medium high-tech", "medium low-tech" and "low-tech" industries. The latter solution was often chosen because of the reduced number of observations in relative terms that were otherwise left once "missing data" problems were taken care of.

The other potentially significant factors include the possible existence of a full-blown research department in the enterprise and whether the firm is part of a larger group. However, the necessary data to include the corresponding variables were lacking. There are certainly good grounds to assume that adverse effects of "omitted variables" may be present, which means that we will not be able to bluntly assume that the error term is independently distributed. This also strengthens the case for a supplementary qualitative part of the present analysis.

Appendix 2

The model and the raw results

We proceeded from the following equation:

$$RDI_{it} = \alpha_o + \sum_{k=1}^{K} \alpha_k X_{kit} + \beta_o\, IWTSUBI_{it} + \beta_1\, IWTSUBI_{it-1} + \gamma\, RDI_{it-1} + u_{it}$$

$$u_{it} = \rho\, u_{it-1} + \varepsilon_{it}$$

i is the firm index, *t* is the time index. *RDI* is R&D-intensity, defined as total *intra muros* R&D expenditure in proportion to turnover; *IWTSUBI* is the IWT subsidy granted in proportion to turnover; and X_k ($k = 1, \ldots, K$) are the other explanatory variables that are thought to be relevant and on which we have data. The latter specifically concern the logarithm of real turnover, the current and lagged value of the real growth rate of turnover, the recent subsidisation history as measured by the cumulated number of IWT projects in which the firm has been involved (*#IWT_cum*), and the degree of participation in EU R&D projects, again measured by a cumulated number.

It is safe to assume that the specification is incomplete. Hence, the possibility that the error term has an autoregressive structure.

The regression also contains technological discipline dummies. We also experimented with interaction effects (discipline dummies combined with *IWTSUBI*), and with a term that was to capture technological spillover effects (the aggregate amount of IWT subsidies, current and lagged), but neither of these attempts yielded significant results. Nor did the introduction of a leverage variable: we obtained significantly positive or statistically insignificant results (cf. the “reverse causation” argument in the previous section).

From the above regression equation, it follows that the estimated value of the long-term influence of IWT subsidisation on *intra muros* R&D is given by the following expression:

$$\hat{\beta}_L = \frac{\hat{\beta}_o + \hat{\beta}_1}{1 - \hat{\gamma}}$$

The long-term impact on *intra muros* expenditure financed with means other than IWT funding is therefore:

$$\hat{\beta}'_L = \hat{\beta}_L - 1,$$

and the estimated corresponding average point-elasticity *e* is then, of course, given by the expression

$$e = \hat{\beta}'_L \frac{\overline{IWTSUBI}}{\overline{RDI}}$$

Note that our prime interest is in the $\hat{\beta}'_L$ coefficient, since it expresses, in money terms, the amount of private funds that a firm is willing to add to the funds made available by the authorities. The elasticity *e* is computed for reasons of comparability with previously published results (see *Table 1*).

A significantly positive value for $\hat{\beta}'_L$ (and for *e*) is an indication of "additionality", i.e. the R&D expenditure of the "representative" firm increases more than by the amount of the subsidy. In other words, the firm increases its expenditure financed with resources other than IWT funding (that is, mostly, with own funds). A significantly negative value is an indication of "substitution".

The panel data that we use allowed us, at least in principle, to choose between two different estimation techniques:
- the panel version of the so-called NLS model in which, by means of an ML method, a non-linear one-step procedure leads to the simultaneous estimation of the regression coefficients and the autoregressive coefficient ρ ;
- the panel version of the GMM model.

The latter method is very powerful, but only yields good results with sufficiently large samples. The presence of a lagged endogenous variable in the specification, however, results in a severe reduction of the number of usable observations. This reduction appeared to be prohibitive: the GMM estimates proved to be very sensitive to small changes in the specification and the set of observations. We confine the report on the estimation results to the first method.

Table A2 contains the results of the NLS estimation after having applied a "general-to-specific" reduction. The procedure has been applied to the complete data set and to separate data sets for "large" (at least 250 employees), "medium-sized" (between 50 and 249 employees) and "small" firms (less than 50 employees), as well as for the ICT sector (NACE-Bel codes 30, 32, 64.2 and 72). Regressions for other sector aggregates (chemicals, metallurgical industry, etc.) displayed too few observations to be meaningful.

TABLE A2 **Final forms of the regressions of the R&D intensity equation**

Flemish Region • 1992-1997 • NLS model *

Data-set	Structure of data set**	Constant	*RDI*(-1)	Log (turnover)	Turnover growth
Complete data set	NI=123; TMIN=1, TMAX=4; NOBS=280	**0.132** **(2.64)**	**0.203** **(13.32)**	**-0.00715** **(-2.11)**	
"Large" firms (# of employees ≥ 250)	NI=44; TMIN=1, TMAX=4; NOBS=106	**-0.133** **(-3.62)**	**0.746** **(7.79)**	**0.00888** **(3.71)**	**0.109** **(3.49)**
"Medium sized" firms (# of employees between 50 and 249)	NI=45; TMIN=1, TMAX=4; NOBS=103	**0.446** **(2.21)**	**0.166** **(7.85)**	**-0.030** **(-2.09)**	
"Small" firms (# of empoyees < 50)	NI=25; TMIN=1, TMAX=3; NOBS=36	**0.137** **(2.20)**	**0.888** **(32.79)**	**-0.011** **(-2.16)**	**0.112** **(4.31)**
All firms in the ICT-sector (NACE-Bel 30, 32, 64.2, 72)	NI=16; TMIN=1, TMAX=4; NOBS=38	**0.214** **(2.32)**	**0.176** **(20.38)**	-0.010 (-1.62)	-0.265 (-1.33)

* The values between brackets are t-values. Bold cells refer to coefficients that are statistically significant at the level of 95% or more.
** NI is the number of firms (i.e. with at least 1 year's observation) in the regression; TMIN and TMAX are the minimal, respectively maximal, number of year observations per firm; NOBS is the total number of observations.

