NATIONAL INNOVATION SYSTEMS

PILOT STUDY OF
THE BELGIAN INNOVATION SYSTEM

Study carried out for the
Belgian Federal Office for Scientific, Technical and Cultural Affairs (OSTC) in the context of the OECD Working Group on Innovation and Technology Policy

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1. Introduction

A number of reasons concur to place the study of national systems of innovation high on the agenda of the authorities of OECD countries, and of course also of Belgium. First there is the changing international economic environment. With European integration reaching the stage of a single market and a monetary union, the degree of openness of the EU-countries, and indeed also of the countries in the wider OECD context, has made a qualitative leap. As a result, their governments have become more attentive to issues of international competitiveness and to identifying the determinants of the latter. Research along the lines of the technological gap approach of international trade provided already some quite substantial and robust results and contributed to the more general acceptance of the idea that the technological factor, rather than cost factors, is the driving force behind the competitiveness of nations. The fact that the rate of technological progress today seems to be higher than in the past, and governments therefore have to be more alert than ever when formulating and implementing their S&T policy only emphasises this first point.

The second reason concerns the *systemic* character of national innovation systems. One could indeed argue that this particular feature of the 'technological' part of the economy has become more prominent as the result of a number of relatively recent phenomena. The first one is the phenomenon of globalisation. With markets becoming larger, communication becoming swifter, deregulation continuing and internationally operating firms tending to grow beyond optimal physical scale, networking between firms becomes more important, especially with respect to R&D. Dunning uses the term 'alliance capitalism' to describe this new phase of developed economic systems (Dunning, 1997). A main feature of this 'alliance capitalism' is the coexistence of competition, sharpened by globalisation and liberalisation, with an increasing number of network relations of R&D co-operation and strategic alliances. Carlsson and Jacobsson (1997, p. 271), following Håkansson (1989), give a rationale for this. Technological networks, through the reciprocal flow of information, result in a 'blending of visions' on the future technological evolution of markets. This leads to a reduction in perceived risk and to a better co-ordination of investments. Innovation and diffusion turn into a collective action. Networking becomes a substitute for scale increases. The second phenomenon which has accentuated the systemic aspects of national innovation systems concerns the R&D policy pursued by the EC. The linear causal model of innovation in which fundamental scientific research leads to the actual implementation of new technologies in production and the introduction of new products on the markets for final goods, over applied technology research, first industrial prototypes and upscaling, was indeed taken as inspiration by governments, and more in particular also by the European Commission. Their aim was to promote liaison functionality through cross-national funding of pre-competitive research jointly undertaken by firms, universities and research laboratories (the Framework programmes), and the stimulation of 'near-market' research (the EUREKA initiative). In doing so they acted as a powerful catalyst in turning this same linear structure into a systemic (network) structure.

The third reason is specific for Belgium. Belgium is a country with a highly educated and industrious population and is located in the economic centre of Europe. These are important advantages. In order to understand properly the specificity of its NIS one has however also to take account of three major characteristics of this country which cannot from all points of view be considered as beneficial: its *early* industrial development following the lead of Great Britain, its geographical location on horseback of the Latin and Germanic culture and its small

size. These three properties each have, as we shall demonstrate in this report, specific consequences for the structure of the NIS and the S&T policy of the government.
Especially the spatial component of the innovation process will call for our attention. Feldman (1996) has shown that innovative activities tend to cluster spatially and that location matters. In the same vein, others have drawn the attention to the existence of technological districts and innovative ‘milieux’ which have played and continue to play a central role in the dynamics of world competition (Castells and Hall (1994)). Furthermore, a trend towards the regionalisation of research and development policy has been observed over the last decade. In some countries regional initiatives have become the cornerstone of national science and technology policy. Indeed, regional incubator centres, science and technology parks, 'technopoles' and technology transfer centres have proliferated in all the industrialised countries. At the European level the regional dimension of science and technology policy has become a main aspect of the action aimed at reinforcing economic and social cohesion. The increasing importance of regions in science and technology policy is however a challenge for the coherence of national innovation systems and, consequently, there is a need for national governments to co-ordinate regional action in the field. To conclude, given that Belgium is a federal state, *both* the federal and regional authorities are central actors of the NIS. In order to have a clear understanding of the Belgian NIS, it is therefore important to look at the regional components of the innovation process (see also Lundvall (1992)).

The text of this pilot study, although by its very nature focussing on the systemic as opposed to the ‘linear’ aspects of the relations between R&D, technology, innovation and economic performance, has a linear structure.
In the second chapter we study the *institutional setting* and devote, in the light of what preceded, much attention to it. It is indeed natural to begin the analysis of the Belgian innovation system by describing the institutional framework which supports the innovation process. We continue with the *inputs* in the technological system. Chapter 3 discusses the structure of R&D expenditures at both the global, i.e. macro-economic, and sectoral levels. A quantified content is given to the main private and public actors of the Belgian NIS. This chapter also includes an examination of the Belgian position with regard to the formation of university graduates. We continue on the same subject in the next chapter, but examine R&D expenditures this time at firm level. The chapter gives some important complementary pieces of information on the orientation of R&D and its distribution according to firm size. It also deals briefly, as a bridge to the next part of the report, with the extent and the nature of collaborations. Chapters 5 and 6 deal with *diffusion* aspects. In chapter 5 we successively deal with international technology transfers in the form of exports and imports of technology-intensive goods and in the form of foreign direct investment. We also examine the structure of the balance of technology payments and trade specialisation patterns. A final section is devoted to the Belgian participation to European networks. Chapter 6 goes deeper into this last subject and deals with diffusion in the form of joint R&D projects and R&D alliances between firms. The methodology which is used is based on the techniques of social network analysis. The *outputs* of the NIS are studied in chapter 7. We start with ‘first level’ outputs (patents, scientific publications and trademarks), and continue with ‘second level’ outputs, i.e. we study the relation between technological performance and economic performance.
Chapter 8 contains the *conclusions* as well as a number of *recommendations* directed towards public actors of the NIS. The recommendations are focused on some lines of action which could help policy organisations to correct the mismatches detected in the analysis.

2. Institutional Profile

2.1. Introduction ([1])

The Belgian institutional framework and its relation to the national innovation system is quite complex. The Belgian organisation of scientific policy was given its first impulse in 1928 with the creation of the National Foundation for Scientific Research (NFWO/FNRS). A second important stage was attained in 1947 with the creation of the Institute for the Encouragement of Scientific Research in Industry and Agriculture which laid the foundation of technology policy (IWONL/IRSIA). In 1959, the organisation of scientific policy was improved by the creation of a number of central consultative organs, i.e. the National Science Policy Council, the Interministerial Science Policy Council and the Ministerial Science Policy Council. Since 1968, first a State Secretary and then a Science Policy Minister were appointed whose actions were co-ordinated by a specific administration, the Scientific Policy Planning Services (DPWB/SPPS). The continuing federalisation of the Belgian State eventually led to a state reform in 1980 which recognised, among other things, own regional competence in the field of applied scientific research. In 1989, a further step in the reform of the state was taken, which retroceded the Ministry for National Education to the French-speaking and the Dutch-speaking Communities and further extended the ’community’ and regional authority in the field of science and technology policy.

Since 1993, Belgium consists of a Federal Government and lower-level entities (regions and ’communities’) with specific authority with regard to the S&T policy and connected fields. The ’federated’ entities are the Flemish Community, the French-speaking Community, the German speaking Community, the Flemish Region, the Region of Brussels-Capital and the Walloon Region. The three Belgian Communities which are based on language differences, correspond to population groups. The establishment of the three regions on the contrary, is inspired by economic concerns ([2]). To some extent Belgian regions are now similar to American States or German ‘Länder’. A major question in the analysis of the Belgian innovation system is to disentangle to what extent it is still really national, or if it is becoming increasingly and irreversibly regional.

Each federated entity has its own political, administrative and consultative structure. The management of the Belgian S&T policy is jointly assumed by these several partners in accordance with their respective areas of authority. The general support to industrial and technological research falls within the authority of the regions, while the 'communities' provide support for fundamental research, in particular research carried out by the universities. The Federal Government has competence on the necessary research to support its own functions, i.e. the data exchange networks operating among scientific institutions at the national or international level, the research and public service activities of the remaining federal scientific and cultural institutions, space research, and - according to the rules laid down by co-operation agreements with the 'federated' entities - all programmes and activities requiring a uniform implementation at the national or international level, including the permanent inventory of the scientific potential of the country, and Belgium’s participation in the activities of international

[1] Some material presented in this chapter is based on or updates the COPOL report by Fagianelli (1994).
[2] Evidently regions and communities to a large extent overlap. The Councils and Governments of the Flemish Region and the Dutch-speaking Community have therefore merged to form a single Flemish Council and Government respectively. This merged entity is named the ‘Flemish Community’.

research bodies. The Federal Government can also take initiatives, create structures and provide financial means for scientific research in matters that fall within the authority of the 'federated' entities, if acting on the basis of an advice expressed by the Federal Council for Science Policy. These matters are either covered by international or supranational acts or agreements, or relate to activities and programmes going beyond the interests of a 'community' or a region. Each 'federated' entity may decide not to participate in a federal initiative of this kind. Finally, and more generally, the law allows the Federal State, the Regions and the Communities to sign co-operation agreements among each other relating to the creation and joint management of joint services or institutions, the joint exercise of their own powers or the development of joint initiatives.

In addition to these public authorities, the core of the Belgian Innovation System is composed of 40 higher education institutions (HEIs), 170 public or non-profit-making associations active in the field of S&T, and about 1400 enterprises known to be performing R&D activities or connected S&T activities ([3]). An overview of the Belgian S&T institutional profile is given in Figure 2.1 ([4]). Section 2.2 discusses the political, administrative and advisory structure of the Federal Government as well as of the 'federated' entities. Sections 2.3 to 2.5 are mainly concerned with a description of the most important public S&T institutions as well as organisations with significant links to S&T activities. Section 2.6. presents the Belgian S&T policy framework, with a particular emphasis on diffusion-oriented policies and the development of networks and bridging institutions. The main functions carried out by the actors in the NIS as regards S&T activities are summarised in the last section.

2.2. The political, administrative, financing and advisory structure ([5])

2.2.1. The Federal State

The Council of Ministers is the highest authority deciding on the major options of the Federal Government as regards science policy.

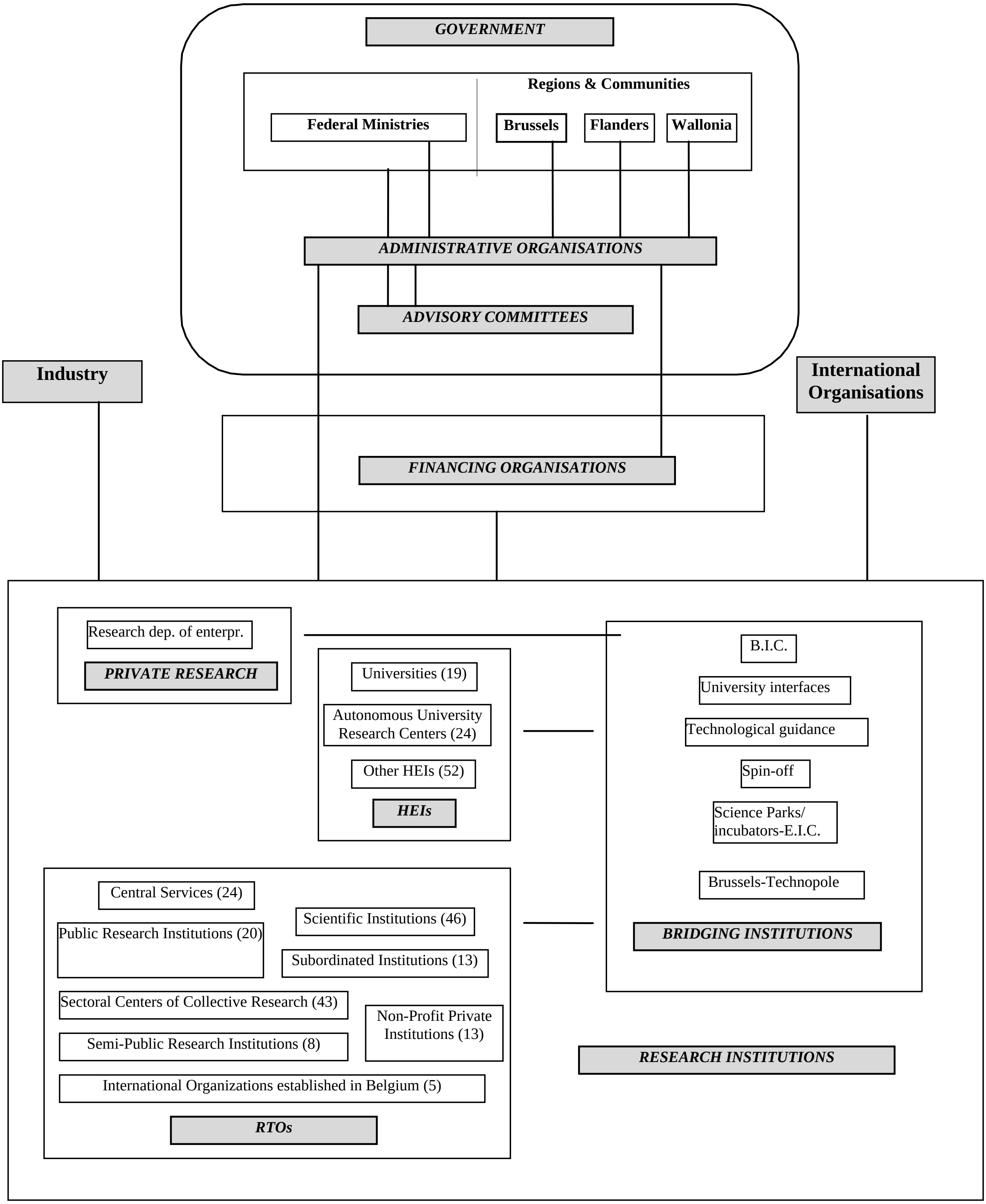
In addition to the activities for which he is directly responsible, the Minister for Science Policy also has a co-ordinating role with respect to the general guidelines and the implementation of the science policy of the Federal Government. The functions of various other Ministers may also include activities relating to research and scientific public services connected with matters falling within their competence.

Administratively attached to the services of the Prime Minister and placed under the control of the Minister for Science Policy, the Office for Scientific, Technical and Cultural Affairs (OSTC) carries out horizontal co-ordination and programming tasks at the federal level. It also prepares and conducts various research activities falling within the competence of the Federal State.

[3] DPWB (1996).
[4] See also the Appendix.
[5] Institutions documented in boxes serve as important examples.

The other federal departments managing major research budgets are: Economic Affairs, Agriculture, Development Co-operation, National Defence, Public Health and Environment.

FIGURE 1. BELGIAN INSTITUTIONAL PROFILE



The Interministerial Science Policy Commission (ICWB/CIPS), following ministerial instructions, co-ordinates the preparation and implementation of governmental decisions requiring concerted action by two or more federal departments. The CIPS consists of senior civil servants from those federal ministerial departments which include scientific activities among their functions. It is chaired by the General Secretary of the OSTC and its secretariat is run by this Office. An important task of the CIPS is to prepare the annual outline of the Interdepartmental Science Policy Budgetary Programme, which centralises and decides on the proposed budgetary allocations to the various federal ministries of research and scientific public service means.
At the administrative level, there are two commissions dealing with the internal affairs and the international affairs respectively: the Federal Co-operation Commission (CFS) and the International Co-operation Commission (CIS).
An advisory body, the Federal Council for Science Policy is responsible for advising the Government on the broad lines of science policy. It is assisted by the OSTC, which runs the secretariat, and consists of prominent personalities from scientific, university, economic and social circles. The 'communities' and the regions are represented in this council.

Traditionally, Belgium uses a wide range of methods for the allocation of public research appropriations. Some of these are made directly available for research by the administrations, some indirectly through independent funds or financing institutions. The latter decide themselves how these appropriations are to be used. Many of these financial institutions operate at the regional level.

The National Fund for Scientific Research (FNRS/NFWO) is a private establishment of public utility created in 1928. In 1992, the Statutes were adapted in line with the new reality resulting from the reform of the State. Following this modification, the FNRS remains a national institution but its two main parts, the Flemish (FWO) and French-speaking part (which continues to use the old denomination FNRS), are independently administered by two separate boards. The latter manage and allocate the resources released by their respective 'community', together with resources allocated by the Federal Authority and transferred by the National Board.
This leads us to the institution falling under the authority of the 'federated' entities.

2.2.2. The ’federated’ entities

• The Collective Basic Scientific Research Fund on Ministerial Initiative (FRSFC-IM)
Every year, budgetary means are included in the budget of the Community Ministers who have education among their responsibilities, with a view to finance various scientific research programmes without immediate application objectives. The programmes are annual and the higher education and scientific research administrations negotiate contracts with their promotors in a similar way as with the procedure for the FRSM and the IISN. In the Flemish Community, FRSFC-IM research contracts cover pedagogical research in the short and medium term, to enable policies to be evaluated and defined. In the French-speaking Community, all fields are eligible, apart from research in medicine and nuclear sciences, for which two separate funds exist (the FRSM and the IISN), agricultural research and, in general, those fields where other Ministries can intervene.

2.2.2.1. The Flemish Community

The Minister-President of the Flemish Government is responsible for the science policy of the Flemish Community. The activities falling directly within his competence as Minister for Science Policy are co-ordination and co-operation activities, multisectoral activities (in conjunction with other Ministers concerned) and activities in support of sectoral scientific policy. Moreover, each member of the Flemish Government has authority on the sectoral science policy activities connected with the matters assigned to him.

The Administration for Science and Innovation (AWI) has the general co-ordination of science policy as one of its functions, both at the level of the Flemish Community and in the context of federal and international co-operation (European in particular), together with tasks relating to studies, analyses and research inventories.

• The Scientific Research Fund (FWO)
The F.W.O. was founded in 1928 as an Institution of Public Interest for the support of scientific research, at the initiative of King Albert I. In 1992 the Fund receives a federal structure and since then, the Flemish Board of Trustees has fully autonomous power of decision. The F.W.O. encourages and finances fundamental scientific research in universities of the Flemish Community and in institutions for scientific research. The activities of the F.W.O. aim to expand the frontiers of knowledge in all fields of science including humanities. The F.W.O. endeavours to achieve its purpose by training and supporting researchers, supporting prominent research teams, by promoting national and international scientific contacts and co-operation and by awarding scientific prizes. The FWO is managed by representatives of the Flemish universities, the Flemish and national authorities and the Flemish socio-economic world. The FWO is funded by the Flemish Community, the federal Government and patronage.

• The Administration for Science and Innovation (AWI)
AWI is the central administration for the Flemish Science Policy, created in 1990. It comes under the Department for Science, Innovation and Media of the Flemish Community. Its main task consists in the preparation, the implementation, the co-ordination and the support of the Flemish minister for Science and Technology’s policy. Furthermore it supports the Flemish Government’s policy in Federal and International deliberative bodies. AWI co-ordinates and promotes actions for scientific information and follows the evolution of science and technology. It is entirely financed by the Flemish Community.

• The Flemish Institute for the Promotion of Research in Industry (IWT)
The IWT is the institution, created in 1992, that is responsible for the implementation of the Flemish Minister for Science and Technology's policy towards the industry, especially with regard to the promotion of scientific research in agriculture and the industry. Its main task is to finance R&D (basic and applied) in companies and research institutions on its own initiative ('autonomous function') or as part of specific programmes on initiative of Flemish authorities ('advisory function'). Some programmes are tailored to SMEs. The IWT also provides services with regard to the diffusion and transfer of technology, the participation and the valorisation of R&D results. IWT is entirely financed by the Flemish Community.

An advisory body, the Flemish Council for Science Policy (VRWB) presents opinions and proposals to the Flemish Government, either at the request of the latter or on its own initiative. The VRWB consists of representatives of institutions and scientific research bodies, on the one hand, and socio-economic circles on the other.

• The Flemish Council for Science Policy (VRWB)
VRWB is the main Flemish advisory body. It operates since 1995 and its 16 members are nominated by the Flemish Interuniversity Council (VLIR), the Social Economic Council of Flanders (SERV) and the minister for Science and Technology. They are appointed by the Flemish Government. The Council formulates recommendations, requested or on its own initiative, with regard to all matters of the Flemish Science and Technology policy.

The Royal Academy for Sciences, Literature and Fine Arts and the Royal Academy for Medicine are two other institutions with advisory activities.

• The Royal Academy for Sciences, Literature and Fine Arts (KAWLSK)
This Academy was created in 1938 for the stimulation of Sciences, Literature and Fine Arts in the at the time unitary Belgium. At present the Academy is under tutelage of the Flemish Minister for Education and it advises the Flemish Government in all matters related to sciences, literature and fine arts. Through publications, colloquia and readings the Academy aims at the co-operation between scientists in different disciplines on the Federal and international level.

• The Royal Academy for Medicine (KAG)
The Royal Academy for Medicine was also created in 1938 and at present is under tutelage of the Flemish Minister for Health Service. It advises Federal and regional authorities with regard to matters of medical sciences, education and medicine in general. The academy organises public meetings and publishes scientific work.

2.2.2.2. The French-speaking Community

Within the Government of the French-speaking Community, the Minister in charge of higher education is also responsible for scientific research. The Community essentially exercises its authority within the field of university and basic research. The other Ministers also have competence on science policy activities connected with their particular areas of authority such as health, socio-cultural matters, sports and tourism.

The Directorate General for Higher Education and Scientific Research (DGESRS) is responsible for implementing the science policy of the Community. Among other things, it handles the financing of the university institutions, the non-oriented scientific research funds (FNRS and associated funds) and the concerted research activities. The DGESRS also carries out all the co-ordination and co-operation tasks involved in the field of science policy, both for the Community itself and at federal and international level.

• The Fonds National de la Recherche Scientifique (FNRS)
The Fund supports researchers personally by awarding grants, either while they prepare their theses in the case of degree candidates or throughout the subsequent period in the case of research team leaders. It also provides permanent remuneration for qualified researchers, scientific research workers and research managers. These researchers are closely associated with the educational and scientific work of universities. In addition to these individual mandates, the F.N.R.S. grants research credits as well as allowances intended to cover the costs of stays in foreign countries and attendance at overseas conferences. It also provides financial assistance for the organisation of seminars or symposiums and promotes the formation and activities of contact groups between researchers from universities in the French-speaking Community of Belgium on the one hand and their foreign counterparts on the other. Finally, the National Fund awards prizes for achievement in the field of research. Three associated Funds (I.I.S.N., F.R.S.M., F.R.F.C) support research programmes undertaken by teams, assuming responsibility for personnel costs and making available to order them equipment, sometimes of a very expensive nature; the fourth associated Fund (F.R.I.A.) awards grants to university graduates aiming to make a career in industrial or agricultural research. The resources available to the F.N.R.S. and its associated Funds consist of subsidies granted to them by the French-speaking Community and by the federal state. Public bodies exercise a close control over the use of the financial means provided by them. The F.N.R.S. also appeals for private aid which it distributes within the scientific community according to the same criteria of excellence.

2.2.2.3. The Region of Brussels-Capital

The Government of the Brussels-Capital Region has made its Minister for Economic Affairs responsible for scientific research with economic objectives. Research with non-economic objectives is managed by the Secretaries of State under the Minister-President of the Government and the Minister for Economic Affairs.

At the administrative level, research management is in the hands of the Research and Innovation Service (SRI), located within the Economic Affairs and Employment Services. The technical management of the dossiers is delegated to the IRSIA, a federal semi-public body.

• The Research & Innovation Service (SRI/DOI)
The SRI provides assistance to research and innovation activities of companies, in particular SMEs (subsidies for basic industrial research, 'prototype' advances relating to the industrial R&D, subsidies for participations in European Research programmes).