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Turnover growth(-1)	#IWT_cum	*IWTSUBI*	*IWTSUBI*(-1)	R_{adj}	ρ
		1.166 **(2.14)**	**2.557** **(2.94)**	0.886	-.103 (-8.11)
		1.396 **(2.80)**		0.741	-0.258 (-1.795)
	-0.015 (-1.66)		**5.753** **(3.67)**	0.941	-0.088 (-8.57)
-0.073 **(-7.15)**		**0.681** **(4.12)**		0.970	-0.219 (-2.02)
			2.844 **(2.565)**	0.966	-0.083 (-9.44)

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How important are multinational firms for the local innovation system? Some empirical evidence from Belgium*

Reinhilde Veugelers

1. Introduction

Innovation strategies require increasingly more global sourcing: sensing new market and technology trends worldwide, while responding to them adequately through generating new ideas which are then implemented around the world. These tendencies lead to important flows of know-how within and around international firms.

This paper tries to empirically assess the technology flows occurring in international firms and their impact on the innovative system in Belgium, traditionally a small and open economy with an important multinational presence. Belgian company data from the EUROSTAT Community Innovation Survey are used, which allows the mapping of national and international technology transfers and acquisition of know-how used by international firms. Different types of international firms can be distinguished: subsidiaries of foreign MNEs and headquarters of Belgian MNEs. We measure the impact on the Belgian economy through the relative importance of international information in-flows created by the different types of organisations, either by selling technology to, or R&D collaboration with, local partners. International sourcing is proxied by international acquisition of know-how, or collaboration in R&D with international partners. By analysing the know-how flows within different types of firms, the data make it possible to check to what extent trends towards truly global transnational technology sourcing have materialized and what the impact is for Belgium.

The results indicate a positive correlation between international sourcing and local know-how transfers. Multinational companies that source more technology internationally, both internally and outside the group, are also found to be more active in generating know-how transfers locally, especially through local collaboration. An important implication for the host economy is that transfers to the local economy from MNEs, most often through local technological collaboration, are more likely to come from firms that buy technology internationally and are engaged in global R&D collaboration.

* Original version.

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2. Subsidiary Innovations and Impact on the Host Economy

2.1 Changing innovative strategies of multinational companies

In the current international environment, a company's ability to innovate is becoming an important source of competitive advantage. The pace and scope of technological and market change result in the increasing importance of external sources of technology for innovation. Companies need to be responsive technology opportunities worldwide (Bartlett & Ghoshal (1997)). Global firms are increasingly spreading their operations not only to serve foreign markets or benefit from cheaper factor costs in other countries, but also to create or acquire new assets through, for example, undertaking decentralised Research and Development activities. The challenge for the MNE is how to best organise globally in order to recognise the potential of innovations, exploit them and protect the revenue from them in the current international environment.

All this implies a different role for subsidiaries in the innovative strategy of the MNE. Depending on the level of technological capabilities and the strategic importance of the host market, subsidiaries can play a specific role in the innovative process of the MNEs. On the one extreme, subsidiaries can play a purely implementing role for projects where they hold low levels of technological expertise and the market is of low strategic importance. In this case, the technology transfer is one of pure import into the local market.

As soon as the location has a high level of technological capability for a particular innovative project, it can be assigned a contributing role to develop generic central know-how or even play a more crucial leading role as a "centre of excellence", with a "global product mandate" (Rugman & Poynter (1982)). In such cases, the transfers of know-how are multiplex, with the subsidiary responsible for sourcing know-how in other units of the MNE (incl. headquarters), as well as accessing external sources. These external parties can be found in the local environment if the subsidiary's technological capability follows from being embedded in a "national innovation system", though third parties can be sourced across the globe. To summarise, international R&D units are becoming increasingly engaged in cross-border interactions both across units within the MNE as well as between units and external partners. Know-how needs to flow across units and locations. This requires working on effectively linking R&D units, stimulating the mobility and transfer of people, building long distance inter-personal communication (Westney (1997), Bartlett & Ghoshal (1997)).

Empirical evidence on the (changing) role of subsidiaries in MNE innovative strategies has never been abundant. Recent studies can easily show the transfers of know-how from parents to affiliates, but find less conclusive support for the reverse direction, from subsidiaries to headquarters. Frost (1998), using USPTO data for 1980-1990, found evidence of the importance of headquarter patents for the innovations of subsidiaries, while patent data provided only limited evidence for the transfer of know-how from subsidiaries to headquarters. In addition, subsidiaries were using local sources, i.e. proximity mattered a lot: patents from subsidiaries cited more often other entities located in the same state.

Case or survey-based evidence confirms that MNEs are increasingly engaged in cross-functional learning from different sites[1]. PEARCE & SINGH (1992), based on a sample of international firms, conclude that, on average, adapting innovations to local markets is still an important task for subsidiaries, though the development of products also used in other markets is becoming more widespread (see also PEARCE (1999)). They found little evidence that subsidiaries have a role in basic research through wider programmes. The "supervised freedom" granted to subsidiaries leads to less feedback to the parent. The level of integration within the MNE of subsidiaries' innovative strategies often depends on historical factors, such as mergers & acquisitions, the type of industry (science versus market-based), as well as home market characteristics such as size and technological competence (NIOSI (1999)).

2.2 The impact of know-how flows on the host economy

With changing innovative strategies for MNEs, an important question to be examined is the impact of these organisational changes on the local economy hosting subsidiaries or parents of multinational firms. From the point of view of countries acting as hosts to MNEs, such shifts may be seen as having the doubly worrying implications that local resources applied to basic R&D work lead to results that will leave the country, while the adaptation work remains dependent on the assimilation of know-how developed elsewhere in the company.

In the traditional economic literature, subsidiaries of MNEs are seen as vehicles for the international diffusion of technology (see, for example, BLOMSTRÖM & KOKKO (1998)). Subsidiaries increase the efficiency of local firms through transfers of technology by directly or indirectly interacting with local firms, f. i through technical support to local suppliers and customers or R&D contracting or through informal channels such as movement of personnel, conferences and meetings, etc. Empirical studies at the firm level (see LALL (1980), CAVES (1996)) seem to suggest that such spillovers are positive, but not always significant. MANSFIELD & ROMEO (1980) found that two third of UK firms indicated that their technological capabilities were raised by technology transfers from US firms to their overseas subsidiaries. But only 20% felt this effect was of importance. A critical factor for exploiting spillovers is the technological capability of indigenous firms (BLOMSTRÖM (1986)). CANTWELL (1989) also stresses the need for a high level of local competence, a competitive environment and sound host policies to be able to absorb spillovers from multinational presence. VEUGELERS and VANDEN HOUTE (1990) provide evidence for Belgium that the presence of foreign MNEs reduces innovative investment for local firms when the competitive pressure outweighs any positive impact from technology spillovers, for instance when foreign and domestic products are more similar.

While MNEs may or may not generate positive spillovers for the host economy, they might at the same time extract know-how from the host economy. Through their foreign affiliates, MNEs may find it easier to absorb knowledge spillovers. To the extent

[1] For some recent studies, see the *Research Policy Special Issue on the Internationalisation of Industrial R&D*, 1999, 2-3.

that the MNE interacts with agents in the home market, this know-how may then spill over to the home country. This effect has been researched to a much lesser extent. Evidence of technology sourcing as a motive for FDI is provided by KOGUT & CHANG (1991). They find that FDI by Japanese companies in the US is more likely in industries where the R&D intensity in Japan is lower than in the US. However, here, too, technology sourcing requires an absorptive capacity to learn, typically attributed to Japanese companies. GLOBERMAN *et al.* (1996) find positive feedback effects for outward FDI in Sweden, at least when affiliates of Swedish MNEs are located in the US, Japan or Germany.

Of course, MNEs are but one mechanism for diffusing international know-how. Technology is transferred internationally through channels other than subsidiaries, such as licensing, purchase of equipment, international movement of personnel, the reverse engineering of final goods and other, more informal, channels. While the existing studies have focused on involuntary spillovers, there is growing emphasis on the importance of cross-border networking and the formation of international alliances in order to access and transfer technology. TEECE (1997) and MOWERY (1992), for example, emphasise that alliances can be a particularly effective and often more superior mechanism for linking external technology sources. Compared with market transactions and internal development, collaboration allows a faster, less costly and lower risk mode of accessing new technology, while exploiting partner complementarity and actively managing the transfers of know-how between partners (PISANO (1990)). The inherent reciprocity, which can be considered a simultaneous technology sell transaction, makes it possible to manage the risks of partner opportunism, reducing transaction costs (OXLEY (1997)).

Combining the evidence of MNEs as generators and receptors of technology flows and viewing the changing role of subsidiaries in the global innovative strategies of MNEs, the impact on the host economy can be manifold. Strong economies can become innovation centres in which MNEs participate directly, creating innovation, absorbing know-how from other parties, and creating further innovation in a “virtuous cycle”. However, CANTWELL (1989) also warns of “vicious cycles”, with MNEs restricting affiliates to low value-added activities, while importing/implementing high value-added activities. By driving out weaker local competitors, they deprive the region of opportunities for technological advancement.

3. Research agenda and data

3.1 Research Agenda

Growing emphasis on international sourcing within international companies in order to successfully implement global innovative strategies is profoundly influencing the pervasiveness of technology flows, both internally within international companies as well as externally between international companies and the local or global environment. Host economies will not remain unaffected by these changing international sourcing phenomena. This paper attempts to characterise in empirical terms how technology flows within and around different types of companies in Belgium, a typical host economy to foreign firms. The focus will be mostly on subsidiaries of foreign firms, though the headquarters of multinational firms will also be discussed[2].