The creation of an Advisory Council for Science Policy is currently under discussion at legislative level.

2.2.2.4. The Walloon Region

The main responsibility for research within the Walloon Government lies with the Minister for Technological Development and Employment. He manages the most important item of regional R&D policy, that of research with technological objectives. The other Ministers are also empowered to finance research and studies within their own spheres of competence.

The Walloon Region has made a single department - the Directorate-General for Technologies, Research and Energy (DGTRE) - responsible for supervising and financing projects and monitoring work in the research field. The DGTRE also has a task of overseeing Walloon participation in European and international research programmes and co-ordinating all data relating to the research activities supported by the different administrations of the Walloon Region. The DGTRE consists of two divisions, the Research Division and the Division for Company Assistance and Energy.

In particular, the Research Division has the task of handling all problems connected with the funds allocated to universities and research centres, initiating and managing regional programmes, promoting transregional and transnational scientific co-operation and managing interventions in favour of innovation in the Walloon SMEs and in support of individual inventors.

Among other things the Division for Company Assistance and Energy is responsible for various activities to promote technological development, namely the management of programmes relating to energy control, recovery and savings and of requests for intervention from companies for projects connected with basic industrial research, applied research or development.

• The General Directorate for Technology, Research and Energy (DGTRE)

The main mission of DGTRE is to promote technological innovation in enterprises, particularly SMEs, but also in various institutions (applied R&D at universities, Research Centres).
other activities:
- granting of subsidies for research, development and demonstration,
- insertion of the technological and scientific potential of Wallonia in European initiatives,
- management of subsides' accounting,
- monitoring of contracts' performance,
- subsides' agreement and decree,
- impact's measure of actions implemented.

Several supporting measures are put at the disposal of Walloon actors carrying out research activities. These measures can vary according to the actor (enterprise, SME, university, research centre or industrial higher institute) and its geographic localisation.
There are about twenty measures which can be broken down in four R&D supporting categories and which are structured around two financing modes: subsidies and refundable loans:
1. accompanying measures to R&D,
2. financing of R&D,
3. measures for exploiting the results of R&D activities,
4. Information to enterprises.

An advisory body, the Council for Science Policy of the Walloon Region (CPS) gives advice to the Walloon Government with respect to the preparation of the science policy of the Region. It comprises representatives of universities and higher non-university education establishments, research centres and social interlocutors.

• The Walloon Council of Scientific Policy (CPS)

Created in 1990, the Council for Science Policy of the Walloon Region (CPS) has the role of formulating opinions and recommendations on science policy, either on its own initiative or at the request of the Walloon government. The CPS brings together 25 members:
- 14 representatives of the social interlocutors i.e. employers' and trade-union mediums;
- 6 representatives of the academic world;
- 2 representatives of non-university teaching;
- 2 representatives of the research centres;
- 1 representative of the administration.

2.3. Higher Education Institutions ([6])

2.3.1. Universities (19)

In Belgium, science has traditionally been connected with education. Since 1874, basic research takes place at universities. Today, along with private European research activities, various Belgian university research institutes are centres of scientific excellence. Among main poles of excellence of international repute, we can cite the Inter-University Microelectronics Centre in Leuven (IMEC) that was set up in 1984. Liège University's Space Research department is an influential laboratory which works in close collaboration with the European Space Agency. The Flanders Interuniversity Institute for Biotechnology (VIB) co-ordinates scientific efforts in biotechnology carried out at 9 Flemish university laboratories, some of which have world renown. At the Institute for Cellular and Molecular Pathology at Louvain-la-Neuve University, researchers are trying to find a way to link fundamental biological research and medical research. The Department for Molecular Biology at Brussels University (ULB) specialises in the field of genetic manipulation.

Belgium has 19 universities, among which 6 institutions, covering the full range of academic fields. Except for the Royal Military School, the universities are now directly financed by the 'communities'. The universities are distributed all over the country, but 8 university institutions are located in the Brussels-Capital Region and its hinterland (the Flemish and the Walloon part of the Brabant province). About 29% of Belgian R&D is realised at universities. Presently, universities are facing drastic restrictions of the public financial support. The limited public resources allocated to research have induced Belgian universities to increase their participation in research programmes financed by external contracts. A main consequence of the weakness of the public support is an increased instability of research teams and an increased rotation of the academic research personnel (due to the fact that most contract-research is financed on a short-term basis).

2.3.2. Autonomous university and inter-university research centres (24)

There are 24 autonomous university and interuniversity research centres in Belgium active in different scientific fields. Some of these centres carry out applied research in fields relevant for the development of new products or processes by spin-offs or interested firms. A list is given in appendix A.2.1.

2.3.3. Non-university HEIs (52)

Some of the 52 Belgian non-university HEIs play an important role in the formation of applied scientists and engineers and carry out applied research, often in collaboration with private firms, universities and RTOs.

[6] In what follows, the main institutions with high links to R&D activities are described. The number of institutions is given in brackets.

2.4. Research and Technology Organisations (RTOs)

Table 2.1 gives the distribution of Research and Technology Organisations across Belgium.

Table 2.1. RTOs in Belgium

	Belgium	Federal State	Brussels-Capital Region	Flemish Community	French-speaking Community/ Walloon Region
Central Services	24	16	1	4	3
Scientific Institutions	46	38		5	3
Other Public Institutions	20	6	1	6	7
Subordinated Institutions	13				
Semi-public Institutions	8				
Non-profit Institutions	13				
Sectoral Centres of Collective Research	43				
Internat. Organ. Established in Belgium	5				
TOTAL	172				

Source: OSTC (1996)

2.4.1. The Federal State

• The Royal Belgian Institute of Natural Sciences (RBINS)

The Royal Belgian Institute of Natural Sciences preserves and studies the natural historical collections belonging to the State. In the various areas of its competence, the Institute organises missions of exploration and sample collecting, of investigation and classification, of public service at a national and international level. The Museum of the Institute aims particularly at the widest possible spread among the public at large of knowledge in the field of natural sciences.

• The Belgian Institute for Space Aeronomy (BISA)

The Belgian Institute for Space Aeronomy is one of the federal research institutions controlled by the Belgian Government. It is entrusted to acquire, to interpret and to store data about the composition and the evolution of the atmosphere of the earth and other planets. As a research institute the institute is also responsible for the development of experimental methods used in space Aeronomy, for the construction of space borne experiments and for research in connection with mathematical models. Measuring techniques and relevant instrumentation are developed in the Institute.

• The Centre of Nuclear Studies (CEN/SCK)

SCK-CEN, situated in Mol, is the national research centre for nuclear energy. The research focuses on the environmental and safety aspects of nuclear energy. Today it employs 600 people (some 30 employees work towards a PhD or do postdoctoral work) and has an annual budget of 3 billion BEF, financed half by government and half by own revenues.

2.4.2. The Flemish Community

• The Interuniversity Microelectronics Centre (IMEC)

IMEC is a laboratory for advanced research in microelectronics, operational since 1984. It was created as part of the 1982 programme of the Flemish government to strengthen the microelectronics industry in Flanders. It performs scientific research which runs ahead of industrial needs, with a view to practical applications. Today it employs over 600 people and is involved in a large number of national and international R&D projects in the fields of Information Technology and Telecommunication in general and microelectronics in particular. There are 4 divisions: VLSI system Design methodology, Advanced Semiconductor Processing, Materials and Packaging and the division for Industrial Formation. Its main academic links are with the University of Leuven (KUL) and the University of Ghent (UG). It has personal and collaborative links with Alcatel, Philips and Siemens and a large number of other Belgian and foreign companies and research institutions. Some 13 spin-off companies proceeded from IMEC. It is financed by the Flemish government and has own income from contract research.

• The Flanders Interuniversity Institute For Biotechnology (VIB)

VIB was created in 1995 to co-ordinate scientific research in the field of Biotechnology. The institute joins 9 renowned biotechnology departments from 5 Flemish Universities. Its board of directors is composed of representatives from the industry, universities and the Flemish minister of science and technology. Its main task is the stimulation of strategic fundamental research carried out in the 9 departments or within the framework of specific projects. Furthermore VIB is responsible for the valorisation and promotion of research efforts, the stimulation of the Flemish biotechnology industry and technology assessment. VIB is financed by the Flemish government.

• The Flemish Institute for Technological Research (VITO)

VITO was created in 1991 by the Flemish government and employs over 400 people. It is a multidisciplinary research centre, active in the fields of environment, non-nuclear energy, new materials and raw materials. It performs own research and formulates policy advice in the fields mentioned above. VITO stimulates the valorisation of research results, the diffusion and transfer of technological knowledge with the intent to reinforce the innovative competitiveness and the fulfilment of the industrial needs of Flemish companies. As with the 2 other Flemish research institutions the management agreement (1994-1998) stipulates the strategy and the results expected of VITO whereas the Flemish government guarantees further financing.

2.4.3. The Walloon Region / French-speaking Community

• The Scientific Institute of Public Service (ISSeP)

ISSeP is at the same time an establishment performing research and development, a centre of industrial projects, an expertise-, testing, and analysis laboratory. ISSeP is financed by the DGTRE and is active in three main areas:
- mineral resources and energetic minerals;
- environment and pollution problems;
- technical and industrial security.

2.4.4. Sectoral Centres of Collective Research

The Sectoral Centres of Collective Research have a special place in the Belgian R&D system. Spread out all over the territory, their objective is to meet the specific scientific and technological research requirements of companies, generally medium-sized, in the sector concerned. Basic technological research (pre-competitive and pre-normative) and the introduction of new technologies in industry constitute their main activities. The joint research also promotes the exploitation of the results of basic research, thus allowing companies, especially SMEs, to keep in contact with the world of research. The 12 largest of these sectoral centres are those connected with the following industries: wood, ceramics, cement, building, electricity, metallic constructions, gas, metallurgy, paints and coatings, roads, textile and glass. They represent some 1200 specialists. Most of the income of these centres comes from compulsory contribution from companies in the branch of industry concerned and also from the authorities in so far as exploratory research is concerned. A third source of income is the provision of technological assistance to companies (funded by the Regions). Under a co-operation agreement signed in 1991 between the Federal State and the Regions, half of public support for research at these centres comes from the Federal Authority (Economic Affairs) and the other half comes from the three Regions. The list of centres is given in Appendix 2.1.

2.5. Bridging Institutions

2.5.1. Brussels - Technopole

• Brussels – Technopole
In keeping with both the objectives of the European Union and the strategy adopted within the Brussels-Capital Region, Technopole exists by virtue and on behalf of participants in the Brussels economic, social and scientific life. The situation enables it to keep its finger on the pulse of the companies and research centres, so it is directly aware of their needs in all aspects of the new technologies. Brussels Technopole's most important function is to promote access and integration of innovation within companies on the basis of a systematic methodology: Identifying needs, guiding the company to the technological source, promoting co-operation between businesses, directing companies into European programmes and promoting quality. The other functions of Brussels Technopole are encouraging research through synergy and partnerships, safeguarding results, development of international co-operation, promoting research, developing co-operation, protecting Innovation and funding innovation. Brussels Technopole is also engaged in European activities through its Brussels Innovation Relay Centre (B.I.R.C.) and the Midas-Net node.

2.5.2. Business - University/HEIs Interfaces

The Business - University/HEIs Interfaces directly assist companies in solving technical problems, elaborating new products and processes, integrating new technologies and training. They bring the company in direct contact with the laboratory or the unit best placed to provide suitable responses to the industry's needs. The work of the interfaces can involve various forms of co-operation between companies and research centres:

- ad hoc services,
- consultancy assignments,
- joint research programmes,
- license transfers...

By means of publications, seminars, technological demonstrations etc., the interface cells also provide business with information on prospects offered by most recent technological developments and on the help their respective institutions can offer in implementing these new technologies. The promotion and benefits that can be derived from universities and higher education establishments technological potential can lead to partnerships with existing companies or to the creation of new industrial activities.

Brussels-Capital Region

Four operational interface cells are attached to universities and higher education institutions located within the territory of the Brussels-Capital Region:

- Université Libre de Bruxelles (see also French-speaking Community).
- Vrije Universiteit Brussel (see also Flemish Community),
- Université Catholique de Louvain (area of health care),
- Higher education establishments, in the form of a joint structure.

Flemish Community

All Flemish universities have an interface service for the valorisation of scientific results and know-how through the diffusion of information and technology. Some of them work in close collaboration with an incubator centre and stimulate spin-offs.

- KUB,
- KULeuven (Leuven Research and Development),
- LUC (FTO- Fonds Technologisch Onderzoek),
- UG (Part of the university service for research policy),
- UA (UBCA),
- VUB (Commission 'Industry & Service' of the university department for R&D).

Walloon Region / French-speaking Community

• University of Liège
The Business-University Interface of the University of Liège provides expertise, advice and expensive and sophisticated equipment to support projects of private companies requiring extremely specialised knowledge. An extensive list of the equipment is available on request.

2.5.3. Science Parks/Incubators

Science or research parks are regional instruments for the diffusion of technology and knowledge and the valorisation of research results. Sometimes a distinction is made between 4 types of parks: science parks, research parks, technology parks and business parks. For the last two categories the involvement of HEIs or research organisations is optional. In 1974 Belgian universities were offered the opportunity to start a research park. More recently most of the university related science or research parks took up the role of innovation and incubation centre with as main objective the stimulation and support of spin-off activities and the start up of high-tech companies.

Brussels-Capital Region

Four science parks are located within the territory of the Brussels-Capital Region:
- Da Vinci Park in Evere
- Mercator Park in Neder-over-Heembeek
- Erasmus
- Hof-Ten-Berg Vesalius Park.

These science parks are administered by the 'SDRB' (Brussels Regional Development Company) attached to three universities which are located in the territory of the region: Université Libre de Bruxelles, Vrije Universiteit Brussel and Université Catholique de Bruxelles. These parks cover a total of 61 ha and house 79 companies, providing jobs for almost 5000 people.

Flemish Community

University Science and Research Parks/Incubators in the Flemish Region:

- KULeuven (Research Park + Incubator)
- KULAK (Research Park + Incubator)
- LUC (Research Park + Incubator)
- UA (Research Park + Incubator (UBCA))
- UG (Research Park + Incubator)
- VUB (4 Research Parks + 1 Incubator)

• INNOTEK (Innovatie- & Technologiecentrum Kempen)

Innotek is the Flemish partner of the European BIC network. It combines the activities of a business park with the activities of an incubator. It participates, together with the GIMV, in the Seed Capital Fund of the Kempen which provides risk capital for starting companies and other innovative projects.

Walloon Region / French-speaking Community

• The Namur Province Science Park

The Namur Province Science Park, created in 1988, is designed to provide a home for companies active in the agro-food produce industry and in environmental sciences, biotechnology and genetic engineering, information technology, new materials and physical and chemical surface analysis. Appropriate infrastructure is also available for newcomers, including an information centre integrated in the park, the technological centre of the Agricultural Science Faculty of Gembloux, which comprises two pilot-units focusing on agro-food produce and bio-industry, an innovation incubation centre for young businesses starting up, with a second similar structure soon to be completed. The other companies that wish to set up business in the science park have the benefit of a full network of aid packages and accompaniment schemes:
- in the economic, financial and administrative fields, in particular with the support of the Business and Innovation Centre of the 'Bureau Economique de la Province de Namur';
- in the field of science, through the active partnership of the research departments of the 'Faculté des Sciences Agronomiques de Gembloux' and the 'Facultés Universitaires Notre-Dame de la Paix', the Agricultural Research Centre and the Gembloux Higher Industrial Institute. This synergy has also contributed to attracting famous companies such as Smithkline Beecham Biologicals to set up business in the science park. This economic and scientific synergy is also evident at the Technological Centre of the 'Facultés Notre-Dame de la Paix': this centre has been active on the university campus since 1990, and at present is home to several companies that share the aim of developing and perfecting technologically innovative products.

• Sart Tilman Science Park

The Sart Tilman science park, on the university of Liège campus, houses some 40 SMEs in the high technology field that closely co-operate with the university for research in aeronautics, human health, animal health, optics, etc.

• UCL Science Park

The university reserves on its sites of Louvain-la-Neuve and of Brussels (Louvain-en-Woluwe) more than 160 ha of grounds in order to allow industrial high technology establishments. By creating 2 science parks, UCL wishes to intensify its collaborations with the companies which are established there. These collaborations are concretised in the form of research conventions, exchange of privileged scientific information and by using the scientific infrastructure of the university. Several high technology companies which are localised there find their origin in the research developed within the laboratories of the university. A close scientific co-operation is maintained with these companies. The university also has buildings ready to accommodate companies.

2.6. Diffusion-oriented policies and the development of technology networks and bridging institutions

S&T policy in general and innovation policy in particular are increasingly oriented towards the diffusion of knowledge and technological know-how. Endogenous growth theory offers a framework to understand this recent shift in emphasis in policy. Many of the models used in endogenous growth theory rely on the mechanism of increasing returns to scale, and predict therefore that large economies tend to grow faster than smaller economies due to these scale effects. Since the creation of networks of R&D co-operation, which by definition encourage diffusion, can be seen as a substitute for scale increases, governments of small countries like Belgium dispose in this way of an obvious tool: the development of technology networks and bridging institutions such as HEIs interfaces, science parks and incubators is either initiated or supported by authorities with the explicit aim of enhancing technological diffusion. The same reasoning leads the authorities in small countries to direct a relatively large part of the ‘bridging’ effort to SMEs.

In Belgium, most areas of competence related to S&T and innovation have been transferred to the regional level. In 1992 the Flemish government created IWT, a semi-autonomous institute which apart from financing (co-operative) R&D in companies and research institutes, also provides services with regard to the diffusion of knowledge and technological know-how. Furthermore three Flemish research institutes (IMEC, VITO and VIB) have been created with an objective of transferring technological knowledge and valorising the results of own fundamental and applied research through co-operation or the creation of spin-off companies.
As will be shown in Chapter 6 the interuniversity microelectronics centre (IMEC) intensively participates in international R&D co-operation and relatively often assumes the role of project leader. The Flemish Institute for Technological Research (VITO), although only created in 1991 has also a central position in the Belgian R&D network, especially in its fields of activity (environment, energy and materials technology). The interuniversity biotechnology research institute VIB was only created in 1995, and it was therefore not possible to evaluate properly its diffusion-role, and its participation in joint R&D-projects.
Each province in Flanders has its Regional Development Company (GOM) which is to promote the socio-economic development of the region. They promote new investments and innovation projects and support starting companies. They play an important role in technology diffusion, especially towards SMEs. The 5 Flemish Regional Development Companies have created a common 'Technological Innovation Cell' (TIV) to track possibilities for new products, processes and services in companies.

In the Walloon Region the competence with regard to diffusion remains under direct control of the regional administration (DGTRE). Apart from ISSEP (Institut Scientifique de Service Public) Wallonia has so far no autonomous research institutes aimed at diffusing technological know-how, similar to the three Flemish research institutes mentioned above. However some science parks of the Walloon Region (Namur Province Science Park and Sart Tilman Science Park) actively promote synergy and co-operation between universities and firms (mostly high-tech SMEs). As will be shown in section 6, Walloon universities have relatively central positions in the R&D network. Unfortunately the same does not hold true for Walloon firms which, with some exceptions, do not actively participate in international R&D co-operation. Moreover co-operation between Walloon firms, universities and research institutes seems limited in comparison with what happens in the Flemish part of the country. Undoubtedly, a more active diffusion policy could increase the valorisation of the scientific and technological potential in the Walloon region.

In the Brussels-Capital Region, as shown above, Brussels-Technopole promotes technological diffusion and R&D co-operation with regard to firms and institutes.

2.7. Functional matrix

The functional matrix in table 2.1 shows which functions are performed by the main organisations within the Belgian NIS with regard to innovation policy. Most areas of competence have been regionalised, which is revealed by the fact that a large number of functions are at present carried out by regional organisations. The promotion of human resources development and mobility and the financing of technology-based firms and the stimulation of a venture capital market is generally under-performed in Belgium although with respect to the latter recently some organisations (e.g. the GIMV in Flanders and INVESTs in Wallonia) have actively supported and even participated in a considerable number of venture capital initiatives. In Flanders the administration for science and innovation (AWI) focuses on universities whereas the implementation of innovation measures of more applied R&D towards firms and research institutes is carried out by the autonomous institute IWT. In Wallonia these areas of competence remain under the direct regional authority of DGTRE.

Table 2.2.
Functional institutional matrix

FUNCTION	O S T C	F | F N | W R | O S	S | D R | O I | I	A W I	I W T	D G T R E	Sect. Cent. of Collective Research	Reg. Res. Inst.	Reg. Inv. Comp.	H E I	Univ. Res. Cent./ Spin-of	R&D dep. of entr.	Joint res. inst.of entr.	Science Parks	bridg. inst.	Venture Capital comp.
Technology and innovation policy, formulation, co-ordination, supervision and assessment	*			*												
Performing R&D																
- Basic							*	*		*	*					
- Pre-competitive							*	*		*	*	*	*			
- Applied							*				*	*	*			
Financing R&D																
- Support to non-business institutions and organi-sations undertaking basic or applied research	*	*	*	*	*	*										
- Support of R&D projects in the business enter-prise sector	*		*		*	*	*						*			
- Support of special areas of research independent from the institution or firm where it is undertaken	*			*	*	*										
Promotion of human resource development and mobility				*					*							
Technology diffusion																
- improve the adoption and adaptation of specific technologies			*		*	*	*	*	*		*		*	*	*	
- improve the general technology receptor capacity of firms			*		*	*	*	*	*		*		*	*	*	
- build the innovation capacity of firms			*		*	*	*	*	*				*	*	*	
Promotion of techn. Entrepreneurship																
- Financing technology-based firms (eg. venture capital)									*							*
- other				*	*	*	*	*	*		*			*	*	*

3. R&D Expenditures and the National Innovation System

3.1. Introduction

The conduct of science and technology policy is radically different in small countries compared to large ones. Johnson (1988, p. 297) rightly pointed out that ‘*the need for an institutional system is relatively strong for small countries. The possible benefits of such a system are considerable, and so are the potential costs of institutional rigidity*’. He adds that the coherence and the consensus-generating capacity of the institutional system are vital elements for its efficiency. As implied in the previous chapter, there is at least the suspicion that the Belgian innovation system has problems with the volatility of the institutional setting, rather than with its rigidity. High volatility means high uncertainty and adverse effects on the propensity to invest in technology.

In order to compensate for their limited market, small countries have to turn to the international market. Stabilising, let alone improving the trade performance in the face of a high competitive pressure on world markets, entails that small countries have to invest in R&D. Their market shares in international trade are indeed strongly dependent on the ability to adapt trade patterns to structural changes. The ‘squeeze’ on small industrialised countries by large countries on the one hand, and newly industrialised countries on the other hand (Walsh, 1988) makes the implementation of an efficient S&T system more necessary than ever.

The present Belgian prosperity is rooted in a long-standing tradition of openness to innovations and new ideas, which is witnessed by an early, in historical terms, development of the necessary government authorities and institutions needed to monitor this openness.

In this chapter, we will limit the analysis to the present structure of the Belgian R&D expenditure. Given the autonomy of regions, regional R&D patterns are also discussed when regional data are available.

3.2. Financing and performing sectors

Table 3.1 allows to compare Belgium with other industrialised countries with respect to the relative efforts devoted to research activities and to government subsidisation rates. The international comparison of gross domestic expenditures on R&D (GERD) is done through two different scaling factors: population and GDP. GERD per capita has increased in all countries during the eighties. The US has the highest level of R&D expenditures per capita (index 508 at US PPP exchange rates in 1990) and is closely followed by Japan (452) and Germany (421). Belgian R&D investments per capita (230) were as high in 1990 as those of Canada (229). In terms of R&D expenditures related to GDP, the usual R&D intensity measure, the evolution during the eighties is however quite different. In general, R&D intensities with respect to GDP have shown a more stable pattern and have increased only in Japan and Italy from 1985 to 1990. In 1990, Belgium (1.7%) is situated above the Canadian and Italian levels and under the levels of the other industrialised countries. Japan (3.1%) and the US (2.7%) have the highest R&D intensities. The nineties are characterised by a slowdown and, in some countries, a reduction of R&D expenditure per capita.