We first characterise differences in innovative strategies of firms that are part of an international group. A firm can rely on a combination of different strategies to manage its innovation process and engage in innovation. More specifically, differences in technology acquisition strategies and differences in technology selling strategies will be examined. With respect to *technology acquisition*, firms can conduct R&D in-house and develop their own technology, which we see as the firm's **MAKE** decision. A second strategy is to acquire technology externally, the **BUY** decision. Within the BUY decision, a firm can acquire new technology that is embodied in an asset acquired, such as new personnel or (parts of) other firms or equipment. Alternatively, new technology can also be obtained disembodied, such as in blue prints through a licensing agreement or by outsourcing the technology from an R&D contractor or consulting agency.[3]

As part of its innovation strategy, the firm also decides on knowledge outputs through the *transfer of technology* to interested parties, which we see as the firm's **SELL** decision. Similarly to the BUY decision, a firm can transfer technology disembodied through licensing and/or R&D contracting. It can also be embodied through the sale of (part of) the company, the sales of produced goods or by skilled employees leaving the company. A more hybrid form of obtaining knowledge and developing new technology is through cooperative agreements between firms or other research institutions, **COOP**. We will consider an innovation strategy that includes collaboration as evidence of a firm's simultaneous buy and sell activities (see Teece (1992) and Mowery (1992)).

Mapping the innovation strategy of multinational firms generates the following research questions:

- Do international firms source externally? What are the important technology sources for headquarters and subsidiaries of MNEs? Are they national or international? Are they internal (within group) or external? Do subsidiaries of MNEs get their technology inputs from headquarters? From local external sources? From global external sources?
- Do international firms transfer technology? Are these transactions national or international, internal or external? Do subsidiaries transfer their know-how to headquarters or other parts of the company?
- Is the local economy benefiting from foreign subsidiaries through technology transfers? From which type of subsidiary is the local economy most likely to benefit in terms of local technology transfers?

[2] See Veugelers & Cassiman (2002) for a more detailed comparison of headquarters and subsidiaries with local firms and exporting firms.

[3] Another knowledge sourcing strategy is to absorb existing technology without any explicit involvement from the innovator. Freely available information or involuntary spillovers from innovators can be used by companies in their innovation process.

3.2 The data

The analysis draws on innovation data for the Belgian manufacturing industry that were collected as part of the Community Innovation Survey conducted by EUROSTAT in the different member countries in 1993. A representative sample of 1335 Belgian manufacturing firms was selected and the 13-page questionnaire sent out to them. The response rate was higher than 50% (748). The survey made it possible to identify companies based on their size and innovativeness, as well as on their international linkages: whether they belonged to an international group, with foreign or local headquarters. Besides questions on the motives and problems of innovations, it also contained questions on the importance of internal and external sources for innovation, the use of different mechanisms to acquire technology (nationally and internationally), the use of different mechanisms to transfer technology (nationally and internationally), and the use of collaboration in R&D with different types of partners (nationally and internationally)[4]. This makes it possible to empirically identify the different MAKE, BUY, SELL and COOP strategies for the different types of companies. Given the lack of available data at the project level, the decisions are studied at the firm level. Identification of the presence of an innovation strategy and whether this innovation strategy includes make, buy, sell or cooperate is based only on the extent to which these strategies have been used or not. Information on budgets was incomplete and unreliable. Hence, while this study uses direct survey evidence on the occurrence of technology acquisition and transfers, it cannot provide evidence on the size of these flows and their impact on other economic variables.

The companies in the sample could be identified by their international involvement: **SUB** if the company is a subsidiary of an international group. Within this classification, we will make a distinction between **FSUBs** that are subsidiaries with foreign headquarters and **BSUBs** that are subsidiaries of an international group with Belgian headquarters[5]. **HQ** when the company is the headquarters of an international group located in Belgium. 32% of the sample companies are subsidiaries, most of which are foreign (28%) and 4% of the sample companies are in the HQ category. This distribution is very typical for Belgium, which has few multinationals of its own but a pervasiveness of foreign affiliates.

With regard to industry distribution, foreign subsidiaries are over-represented in chemicals and electronics. Headquarters are mainly found in chemicals, (non-ferrous) metals and textiles. With almost two thirds in the category of >250 employees, headquarters and subsidiaries are over-represented in the largest size category. In line with industry distribution and size correlation, an international strategy is also strongly associated with innovation. All headquarter-type firms are innovative (i.e. claimed to have introduced new or improved products and processes between 1990-1992 and reported a budget for innovation), while 85% of subsidiaries are innovative. The latter figure confirms that affiliates are indeed active in the area of innovation, indicating that innovation appears as an important subsidiary-level function. It furthermore

[4] Questions on the use of different mechanisms to acquire and transfer technology, nationally and internationally, internallly and externallly, are only available in CIS-I. They are not included in CIS-II.

[5] Incorporating BSUBs with their HQ group did not significantly alter the results of the analysis.

remains to be investigated whether this subsidiary innovation derives from implementing existing centralised know-how or relies on locally generated know-how, a topic that will be analysed in the following section. In the remainder, the sample will be restricted to innovative companies only, since the survey only provides information on knowledge flows for this sub-sample.[6]

4. Results

Section 4.1 discusses innovative strategies for each type of international firm in terms of make, buy, sell and cooperate. The national versus international dimensions of technology flows through buy, sell and cooperate are detailed in section 4.2. The subsequent sections focus on technology transfers to the local economy. Section 4.3 includes the interaction between international know-how sourcing and transfers to the local economy, while Section 4.4 presents a typology of foreign subsidiaries on the basis of transfers to and from affiliated firms and its implications on local transfers.

4.1 Innovative strategies of multinational firms

Acquisition and Transfer of Technology

TABLE 1 **Innovative Strategies of Belgian Manufacturing Firms**

	TOTAL	HQ	SUB
N	*494*	*30*	*202*
MAKE	80%	100%	93%
BUY	74%	90%	81%
SELL	44%	83%	59%
COOP	44%	67%	61%

MAKE= innovative companies that have their own R&D activities and a positive R&D budget.
BUY= innovative firms acquiring technology through licensing and/or through R&D contracting and/or through consultancy services (DEMB) and/or purchase of another enterprise and/or hiring skilled employees (EMB).[7]
SELL= innovative firms selling technology through licensing and/or through R&D contracting and/or through consultancy services (DEMB) and/or purchase of another enterprise and/or hiring skilled employees (EMB).
COOP=innovative firms that collaborate in R&D, where both parties are actively involved.

At the firm level, innovative companies typically combine internal and external sources of innovation, witnessing the high percentage of companies making technology (80%) as well as the high percentage buying technology (74%)[8]. All firms that cooperate in R&D also have their own R&D activities.

[6] Of the total 494 innovative companies, 6% are HQs and 41% are SUBs (35% FSUBs and 6% BSUBs).

[7] We disregarded the “embodied” purchase of equipment, mainly because too many firms responded positively on this item. The reported results are not affected by the inclusion or not of purchasing equipment in the buy option.

[8] The fact that selling technology is complementary to buying technology can also be demonstrated by the following numbers: 40% of all innovative companies buy and sell technology at the same time, while 22% neither buys nor sells technology.

Compared with the total sample, firms belonging to international groups (HQ and SUB) have a significantly higher probability of having their own R&D. They are also significantly more active in acquiring and selling technology as well as in R&D collaboration. Hence, being part of an international group is mostly associated with combining internal and external sources for innovation. With the acquisition of technology elsewhere developed to such a pervasive extent among companies that belong to international groups, it remains to be investigated whether this external sourcing is local or global, a topic discussed in section 4.2. However, it is already important to note that 47% of headquarters reporting technology acquisition indicate internal acquisition within the group, while for subsidiaries this number is 56%.

In order to begin understanding whether Belgium gains from its openness, the other side of the transaction market should also be considered, namely the supply of know-how. The table shows that 44% of all innovative companies in the sample are engaged in transferring know-how. This number is considerably lower than the number of companies acquiring know-how, but varies for the different types of companies. 83% of headquarters are involved in transferring know-how. Subsidiaries, although comparable in size, are involved in transferring technology to a significantly lesser extent, though more than half of them are involved in know-how sales. These results should not surprise us given that headquarters are supposed to be more active in acquiring knowledge and transferring it to subsidiaries. Intra-company transactions are quite pervasive: 90% of headquarters that transfer technology report transferring technology to affiliated companies, while this percentage is 60% for subsidiaries reporting transferring to other group members.

Importance of external sources

While the analysis thus far has detailed how international companies actively access external sources, it remains to be examined how important these sources are in the innovative process of these companies. The CIS survey data make it possible to assess the importance of internal and external sources of technological information for innovative companies. The respondents were asked to rate the importance to their innovation strategy of different information sources for the innovation process on a 5-point Likert scale (from unimportant (1) to crucial (5)). The percentage of companies rating the various sources as very important to crucial (i.e. a score of 4 or 5) is reported in *Table 2*.

TABLE 2 **Sources of Information for the Innovation Process**
• % of firms rating source as very important to crucial

	TOTAL	HQ	SUB
INTERN	72%	87%	79%
INTGR	36%	37%	57%
LINK	45%	60%	45%
COMP	33%	47%	36%
SCIENCE	4%	0%	5%
GINFO	17%	33%	23%

INTERN: information within the company
INTGR: information within the group
LINK: information from vertically related firms (suppliers, equipment suppliers, customers)
COMP: information from close competitors
SCIENCE: information from research institutes (universities, public research institutes and technical institutes)
GINFO: freely available information (patent information, specialised conferences, meetings, publications, trade conferences, seminars)

Sources internal to the company (INTERN) are the most important source for innovation for all companies. The headquarters score particularly high on this item. Subsidiaries, given their comparable size, rate this source as less important compared with headquarters, although it is still their most important technology information source. In addition for subsidiaries, internal sources within the group (INTGR) are very important. This source is ranked second. For headquarters suppliers and customers are the second most important information source. These results correspond to Pearce & Singh (1992), who also found that 77% of subsidiaries indicated that their own ideas, approved by the parent, were a regular source of project concepts. Only 13% indicated suggestions from parent labs as being a regular source, though 70% rated them as an occasional source.

It is interesting to note the low level of importance of research institutes, with only 4% rating them to be very important or crucial. Although this source is never crucial, it is still moderately important. The percentage of companies rating this source at least moderately important (i.e. a score of at least 3) is, on average, 25%, though this percentage increases to 50% for headquarters. A sectoral differentiation is typical here, depending on the science-based nature of the technology used.

One mechanism through which external sources may be accessed concerns cooperative agreements. As reported in *Table 3*, disentangling different types of cooperative partners for the various firm types confirms the importance of intra-group collaboration for headquarters and subsidiaries. For subsidiaries, this is the most important type of cooperative agreement, matching the importance of intra-group information sources. The importance of intra-group collaboration for headquarters confirms the fact that cooperative agreements perform an important knowledge transfer function within the MNE. Research institutes are, somewhat unexpectedly, important cooperative partners - especially for the headquarter firms-, which does support their - albeit only moderate - importance as an external source, cf. supra.