The share of Government R&D in GERD has been reduced from 1980 to 1990 in all countries, but Italy. Japan is associated to the lowest degree of government interventionism measured as a proportion of total R&D expenditures (18% in 1990). In Belgium, government R&D is also relatively weak (28% in 1995) compared to the other countries. Furthermore, the country is characterised by a very high decrease of this share. The reason is of course the snowball effect on government debt which developed in the beginning of the eighties, and the budgetary squeeze which followed.Yet, the beginning of the nineties shows an increase of the government share, as a result of the regionalisation of R&D policy (and because the federal debt was not regionalised).

Government R&D includes, in a large number of countries, a large part of the financing of R&D which takes place within the higher education sector. This has to be accounted for in cross-country comparisons. At the European level, while Belgium is in a medium position for business and higher education R&D, it is in the last place regarding government R&D infrastructure (Capron (1997)). Although the absence of defence-oriented R&D in Belgium can partly explain this observation, it remains that the relatively weak contribution of Belgian authorities to R&D efforts is, per capita, largely inferior to the one observed in diffusion-oriented countries as Germany and Japan (see again the Belgian government debt imbroglio).

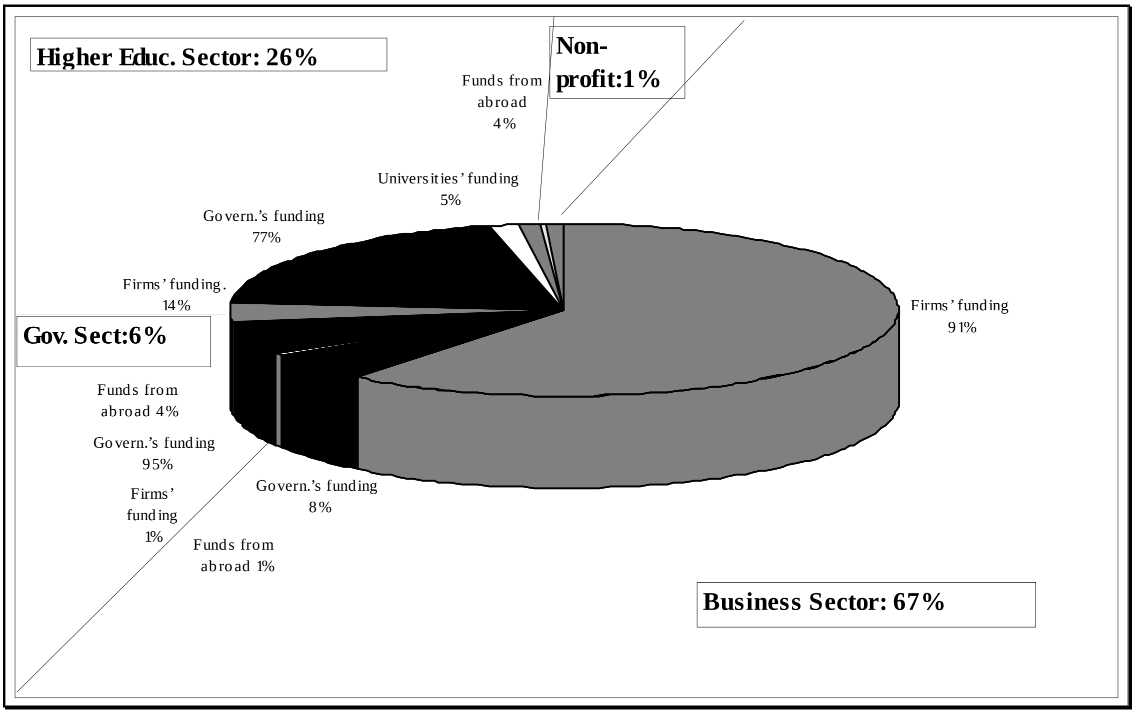
Figure 3.1 provides a more precise illustration of the importance of the various financing and performing sectors in Belgium during the early nineties. The private business sector is by far the largest R&D performing sector, in which 67% of GERD were expended. The higher education and government sectors performed 26% and 6%, respectively, of total R&D investment in Belgium. Funding by the government is the larger source of financing for the higher education sector (77%) and is fairly weak in the business sector (8%).

Table 3.1 : International comparison of total R&D intensities and government subsidisation rates (1981, 1985, 1990 and 1995) [(2)]

		USA	Canada	Japan	Belgium	France	Germ.	UK	Neth.	Italy
Total R&D per capita[(1)]	1981	375	174	241	169	221	274	240	205	90
	1985	485	210	334	181	264	368	261	244	131
	1990	508	229	452	230	349	421	290	265	173
	1995	477	242	480	249	348	407	284	274	151
Total R&D / GDP	1981	2.4%	1.2%	2.3%	1.6%	2.0%	2.4%	2.4%	1.9%	0.9%
	1985	2.9%	1.4%	2.8%	1.7%	2.3%	2.7%	2.3%	2.1%	1.1%
	1990	2.7%	1.4%	3.1%	1.7%	2.4%	2.7%	2.2%	2.1%	1.3%
	1995	2.5%	1.6%	2.8%	1.6%	2.4%	2.3%	2.1%	2.1%	1.2%
Private R&D / GDP	1981	1.2%	0.5%	1.4%	1.0%	0.8%	1.4%	1.0%	0.9%	0.4%
	1985	1.4%	0.6%	1.9%	1.1%	0.9%	1.7%	1.1%	1.1%	0.5%
	1990	1.4%	0.6%	2.3%	1.2%	1.1%	1.7%	1.1%	1.1%	0.6%
	1995	1.5%	0.7%	1.9%	1.0%	1.2%	1.4%	1.1%	0.9%	0.6%
Government R&D / GDP	1981	1.2%	0.6%	0.6%	0.5%	1.1%	1.0%	1.2%	0.9%	0.4%
	1985	1.4%	0.7%	0.6%	0.5%	1.2%	1.0%	1.0%	0.9%	0.6%
	1990	1.3%	0.5%	0.6%	0.5%	1.2%	1.0%	0.8%	0.9%	0.7%
	1995	0.9%	0.6%	0.6%	0.5%	1.0%	0.9%	0.9%	0.9%	0.6%
Government share in	1981	49.3%	49.6%	26.9%	33.4%	53.4%	40.7%	49.0%	47.2%	47.2%
total R&D	1985	48.3%	47.6%	21.0%	31.6%	52.9%	36.7%	42.8%	44.2%	51.7%
(higher education included)	1990	47.1%	36.2%	18.0%	27.6%	48.3%	34.7%	35.2%	41.2%	51.5%
	1995	36.9%	40.1%	21.5%	32.5%	41.6%	37.2%	32.7%	43.9%	46.4%

Sources: STI/OECD. ; own calculation. (1): Total R&D investment in constant prices and US PPPs of 1985; (2): 1983 instead of 1981 for Belgium.

Figure 3.1 : Belgian R&D, by source of funds and sector of performance (average 1989-1991)



Sources: STI/OECD.

3.3. General structure of the industry : R&D and value added

The distribution of value added and R&D expenditures across the Belgian manufacturing and services industries is presented in Table 3.2 for the year 1995. Focusing firstly on manufacturing industries, Figures 3.2 and 3.3 show the industrial distribution of value added and R&D expenditures according to four classes of technology intensity. High tech industries account for about 7% of total manufacturing value added; medium-high tech industries account for 32%, medium-low tech industries for 14% and finally, low tech industries for 47%. The largest industries in terms of value added are food and beverages (14%), Chemicals (13%), and motor vehicles (9%).

The distribution of R&D expenditures across manufacturing industries is substantially different from the distribution of value added. The high tech and medium-high tech industries account for more than 80% of R&D expenditures in manufacturing industries, whereas this ratio was under 40% regarding value added. The low tech and medium-low tech industries expended 20% of R&D investments in manufacturing and produced more than 60% of the value added.

A similar distortion occurs when the services industries are compared to the manufacturing sector. Table 3.2 indicates that the services industries and the construction sector are the main source of value added creation in Belgium, accounting for 80% of all industries. However, in terms of research activities, the manufacturing industries invest 87% of total R&D outlays.

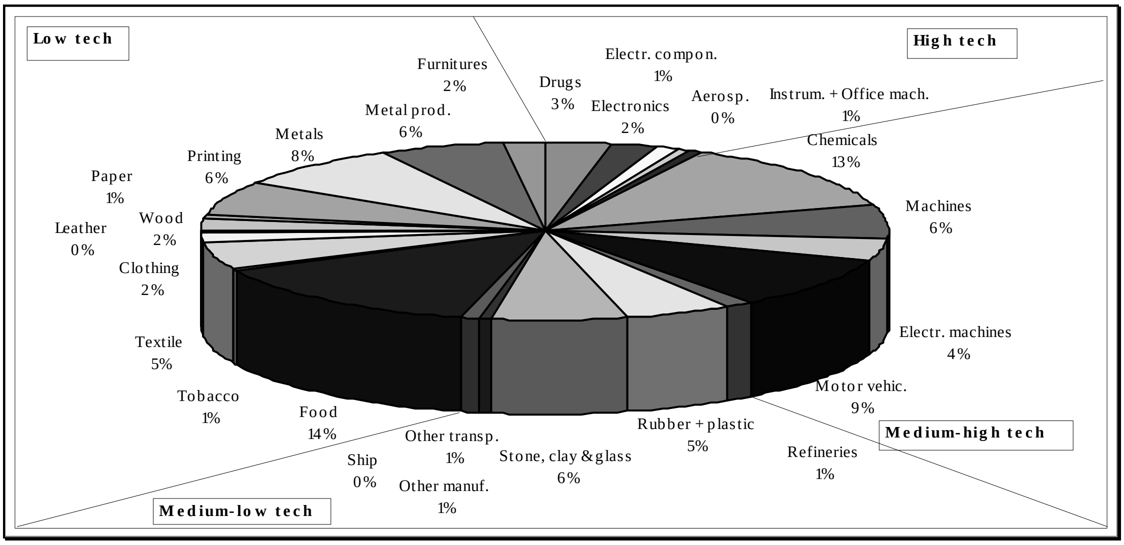
Table 3.2 : Value added and intra-muros R&D in Belgian industries in 1995

NACE-Bel		Value added (BEF Mio)	R&D (BEF Mio)	R&D intensity	VA shares	R&D shares
1	**Agriculture**	**114790**	**249**	**0.22%**	**1.55%**	**0.30%**
14	**Mining**	**1007**	**7**	**0.71%**	**0.01%**	**0.01%**
	High tech industries	**115251**	**32139**	**27.89%**	**1.56%**	**38.48%**
24.4	Drugs[e]	45447	14235	31.32%	0.61%	17.04%
32	Electronic equipment (excl. components)[a]	33003	14090	42.69%	0.45%	16.87%
32.1	Electronic components[a]	18564	1006	5.42%	0.25%	1.20%
35.3	Aerospace[b]	6743	394	5.84%	0.09%	0.47%
33	Instruments and Office machines	11493	2413	21.00%	0.16%	2.89%
	Medium-high tech industries	**491421**	**26762**	**5.45%**	**6.63%**	**32.04%**
24	Chemicals (excl. drugs) [e]	193749	17551	9.06%	2.61%	21.01%
29	Non electrical machines	93119	3293	3.54%	1.26%	3.94%
31	Electrical machines[a]	60536	3217	5.31%	0.82%	3.85%
34	Motor vehicles	144018	2701	1.88%	1.94%	3.23%
	Medium-low tech industries	**213739**	**4616**	**2.16%**	**2.88%**	**5.53%**
23	Refineries	20860	12	0.06%	0.28%	0.01%
25	Rubber and plastic products	74101	2450	3.31%	1.00%	2.93%
26	Stone, clay & glass	96497	1104	1.14%	1.30%	1.32%
35	Other transport[b]	8472	654	7.72%	0.11%	0.78%
35.1	Shipbuilding[b]	2075	15	0.73%	0.03%	0.02%
36	Other manufacturing[c]	11734	381	3.24%	0.16%	0.46%
	Low-tech industries	**703168**	**9293**	**1.32%**	**9.49%**	**11.13%**
15	Food and beverage	207082	2292	1.11%	2.79%	2.74%
16	Tobacco	11148	0	0.00%	0.15%	0.00%
17	Textile	69091	987	1.43%	0.93%	1.18%
18	Clothing	31706	7	0.02%	0.43%	0.01%
19	Leather and shoes	1923	13	0.70%	0.03%	0.02%
20	Wood and wood product	36518	39	0.11%	0.49%	0.05%
21	Paper	13182	134	1.02%	0.18%	0.16%
22	Printing	92155	288	0.31%	1.24%	0.34%
27	Iron & Steel and non ferrous metals	121566	3150	2.59%	1.64%	3.77%
28	Metal products	87690	2248	2.56%	1.18%	2.69%
36.1	Furnitures[c]	31108	135	0.44%	0.42%	0.16%
	Total manufacturing industry	**1523579**	**72810**	**4.78%**	**20.56%**	**87.18%**
40	**Utilities**	**160302**	**1**	**0.00%**	**2.16%**	**0.00%**
45	**Construction**	**405517**	**514**	**0.13%**	**5.47%**	**0.61%**
50	Wholesale and retail trade	1121442	94	0.01%	15.13%	0.11%
55	Hotels and restaurants	250561	0	0.00%	3.38%	0.00%
60	Transportation and storage	595945	28	0.00%	8.04%	0.03%
64	Telecommunications	158906	483	0.30%	2.14%	0.58%
65	Financial intermediates	371558	192	0.05%	5.01%	0.23%
72	Computing services[d]	27237	1737	6.38%	0.37%	2.08%
72.2	Software production[d]	15365	3659	23.82%	0.21%	4.38%
73	Research and development[d]	23047	646	2.80%	0.31%	0.77%
74	Other services to firms[d]	628556	3070	0.49%	8.48%	3.68%
90	Other individual and social services	2013085	27	0.00%	27.16%	0.03%
	Total services	**5771521**	**9939**	**0.17%**	**77.88%**	**11.90%**
	Total	**7410897**	**83519**	**1.13%**	**100.00%**	**100.00%**

Sources: R&D figures: SSTC-DWTC, 1997, provisional data; value added figures: BNB, 1997. (a, b, c, d, e) denote the industries belonging to a more aggregated industry for value added figures, the desegregation has been made according to employment figures; own calculations.

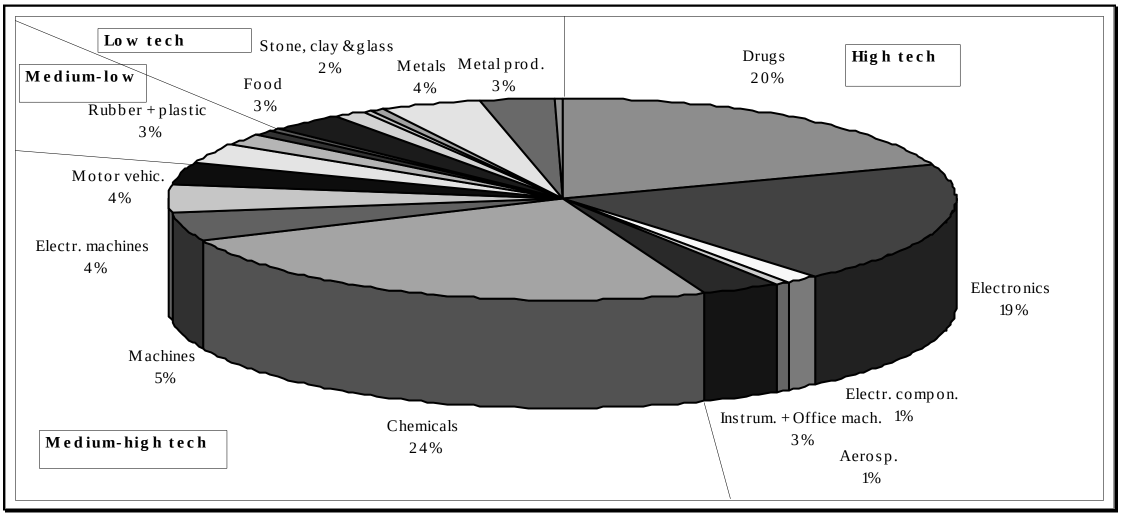
This asymmetry between value added creation and R&D performance is due to the different R&D intensities characterising each industry. The ratio of R&D investments to value added is equal to 28% for the high tech industries, 5% for medium-high tech, 2% for medium-low tech, 1% for low tech, and about 0.2% for services industries. In addition, Table 3.2 clearly shows that there are strong variations within each subgroup of industries. In Figure A.3.1 the share of each industry is shown, ranked according to their share in value added, in total R&D. There is no clear relationship between an industry’s share in value added and its share in R&D. This is due to the high heterogeneity in R&D intensities as can be seen in Figure A.3.2.

Figure 3.2 : Value added in the Belgian manufacturing industry, by technology intensity, 1995



Source: cf. Table 3.2.

Figure 3.3 : Intra-muros R&D investments in the Belgian manufacturing industry, by technology intensity, 1995



Source: cf. Table 3.2.

The evolution of R&D outlays in the Belgian industries from 1981 to 1995 is presented in Table A.3.1. For the average manufacturing industry, intra-muros R&D investments have increased by 36% from 1981 to 1991. In 1995, there has been a slight decrease in total R&D expenditures, as compared to 1991 (the index falls from 136 to 133). The services industry has followed a different trend. During the eighties R&D investment in services has sharply fallen from an index of 100 in 1981 to 68 in 1991. The early nineties are characterised by a reverse trend, with R&D expenditures rising with 47% in 1995, as compared to 1981. On average, the yearly growth rate of total intra-muros R&D investments in Belgium has been of about 2%. The services industry, the high tech and medium-high tech manufacturing industries show the highest growth rates.

3.4. Employment in R&D activities

The qualification of human capital devoted to research activities in all industries is presented in Table 3.3. The R&D personnel is split into three classes: university (or long term higher education), short term higher education, and others. There is a sharp contrast between manufacturing and services industries. In the former, less than half of the R&D personnel possesses a long term higher education diploma, whereas in the latter more than 70% has a high level of qualification.

Table 3.3 : R&D employment by level of qualification, by industry, and as a share of total employment, 1995 (Full time equivalent)

NACE -Bel		University	Short term	Others	Total R&D personnel	Total employment	Share of R&D pers.
01	**Agriculture**	**70,75%**	**25,71%**	**3,54%**	**85**	**112408**	**0,08%**
14	**Mining**	**66,67%**	**33,33%**	**0,00%**	**3**	**6153**	**0,05%**
	High tech industries	**58,58%**	**17,59%**	**23,83%**	**7371**	**60745**	**12,13%**
24.4	Drugs	38,36%	26,23%	35,41%	2798	13737	20,37%
30	Office machines and computers	36,66%	34,90%	28,44%	257	591	43,43%
32	Electronic equip. & components	72,08%	10,01%	17,91%	3368	13023	25,86%
32.1	Electronic components	70,72%	19,53%	9,74%	206	7189	2,87%
33	Instruments	83,49%	12,54%	3,97%	640	19746	3,24%
35.3	Aerospace	42,16%	14,71%	43,14%	102	6459	1,58%
	Medium-high tech industries	**39,70%**	**27,31%**	**32,98%**	**7503**	**177859**	**4,22%**
24	Chemicals (excl. drugs)	37,68%	31,01%	31,31%	4677	57033	8,20%
29	Non electrical machines	47,24%	22,73%	30,03%	949	43187	2,20%
31	Electrical machines	51,65%	22,10%	26,25%	1044	23880	4,37%
34	Motor vehicles	27,50%	18,33%	54,18%	833	53759	1,55%
	Medium-low tech	**40,39%**	**24,76%**	**34,86%**	**1266**	**82223**	**1,54%**
23	Refineries	56,41%	43,59%	0,00%	4	4854	0,08%
25	Rubber and plastic products	39,35%	26,40%	34,25%	703	23224	3,03%
26	Stone, clay & glass	42,61%	24,45%	32,94%	306	34714	0,88%
35	Other transport	25,49%	32,68%	41,83%	153	8106	1,89%
35.1	Shipbuilding	2,73%	0,00%	97,27%	37	1846	1,98%
36	Other manufacturing	98,10%	1,90%	0,00%	63	9479	0,67%
	Low tech industries	**44,90%**	**25,47%**	**29,63%**	**2995**	**403822**	**0,74%**
15	Food and beverage	42,34%	37,01%	20,65%	1035	112408	0,92%
16	Tobacco				0	3115	0,00%
17	Textile	72,17%	14,70%	13,13%	237	50825	0,47%
18	Clothing	0,00%	100,00%	0,00%	7	22090	0,03%
19	Leather and shoes	100,00%	0,00%	0,00%	7	5362	0,12%
20	Wood and wood product	84,62%	11,54%	3,85%	10	25659	0,04%
21	Paper	51,53%	23,64%	24,83%	59	16621	0,35%
22	Printing	71,96%	21,59%	6,45%	40	35123	0,11%
27	Iron & Steel, non ferrous metals	38,02%	11,67%	50,31%	758	49334	1,54%
28	Metal products	45,29%	27,85%	26,86%	775	61636	1,26%
36.1	Furniture	32,38%	14,69%	52,92%	67	21649	0,31%
	Total manufacturing industry	**47,83%**	**23,11%**	**29,06%**	**19135**	**724649**	**2,64%**
40	**Utilities**	**100,00%**	**0,00%**	**0,00%**	**2**	**28252**	**0,01%**
45	**Construction**	**51,35%**	**28,15%**	**20,50%**	**148**	**243188**	**0,06%**
50	Wholesale and retail trade	37,08%	2,85%	60,07%	56	575776	0,01%
55	Hotels and restaurants				0	142473	0,00%
60	Transportation and storage	42,86%	57,14%	0,00%	12	243566	0,00%
64	Telecommunications	80,39%	19,61%	0,00%	97	75881	0,13%
65	Financial intermediates	89,41%	8,13%	2,46%	41	149271	0,03%
72	Computing services	42,05%	53,79%	4,16%	457	11385	4,01%
72.2	Software production	76,06%	21,70%	2,24%	1081	6485	16,67%
73+74	Other services to firms	85,48%	10,01%	4,51%	985	283685	0,35%
90	Other services	83,87%	16,13%	0,00%	12	207928	0,01%
	Total services	**73,94%**	**21,55%**	**4,52%**	**2921**	**1706195**	**0,17%**
	Total	**51,37%**	**22,95%**	**25,68%**	**22293**	**2820845**	**0,79%**

Sources: SSTC-DWTC, 1997; ONSS, INASTI; own calculations.

On average, manufacturing industries use a larger share of relatively lowly qualified ('others': 29%) than average qualified R&D personnel ('short term higher education': 23%). In the services industry, only 5% of the R&D personnel is composed of lowly qualified employees. However, it is worth noting that in the manufacturing industry the share of total R&D personnel in total employees (2.6%) is much higher than in the services industry (0.2%). The only service industry which uses a relatively large number of employees devoted to R&D activities (17%) is the software production industry.

Large firms with more than 1000 employees accounted for more than half of total intra-muros R&D investments in 1995 (business sector R&D: BERD; cf. Tables A.3.2 and A.3.3). In contrast, the smallest firms, with less than 20 employees, accounted for only 3% of BERD. As compared to 1994, the largest increase in BERD was by the smallest firms. The analysis of the number of R&D employees by firm size emphasises that the smallest firms use relatively more R&D employees than the largest firms with respect to R&D investments. Indeed, the firms with less than 20 employees accounted for 7% of total R&D employees in the business sector, against the 3% share in BERD. This suggests that small firms rely relatively more on human capital than the largest firms.