TABLE 3 **Cooperative Agreements by Type of Partner**

	TOTAL	HQ	SUB
%COOPLink	28%	50%	38%
%COOPComp	7%	13%	8%
%COOPScienc	28%	57%	39%
% COOPIntgr	24%	53%	47%

COOPLink: at least one cooperative agreement with suppliers or customers
COOPComp: at least one cooperative agreement with competitors
COOPScienc: at least one cooperative agreement with universities, public or private research institutes
COOPIntgr: at least one cooperative agreement within the group

To summarise, internal and external information sources are important to subsidiaries. Nevertheless, their higher share of inside-group sources and their lower share of inside-company and external sources in comparison to headquarters suggest that the role of subsidiaries in generating global innovations is, on average, not very pervasive in the Belgian economy. Along with Frost (1998) and Pearce & Singh (1992), these results support the importance of headquarters for subsidiaries, while the evidence of transfer of know-how from subsidiaries to headquarters is more limited. The lesser importance of science as a source of information indicates that, on average, the Belgian science system does not seem to be a crucial location factor for subsidiaries on average.

4.2 National versus International Innovation Strategies

Given that information exchanges are an important element in the innovation strategy of multinational firms, it remains to be investigated whether these exchanges are national or international. This should reveal the directionality of these information flows, which is important for local policy-makers attempting to maximise the knowledge in-flows through MNEs. We are in a position to analyse which type of firms is more likely to generate these kinds of information flow.

National versus International Technology Acquisition

When buying technology, both national and international sources are used, though international transactions are used more than national transactions. *Table 4* presents the results. On average, 57% of companies buy technology internationally, versus 53% nationally. Headquarters display the highest frequency of technology buy transactions, nationally as well as internationally. It is interesting to note the position of subsidiaries. Foreign subsidiaries buy relatively less technology nationally (50%) and relatively more internationally (76%). For every 2 foreign affiliates that buys technology nationally, there are 3 foreign affiliates that buy technology internationally, the highest ratio among all types of companies.

TABLE 4 **National and International Technology Acquisition and Sale**

	TOTAL	HQ	SUB	
			FSUB	BSUB
%BUY NAT	53%	67%	50%	55%
%BUY INAT	57%	80%	76%	66%
%SELL NAT	17%	13%	17%	31%
%SELL INAT	39%	77%	56%	69%

The national-international ratio can be further detailed for the different modes of technology purchase. The most internationally oriented are licensing: for 1 company buying licenses nationally, there are 5 companies buying licenses internationally. For personnel mobility, the opposite holds: for every 2 internationally transacting companies there are "only" 5 nationally transacting companies. Hence, know-how acquisition through personnel mobility is the most localised.

In conclusion, although a majority of companies acquire technology nationally, local embeddedness should not be over-rated since international technology acquisition is even more prevalent, especially disembodied technology acquisition through licensing. Only embodied acquisition through personnel mobility has a more distinctly national orientation. The international orientation of external sourcing is more pronounced for the headquarters and subsidiaries of foreign companies. In the case of foreign subsidiaries, this result puts the importance, on average, of local external technology sourcing as a motive for foreign presence through embedded affiliates in Belgium in perspective. The high percentage of international technology acquisition for headquarters suggests that having their own affiliates abroad is conductive to acquiring technology internationally.

Internal versus External International Technology Acquisition

In order to better understand the role of international technology acquisition in the innovative strategies of affiliates, it is important to assess the extent to which these international flows are received from within the company, typically the headquarters, or are obtained externally from third parties. The survey data makes it possible to assess, for companies belonging to an international group, whether international acquisition is internal within the group or not. 42% of headquarters that acquired technology internationally reported internal acquisitions within the group, i.e. transfers from subsidiaries to headquarters. This indicates the importance for headquarters of having a network of foreign subsidiaries when sourcing technology internationally. 66% of foreign affiliates located in Belgium and acquiring technology from abroad indicated international internal transfers within the group, from sister or, typically, parent companies. The higher percentage of internal acquisition for subsidiaries compared with headquarters underscores, in line with Frost (1998), the importance of headquarters or other leading sister companies as a source for innovation within subsidiaries located in Belgium.

National versus International Technology SELL

Table 4 shows that selling technology to the local market is relatively less frequently reported. Only 17% of innovative companies have transferred technology locally, while 39% transfer technology internationally. Nevertheless, it is interesting to note that local technology transfers by Belgian subsidiaries are significantly higher. However, we should consider that 74% of these subsidiaries transfer technology internally within the group.

Detailing the channels that are used most often to transfer know-how, we find that, for international transactions, consulting is used most frequently, followed by personnel mobility, informal contacts, licenses and R&D contracts. The selling of companies and equipment is of minor importance to transfer technology. In the case of national transactions, personnel, consulting and informal contacts are used most frequently. There are no significant differences in the relative importance of these channels according to the type of firm. However, all these channels are used more often by firms belonging to an international group.