3.5. Financing sources by industry

There are five potential financing sources for intra-muros research activities in business firms: own funds, funds of other firms, government subsidies, others funds (e.g. from non-profit organisations), and funds from abroad. Table 3.4 presents the relative importance of each of these financing sources in the manufacturing and services industries. The manufacturing and services industries finance their R&D projects from noticeably different sources. On average business firms in the manufacturing sector finance the lion's share of their R&D investments with their own funds (91%). In the next place come other business firms, government subsidies, and funds from abroad. Each of these three sources account for about 3% of total intra-muros R&D outlays by business firms. The services industries rely much more than the manufacturing industries on outside funding. Although the largest share of their R&D activities is also financed by their own funds (72%), they use more than manufacturing industries funds from abroad (13%) and the government subsidies (12%).

Interestingly, the share of R&D subsidies in total intra-muros R&D expenditures is more important in low tech (6%) and medium-low tech manufacturing industries than in high-tech (2.5%) and medium-high tech industries. The most subsidised industries are *Electronic components*, *Aerospace*, *Computing services*, and *Research and development services.*

Another feature that distinguishes the services from the manufacturing industries is the extent to which they finance extra-muros R&D projects. Business firms in the manufacturing industry invest about 11% of their total R&D expenditures in projects realised in other organisations. For the firms in the services industry, this share is 22%.

Table 3.4 : Intra- and extra-muros R&D expenditures: Financing sources by industries, 1995

	Intra-muros					TOTAL	Extra-muros	extra m./total
BEF Mio, and %.	Own funds	Other firms	Government	Others	fr. Abroad	*(i)*	*(ii)*	*(ii)/((i)+(ii))*
Agriculture	**95.45%**	**0.00%**	**2.73%**	**0.00%**	**1.82%**	**249**	**35**	**12.23%**
Mining	**100.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**7**	**1**	**6.50%**
High tech industries	**86.11%**	**4.24%**	**2.47%**	**0.00%**	**7.18%**	**32139**	**3773**	**10.51%**
Drugs	98.87%	0.00%	1.11%	0.00%	0.02%	14235	2550	15.19%
Office machines	83.16%	14.75%	1.53%	0.00%	0.56%	854	10	1.16%
Electronic equipment (excl. components)	74.61%	8.78%	1.68%	0.00%	14.93%	14090	928	6.18%
Electronic components	72.77%	0.00%	18.46%	0.00%	8.77%	1006	90	8.21%
Instruments	89.60%	0.07%	8.55%	0.00%	1.78%	1560	121	7.20%
Aerospace	63.12%	0.00%	16.57%	0.00%	20.31%	394	75	15.96%
Medium-high tech industries	**95.07%**	**1.60%**	**1.60%**	**1.09%**	**0.64%**	**26762**	**3745**	**12.28%**
Chemicals (excl. drugs)	98.45%	0.22%	0.99%	0.01%	0.34%	17551	2841	13.93%
Non electrical machines	84.01%	2.07%	4.06%	8.82%	1.04%	3293	303	8.42%
Electrical machines	84.18%	10.01%	3.39%	0.00%	2.42%	3217	167	4.95%
Motor vehicles	99.57%	0.00%	0.41%	0.00%	0.02%	2701	434	13.84%
Medium-low tech industries	**92.97%**	**0.05%**	**3.69%**	**0.44%**	**2.85%**	**4616**	**369**	**7.39%**
Refineries	100.00%	0.00%	0.00%	0.00%	0.00%	12	6	32.46%
Rubber and plastic products	90.78%	0.04%	3.28%	0.83%	5.06%	2450	180	6.84%
Stone, clay & glass	94.47%	0.11%	5.33%	0.00%	0.09%	1104	157	12.45%
Other transport	98.32%	0.00%	1.61%	0.00%	0.07%	654	26	3.77%
Shipbuilding	100.00%	0.00%	0.00%	0.00%	0.00%	15	0	0.00%
Other manufacturing	93.01%	0.00%	5.41%	0.00%	1.57%	381	0	0.00%
Low-tech industries	**93.59%**	**0.58%**	**5.54%**	**0.06%**	**0.24%**	**9293**	**1435**	**13.38%**
Food and beverage	92.69%	0.00%	7.05%	0.00%	0.25%	2292	351	13.28%
Tobacco	0.00%	0.00%	0.00%	0.00%	0.00%	0	0	0.00%
Textile	95.72%	0.00%	4.28%	0.00%	0.00%	987	198	16.75%
Clothing	100.00%	0.00%	0.00%	0.00%	0.00%	7	0	0.00%
Leather and shoes	100.00%	0.00%	0.00%	0.00%	0.00%	13	0	0.00%
Wood and wood product	100.00%	0.00%	0.00%	0.00%	0.00%	39	2	3.89%
Paper	100.00%	0.00%	0.00%	0.00%	0.00%	134	9	6.56%
Printing	100.00%	0.00%	0.00%	0.00%	0.00%	288	3	1.10%
Iron & Steel and non ferrous metals	94.83%	1.19%	3.84%	0.02%	0.11%	3150	419	11.73%
Metal products	90.05%	0.71%	8.45%	0.22%	0.57%	2248	453	16.77%
Furniture	100.00%	0.00%	0.00%	0.00%	0.00%	135	0	0.00%
Total manufacturing industry	**90.80%**	**2.54%**	**2.62%**	**0.44%**	**3.62%**	**72810**	**9322**	**11.35%**
Utilities	**100.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**1**	**0**	**0.00%**
Construction	**90.12%**	**0.00%**	**9.88%**	**0.00%**	**0.00%**	**514**	**89**	**14.72%**
Wholesale and retail trade	95.11%	0.00%	4.89%	0.00%	0.00%	94	17	15.17%
Hotels and restaurants	0.00%	0.00%	0.00%	0.00%	0.00%	0	0	0.00%
Transportation and storage	100.00%	0.00%	0.00%	0.00%	0.00%	28	4	13.56%
Telecommunications	97.59%	0.00%	0.12%	0.48%	1.81%	483	814	162.77%
Financial intermediates	88.25%	0.00%	11.75%	0.00%	0.00%	195	85	30.29%
Other services to firms	58.73%	9.80%	5.55%	0.00%	25.92%	2716	702	20.53%
Computing services	73.14%	0.00%	22.89%	0.00%	3.98%	2091	140	6.29%
Software production	82.90%	0.55%	8.68%	0.00%	7.88%	3659	852	18.89%
Research and development	37.85%	2.11%	22.70%	0.00%	37.34%	646	166	20.41%
Other services	90.97%	2.62%	0.00%	0.00%	6.41%	27	12	31.34%
Total services	**72.32%**	**3.02%**	**11.29%**	**0.02%**	**13.35%**	**9939**	**2792**	**21.93%**
Total	**88.61%**	**2.57%**	**3.69%**	**0.38%**	**4.75%**	**83519**	**12238**	**12.78%**

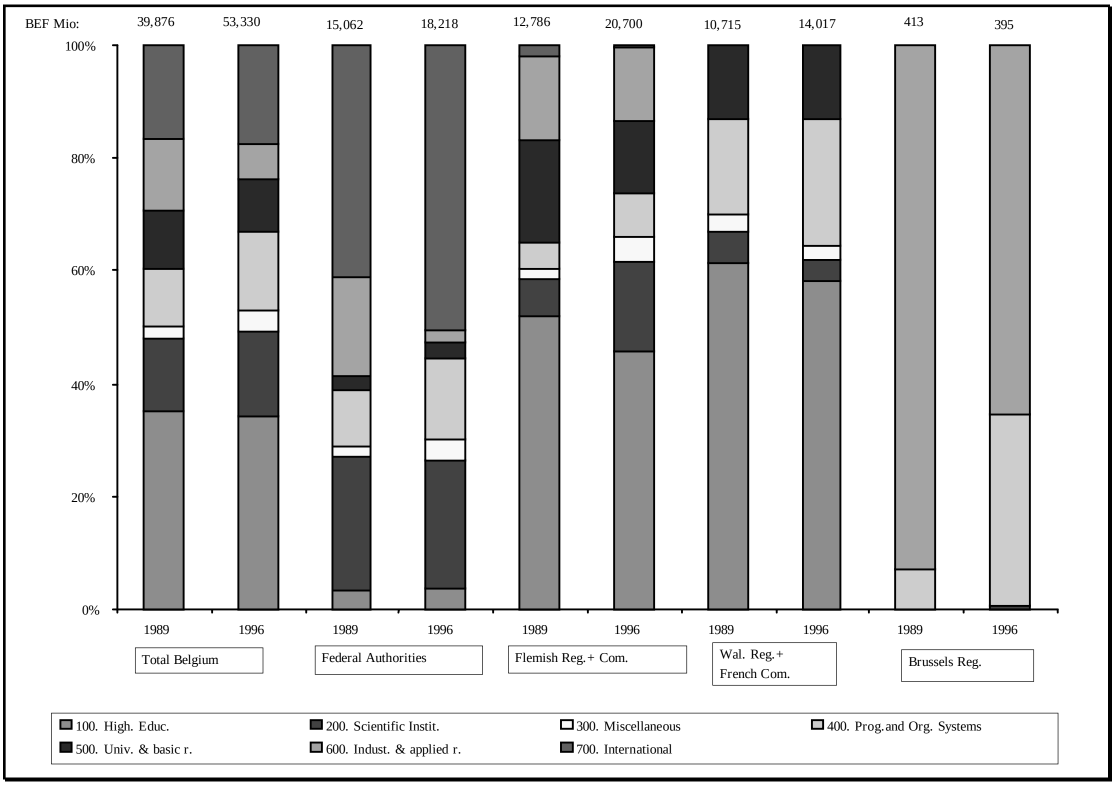
Sources: SSTC-DWTC, June 1997, provisional data; and own calculations.

3.6. The role of the federal government and the emergence of regional authorities

Tables A.3.4 and A.3.5 show the main public budget allocations with respect to functional destinations, by institution. These data enable the regional analysis of government support to R&D activities. They are given in Figures 3.4 and 3.5. Three main conclusions emerge from these figures.

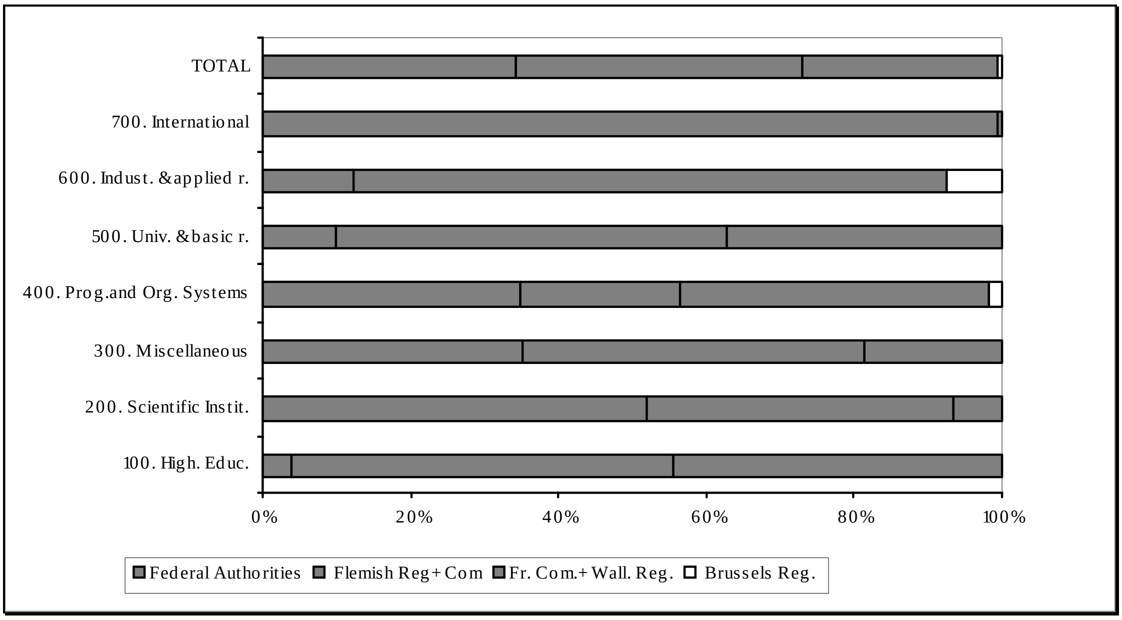
First, there is a clear tendency towards the regionalisation of S&T policies in Belgium. In 1989, the Federal authority had the highest share of budget allocations (39%) as compared to the Flemish Community (33%) and the French-speaking Community and Walloon Region (28%). In 1996, the Flemish Community expended 39% of the total amount spent by all Belgian authorities, whereas the Federal budget allocations fell to 34% and those of the French-speaking Community and Walloon Region dropped to 27%.

Figure 3.4 : Functional destination of public budget allocations to S&T activities,
By institution (1989 and 1996)



Sources: Table 3.4.

Figure 3.5 : Institutional distribution of public budget allocations to S&T activities,
By function (1996)



Sources: Table 3.4.

Second, the Federal authority devotes the larger share of its budget to international actions and specific scientific institutions. All other functional budget allocations are increasingly under the control of the regional authorities. Figure 3.5 illustrates the largest shares held by the Flemish Community in these other functional directions. Globally speaking, the main functional direction of total public budget allocations to S&T activities is towards the higher education sector (34%). Then come the international actions (17%), especially the 'space related' programmes (12%).

Besides the emergence of regional authorities, there is an impressive contrast between the two main regions with respect to public institutions engaged in Science and Technology activities and private business firms known to be active in R&D activities. The first half of Table 3.5 reports the number of Higher Education Institutions, Research and Technology Organisations and Bridging Institutions. The second half of Table 3.5 shows the number of firms carrying out R&D activities in each industry in the Flemish region, the Walloon Region and the Brussels Region. The Flemish Community has by far the largest number of private firms (640) performing research activities. Then comes the Walloon Region with 222 private firms and the Brussels Region with 116 firms. This contrast between the Flemish and the Walloon regions is reproduced for all services and manufacturing industries, although to a lesser extent in the high tech industries. In the latter, the number of firms carrying out R&D activities is still higher in the Flemish Region than in the Walloon, but in a less outspoken way (58 and 39, respectively). More precisely, there are nine firms belonging to the *drug industry* in each region, and the firms of the aerospace sector are all situated in the Walloon region. Map A.5.1 to A.5. 3 show a similar contrast at the district level, with respect to the number of private firms doing R&D activities, the number of libraries and documentation centres, and the number of research centres.

It is probably fair to say that at least part of the observed difference between the regions is attributable to the relatively tighter budgetary situation in the Brussels Region and in the southern part of the country.

Table 3.5 : Number of HEIs, RTOs, Bridging Institutions, enterprises engaged in R&D activities

	Belgium	Bxl-Capitale	Flanders	Wallonia
HEIs	**95**	**28**	**39**	**28**
UNIVERSITIES	19	6	6	7
AUTONOMOUS UNIVERSITY RESEARCH CENTRES	24	6	12	6
OTHER HEIs	52	16	21	15
RTOs	**172**	**78**	**68**	**26**
FEDERAL CENTRAL SERVICES				
Central Services	16	8	8	0
Scientific Institutions	38	29	8	1
Other Public Institutions	6	4	1	1
FLEMISH COMMUNITY				
Central Services	4	2	2	0
Scientific Institutions	5	2	3	0
Other Public Institutions	6	4	2	0
WALLOON REGION / FRENCH-SPEAKING COMMUNITY CENTRAL SERVICES				
Central Services	3	1	0	2
Scientific Institutions	3	0	0	3
Other Public Institutions	7	2	0	5
BRUSSELS-CAPITAL REGION CENTRAL SERVICES				
Central Services	1	1	0	0
Other Public Institutions	1	1	0	0
SUBORDINATED INSTITUTIONS	13	1	8	4
SEMI-PUBLIC INSTITUTIONS	8	4	4	0
NON-PROFIT MAKING PRIVATE INSTITUTIONS	13	7	6	0
SECTORAL CENTRES OF COLLECTIVE RESEARCH	43	10	23	10
INTERNATIONAL ORGANIZATIONS ESTABLISHED IN BELGIUM	5	2	3	0

Table 3.5 : Number of HEIs, RTOs, Bridging Institutions, enterprises engaged in R&D activities (con't)

BRIDGING INSTITUTIONS[a]	112	37	51	24
University/HEIs Interfaces	9	4	6	3
Science Parks	9	4	7	3
# of firms housed		79		
Number of firms carrying out R&D activities[b]	**978**	**116**	**640**	**222**
Agriculture	**5**	**0**	**5**	**0**
Mining	**5**	**1**	**3**	**1**
High tech industries	**119**	**22**	**58**	**39**
Drugs	**26**	8	9	9
Office machines	**7**	0	5	2
Electronic equipment and components	**41**	10	22	9
Instruments	**40**	4	22	14
Aerospace	**5**	0	0	5
Medium-high tech industries	**223**	**22**	**140**	**61**
Chemicals (excl. drugs)	**78**	10	49	19
Non electrical machines	**84**	7	53	24
Electrical machines	**46**	5	25	16
Motor vehicles	**15**	0	13	2
Medium-low tech industries	**124**	**5**	**89**	**30**
Refineries	**7**	1	5	1
Rubber and plastic products	**41**	1	31	9
Stone, clay & glass	**41**	3	25	13
Other transport	**6**	0	5	1
Shipbuilding	**6**	0	5	1
Other manufacturing	**23**	0	18	5
Low-tech industries	**227**	**8**	**176**	**43**
Food and beverage	**58**	0	50	8
Tobacco	**2**	0	1	1
Textile	**46**	2	40	4
Clothing	**4**	0	4	0
Leather and shoes	**4**	0	3	1
Wood and wood product	**10**	0	10	0
Paper	**11**	0	6	5
Printing	**9**	2	6	1
Iron & Steel and non ferrous metals	**24**	1	13	10
Metal products	**59**	3	43	13
Total manufacturing industry	**693**	**57**	**463**	**173**
Utilities	**4**	**1**	**2**	**1**
Construction	**27**	**3**	**21**	**3**
Wholesale and retail trade	**19**	6	10	3
Hotels and restaurants	**2**	0	2	0
Transportation and storage	**9**	5	4	0
Financial intermediates	**4**	2	2	0
Other services to firms	**67**	16	37	14
Computing services	**63**	16	34	13
Research and development	**13**	1	10	2
Other: Individual and social services	**5**	1	2	2
Total services	**182**	47	101	34
Others, non-classified	**62**	7	45	10

Sources: SSTC-DWTC, 1997.
a) not exhaustive b) About 400 firms are missing

3.7. The Performance of Higher Education

As part of the innovation system, the educational sub-system has very intense interactions with other components. It plays a capital role in knowledge transmission. More specifically, the number of graduates in science and engineering is the essential source of the research workforce and is important for the overall competitiveness of a country.

Hereafter some indicators are presented to give a global view of the role of higher education in the innovation system. As much as possible Belgian data are compared with those of other similar countries. Given the scarcity of data, only some albeit important questions are reviewed: on the one hand higher education training as a measure of the increase of the human capital stock, and on the other hand human capital mobility, here limited to students and researchers. The latter phenomenon constitutes an important channel in the knowledge acquisition process and the participation in European framework programmes.

One hears often that some European countries have a deficit with regard to the number of graduating engineers and scientists. Table 3.6 shows that this is particularly the case in Belgium. Despite the favourable evolution of the number of university graduates, Belgium is under both the European and the Triad averages. Not only is the relative number of graduates in natural and applied sciences dramatically inferior compared to the main industrialised countries but, what is more disturbing, the deficit is growing over time.

Table 3.6 : Higher education graduates (University degree)

	EUR15		TRIAD	
	1983	1991	1983	1991
Total share (%)	2.20	2.53	0.82	1.03
Natural and applied sciences share (%)	1.75	1.55	0.69	0.67
Total index	81	93	63	79
Natural and applied sciences index	65	57	53	52

Note: The indexes are the variables weighted by population divided by the similar value calculated for Europe and the Triad respectively.
Source: First European Report on S&T Indicators, own calculations.

As pointed out by the OECD (1992), there is a growing concern among industrialised countries about serious shortages of scientists and engineers. In the case of Belgium, the main reason must not be attributed to demographic factors but to a decreasing interest in scientific matters among the student population. The study of EGOR (1990) reveals that there is a shortfall of four thousand scientists and engineers in Belgium. This deficit is, in relative value, the highest among the European countries (see Table 3.7). Consequently, an important mismatch of the Belgian educational system is identified. The low value of the index for the flow of graduates in natural and applied sciences does not allow one to expect an improvement of the situation in the near future.

Table 3.7 : Shortfalls of qualified engineers in some European countries (1990)

	BE	DE	UK	NL	SP	IT	DA	SW	FR	P
Shortfall (in thousand)	-4	0	-8	+2.2	-5.3	-14.5	+0.8	-0.3	-11	-1.5
Per thousand inhabitants	-.40	0	-.14	+.15	-.14	-.26	+.01	-.04	-.19	-.15

Source: EGOR (1990)

The degree of the human capital mobility is another major means to increase the transfer of tacit knowledge. Unfortunately, only some fragments of information are available in the Belgian case, limited to the higher education sector. The role of Belgium in international human capital mobility can be partially appreciated through its position as a destination country for foreign students as well as an origin country of students moving to other countries. Table 3.8 gives a view of the Belgian position in both cases.

With regard to the Belgian position as a destination country, Belgium seems, at the European level, to benefit from a high attraction power on foreign students, especially from Italy, Luxembourg, The Netherlands and Spain. Yet, around 53% of foreign students come from developing countries, which can be explained by its colonial past. A second explanation is the high ratio of the foreign population which is equal to about 9 %. These two elements are certainly important sources of bias.

Turning to the Belgian students in foreign universities, we observe that Belgium is 11% above the European average for the within Europe exchange and 4% below the European average when Japan and the USA are included as countries of destination. Around 53% of Belgian students in other countries are concentrated in the neighbouring countries. The main countries of destination are respectively France, the USA, the UK, Germany and the Netherlands. Consequently, the Belgian mobility of students is to a large extent comparable to the one observed in other European countries.

Table 3.8 : Patterns of student mobility from and to Belgium

		Country of Destination			Country of Origin		
		EUR15	EUR, JAP, USA	Total	EUR15	EUR, JAP, USA	Total
Share	EUR15	11.7	9.9	7.5	3.0	2.5	0.9
	EUR, JAP, USA	8.7	6.4	3.7	2.6	1.8	0.5
Index	EUR15	432	365	276	111	193	-
	EUR, JAP, USA	670	493	285	96	139	-

Note: The indexes are the variables weighted by population divided by the similar value calculated for Europe and the Triad respectively..
Source: First European Report on S&T Indicators, own calculations

Specifically regarding research mobility, we can refer to the European Union programmes which have specific measures in this field. Table 3.9 summarises the Belgian participation in these actions. The scores obtained are globally satisfactory in both categories of indicators, i.e. from the perspective of partner country as well as host country. Consequently, we can consider that the Belgian research teams are relatively well integrated in the European research network.

Table 3.9 : Belgian Participation to European Actions (%)

Actions	Fellow Nationality	Host Institution
SCIENCE (1988-1992)	6	5
SPES (1989-1991)	2	28
HCM (1992-1994)	4	6

Source: First European Report on S&T Indicators, own calculations

3.8. Conclusions

The findings that emerge from this third chapter may be summarised as follows:

1. The relative R&D efforts in Belgium are higher than in Italy or Canada, but still lower than those of the US, Japan, and the other large European countries. The share of government R&D in total R&D outlays is relatively weak. The business sector is by far the largest financing source and the largest R&D-active sector in the Belgian economy.