Internal versus External International Technology Transfer

Given this strong prevalence of international know-how flows in international groups, it is interesting to check whether these transfers remain within the group. 91% of headquarters that transact technology internationally report that they transfer technology internationally within their group. For foreign subsidiaries this is 81%. This again reflects the importance of internal transfers crossing national boundaries within MNEs. At the same time, however, it once again confirms the less intense transfers of know-how from subsidiaries to headquarters compared with the flows from headquarters to subsidiaries. Nevertheless, we find that Belgian subsidiaries play an important role for foreign sister companies, consistent with an innovation strategy of the subsidiary that is globally linked.

National versus International Collaboration

Although the evidence of geographical proximity in technology sourcing appears not to be very strong for foreign subsidiaries, there are other modes through which companies can access externally available know-how. Cooperating in R&D is increasingly used as a mechanism to exchange technology externally. The survey makes it possible to check whether partners in collaboration are national or international, affiliated companies or independent third parties.

Table 5 reveals that most companies, especially those belonging to an international group, combine national and international collaboration. It is interesting to note that headquarters tend to be engaged in cooperative agreements to a greater extent than subsidiaries.

TABLE 5 **National and International Cooperation by type of partner**

	TOTAL	HQ	SUB	
			FSUB	BSUB
%COOP NAT	**36%**	**57%**	**53%**	**55%**
% COOP NAT link	26%	50%	35%	45%
% COOP NAT science	21%	47%	28%	38%
% COOP NAT comp	6%	13%	6%	14%
% COOP NAT intgr		37%	35%	38%
%COOP INAT	**32%**	**60%**	**49%**	**52%**
% COOPINAT link	14%	33%	19%	17%
% COOPINAT science	18%	37%	24%	38%
% COOPINAT comp	2%	7%	2%	7%
% COOPINAT intgr		40%	27%	31%

The type of partner differs between national and international R&D cooperative agreements. The largest category of external partners for international alliances comprises research institutes, with 18% of companies having international alliances with research institutes. 26% of innovative companies have national alliances with vertically related partners, while only 14% of companies have international vertical alliances. The national orientation of alliances is highest for vertical alliances and lowest for research: for 1 company with an international vertical alliance there are about 2 companies with national vertical alliances. For research, the ratio is 1 to 1. This indicates that geographical proximity might be more important for a cooperative agreement with suppliers or customers, while the market for research partners is more internationally oriented.

Although more than one third of foreign affiliates active in innovation have vertical alliances with national partners, foreign affiliates have the lowest share of local vertical partners in national collaboration: 67% of nationally cooperating foreign subsidiaries have vertical partners, while this figure is 88% for the headquarter category. Similar results hold for national collaboration with research institutes, i.e. 28% of innovative foreign affiliates collaborate with research partners locally, compared with 47% for headquarters. So, once again, we find, on average, little evidence of MNEs using foreign affiliates to access the local science system in Belgium.

For companies belonging to an international group, collaboration with affiliate firms is quite pervasive. In the case of foreign subsidiaries, affiliated companies are the most frequent partners, especially in international collaboration, reflecting that these subsidiaries do have a function in globally linked innovations within the group.

To summarise, Belgian headquarters are very active in national as well as - and to the same extent - international alliances and this with several different types of partners: vertically related firms, research institutes and affiliates of the same international group. Foreign affiliates are also active in alliances, and to a somewhat greater extent in national than international alliances, with a larger share of affiliated companies as partners. All this seems to suggest that, foreign affiliates located in Belgium, have a "contributing" role in their parent's global innovative strategy, with specific tasks for globally-related innovation projects. A key point for the local economy is that technology transfers to the local economy are more likely to occur through cooperative agreements than through technology sell transactions. If these alliances were effective mechanisms through which technology is diffused, the Belgian economy might stand to gain substantially from its openness through exploiting collaboration, since subsidiaries and headquarters, in particular, have a very high frequency of national alliances.

4.3 International Innovation Inputs and Host Economy Benefits

If multinational firms are important sources of technology transfer to the host economy, what makes them so interesting as source? Is it because they have a larger internal know-how base and/or because they have easier or better access to international technology markets? To start answering these questions, we need to map international acquisition with national transfers of know-how.

TABLE 6 **International Technology Acquisition and National Technology Transfer**

	TOTAL	HQ	SUB	
			FSUB	BSUB
Firms Innovating	*494*	*30*	*173*	*29*
% SELL NAT	17%	13%	17%	31%
% COOP NAT	37%	57%	53%	55%
Firms Buying Internat	*280*	*24*	*131*	*19*
% SELL NAT	23%	17%	20%	32%
% COOP NAT	49%	58%	59%	68%
Firms COOP INAT	*156*	*18*	*84*	*15*
% SELL NAT	19%	22%	24%	40%
% COOP NAT	85%	89%	86%	87%

Companies that buy technology internationally, either directly or through international cooperative agreements, are more likely to transfer know-how nationally through the sale of technology, in particular through national cooperative agreements. Similarly, firms that collaborate internationally are more likely to sell nationally and collaborate nationally. The case of national collaboration is especially striking, with 85% of the companies that collaborate with international partners also collaborating with national partners. Given that international technology sourcing is positively associated with local technology transfer, hosting multinational firms is favourable for technology transfers, certainly when firms that are part of a multinational group have a higher probability of buying technology internationally as well as cooperating internationally.

To summarise, these results seem to suggest that Belgium benefits from its openness through technology transfers to the local economy from multinational firms. An important dimension in this regard is the access to international technology markets, which MNEs enjoy. The local economy is likely to gain from internationally operating firms, but only to the extent that these firms have a higher probability of sourcing technology at international level. It is only through a higher probability of international technology sourcing that these firms have a significantly positive effect on the probability of local transfers through local collaboration[9].

4.4 Internal Transfers within MNEs and host economy benefits

Does the Belgian economy benefit from the technology transfers received internally by foreign affiliates located in Belgium? What is the impact of internal transfers generated by the subsidiary to its foreign parents on the local economy? Zeroing in on the foreign subsidiaries only, the information available in the survey on internal transfers of information within multinational groups makes it possible to classify foreign subsidiaries according to their role in the MNE's innovative strategies, more particularly whether they receive and/or generate internal transfers. Once subsidiaries have been identified according to this role, the classification can then be helpful to assess which types of foreign subsidiaries are most attractive for the host economy in terms of generating technology transfers.

The 160 subsidiaries with own R&D capacities (MAKE) can be classified according to whether or not they receive know-how from within the group and/or whether they generate know-how transfers to the group. About 31% of foreign subsidiaries do not receive transfers or generate transfers to the group. These are *independent* or *autonomous* subsidiaries. These affiliates, quite important in number, may be older, longer established subsidiaries that have traditionally built up an independent local innovation strategy. The largest group of foreign affiliates (39%) is the one which comprises affiliates who simultaneously receive and generate internal know-how transfers (*integrated* subsidiaries). The two-way internal flows in which they are engaged could indicate a leading role in globally linked innovations, as well as a contributory role, with specific tasks in innovations developed elsewhere in the company[10].

An important question from a policy point of view is to find out which type of subsidiary is most attractive for the host economy in terms of being able to absorb most know-how from the group. Having classified subsidiaries according to their role in global innovations, it remains to be analysed whether different types of subsidiaries might differ in external technology transfers to the local economy. *Table 7* presents these results.

[9] In a companion paper, Veugelers & Cassiman (1999) confirm these findings using a fully specified econometric analysis.

[10] The *integrated* subsidiaries have the highest score, both in relation to the importance of internal sourcing and inside-group sourcing, given that internal sourcing is typically more important than inside-group sourcing. This profile on both internal and inside-group sourcing underlines the active, but integrated innovative role for this type of subsidiary. For *independent* subsidiaries, the internal sources should clearly be dominant. Indeed, the difference in average importance between internal and inside-group sources is greatest for this type of company. Another important mode through which know-how transfers can materialise are cooperative agreements among affiliated companies. Consistent with the classification, we find independent subsidiaries to be engaged least of all in such alliances and the integrated subsidiaries the most involved.

TABLE 7 **Internal Technology Transfers and National Technology Transfers**

	%SELLNAT	%COOPNAT	%BUYNAT
All Innovation Active FSUB	*17%*	*53%*	*50%*
Integrated FSUB Transferring TO & FROM Group (39%)	25%	62%	55%
Independent FSUB NOT Transferring TO nor FROM Group (31%)	4%	42%	46%

The integrated affiliates have a higher propensity to transfer technology to local partners. In combination with the high frequency of allying with local partners, these companies represent an important source of accessible know-how for the local economy. At the same time however, these integrated affiliates have the highest frequency of buying technology locally. The independent subsidiaries are least involved in local technology transfer. The independent subsidiaries, for which this lack of local selling comes on top of the low propensity to ally locally, are therefore the least interesting for the local economy in terms of know-how transfers. Furthermore, they are less actively engaged in accessing external local know-how, which means that the independent affiliates under-utilise collaboration with local partners, and are less involved in the buying of local technology. Hence, the subsidiaries that operate independently of the group - although they are actively involved in innovation - appear to be not only independent of their group, but also independent of external local sources in general.

5. Conclusions

The EUROSTAT/CIS-I survey results for Belgium indicate that companies belonging to an international group as affiliates or headquarters are highly active in the area of innovation and rely on internal as well as external sources for such innovation. Internal inside-group transfers and intra-group collaboration are quite pervasive in these companies. In addition, they access external sources located not only nationally but also internationally through various technology buying strategies as well as cooperative R&D agreements.

Nevertheless, the evidence available concerning the difference between headquarters and affiliates in their frequency of internal international buying and selling, plus the importance of intra-group sourcing, suggests, in line with previous studies, that transfers from headquarters to subsidiaries are more frequent and important than the reverse flow from subsidiaries to headquarters.

An important result for the host economy is that transfers to the local economy are more likely to come from firms buying technology and cooperating internationally. As a consequence, the local economy is likely to gain from MNEs in terms of local technology transfers, as long as these firms have access to international technology markets. When integrated into the multinational innovative process, foreign affiliates receiving internal know-how are also more likely to generate local transfers and collaborate with local partners. Those affiliates that operate the most independently within their multinational structure are also less likely to transfer know-how locally or collaborate locally.

This result suggests that a trend towards subsidiaries playing a more integrative role in multinational innovations is not necessarily detrimental to the host economy, at least in terms of being able to benefit from the spillovers of this know-how.

Before the results of this study are moulded into firm conclusions for the innovative strategies of MNEs and the host government's policy towards MNEs, more work is needed to test the robustness of these results. The analysis should be extended beyond whether know-how flows occur or not in order to include assessment of the efficiency of such flows, as well as their impact on innovative performance and growth of local firms. Furthermore, the EUROSTAT CIS-I data allow us to compare results across EC countries. This would facilitate identifying possible host market characteristics such as regional technological absorptive capabilities that might influence the results.

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