2. High tech and medium-high tech industries account for only 8% of the total value added created by the whole business sector (including services), but implement 71% of total business R&D activities. The reverse is true for the services industry. The qualification level of total R&D personnel is much higher in the services industry than in the manufacturing industry. However, the manufacturing industry relies ten times more on R&D personnel than the services industry.

3. The services industry relies much more than the manufacturing industry on outside funding of intra-muros expenditures and more precisely, on funds from abroad and by the government. The services industry has also a higher propensity to finance extra-muros R&D.

5. There is a trend towards the regionalisation of S&T policies and a reduction of the role of the federal authority. Furthermore, the functional distribution of public budget allocations varies substantially across regional authorities, which denotes different regional behaviour regarding the organisation of their respective innovation systems.

6. Despite a favourable positioning with regard to the total number of graduates, Belgium is suffering from an insufficient number of graduates in natural and applied sciences. This deficit can be considered as a mismatch of the higher education system. The role played by Belgians in international human capital mobility witnesses the high degree of openness of Belgium comparative to other European countries.

4. R&D activities at the firm level

This section aims at describing some aspects regarding the orientation of R&D activities of Belgian firms. To begin with, the distribution of firms' R&D activities in several components, i.e. research versus development, process versus product R&D is given. Then the Schumpeterian hypothesis relating 'firm size and innovativeness' is examined. Finally, a first analysis regarding the pattern of Belgian firms in terms of R&D collaboration with the other actors of the NIS is presented.

4.1. R&D orientation of the Belgian firms

The R&D orientation of Belgian firms will only be briefly discussed. A clarification of the design and the preparation of the analysis, together with a full description and interpretation of the compounded tables - and the actual tables - can be found in K.Vandewalle (1998). The reported figures are for the year 1995, unless stated otherwise.

4.1.1. Research vs development

In the 1995 OSTC-sample of firms active in R&D, 424 reported on the distinction between research and development activities. We found that three-quarters of the total intramural R&D budget of these firms is used for the 'development' of new products and processes, and one quarter was spent on 'research' ([7]). Veugelers et al. (1995), taking into account the total R&D expenditure of Flemish firms only, report for the year 1993 a comparable research share of 28 %. The same relative quantities are found for other European countries (see for instance Pavitt (1984)).

Nelson's opinion (1959, p.299) in this context is of particular relevance: 'Research, and especially basic research, is an uncertain activity, yielding inventions and discoveries in unexpected areas. The firm with interest in a diversity of fields will generally be able to produce and market a higher proportion of these unexpected inventions than a firm whose product line is narrow'. This means that, in general, larger firms, mainly due to the existence of economies of scope, are expected to contribute a relatively larger share of their R&D budget to research activities proper ([8]).

The share of intramural research accounted for by the five largest firms of our sample is - consistent with Nelson's statement - indeed well above their share of intramural development, and in general larger firms (500 employees and more) are found to be relatively more research-oriented. However, at the other end of the scale, the smallest firms (fewer than 25 employees) are also found to be relatively more research-oriented.

[7] OSTC is the Federal Government agency responsible for R&D Policy and centralizes the results of biannual surveys carried out on regional level.
[8] As it is expected that larger firms will generally have a larger number of existing product lines and so are expected to have interests in a diversity of fields.

Calculation of the relative amount of intramural R&D expenditure in the above mentioned sample, allocated respectively to research and development, for the manufacturing sector as a whole and some sub-sectors, revealed relatively large interindustry differences. The *chemicals* industry in Belgium for instance allocates on the average more than one third of the total intramural R&D budget to research, while for the *electrical equipment & components* industry the share is only about 10%. Taking the overall manufacturing shares as a reference, we can say that both the *chemicals* and the *iron & steel and ferrous metals* industry are, relatively spoken, much more research-oriented than the *textile*, *electrical equipment & components* and *non-electrical machines* industries, which are preponderantly development-oriented.

Rather surprisingly, we established that taken as a whole the high-tech industries spent the smallest percentage of their total intramural R&D budget on research. However, both the smallest firms and the firms employing 500 up to 1,000 people in the high-tech industries contribute nearly 45 % of their total intramural R&D budget to research activities. For firms employing between 25 and 50 people the share drops to 23 %, and for the size class '50-100' it drops down to only 8 %.

A similar research orientation is found for 'medium high-tech' firms active in R&D. Again the smallest firms are, relatively speaking, the most research-oriented, with a share of about 42 %. The next size class devotes only 26 % to research, and the size class '50-100' less than 12 %. The 'medium-low' and low-tech industries show a different picture, with respectively the medium large firms (250 up to 500 employees) and the largest firms (more than 1,000 employees) being the most research-oriented.

4.1.2. Product vs process innovation

In discussing the breakdown of the innovative effort into product and process innovation it should be remarked first that a relatively large share of total intramural R&D (more than 15 %) of our sample could not be allocated to either product or process innovation. In particular very small firms seem to have some difficulties in assigning their intramural R&D expenditures to one of the two categories ([9]). Taking this into account, we can, with caution however, say that about three-quarters of the allocable intramural R&D expenditure is used for the innovation of products, rather than processes. The larger the firm however, the more process-innovations seem to become more important, except however for the firms with more than 5,000 employees, where again product innovation rises above the average for the whole sample. Pavitt et al. (1987) also found the medium-sized firms to be mostly process-oriented.

For the manufacturing sub-sectors we found that one industry is an outlier in the sense of being extremely process-oriented, viz. the *iron & steel and non-ferrous metals* industry. This industry devotes not less than 70 % of the total intramural R&D expenditure to the development of new processes. In contradistinction, innovation in the *chemicals*, and even more the *electrical equipment & components* industry, can be labelled as rather product-oriented.
The share of intramural R&D expenditure allocated to either product or process innovation, according to the technological level, reveals that the Belgian high-tech sector is strikingly

[9] More than 60% of the total intramural R&D expenditure of the smallest firms (fewer than 25 employees) cannot be allocated to either product or process innovation. The share falls sharply for large firms (500 employees and more), and even disappears for firms with more than 5,000 employees.

product-oriented, while the medium-high and medium-low-tech sectors, although they too allocate more than 50 % of their intramural R&D expenditure to the development of products, contribute to a considerable extent also to the development of new processes. No clear conclusion could be made about the low-tech sector, as nearly 50 % of the total intramural R&D expenditure of this sub-group could not be allocated to either product or process innovation.

4.1.3. Capital vs labour intensive

In conclusion of this section discussing the R&D orientation of Belgian firms, we have a brief look at the capital vs labour orientation of the R&D performing firms. The degree of capital intensity is measured by the share of the R&D budget devoted to investments (as reported in the 1995 OSTC survey). The labour intensity is similarly measured by the share of the R&D personnel expenditure in the total intramural R&D budget.

Apart from these two categories the 1995 OSTC survey reports data on the operational costs as a result of the performed R&D activities ([10]). The latter category is shown to represent more than one third of the total intramural R&D budget. Overall we can say that the R&D activity of the Belgian firms is characterised by a rather high labour-intensity, i.e. as high as in Germany, and higher than in most other European countries and in Japan. More than half of the total intramural R&D budget is used to cover R&D personnel expenditure, while only a small 8 % of the budget is used for investments.

Differentiated over the size classes we can state that small and medium-size firms (up to 500 employees) are somewhat less labour-oriented (in comparison to the average values), but for the SMEs this is due to relatively high operational expenditures. This implies that the SMEs cannot be labelled as (relatively) more capital intensive than the average firm. Firms employing '250-500' persons, on the contrary, are shown to be relatively more capital intensive, reporting an investment share of 14 %. Firms in the size class '500-1,000' employees report also a relatively high investment share, and as consequence can be called, again in comparison to the average values, to be more capital intensive.

Taking account of the manufacturing sector only, a similar breakdown between size-classes is found. We came however across relatively strong interindustry differences, but these again essentially boil down to differences in the share of operational costs. We should stress indeed that the spread between the most and least labour- (or capital-)intensive sectors, after correction for differences in operational cost, was only 4.3 percentage-points. This puts statements about higher or lower labour- or capital-intensity in an ambiguous perspective.

According to the technological level, we found that for both high-tech and medium-low tech industries the operational expenditures represent a relatively large share of the R&D budget. Omitting the latter costs, the medium-low industries are found to be the most labour intensive (with a labour share of 93.7 %), while the medium-high industries are found to be, relatively speaking, the most capital intensive. The spread between the relative shares being 8.9 percentage-points.

[10] Operational costs represent for example administration costs, telephone bills, ...

4.2. Firm size and R&D intensity of firms

When studying the determinants of technological progress and the structure of the National Innovation System (NIS), we obviously need a focus on the relation ‘firm size - innovativeness’ as being one of the more specific aspects of the Schumpeterian paradigm. Analogous to the previous section we will only report the results in brief and refer the interested reader to the reports of G.Rayp et al. (1998) and K.Vandewalle (1998) for a more profound discussion of the data for Belgium.

4.2.1. Design of the analysis

Our analysis of the relationship ‘firm size - R&D intensity’ will consist of two parts. The first part will be of a more descriptive nature, i.e. the nature of the relationship will be treated empirically. Making use of the OSTC database for the year 1995, we will discuss a number of tables including, among others, the share of R&D expenditure, the share of sales and some proxy measures for the R&D-intensity. These tables relate to the sample as a whole, as well as to sub-samples (specific industries, subdivisions according to the technological level, etc.), and will provide a first insight about the nature of the relationship.

The second part will contain regression results on the basis of panel data. Making use of the OSTC surveys for the years 1985 through 1989, we were able to build a ‘quasi-panel’ of sufficient size covering these years. The term ‘quasi’ refers to the fact that, rather than considering a true panel relating to a limited number of companies which were present in the 1985 through 1989 samples, we collected data on average values within the period for the relevant inflation-corrected variables for those companies for which we disposed of data in at least two successive surveys. In order to reveal the nature of the relationship we will estimate a simple linear regression, with the dependent variable being R&D-intensity as a proxy measure for innovativeness.

4.2.2. Descriptive approach

The empirical analysis is based on OSTC data for the year 1995, taking into account the R&D reporting firms only. Table 4.1 presents the 505 surveyed companies in a cumulative way according to their size, in terms of the number of employees ([11]). Two R&D intensity measures are reported (Table 4.2), the first defined as the firm’s R&D expenditure over sales, the second as the firm’s R&D expenditure over total employment ([12]).

We immediately notice the relative importance of small firms in the sample ([13]). Firms with fewer than 250 employees account for 18.02 % of total R&D expenditure and employ 20.54 %

[11] Each of the firms was examined individually. Doubtful or clearly wrongly reported figures were corrected where possible (making use of the database of the NBB and Trends Top 5000); if no correction was possible, the firms were excluded from consideration. At the end of this procedure we retained 505 firms.
[12] Following Scherer (1965b) we opted for ‘firm sales’ as a meaningful size variable.
The thresholds were chosen somewhat arbitrarily, but as meaningfully as possible for the Belgian economy (defined as a SME-economy)
[13] The European Commission defines small firms as firms employing fewer than 250 persons.

of R&D personnel, but account for less than 11 % of total sales (Table 4.1). This means that the small firms in this sample of R&D-active companies make a more-than-proportional contribution to the development of new products and processes. Kleinknecht et al. (1991), studying the Dutch economy, also found that smaller firms, although having but little probability of engaging in R&D, are certainly not less innovative than larger firms. Medium large firms are reported to contribute the least. We see also that the contribution share of the largest firms (up to 5,000 employees), when R&D expenditure and R&D employment are considered, is relatively high in proportion to their sales. These findings obviously also apply when the R&D intensity measure (computed as the firm's R&D expenditure over sales) is taken into account (Table 4.2) ([14]). Firms up to 250 employees report very high intensities. Once above 250 employees the measure drops sharply, to rise again for firms with more than 1,000 employees.

Table 4.1 : Cumulative sales, share of R&D expenditure and R&D employment for the sample (1995)

Size by number of employees	Sales (*)	Share of R&D expenditure (*)	Share of R&D employment (*)
< 25	1.00%	2.18%	2.84%
< 50	2.51%	4.97%	6.32%
< 100	4.19%	9.12%	10.82%
< 250	10.49%	18.02%	20.54%
< 500	33.10%	26.28%	29.64%
< 1000	48.48%	37.60%	39.05%
< 5000	78.91%	79.03%	80.84%
Total	100.00%	100.00%	100.00%

(*) as a % of the total
Source: OSTC database; author's calculations

Taking the R&D intensity measure as a proxy for the innovativeness, these results seem to give some support to the hypothesis of an U-shape relationship between firm size and innovativeness, with a relative larger importance of small firms. This agrees with a similar conclusion put forward by the European Commission in the 1994 issue of 'The European Report on Science and Technology Indicators'. Veugelers et al. (1995), studying a subset of Flemish firms, also found evidence in support of the U-shape relationship. Firms with 200 to 1,000 employees are found to contribute the least, while SMEs (here defined as firms with fewer than 200 employees) and firms with more than 1,000 employees are found to have an R&D intensity above the average. A note of warning though: the relatively concentrated innovative activity among small and very large firms does not necessarily also mean that innovativeness relates with firm size on an U-shape basis ([15]). We also stress again that this results relates only to a sample of R&D-active firms. The result therefore tells us little about SMEs as such.

[14] As stated by Acs & Audretsch (1987) ratios are more meaningful, because the absolute R&D expenditure is not standardized by an equivalent measure of firm size.
[15] Although, studies for the UK and US point out that the R&D efficiency of SME's is – particularly in some specific industries – higher than for large firms (Dodgson & Rothwell (1994)).

Table 4.2 : R&D intensity measures per size class (1995)

Size by number of employees	R&D-expenditures/ turnover	R&D-expenditures/ number of employ-ees
< 25	7.86%	0.89
25 < x< 50	6.65%	0.56
50 < x < 100	8.88%	0.61
100< x <250	5.10%	0.42
250 < x < 500	1.31%	0.25
500 < x < 1000	2.65%	0.26
1000 < x < 5000	4.90%	0.39
5000 and more	3.58%	0.18

Source: OSTC database; author's calculations

Table 4.3 shows the share of the sales, the share of R&D expenditure and the share of R&D employment according to firm size. The 505 firms are ranked by sales, in descending order. The share of the R&D accounted for by the largest firms is well below their share of sales. Even the 250 largest firms in the sample make a less-than-proportional contribution to the development of new products and processes. These findings are the opposite of those of Soete (1979), Acs & Audretsch (1991) and others, who found that the share of R&D accounted for by the largest firms slightly exceeded their share of sales. Thus, Table 4.3 also suggests that the smaller firms in the sample contribute a more-than-proportional share of R&D. However - this cannot be stressed enough - this relatively concentrated R&D activity does not necessarily mean that innovative activity itself is in the same way related with firm size.

Table 4.3 : Cumulative share of sales, R&D expenditure and R&D employment according to firm size (1995)

Number of firms ranked by sales	Share of sales	Share of R&D expenditure	Share of R&D employment
first 5 (*)	32.09%	4.78%	4.69%
10	44.70%	28.94%	29.27%
15	52.93%	45.65%	43.36%
20	58.83%	53.41%	52.28%
25	63.17%	58.92%	57.21%
50	76.46%	70.86%	70.03%
100	88.69%	80.62%	78.53%
250	98.31%	93.15%	91.06%
Total	100.00%	100.00%	100.00%

(*) not very robust: when we take the first 6 the share of R&D expenditures and employment almost triples.
Source: OSTC database; author's calculations

As we noted before a variety of possible relationships can be considered to underlie these kind of results. Mansfield (1964) and Freeman (1974), for instance, have argued that the nature of the relationship depends upon the industry. The different proxy measures for the whole of the manufacturing sector also reveal a relative large importance of small firms. Especially very small firms (fewer than 25 employees) are found to contribute more than a proportional share of R&D. While accounting for only 0.28 % of the sales, their share of R&D expenditure amounts to 0.51 % and their share of R&D employees is an even larger 1.18 % (compare this to the total employment share of 0.37 %). The share of R&D accounted for by the largest firms (more than 1,000 employees) is also large in relation to their share of sales, indicating again that both very small and very large firms make a more-than-proportional contribution to the development of new products and processes.

Apart from analysing the manufacturing sector as a whole, we find it worthwhile to take a closer look at some specific manufacturing industries. As claimed by Cohen et al. (1987, p. 545): ‘Interindustry differences in technological opportunities and in the appropriability of returns from R&D investment may (...) influence the degree to which size confers advantages or disadvantages’. And they continue and state that: ‘(...) a spurious statistical connection between R&D and size may arise as a consequence of failure to take adequate account of interindustry differences’.

Table 4.4 reports similar findings for the main sub-sectors as for the whole of manufacturing, with an exception for the *chemicals* industry. Only in the latter industry do we find that the share of the R&D budget compared to sales is higher for large firms than for small firms. For all the other sectors we can again conclude that the proportional R&D share of small businesses is, most of the time substantially, higher than the contribution of large firms. And as a consequence we can argue that small firms active in the R&D field contribute a more-than-proportional share of R&D and are not, as claimed by the Schumpeterian hypothesis, of less importance for the development of new products and processes. We need to stress that, in general, the importance of small firms is found to be rather limited in industries characterised by high capital and/or R&D requirements and high entry costs (e.g. *aerospace*, *motor vehicles* and *pharmaceuticals*).

Table 4.4 : R&D intensity measure, defined as R&D expenditure over sales (1995)

Size by number of employees	Textile	Chemicals	Iron & Steel and non ferrous metals	Electrical machines	Electrical equipment & components	Non-electrical machines
< 250	1.1%	2.5%	1.4%	4.3%	14.2%	5.0%
250 < x < 1000	0.6%	3.6%	0.3%	3.4%	11.8%	3.7%
1000 and more	0.5%	6.4%	1.2%	3.0%	11.4%	5.1%

Source: OSTC database; author’s calculations

Although the nature of the relationship between size and R&D intensity seems to be similar in most sub-sectors we notice considerable intersectoral differences as far as the R&D intensities themselves are concerned. The extremely high values for the *electrical equipment & components* industry, and to a lesser extent for the *non-electrical machines* industry, were also found by Acs & Audretsch (1991)([16]). Scherer (1967) argues that these kinds of interindustry differences are mainly due to the ‘vigorous scientific climate’ typical for these industries. Klevorick et al. (1995) explain the interindustry differences by differences in technological opportunities. *Electrical equipment & components* and *chemicals* (mainly drugs) are both labelled as ‘high opportunity sectors’. They also stipulate that R&D intensity in an industry is strongly correlated with the strength of the connections of that industry with several of the fields in science and with the contributions made by university research and government laboratories. Klevorick et al. (1995) further state that the interindustry differences in the amount of resources devoted to R&D, whether measured in absolute terms or relative sales, can be explained by two key variables: technological opportunity, and the ability to appropriate the returns from new developments.

Scherer noted in his 1965 papers that, in order to obtain a clear view on the nature of the rela-

[16] Acs & Audretsch (1991) also found relatively high R&D expenditures for the computer and office equipment industry.

tionship ‘size - innovativeness’, it can be worthwhile to divide the firms into different classes according to their relative level of innovativeness, and then to estimate separate regressions for these subgroups. In the following Tables 4.5 and 4.6 we make a related distinction according to technological level. We will distinguish among ‘high-tech’, ‘medium-high-tech’, ‘medium-low-tech’ and ‘low-tech’ industries, following the classification used by the European Commission.

The relative contribution of large firms (as opposed to that of small firms) is found to be the highest in the ‘High Tech’ industry. Also, the lower the technological level, the higher the relative importance of small firms.
A particular problem when analysing the total R&D expenditure arises in the sense that most firms report both intramural and extramural R&D expenditure. The extramural R&D contribution of one firm may be part of the intramural R&D expenditure of another firm. In order to avoid such cases of ‘double counts’ it is appropriate to have a closer look at the relationship ‘firm size - intramural R&D expenditure’. Moreover, following Griliches (1986): ‘the correlation between in-house R&D and innovativeness seems to be higher than between total R&D and innovativeness’. This makes it even more appropriate to exclude extramural R&D expenditure.

Table 4.5 : Share of sales and R&D expenditure for different technological levels (cumulative data), 1995

Size	High Tech		Medium-high Tech		Medium-low Tech		Low Tech	
by number of employees	Share of sales	Share of RD exp.	Share of sales	Share of RD exp.	Share of sales	Share of RD exp.	Share of sales	Share of RD exp.
< 25	0.6%	0.43%	0.2%	0.4%	0.1%	0.8%	0.2%	1.3%
< 50	1.4%	1.17%	1.6%	0.9%	3.1%	3.4%	1.6%	5.2%
< 100	2.3%	1.57%	4.2%	2.8%	4.8%	5.2%	2.5%	7.0%
< 250	6.3%	4.20%	10.7%	9.6%	14.7%	14.0%	10.5%	13.6%
< 500	13.5%	6.54%	22.0%	22.2%	25.8%	24.8%	26.1%	20.0%
< 1000	23.9%	14.67%	28.1%	27.2%	69.4%	66.3%	48.5%	38.7%
Total	100.0%	100.00%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: OSTC database; author’s calculations

Starting from the original sample of 505 firms, we eliminated 11 firms which reported doubtful figures regarding the division of intramural and extramural R&D expenditure. More than half of the firms (51%, to be exact) said not to contract out any R&D, and as a consequence reported intramural R&D expenditure only.

Table 4.6 : R&D intensity measures for different technological levels, 1995

Size by number of employees	High Tech R&D intensity (*)	Medium-high Tech R&D intensity (*)	Medium-low Tech R&D intensity (*)	Low Tech R&D intensity (*)
< 25	8.9%	6.3%	(**) 18.8%	5.5%
25 < x < 50	11.4%	1.2%	1.5%	2.8%
50 < x < 100	5.4%	2.4%	2.0%	1.8%
100 < x < 250	8.1%	3.4%	1.6%	0.8%
250 < x < 500	4.0%	3.6%	1.7%	0.4%
500 < x < 1000	9.8%	2.6%	1.7%	0.8%
1000 and more	13.9%	3.3%	2.0%	1.1%

(*) defined as R&D expenditure over sales

(**) not very robust
Source: OSTC database; author's calculations

Table 4.7 : Share of sales and intramural R&D expenditure, and R&D intensity measure for the reduced sample of 494 firms, cumulative and according to size class (1995)

Size by number of employees	Share of sales	Share of intramural R&D expenditure	Size by number of employees	R&D intensity (*)
< 25	1.0%	1.6%	< 25	4.3%
< 50	2.5%	4.6%	25 < x < 50	5.2%
< 100	4.2%	8.8%	50 < x < 100	6.7%
< 250	10.5%	17.1%	100 < x < 250	3.5%
< 500	33.1%	26.4%	250 < x < 500	1.1%
< 1000	48.5%	38.7%	500 < x < 1000	2.1%
< 5000	78.9%	75.2%	1000 < x < 5000	3.2%
Total	100.0%	100.0%	5000 and more	3.1%

(*) defined as intramural R&D expenditure over sales
Source: OSTC database; author's calculations

A familiar pattern can be recognised in Table 4.7: small firms account for a relatively large share of the total R&D expenditure. It should however be noted that the R&D intensity ratio differs less between the different size classes when we consider company-financed R&D only (compare with Table 4.2).

The overall finding that small firms seem to contribute in a more-than-proportional way to R&D has to be handled with some caution. First, because we took account of R&D performing firms only, on the basis of the OSTC sample. This implies that the previous findings are biased because of a serious 'sample selection'- problem. Second, we know that (see, for instance, Kleinknecht (1987)) many small firms often have no formal R&D activity. Technological innovation is, in those cases, said to be the product of a typically unmeasured fraction of time worked by the engineers and managers of the firm, and as a consequence the individually reported R&D efforts of small firms might be 'over-estimated' if reporting is not done properly in full-time equivalents. Third, as argued by Kleinknecht et al. (1991), there are some indications that innovative firms might have a higher propensity to respond (and to do so more completely) to an innovation questionnaire than non-innovative firms. In other words, could it be that the 'big' small innovators (having better figures on their activities) respond more than the 'small' small innovators, and as a consequence the efforts of small firms are over-estimated ?
However, previous research suggests that, generally speaking, small firms underestimate their R&D contributions (see for instance Kleinknecht (1987) and Mansfield (1964)), which would then suggest that our findings of a less-than-proportional relationship imply an even stronger rejection of the Schumpeterian hypothesis than might appear at first sight. Furthermore, studies for the UK and US point out that the R&D *efficiency* of SMEs –particularly in some specific industries – is higher than for large firms (Dodgson & Rothwell (1994)). This implies that (i) a higher proportion of innovative activities of SMEs occurs outside of what is formally defined as R&D, and (ii) the contribution of SMEs towards the development of new products and processes – by using R&D expenditures as a proxy for the R&D efforts and innovativeness – is even underestimated.

In brief, the foregoing findings (of the empirical approach) have to be handled with caution, all the more because, apart from taking account for R&D-performing firms only, we also only accounted for firm size. In order to develop an initial insight, we ignored several other potentially relevant factors influencing innovative activity. In the following section (the quantitative approach) we will bring the relationship into broader perspective by studying it through the use of regression analysis.

4.2.3. Quantitative approach

Many of the earlier (mainly American) firm-level analyses are based on the 500 or 1,000 largest firms in the manufacturing sector, and most of the time firms that reported no R&D were excluded. Apart from obvious measurement problems, this kind of design introduces the difficulty of sample selection bias. By dealing with R&D-performing firms only, our analysis will also be subject to the problem of sample selection bias and as a consequence be similarly open to criticism.

On the basis of the OSTC surveys we tried to construct a panel of Belgian R&D-performing firms ([17]). However, because we were - when constructing a panel covering the years 1985 through 1989 - confronted with serious problems in terms of 'sample size reduction' and 'sample selection bias' (due to the changing sample of firms that was used in the consecutive surveys), we opt for a 'third best' solution which consists of defining a *sample of average values* of the firms with at least two observations over the period. Using a 'semi-panel' technique we are still able to focus solely on the - for our purpose - most relevant independent variable, namely 'firm size', and to take account of individual effects and intra-industry effects via the incorporation of 2- and 3-digit industry dummies ([18]).

The most neutral indicator of firm size is found to be 'sales' (Scherer (1965b))([19]). Analyses using R&D employment, patents or innovation counts as a proxy measure for innovativeness seem to overestimate the R&D contribution of small firms (Soete (1979) ; Acs & Audretsch (1991)). In view of these findings we define our proxy measure for the 'innovativeness' as the firm's (average) R&D expenditure. The size variable is defined as one period lagged (average) sales ([20]). All data are in fixed prices of 1985 ([21]).

For reasons of simplicity and transparency we will specify a simple linear regression between

[17] The advantage of panel data is that, using the technique of 'fixed effects model' estimation, we are able to (i) concentrate on the main estimator (in casu the size variable), (ii) take account of *'omitted variables'* influencing the R&D activity via the incorporation of unobserved individual firm effects and (iii) account for industry differences by means of the incorporation of industry dummies.

[18] For practical reasons we assigned each sample firm to a primary industry using the two-digit NACE-classification. However, Cohen et al. (1987, p.545) warn against such a practice. They argue that by doing so interindustry differences are not accounted for in an adequate way, and the risk of a spurious statistical connection between size and R&D may arise.

[19] Scherer (1967) argues that the 'sales' variable is most likely to be responsive to short term changes in demand, while it is neutral with respect to factor proportions. 'Sales' has also been proven to be the principal scale variable considered in company R&D budget decisions.

[20] The average sales are defined as the average of the *one period lagged* sales in order to reflect the fact that the decision about the amount spent on R&D in period t relies generally one the sales (or cash flow) of the previous period (t-1).

[21] The R&D expenditure were deflated using the general OECD-Basic Science and Technology Statistics (BSTS) deflator, defined as the Belgian R&D expenditure in current prices over the R&D expenditure in fixed 1985 prices. For the transformation of the current sales we applied nace 2-digit deflators based on the added value of the specific industry.

the firm's R&D expenditure (RD) and sales (S). We finally opt for a logarithmic specification, as it is shown to be the least sensitive for 'outliers' and presents the best 'goodness of fit' (see Rayp et al. (1998)) ([22]).

$$\log (RD_i) = \alpha + \beta \log (S_i) + \gamma D_i + \varepsilon_i \ ,$$

with D_i being a vector of the relevant 2- and 3-digit industry dummies.

Table 4.8 : Estimation results for the eight sub-samples

Industry	**Logarithmic specification**			
				estimation problems
Chemical	$\beta = 0.63$ [0.47 ; 0.79]	n = 64	Adj-R^2 = 0.60	Functional misspecification
Food	$\beta = 0.58$ [0.26 ; 0.90]	n = 24	Adj-R^2 = 0.73	
Textile	$\beta = 0.92$ [0.64 ; 1.2]	n = 22	Adj-R^2 = 0.69	Functional misspecification (CI-90%) Parameter stability (CI-90%)
Metal	$\beta = 0.95$ [0.77 ; 1.13]	n = 62	Adj-R^2 = 0.77	
Electrotechnics	$\beta = 0.75$ [0.57 ; 0.93]	n = 38	Adj-R^2 = 0.78	Functional misspecification
Wholesale	$\beta = 0.73$ [0.53 ; 0.93]	n = 20	Adj-R^2 = 0.74	
Ferro & non-ferrous metals	$\beta = 0.57$ [0.47 ; 0.67]	n = 20	Adj-R^2 = 0.93	
Services for companies	$\beta = 0.63$ [0.43 ; 0.83]	n = 30	Adj-R^2 = 0.55	Parameter stability

Increasing returns are reflected by the scale parameter β greater than unity. Estimating the sample as a whole (375 observations) we came up against a strong rejection of the 'normality property', mainly due to the overall heterogeneity of the data. In order to resolve this we divided the sample - on an 'ad hoc' basis of prior homogeneity expectations - into eight sub-samples, each counting at least 20 observations. The estimation results are given in Table 4.8. We report on the coefficient of the scale parameter, the 95% confidence interval of β, the sample size (n), the adjusted R^2, and the statistic irregularities - at 95% confidence level unless otherwise specified - of each specification. The coefficients of the dummy variables in each equation are not reported.

For all industries but two, we found a *'less-than-proportional'* relationship between R&D efforts and firm size. Only for the *textiles* and *metal* industry the zero-hypothesis - a proportional relationship between R&D expenditure and firm size - could not be rejected. The latter industries account for approximately 15 % of the total R&D expenditure of the overall sample, a quarter of the sales, and represent some 30 % of the number of firms in the sample.

Once again, the foregoing findings have to be handled with caution, all the more, because

[22] Rayp et al. (1998) use three different specifications: a quadratic, a logarithmic and an intensity specification. The best results are given by the logarithmic specification.

apart from taking account for R&D-performing firms only, we have to bear in mind that a logarithmic specification places a greater weight on small firms, and as a consequence may lead to an over-estimation of the R&D contribution of these firms (Acs & Audretsch (1991)). However, a similar conclusion can be drawn when analysing the 1995 (OSTC) figures by means of a more straightforward method. Using a 'crosstabs' procedure we produced, in order to test the association between the two variables, a two-way table between a proxy measure for innovativeness and firm size. Innovativeness now being defined as the *percentage of new products in the total sales* (NEWPROD) ([23]). We distinguished 3 categories: (1) fewer than 10%; (2) between 10% and 30%; and (3) more than 30%. The scale variable (SIZE), also a dummy variable, discriminates between SMEs (firms with fewer than 250 employees) and large firms (250 employees and more).

According to the Schumpeterian hypothesis - stating that large firms make a more than proportional contribution to the development of new products and processes - it is expected that the percentage of sales originating from new products is bigger for large firms. That is, the observed number of large firms in the third category of NEWPROD is expected to exceed the number count on the basis of an 'equal distribution'.

The results - carried out on the basis of an OSTC sample of 518 Belgian companies - are given by Table 4.9. We took account of R&D-performing firms only and made a selection of those firms reporting the percentage of sales originating from new products.

It appears that:

- the observed number of SMEs (SIZE = 0) in the first category of our innovativeness variable (NEWPROD = 1) is lower than the expected number;
- the number of SMEs that rely for their sales on a large percentage of new products (NEWPROD = 3) exceeds well the expected number;
- the opposite appears for large firms (SIZE = 1).

Table 4.9 : Results of the 'crosstabs' procedure: innovativeness vs size

			NEWPROD			
			1	**2**	**3**	Total
SIZE	**0**	Observed	196	114	90	400
		Expected	205	114	80	400
		%	73.7%	77.0%	86.5%	77.2%
	1	Observed	70	34	14	118
		Expected	61	33.7	23.7	118
		%	26.3%	23.0%	13.5%	22.8%
		Total	266	148	104	518

Four measures of association were computed (Pearson chi-square, likelihood-ratio chi-square, Phi and Cramer's V), all indicating that there is a significant difference between the two size-categories. Taking account of the direction of the difference we can only conclude that large firms are not found to be more innovating. Moreover, our outcomes do suggest a *less-than-*

[23] By taking *the percentage of new products in the total sales* as a proxy measure for innovativeness, we are now dealing with an output-measure (while the previously used *R&D expenditure* was an input-measure), and are – strictly speaking - taking account of *product innovations* only. However, the invention of new products is not seldom related to the implementation of new industrial (or organisational) processes.

proportional relationship between innovativeness and firm size.

In conclusion of this section, we need to stress two points. The relation between technological change and innovativeness may not be seen as being a static one, where small and large firms operate in isolation from each other. Small and large firms do interact, mainly because of the existence of 'dynamic complementarities' that can be exploited (Dodgson (1991)). Some industries, as e.g. the ICT and biotechnology industry, can be characterised by what we could describe as a *'life-cycle'*-structure of the innovation. In the early stages mainly small firms are involved in the act of innovation, because small firms seem to be able (more than large firms) to take advantage of basic research (universities and government labs) and venture capital. These specific R&D efforts by small firms often 'flow' in a later stage towards established (generally) large firms. The advantages related to mutually complementary relationships between small and large firms will become an increasingly important factor for further technological progress. Because of the limitation of SMEs in the act of innovation – mainly due to the lack of a 'critical mass' and an accumulated knowledge stock – they in particular will benefit from further 'networking'.

The last point concerns the life-cycle structure of firms: successful innovative SMEs often enter a growth stage so that after some time they end up in the class of medium-sized or even large enterprises. In trying to detect a relation between innovativeness and size we should therefore try to take full account of the dynamics of firm growth, rather than relying on cross-section data.

4.3. R&D collaborations between Belgian firms and other actors of the NIS

This section studies technological collaborations between Belgian firms and the principal actors of the NIS implied in R&D activities and located in Belgium (b) or abroad (f). Among these actors, one distinguishes customers, suppliers, other firms (including companies of the same group), universities, non-commercial research centres, collective research centres and other partners. Collaborations are defined as formal agreements concluded with other firms and research institutions for the realisation of (common) R&D objectives. Collaborations can relate to the exchange of information, the co-ordination of R&D activities or joint development, within a new physical structure or otherwise. Various collaborations are possible with a same partner in so far as they relate to different projects.

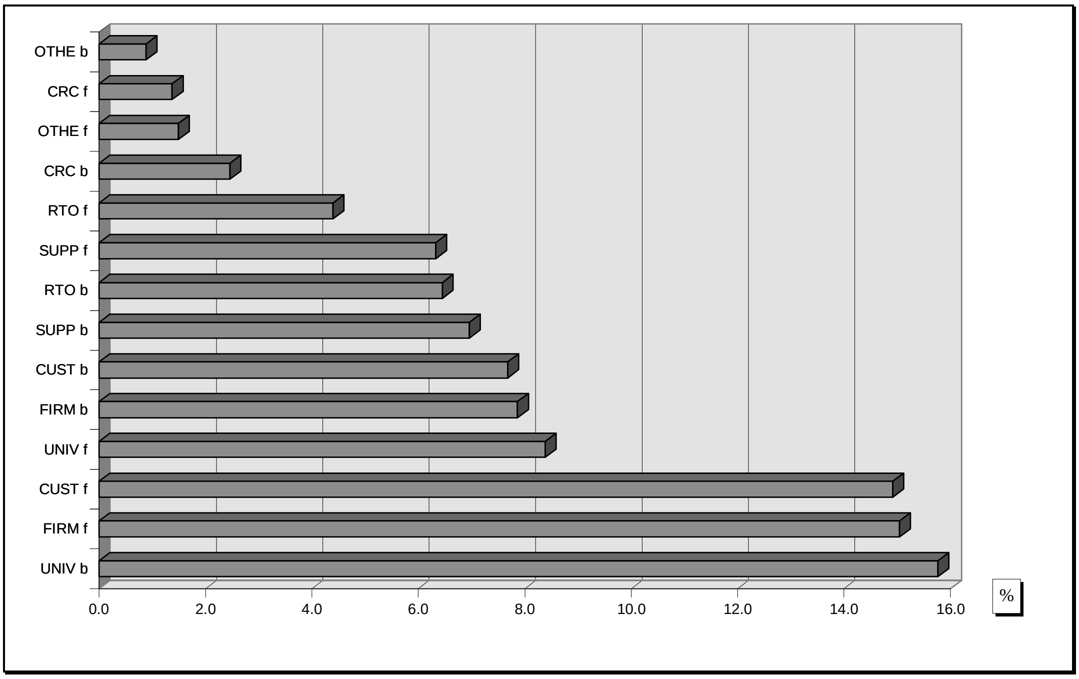
Among the main benefits of R&D collaborations suggested in the literature, we can mention lower costs of developing new technologies by reducing unnecessary duplication of research efforts, sharing the risks of undertaking R&D, getting immediate access to new technologies and cheap production sources, and making big and complex research projects more easily feasible (Kumar and Magun, 1998). Figure 4.1 shows that the principal partners of Belgian firms as regards R&D collaborations are the Belgian universities and the foreign companies as well as the customers abroad. These three types of partners indeed account for 45.7% of all collaborations. The fact that most of the R&D collaborations are found between firms and universities can be explained by the willingness of firms to share increasingly rising costs and risks associated with undertaking basic or pre-competitive R&D activities. The high share of R&D collaborations between Belgian and foreign firms and customers located abroad may be a consequence of the relative high number of multinationals established in Belgium and the willingness of Belgian firms to develop international linkages with foreign customers in order to get access to new markets. The other important partners as regards R&D collaborations are foreign universities (8.4%), Belgian firms (7.9%) and other customers located in Belgium (7.7%).

Since the beginning of the 80's, there has been a rapid evolution in the development of collaborative agreements in strategic technologies. For instance Hagedoorn and Schakenraad (1990) have found that 60% of these agreements are in information technologies, 26% in biotechnology and 15% in new materials ([24]). Figure 4.2 suggests that R&D collaborations in Belgium are mostly found in the 'services to enterprises' sector as well as the chemical and electrical industries (20, 19% and 15% of collaborations respectively). Regarding the last two sectors, these collaborations mainly concern Belgian firms, foreign firms or customers and Belgian universities. Yet, the two main actors which collaborate with Belgian firms operating in the services to enterprises sector (engineering and software specialised firms mainly) are firms and customers established abroad. This observation may reveal a weakness of the Belgian NIS.

It is shown in Figure 4.3 that the strategies developed by Belgian firms as regards R&D collaborations are rather different from one region to the other. Indeed, firms established in Wallonia appear to be more directed towards domestic suppliers and collective research centres as well as foreign universities and public research and technology organisations. On the other hand, Flemish firms are more oriented towards their customers and other firms. Hence, the technological partnerships developed by firms in Wallonia are more integrated vertically and directed towards research institutions located upstream the innovative process, while Flemish firms, at the other hand, seem to have linkages mainly with actors located downstream this process. This may suggest that firms in Flanders undertake more 'near the market' or applied research with faster commercial results. This differentiated behaviour of firms across regions challenges the question of the coherence and the integration of the Belgian NIS.

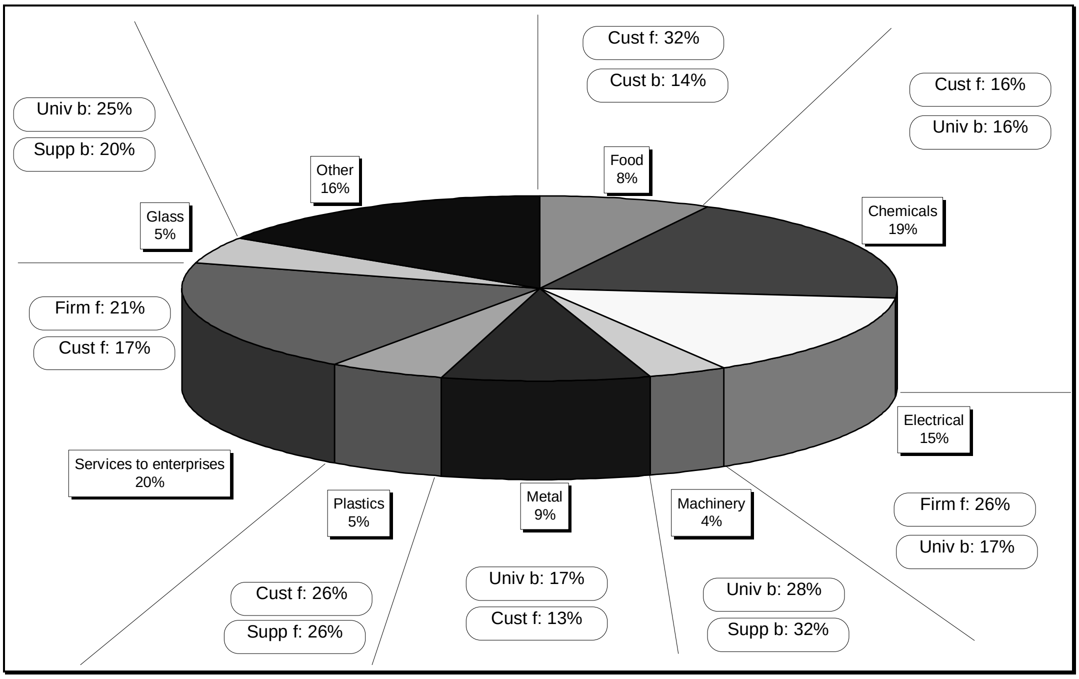
[24] Their analysis is based on 4600 technical co-operative agreements across firms in the Triad reported in the MERIT-CATI database.

Figure 4.1 : R&D collaborations between firms and other actors of the NIS



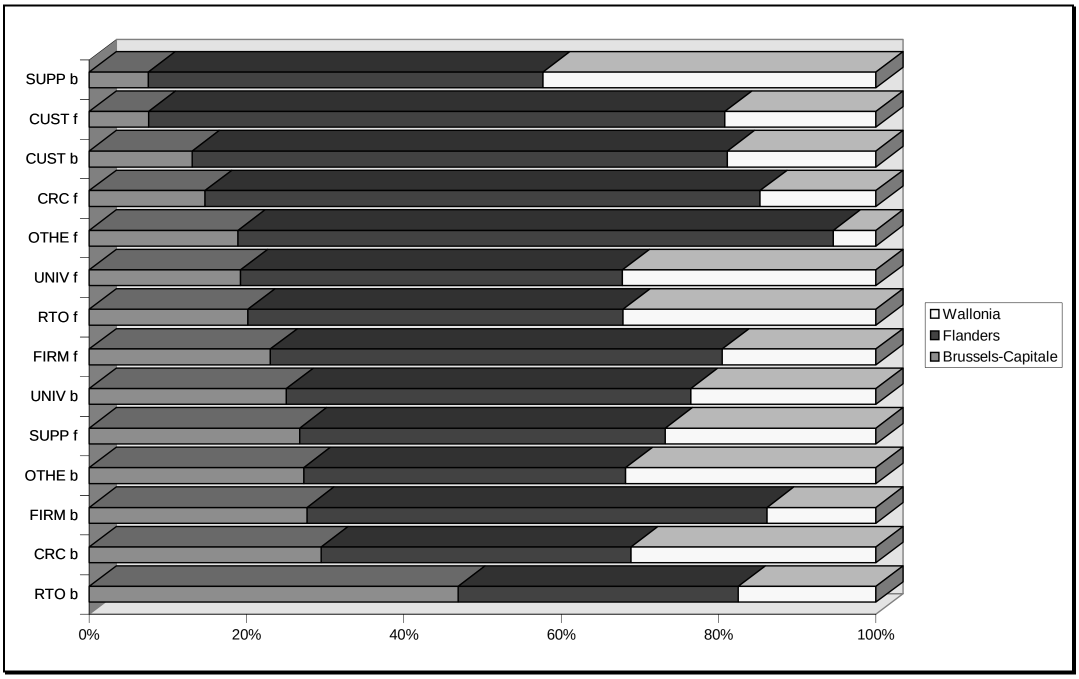
Source: Inventaire Permanent du Potentiel Scientifique, SSTC, 1996
Notes: OTHE = Other partners; CRC = Collective Research Centres; RTO = Research and Technology Organisation; SUPP = suppliers; CUST = customers; FIRM= firms; UNIV = universities; b = Belgium and f = Foreign

Figure 4.2 : R&D collaborations between firms and other actors of the NIS by industry sector



Source: Inventaire Permanent du Potentiel Scientifique, SSTC, 1996
Notes: for each industry sector, the % of collaborations of the two main partners is given

Figure 4.3 : R&D collaborations between firms and other actors of the NIS in the regions of Brussels-Capital, Flanders and Wallonia



Source: Inventaire Permanent du Potentiel Scientifique, SSTC, 1996

Notes: OTHE = Other partners; CRC = Collective Research Centres; RTO = Research and Technology Organisation; SUPP = suppliers; CUST = customers; FIRM= firms; UNIV = universities; b = Belgium and f = Foreign

4.4. Conclusion

A number of conclusions emerge from the analysis undertaken in this chapter:

1. On the basis of an OSTC-sample of R&D-active firms we found that three-quarters of the intramural R&D budget is spent on the 'development' of new products and processes, and only one quarter on 'research' sensu stricto. About two-thirds of the total R&D efforts is allocated towards the innovation of new products and R&D activity is found to be rather labour intensive. As to 'firm size', we found that *in the set of R&D-active firms* the smallest and largest firms are relatively more research-oriented, the latter also being more product-oriented. For the 'research vs. development' and the 'product vs. process' distinctions, we found relatively big interindustry differences. Both the *chemicals* and the *iron & steel ferrous metals* industry were relatively spoken much more research-oriented, the latter being also predominantly process-oriented. Rather surprisingly, we notice that the high tech industries spend the smallest percentage of their total intramural R&D budget on research as opposed to development. They are also strikingly product-oriented.

2. Our quantitative analysis of the relationship 'firm size - R&D intensity' within the set of R&D-active firms is quite conclusive. The outcome of the descriptive approach reveals the existence of a U-shaped relationship between firm size and R&D efforts. The econometric approach gives evidence of a '*less-than-proportional*' relationship between R&D efforts (and therefore, indirectly, innovativeness) and firm size, which stresses – analogous to the descriptive approach - the importance of R&D-active SMEs within the National Innovation System.

3. Among the main actors involved in R&D collaborations with Belgian firms, Belgian universities, foreign firms and customers account for more than 45% of the whole of collaborations. These collaborations predominate in the chemical and electrical industries as well as in the technology services supplied to firms. The R&D collaborative pattern is rather different across Belgian regions: Flemish firms are more directed towards firms and suppliers while in Wallonia, firms do more co-operate with institutions located upstream the innovation process, i.e. universities and public RTOs.

5. The National Innovation System and its international linkages

5.1. Introduction

One of the main subjects of study of the NIS of countries like Belgium is its degree of internationalisation. Not only because there is an impressive number of R&D co-operation between Belgian firms and foreign firms, but also because foreign based firms account for a substantial part of Belgian production capacity and its technology base. Patel and Pavitt (1991) have shown that about 40% of technological activity in Belgium came from non-Belgian large firms. This ratio was the highest amongst industrialised countries.

Important flows of foreign direct investments (FDI) are another indicator of the internationalisation of economic activity. Figure 5.1, which shows the share of net inward FDI in national gross fixed capital formation, leads basically to three conclusions. First, there has actually been a general trend toward globalisation in most countries. That is, inward FDI have increased faster than domestic investments during the eighties. Second, the OECD countries are characterised by a significant heterogeneity with regard to the presence of MNEs inside their boundaries. Belgium is characterised by the highest rate of foreign presence. In the early nineties, MNEs accounted for 20% of national investment. Portugal and the UK are similar to Belgium in this respect. Yet, countries like Germany, Italy, and France are characterised by a relatively weak foreign penetration, with inward FDI accounting only for 1 to 3 percent of their gross fixed capital formation. Third, the presence of MNEs in Japan has been marginal if not non-existent, as opposed to all other industrialised countries.

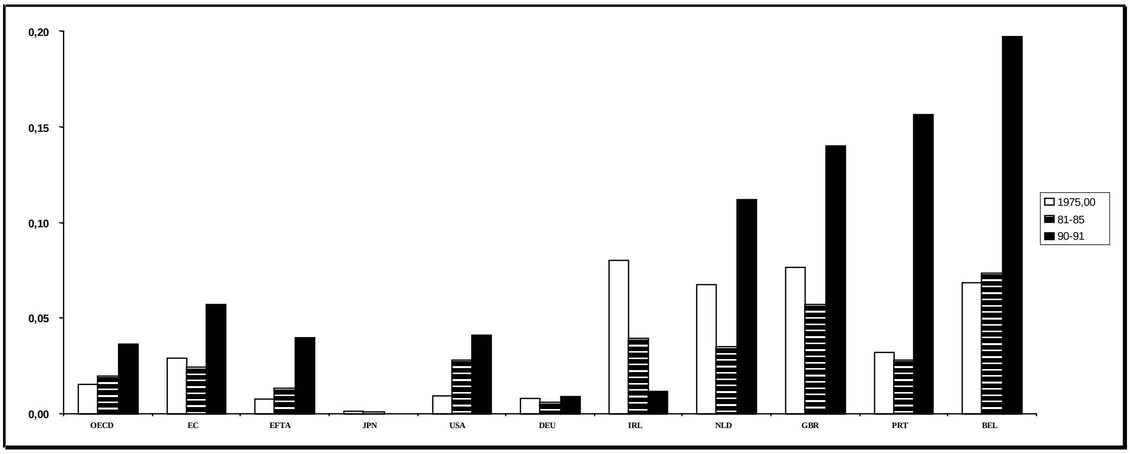
5.2. International technology transfers : concepts and channels

Given their inherent complexity, international technological spillovers are not measured in a widely accepted way. We consider that they surround any R&D externalities that emanate from one country and benefit other countries. Two concepts may be distinguished: rent and knowledge spillovers. International rent spillovers would relate to the fact that the prices of imported intermediate input and capital goods do not embody completely the product innovation or the quality improvement that result from innovation activities. Therefore, indirect benefits may emanate from the technological improvement of imported goods and services produced by trade partners. International knowledge spillovers would arise because of the imperfect appropriability of innovation benefits. It is generally characterised by the international transfer of technology which may occur via different routes: foreign direct investments, foreign technology payments ([25]), international R&D collaboration, publications in technical and scientific papers, and migration of scientists and skilled labour forces. Since these knowledge spillover channels are often associated with some economic transaction or other, the extent to which they also reflect rent spillovers is not so clear-cut.

[25] Foreign technology payments include royalties, licensing fees and patent sales.

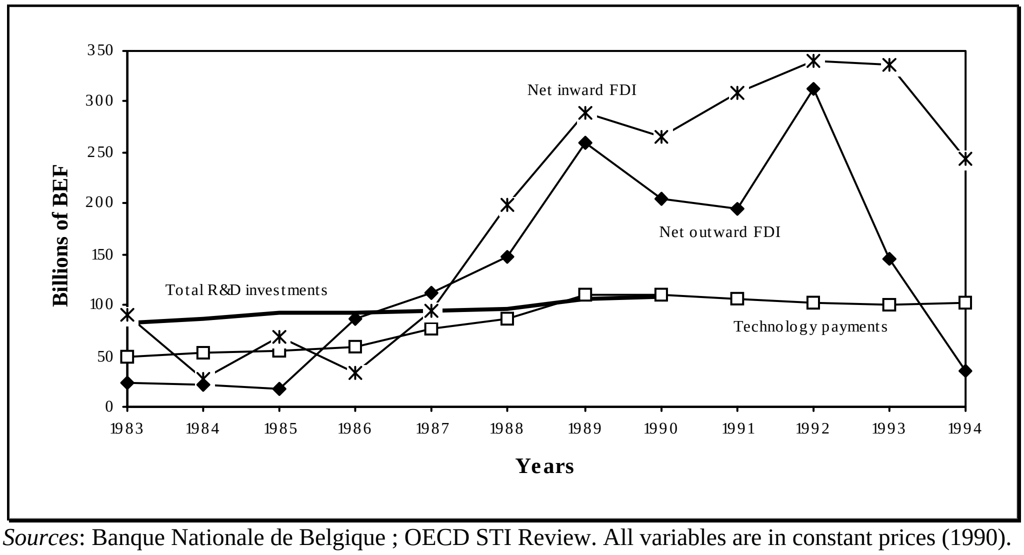
Various international technology transfer processes could be defined as ‘active’ because they imply a transaction between a home country (where the technology originates) and a host country (where the technology is used). Both countries share the benefits coming from such ‘active’ transfers. On the other hand, international knowledge-spillovers could also be ‘passive’ in the sense that the home country, where the technology originates, does not intervene in the international diffusion process of its own technology. In this case R&D spillovers would be the outcome of imitation, reengineering of imported goods, and/or technology sourcing practices. Here, the host country (or the imitator) captures all benefits ensuing from the technology transfer and there is no or little compensation for the home country. These different channels are summarised in Table A.5.1.

Figure 5.1 : The share of inward FDI in gross fixed capital formation - OECD, 3 subperiods



Sources: OECD, National Accounts: 1960-1993, 1995 for national gross fixed capital formation; OECD, FDI - Portugal, 1995 for inward foreign direct investments of the OECD countries.

Figure 5.2 : R&D investments, technology payments and net FDI in Belgium, 1983-1994



Sources: Banque Nationale de Belgique ; OECD STI Review. All variables are in constant prices (1990).

Given this categorisation of the international diffusion of innovation, the issue that logically arises is to evaluate the relative importance of these channels. R&D joint ventures and alliances with foreign firms have been analysed briefly in the previous chapter and will be studied more extensively in the next. Concerning the relative importance of all these modes of technology transfer, it should be noted that most of them are inter-related and that they are generally closely associated to MNE activities. This is obvious for inward FDI, R&D joint ventures, foreign R&D investments, and technology sourcing. Foreign technology payments and international trade are also two channels of technology transfer which are mostly governed by MNEs. Vickery (1986) provides evidence that the major part of foreign technology payments takes place between OECD countries and is dominated by multinational corporations. Similarly, the increasing, but still relatively weak, internationalisation of R&D investments, is essentially driven by MNEs. Since both indicators and international trade are partly dominated by MNEs, they should be closely related to FDI flows. This underlines the need to take the latter into account in any attempt to measure international technological transfers. This chapter is therefore devoted to the analysis of three closely related channels of potential international technology transfer: international trade, foreign technology payments, and foreign direct investments.

Figure 5.2 illustrates the relative importance of total R&D investments and three above-mentioned channels of technology transfer from abroad in Belgium. Total R&D investments have slightly increased along the eighties, from a value of about 83 billion BEF in 1983 to about 109 billion BEF in 1990. Technology payments to foreign countries have leapfrogged R&D investments over the same period, passing from 50 billion in 1983 to 110 billion in 1990. In the early nineties, technology payments decreased slowly to reach a value of 103 billion in 1994. Net inward and outward investments have known a drastic upsurge from the early eighties to the early nineties. Fluctuating under the 100 billion from 1983 to 1986, their real values passed far beyond investments in R&D in the late eighties, to reach a value of about 300 billion in 1992. Afterwards outward FDI sharply decreased to 30 billion in 1994 whereas inward FDI, though also decreasing, was still 250 billion high.

These different aggregates are obviously not directly comparable but they clearly indicate that foreign technology bases most probably yield benefits for Belgium in net terms. But this cuts both ways. Technology payments and the substantial presence of foreign firms within the national boundaries also witness a significant technological dependence of Belgium with respect to outside technology. In the next subsections, these channels are analysed for Belgium in the inward and outward directions. Our concern is to determine the main countries whose technology bases may potentially benefit Belgium. Similarly, the geographical pattern of the technology that emanates from Belgium is analysed.

5.3. Imports and exports of high-tech products

Analysis of export/import ratios for the different categories of industries sheds further light on the positioning of Belgium in the international technological competition. Despite the mismatches identified in the Belgian NIS, it remains that the educational, scientific and technological base is acknowledged to be of high quality. A main question is to know to which extent Belgium succeeds to convert this advantage into high performance in terms of high-tech trade.

Table 5.1 gives data about the global Belgian pattern in world trade. In fact, these data cover the Belgo-Luxembourg Economic Union. Exchange coverage ratios according to the technology intensity of products and the export market share for both the manufacturing and high-tech industries should allow to fix ideas about its international competitiveness.

Although Belgium appears highly specialised in international trade, its export market share in highly R&D-intensive products is only less than half the one obtained for the manufacturing industry as a whole. Yet, we observe a favourable evolution of the coverage ratios in the different categories of industries. Indeed, specialisation in low-tech industries has decreased to the advantage of an improvement of the coverage ratio in high-tech industries and to a lesser extent to a higher specialisation in medium-tech industries.

Table 5.1 : Trade balance trends of Belgium-Luxembourg

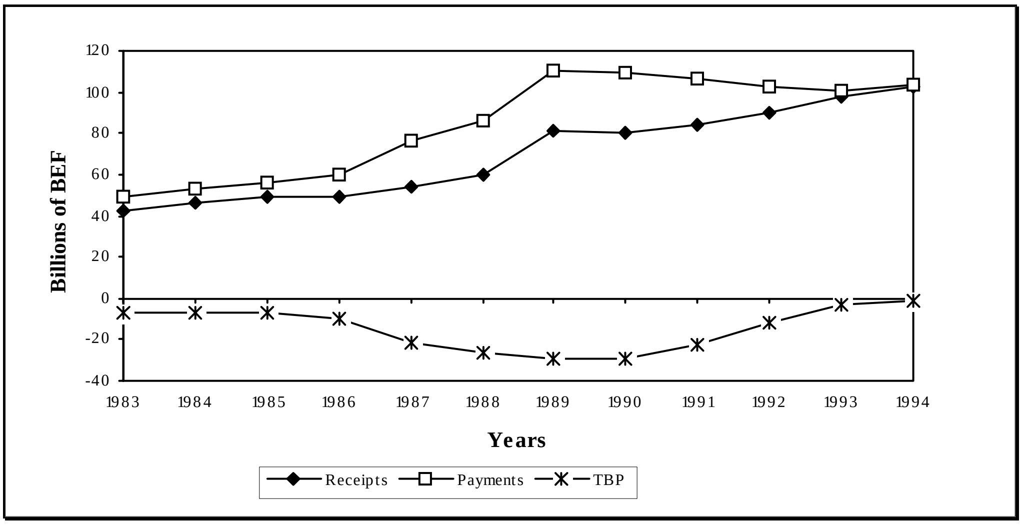
	Exchanges: coverage ratios in the manufacturing industry			Export market share	
	High-tech	Medium-tech	Low-tech	Manufacturing industry	High-tech industry
1975	.81	1.04	1.16	-	2.45
1980	.79	.98	1.14	5.30	2.50
1985	.80	1.08	1.21	4.65	2.00
1990	.77	1.15	1.21	4.96	1.98
1994	1.02	1.28	1.09	4.81	2.02

Source: OECD

5.4. The balance of technology payments

Figure 5.3 shows the evolution of the balance of technology payments over the period 1983-1994. Both the payments of foreign technology and the receipts from Belgian technology have increased along the period from about 50 billions BEF to more than 100 billions. Even though the deficit of the balance of technology payments worsened in the late eighties, it became less important in the early nineties, and was close to equalisation between payments and receipts in 1994 (minus 1 billion BEF).

Figure 5.3 : The technology balance of payments and R&D investments in Belgium, 1983-1994



Sources: Banque Nationale de Belgique.

Figure A.5.1 illustrates the geographical destination of the technology payments realised by Belgium during two subperiods: 1983-1985 and 1993-1995. During the two subperiods the US was the main destination of technology payments by Belgium, accounting for more than

25% of all technology payments to foreign countries. Four European countries receive half of the payments: France, Germany, the UK, and The Netherlands. The main change in the distribution of payments from the early eighties to the early nineties is characterised by the increasing share of Italy, Spain, and the other European countries (OTEC). The share accounted for by all European countries in total technology payments by Belgium increased from 54% in the early eighties to 62% in the early nineties.

The fact that the Belgian technology balance of payments is largely in deficit with respect to the US may be explained by the American technological leadership. Other deficits, but of a lesser amplitude, also appear with France, the UK, and The Netherlands (cf. Table A.5.2).

The geographical distribution of the Belgian technology receipts is also mainly oriented towards the major European countries and the USA (cf. Figure A.5.2). More than half (53%) of the technological receipts came from European countries in the early eighties, especially from Germany, France and The Netherlands. In the early nineties this share increased to 58% thanks to higher technological receipts from the other European countries and the UK. The share of the total receipts originating from the US has been stable around the value of 15%. This is the principal difference with the geographical distribution of technology payments, where the US accounted for a share twice as large as its share in technological receipts. The reverse was true for Eastern and African countries whose cumulated share in technological receipts was equal to 20% in the early eighties but dropped to 9% in the nineties.

5.5. Inward and outward foreign direct investments

Caves (1974) classifies the externalities arising from FDI into three categories: *(i)* the improvement of allocative efficiency (there will be fewer monopolistic distortions if a foreign company enters industries with high entry barriers), *(ii)* the inducement of higher technical efficiency (an increased competitive pressure would spur local firms to more efficient use of existing resources), and *(iii)* increasing rates of technology transfer towards the host country. It is therefore conceivable that the presence of foreign firms within the national boundaries may foster international technology transfer from the home country.

An alternative way of apprehending the likely effects of inward FDI would be to better understand the determinants of these investments. The three traditional incentives are *(i)* offshore production (in order to benefit from own managerial or technological comparative advantages); *(ii)* market proximity (which allows for a quick adaptation to changing demand structure); and *(iii)* defence investment (in order to counter future protectionist measures, such as tariff and non-tariff barriers, higher transportation costs, or Voluntary Exports Restraint measures). More recently, two new incentives emerged: *(iv)* control of international trade (through intra-company shipments between parent companies and their majority owned subsidiaries) and *(v)* technology sourcing (in order to learn or to source knowledge-intensive assets from the host country).

The potential transfers of knowledge associated with inward FDI may apparently have two directions. In the case of offshore production the host country may benefit from technological externalities emanating from the foreign companies. Yet, if foreign companies try to copy or to source the domestic knowledge, their home country may benefit from potential spillovers emanating from domestic firms. In Dunning's (1981) paradigm, a firm would decide to invest abroad if the three following conditions are fulfilled: ownership, localisation, and internalisation advantages. Otherwise, the firm would take advantage of the foreign market through exports or licensing. The 'internalisation' incentive suggests that FDI may be motivated by the desire to avoid the diffusion of firm specific technological assets abroad. This idea is corroborated by Patel and Pavitt (1991) who provide evidence that the production of technology by large multinational corporations remains far from being globalised and is in the first place a domestic affair: foreign companies keep their knowledge activities in their home country. Therefore, caution is called for in the analysis of inward FDI with respect to the potential technology transfer brought about by foreign companies.

The countries which are technological leaders have accumulated substantial scientific and technological capabilities. These technological endowments are likely to be accessible to foreign companies which set up production and research facilities inside the technological leader's boundaries. The benefits for the host country are that the foreign research laboratories ([26]) or foreign production lines may contribute to improve domestic technological capacities.

The mechanisms underlying the main determinants and impacts of foreign direct investments are illustrated in Figure A.5.3. The degree to which foreign ownership is fully accessible to MNEs may be one of the motivations for undertaking the sourcing of foreign intangible assets. This may further allow to control intra-company trade between the host and the home countries. In these two particular cases inward FDI are more likely to benefit the home country than the host country. Yet, in the cases of R&D co-operation and of the establishment of an offshore production line, inward FDI may be a source of value-added and employment creation as well as technology diffusion in the host country. In a nutshell, the net effect of inward FDI is not *a priori* predictable. Concerning our prevailing matter of concern - the diffusion of technology - it would also be precarious to expect an automatic transfer from the home country to the host country.

It is clear that the likely impact of inward FDI depends on the motivations which form their foundation. According to Dunning (1994), there is support both for the proposition that inward FDI may lessen domestic innovative capacity, and for the proposition that it will increase it. However, the author further argues that '*What does seem very plausible is that where foreign production adds to domestic production, the R&D base of the investing company is strengthened - whatever the nationality of the firm.*' (Dunning (1994), p. 81). If the sourcing of the domestic technology base is the principal goal of inward FDI, the latter may take on the characteristics of a Trojan horse and is unlikely to foster international R&D spillovers from the home country to the host country. Lichtenberg and van Pottelsberghe (1996) evaluate the extent to which inward FDI, outward FDI, and imports have been efficient channels of technology transfer between 13 industrialised countries from 1971 to 1990. Their empirical results suggest that outward FDI flows and import flows are two simultaneous channels through which technology is internationally diffused. They therefore confirm the hypothesis of technology sourcing. The technology embodied in inward FDI flows did not seem to contribute to the productivity growth of the host countries.

Summarising, the efficiency of FDI flows as a channel of international technology transfer is a

[26] It is worth noting however that some foreign R&D investments do not contribute at all to technological improvement in the host country because their activities are only related to minor projects (cf. Chesnais (1986)).

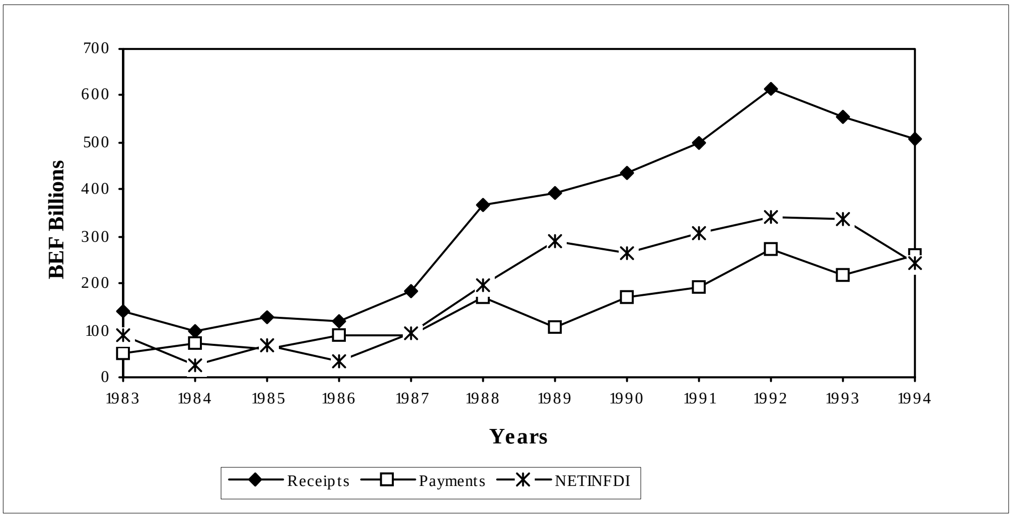
priori unpredictable. Inward FDI may both inflate or deflate the technology base of the host country and improve the technology base of the home country.

Figure 5.4 presents the evolution of the gross inward FDI (receipts) in Belgium, the payments realised by foreign companies, and the net inward FDI (the difference between receipts and payments). Net inward FDI has been positive all along the period 1983-94 and has drastically increased from 1987 to 1992. The decrease in net inward FDI between 1993 and 1994 is due on the one hand to the decrease in gross inward FDI and, on the other hand, to the increase in the payments of foreign companies established in Belgium.

Figure A.5.4 highlights that European countries accounted for about three fifth of total inward FDI in Belgium in the early eighties. At that time, Germany, The Netherlands, the UK, the US and to a lesser extent France where the largest foreign investors in Belgium. This 'European' share increased during the eighties and came close to 75% in the early nineties, at the expense of the US position which fell from 22% in the eighties to 12% in the nineties.

Figure 5.4 : Inward foreign direct investments in Belgium, 1983-94

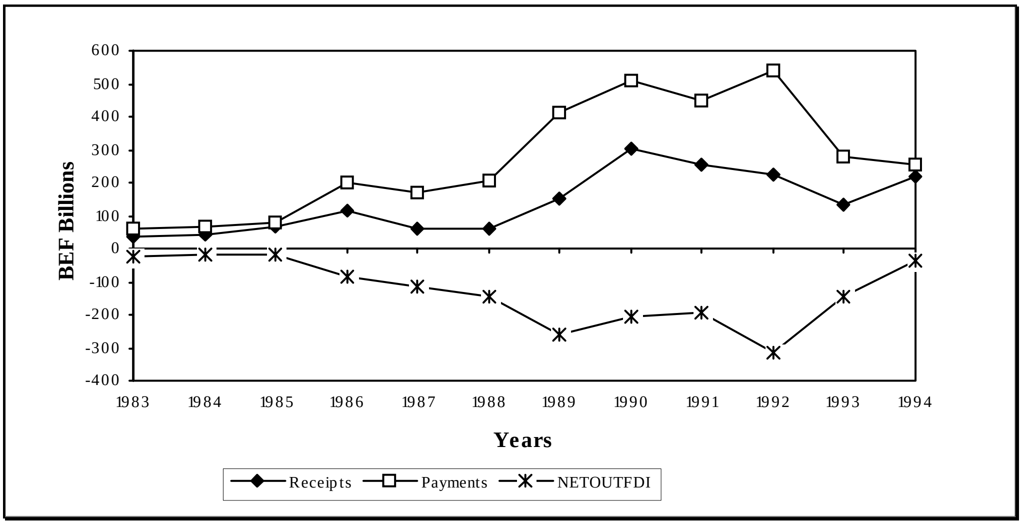
(receipts, payments, and net FDI)



Sources: Banque Nationale de Belgique.

Similarly to net inward FDI in Belgium, net outward FDI from Belgium has also dramatically increased from about 17 billions BEF in 1985 to more than 300 billions in 1992. Figure 5.5 shows that the sharp decrease from 1992 to 1994 is due to very high receipts from foreign subsidiaries. From the early eighties to the early nineties the share of outward FDI directed towards the European countries jumped from 55% to 75% (cf. Figure A.5.5); Germany, the UK, the Netherlands, and France being the main targets. The flow in the direction of the US economy has diminished since it accounted for only 9% of the Belgian outward FDI in the nineties, down from a share of 21% in the early eighties. The figures show that the potential sourcing of foreign technology is more likely to come from European technological leaders than from the US in the near future.

Figure 5.5 : Outward foreign direct investments (receipts, payments, and net FDI)



Sources: Banque Nationale de Belgique

5.6. The Belgian specialisation pattern in international high-tech trade

With regard to R&D intensive products, Edquist and Lundvall, making use of data compiled by Dalum, obtain a low overall Revealed Comparative Advantage (RCA) for Belgium for the period 1961-1987 (Edquist & Lundvall, 1993, p.286, Dalum, 1989). Van Essen and Verspagen (1997) also report a low Belgian RCA in high-tech trade. On the other hand, The *European Report on Science and Technology Indicators 1994* states that Belgium is one of the few countries with a (slightly) positive high-tech balance. The low number of countries with a positive balance is of course the result of the dominance of Japan in this respect. Other reports corroborate this. Daniels finds a small but positive trade ratio for technology intensive manufactures for Belgium (Daniels, 1993). Grupp, using bilateral correlation analysis, shows that Belgium in 1988 had a good high technology competitiveness in EC context (Grupp, 1992) ([27]).

The Belgian trade balance ([28]) is positive both for leading-edge commodities and for high-level technology commodities. Belgium shows strength in *pharmaceuticals* and some other chemical commodities, but also in some leading-edge and high-level telecommunications related goods. Weak trade performance can be found in *electronics* and most areas of *machinery*, with the exception of *advanced electrical machinery.*

The Belgian case shows that a country can very well have a positive trade balance for a broadly defined class of R&D-intensive goods without being a ‘specialist’ on the world trade scene for these goods. The result that we obtain for R&D-intensive goods taken as a whole

[27] Grupp further distinguishes between so-called high-level technology and leading-edge commodities, the latter being defined as the upper segment subset of high-tech commodities. For high-level technology commodities, i.e. not including the leading-edge ones, he finds a positive relationship between the number of patents per GDP (1984-1986) and RCA (1988). The relationship for leading-edge commodities is more complicated, and no clear pattern emerges, which probably reflects the relatively lower importance of formalised property rights in the leading-edge technology sector, due to the nature itself of the activities in this sector, and the fact that they are subject to strong government intervention and protection.

[28] Own calculations based on UN (1996)

does not carry over completely to all subclasses of R&D-intensive goods. For instance we find a high and increasing RCA in advanced organic chemicals and advanced industrial abrasives despite trade deficits in both classes.

Another way of analysing the trade specialisation pattern of a country is through a 'constant market share' analysis (CMS). Overall changes in commodity export shares can then indeed be decomposed in three effects. The 'share effect' measures the part of the overall change due to changing shares in each sector, measured at a constant share composition at the global level ; it is in other words a pure competitivity effect. The 'composition effect' measures the part of the overall change caused by the changing composition of shares at the global level, measured at constant shares in each sector. The third effect, the so-called 'market adaptation effect' or 'interaction effect', is the residual which corresponds to the product of the changes in the sectoral shares in the country studied and the commodity shares changes at the global level. When positive, it indicates that companies are moving into growing, or moving out of declining commodity classes (Fagerberg and Sollie, 1987). As such the 'decomposition effect' is a measure for the possible existence of a mismatch between the evolution in a country and the evolution world-wide. We performed a CMS analysis for both leading-edge and high-level technology commodity classes for which data were available ([29]). In appendix (Tables A.5.3 and 5.4) we present the results for the RCA and the trade balance for leading-edge and high-level technology commodities as well as the results of the CMS analysis. We also report on coverage rates.

Belgian companies showed an overall trade surplus in leading-edge classes and increased their overall share with 5.28 % between 1991 and 1995. On the other hand the overall share of Belgian companies in high-level technology classes decreased with 5.58 % between 1991 and 1995. The decomposition of the overall effect shows that with regard to leading-edge commodities the overall improvement between 1991 and 1995 is essentially caused by Belgian companies gaining shares. The negative composition effect shows that Belgium is specialised in declining commodity classes. Finally the positive adaptation effect shows that Belgian companies are generally moving out of declining leading-edge classes or moving into classes with growing importance. With regard to high-level technology commodities the declining position of Belgian firms is caused by the loss of shares, the 'wrong' specialisation pattern and the 'wrong' adaptation pattern: all three effects are negative ([30]).

A CMS-analysis for the period 1991-1994 for the high-level technology commodities reveals that Belgium, just behind Germany, has the sharpest decline in high-tech market shares for a group of 12 European countries and is one of the few countries with all three CMS-effects being negative (Van Essen & Verspagen, 1997).

It should perhaps be stressed that the terms 'right' and 'wrong' with respect to specialisation do not carry an unambiguous connotation. Dalum, Laursen and Verspagen (1996) for instance point at the risks of a policy aimed at stimulating growth by steering specialisation in the 'right' direction. Because of the relative stickiness of specialisation patterns the outcome of

[29] The high-level technology commodity class is defined as being the class of R&D-intensive goods, not including the so-called leading edge commodities.
[30] The CMS analysis can also be performed on R&D expenditure shares (e.g. Laursen & Christensen, 1996). Laursen and Christensen found a negative structural effect for small countries like Denmark and Finland indicating a 'wrong' specialisation pattern but they rightly claim that, due to the path-dependent nature of technological change, countries cannot dramatically alter their specialisation pattern.

an active policy may remain highly uncertain. Giving up strong positions in declining sectors may for the same type of reasons also be questionable.

5.7. The participation in European networks

Belgian participation to European R&D programmes is very high as can be seen in Table 5.2. We consider three types of indexes (the participation, distribution and collaborative links indexes), and concentrate our attention on the R&D projects in the Fourth Framework Programme (FWP). The higher education sector appears to play a prominent role in the explanation of both the high participation and collaborative links indexes. Yet, the apparent dynamism of Belgian universities and also of other organisations may partly be the consequence of their location advantage due to the direct proximity of European decision centres. Despite this possible advantage, the value of the collaborative links index is impressive. It shows that Belgian organisations have built European linkages at a rate which is about three times as high as the European average.

The three indexes taken together allows one to appreciate the real positioning of Belgium within the European networks. All things being equal otherwise, the distribution index shows to what extent the distribution of participations amongst the different categories of actors is similar to the one observed at the European level. The distribution index for large entreprises is 22 percent under the European average in the Fourth Framework Programme. Yet, the participation index of Belgium as measured by the number of participations per capita relatively to the European average shows that Belgian participation is 70 percent above the European average. Consequently, although the distribution index for the large enterprises is under the European average, and weaker comparative to other types of organisations, we cannot conclude that their degree of participation is inferior to the European average. Indeed, the combination of both the participation and the distribution indexes produces the participation index of large entreprises in European Programmes. In the 4th FWP their index of participation is equal to 133 (= (170*78)/ 100). However, universities are the most committed in networking with an index equal to 226 (= (170*133)/ 100) for the same programme.

Despite a slight reduction of both the participation and collaborative links indexes from the 2nd FWP to the 4th, the integration of the different categories of organisations to the European R&D networks remains very high. The higher value of the collaborative links index comparative to the participation index implies that Belgian participation to European networks involves generally more than one Belgian team in the partnership. These favourable results show that the Belgian S&T system is well integrated in the European S&T network in the making. A question remains with respect to the extent that this phenomenon at the precompetitive level is translated to an equally favourable position in near-market research and strategic alliances.

Table 5.2 : Belgian participation to European programmes

Programmes	Financing						Participation					
	Second		Third		Fourth		Second		Third		Fourth	
	%	Index	%	Index	%	Index	%	Index	%	Index	%	Index
Collaborative links	-	-	-	-	-	-	-	-	8.8	326	7.5	278
Participation	-	-	-	-	-	-	5.7	189	4.9	181	4.6	170
Distribution:												
- Large Enterprises	20.1	49	20.3	59	16.9	63	13.0	59	13.7	64	15.0	78
- SME	16.4	88	17.6	107	14.9	93	18.0	99	16.9	117	18.5	107
- Research Centres	28.4	137	20.2	86	17.9	75	24.7	84	22.6	76	16.5	66
- Higher Education	34.5	183	35.3	157	41.3	151	42.6	146	41.5	132	38.9	133
- Others	0.7	117	6.6	194	9.0	153	1.6	133	5.3	183	12.1	122

Note: Both the collaborative links & participation indexes are the variables weighted by population divided by the European reference value. The distribution indexes are the shares in the total divided by the European reference value.
Source: First & Second European Reports, own calculations

At the regional level, the French-speaking universities appear to be more integrated to the European networks than their Flemish counterparts. The Flemish firms and research centres on the other hand have a higher propensity to collaborate at the European level than their Walloon counterparts (Capron (1998)). When we look at the Belgian participation in EUREKA projects, both Flemish universities and enterprises are more involved in collaborations than the French-speaking ones: around 70% against 30% (Capron (1998)). These observations seem to indicate that the Walloon research system is less business-oriented than the Flemish one. Despite the high level of its university research, the Walloon Region faces lots of difficulties in valorising its R&D potential, e.g. by promoting near-the-market research. Consequently, we can conclude that there is an important spatial mismatch in the Belgian NIS.

If we consider the data published in the *Second European Report on S&T Indicators (1997)* on technological co-operation between enterprises in the world, the very high degree of internationalisation of the Belgian R&D system as exemplified by its participation to European R&D programmes needs to be substantially qualified. Upon a total of about 5000 international technology alliances between EU members, the US and Japan, only 57 collaborations in which a Belgian enterprise are recorded, which represents 1.2% (the weighted by population index equals to 93). When only non-EU technology alliances are taken into account, the number of collaborations is equal to about 47 on a total of 1641. The Belgian share is then equal to 2.9% (index 106). These additional results show that although Belgium has largely developed its European collaborations thanks to the EU programmes and the EUREKA initiative, its position as a partner in strategic alliances is a question mark. In the present era of globalisation of markets, further efforts should be devoted by Belgian public authorities to promote more strategic partnership of Belgian firms at the world level. So far its good performance in pre-competitive research as well as in near-market research does not seem to have much stimulated its participation in strategic alliances.

5.8. Conclusion

International trade, inward and outward FDI flows, and technology payments are three important channels which may foster the international diffusion of technology. It should be kept in mind, however, that trade flows and FDI are not *automatically* associated with international R&D spillovers. Therefore, the analysis of their evolution constitutes only an indicator of the *potential* technology transfers that may occur between countries.

The most salient observations can be summarised as follows:

1. The analysis of all three indicators has shown that Belgium relies substantially on research activities from abroad.

2. Technology payments, or the extent to which Belgium takes advantage of foreign technology, have increased during the eighties and stayed quite stable in the early nineties. During the whole period, the main destination of technology payments was the US. Next in order of importance come four neighbouring countries: the UK, the Netherlands, Germany and France, which received about half of the technology payments to foreign countries.

3. Technology receipts and inward and outward FDI have also substantially risen in the late eighties, and their geographical distribution is comparable to the ones of technology payments. From the early eighties to the early nineties, the most noticeable change in their geographical distribution was the strong reduction of the US share to the advantage of neighbouring countries.

4. The geographical distribution of the various channels of technology diffusion shows that technology transfers are facilitated by *(i)* geographical proximity, *(ii)* technological endowments, and *(iii)* the size of the countries where the technology originates.

5. The analysis of its trade specialisation pattern shows that Belgium, statically speaking, is specialised in declining commodity classes. Yet, in a dynamical sense, companies are generally moving into classes with growing importance. With regard, specifically, to high-level technology commodities the position of Belgian firms is declining. This is caused, simultaneously, by loss of shares, a ‘wrong’ specialisation pattern and a ‘wrong’ adaptation pattern.

6. The position of Belgium compared to the European average regarding technology-based strategic alliances seems to show that its very good performance in terms of collaboration in pre-competitive and near-market research (as shown by its participation in European programmes and EUREKA projects) does not guarantee that Belgium has enough trumps to integrate efficiently into the globalisation process.

6. The network of joint research projects and agreements

6.1. Introduction

We will present some results of the graph-theoretical analysis of the Belgian network of research co-operation and research agreements as it transpires through the projects falling under the general heading of the R&D Framework programmes of the EU, the projects of the EUREKA initiative and finally the private agreements and other forms of co-operation contained in the MERIT/CATI database. Particular attention will be devoted to the clustering issue: how can we define micro-clusters ([31]) in a graph-theoretical context.

The reasons for embarking on a study of joint R&D projects as an approach to the national innovation system are twofold. The first reason is of a purely practical nature. Data on joint R&D projects and agreements are relatively easily available, and they can be quantified in a straightforward way in a network context. The second reason is a fundamental one. Joint research projects often give access to funds, equipment and new potential markets. But most of all, they nearly always give access to information. They can be seen as one of the most powerful ways to disseminate knowledge and know-how within a NIS. But network analysis applied to technological systems is still - despite a burgeoning literature - in a poor, underdeveloped state. A word of caution is therefore appropriate at this stage. It should be clear at the outset that the ambition of the present analysis is limited. We give answers to ‘who co-operates with whom ?’, and look at a number of characteristics of this co-operation, but we do not deal with the direct results of joint R&D projects.

In section 6.2 we characterise the graph in general terms and describe in some detail the data which are used. We also present a summary of a number of results obtained so far. Section 6.3 addresses the clustering issue. In section 6.4 we propose a method to compute intra- and inter-sectoral knowledge flows. In section 6.5 we analyse the participation of Belgian organisations in international R&D co-operation. We conclude in section 6.6 by anticipating on further analytical steps, and on the research questions which we should be able to answer in the future stages of the study. A more detailed analysis of Belgian participation in international R&D co-operation can be found in Meeusen and Dumont (1997a,b), and an analysis of co-operation from a regional viewpoint with incorporation of data on Flemish R&D projects in Meeusen and Dumont (1998a, b).

[31] We define micro-clusters in this context as subgraphs of relatively high density in the graph of joint R&D projects and agreements between individual actors (firms, research laboratories, universities).

6.2. The mapping of the network of joint R&D projects between firms, research institutions and universities

6.2.1. The model and the data

The observations are defined on the level of microeconomic agents: companies, research institutions and universities, i.e. the nodal points of the graph. The network-criterion is primarily the fact that two actors are partners in the same joint research project or alliance.
The obtained graph can be specified as being valued **(**individual lines may be weighted), and as a multigraph **(**two entities can be linked by several lines with different weights).

The graph consisting of nodes and lines, together with their corresponding information is defined as a *network.*

We distinguish between 3 *different projects and agreements (lines)*:

1. R&D projects in one of a selected list of EU RTD Framework programmes (CORDIS database by EUROSTAT) ;
2. EUREKA projects (EUREKA on-line database) ;
3. Private technological co-operative agreements (Belgian part of MERIT-CATI database on strategic agreements).

So as not to overburden the graph and avoid crossing computational thresholds, we discarded the project-lines between the foreign partners in the project or agreement. The actors in the pointset of the graph are identified by a 8-character acronym. The first character of the acronym is a country code. The lines of the graph (in the lineset) are identified by the 'head-tail' sequence of the corresponding acronyms. In addition to the basic point- and line data the values of a number of variables are attached to the points and lines. A more detailed description of the model and the data that were used can be found in Meeusen and Dumont (1997a,b).

6.2.2. Description of the complete graph

6.2.2.1. General features

The complete graph contains 3753 nodes and 14918 lines ([32]). Of these lines 3078 were directed (i.e., lines which connect a main contractor with a partner). These figures actually give an inflated picture of the density ([33]) of the graph, since a relatively large number of nodes are connected through multiple lines. After having combined all multiple lines between two points into one (aggregated) line, 10634 single lines remained, which means that the density of the (combined) graph is equal to .0015. Of the 3885 actors, 776 were Belgian, 626 of which were private companies (private research institutes and consulting firms not included). There are 553 French and German actors, 451 British, 290 Italian, 229 Spanish and 227 Dutch actors.

[32] The software used is GRADAP v. 2.10, a social network analysis programme developed at the University of Groningen (C.J.A. Sprenger and F.N. Stokman (1989)).
[33] The density of a graph is defined as the actual number of lines in proportion to the number which is maximally possible ($n(n-1)/2$).

In Tables A.6.1 and A.6.2 the Belgian companies are classified by size and NACE ([34]) sector. Table A.6.4 compares the representativeness of NACE sectors in the graph, related to the representativeness of the corresponding sectors in the Belgian economy and the repertory of ‘all’ Belgian R&D active firms ([35]). High-tech and medium-high-tech sectors generally have higher shares of companies represented in the graph although some particular medium-low and low-tech sectors also have relatively high shares (i.e. the low-tech sector 27: *Metallurgy*). The same pattern appears when relating the number of companies in a NACE sector present in the graph to the share of that sector in the overall number of companies. Medium-high and high-tech companies are more represented in the repertory than in the graph whereas some medium-low and low-tech companies and the 2 services sectors (NACE 72 and 73) are better represented in the graph than in the repertory. This might reveal that innovation surveys underestimate the innovativeness or at least do not sufficiently account for the participation in co-operative R&D projects of low-tech and services sectors. It also supports the findings of Kleinknecht and Reijnen that R&D co-operation is not an exclusive phenomenon of so-called ‘R&D intensive’ companies (Kleinknecht and Reijnen, 1992).

Table A.6.3 shows the Relative Specialisation Index (RSI) of Belgian organisations for participation in EU and EUREKA projects and in technological agreements. For EU projects the RSI was computed using the number of prime contractors instead of overall participation, both in projects that are completed and projects that are still going on. For the projects that are still going on Belgian actors are apparently relatively specialised in *telecommunications*, *medical technology* and *IT*. The RSI increased for these disciplines, when comparing the indices for completed and on-going projects. Belgian actors were relatively specialised in completed EU projects related to *biotechnology*, but the RSI fell below 1 for the projects that are still going on. Belgium seems relatively unspecialised in *environmental technology*, *aerospace technology* and *transports.* Moreover, with the exception of the latter technological discipline, the RSI further decreased. The distribution of the lines over the points is very skew: a small group of actors takes care of a large number of lines, and there is therefore a large group of actors with low involvement (cfr. Steurs & Cortese, 1993; Garcia-Fontes & Geuna, 1995).

6.2.2.2. Component analysis

We define a component *C* of a graph as a maximally connected subgraph, i.e. every node of *C* is connected with at least one other node of *C* , and there exists no node outside *C* which is connected to at least one node of *C*. There are 45 components in the complete graph that has a density of .0015. The largest component contains 3626 actors and 10528 lines. At multiplicity 4 there are 10 components left with the largest component containing 200 actors and 470 combined lines. The large CORDIS subgraph (3247 actors) has ‘only’ 16 components and is more dense (.0018 against .0006) than the smaller EUREKA subgraph which has 42 components and 600 nodes. The CATI-subgraph has 29 components and a density of .0194.

[34] The sector classification used is the so-called NACE-BEL one, which is the Belgian version of NACE Rev.1.
[35] This repertory is compiled by the Federal Office for Scientific, Technical and Cultural Affairs (OSTC) based on a number of innovation surveys and is an attempt to map all Belgian companies that are active in the field of R&D. Of the 626 Belgian companies appearing in our data on R&D projects and technological agreements the repertory contains less than 200 companies.

6.2.2.3. Centrality indicators

Freeman (1979) distinguishes between three types of point-centrality indicators based on degree, closeness and ‘betweenness’, respectively. Degree-centrality is the most straightforward of the three. A node is considered to be more central than others if more nodes are adjacent to it. The actors with the highest unweighted degree centrality in the complete graph and the main subgraphs are given in Meeusen and Dumont (1997a,b).
An unweighted degree-centrality does not take into account the multiplicity of the lines between nodes nor the different weights that each line may carry. We might consider to assess projects according to their financial value, give more weight to lines backed by a personal tie, give more importance to lines in programmes which are ‘nearer to the market’, discriminate between directed and undirected lines or take the number of partners into account.

The formula for this weighted degree centrality measure takes the following form:

$$C_i^W = \sum_{\substack{j=1 \\ j \neq i}}^{n} \sum_k w_{ij}^k$$

where w_{ij}^k is the weight of the *k*-th line running between i and j.

In Table 6.1 we recompute the degree-centrality in the set of the 200 most central actors and report the result for the 35 most central ones in the new definition: we actually account for multiple lines while combining the last two criteria giving the undirected lines in a project the weight *1/NP* , where *NP* is the number of partners in the project, and the directed lines a double weight of *2/NP*. The acronyms of the actors in Table 6.1 are in Appendix A.6.1.

Table 6.1 : The 35 actors with the highest weighted degree-centrality

BIMEC	51,52	GSIEMENS	11,44	BSCK	8,03	BSOLVAY	5,07	BKARMAN	3,92
BALCATEL	28,16	FTHOMSON	10,57	FCNRS	7,41	BEURDEV	4,82	UBT	3,92
BKUL	19,41	BWTCM	10,37	BLMSINT	7,11	FRANTEL	4,52	BEEIG	3,69
BUG	17,48	FALCATEL	9,69	BVITO	6,11	BBARCO	4,47	BSOCBIO	3,60
BMIETEC	14,56	BUNIVL	9,45	GFRAUN	5,81	BPGS	4,35	GALCATEL	3,51
NPHILIPS	13,03	BVUB	8,98	FMATRA	5,71	BWTCB	4,09	VTT	3,50
BUCL	11,65	BBELGACO	8,11	FCEA	5,24	BULB	4,05	ICSELT	3,40

6.2.2.4. The relation between the position in the R&D-network and firm characteristics

In this section we report on some relations between the participation to R&D co-operation projects and alliances and the position in the R&D network as measured by the unweighted centrality of each firm, and a number of firm characteristics (share of new products in turnover, number of employees and ROE).

a) Innovativeness

We linked the data on R&D co-operation to the results of the 1996 Belgian R&D Survey. In this survey firms were asked which share of their 1995 turnover was realised by products or services that had not been on the market for more than 2 years. Possible answers were ‘less than 10 %’, ‘between 10 % and 30 %’ and ‘more than 30 %’. The χ^2-test on a simple crosstabulation revealed that responding firms that participate in international R&D projects or agreements were not significantly more innovative than those that did not participate in any such project or agreement. On the other hand, firms participating in projects financed at the Flemish regional level are more innovative than respondents that did not (see Meeusen and Dumont (1998)).

b) Size

The plot of the centrality of firms against their size (number of employees) reveals a very scattered pattern in which no clear-cut linear or increasing functional relationship can be detected. The same holds true on the sectoral level (2 digit NACE). In Table 6.2. we present the average centrality for 6 size-classes (standard deviations between brackets).

The higher the number of employees the higher average centrality is. The size classes are not normally distributed and variances differ considerably. The necessary conditions for a variance analysis are therefore not met. We performed the non-parametrical Kruskal-Wallis test to compare the 6 classes. The mean ranks are given in Table 6.2. Kruskal-Wallis reveals the 6 size-classes to differ significantly (.001) from one another with regard to centrality. However Kruskal-Wallis is not a very powerful test, and the obtained significance might as well relate to significant differences in distribution as in population location.

In Table A.6.5 we present the average centrality of the 15 main 2 digit NACE sectors in the graph. Once again the Kruskal-Wallis test is significant (.002).
The main sectors are, not surprisingly, those that are related to the main technological disciplines in the EU-Framework programmes and EUREKA, especially *IT* & *telecommunications*.

Table 6.2 : Average Degree centrality of 6 size classes (number of employees in 1995)

Number of employees (n)	Centrality	Mean Rank (Kruskal-Wallis)
$n > 5000$	61.46 (72.52)	292.73
$1000 < n \leq 5000$	18.18 (18.18)	208.88
$500 < n \leq 1000$	14.59 (14.59)	197.04
$250 < n \leq 500$	10.26 (9.92)	173.84
$50 < n \leq 250$	9.99 (11.21)	169.65
≤ 50	9.99 (11.05)	171.37

c) Other

Finally, there is no clear relationship between centrality and return on equity (ROE) for all firms combined nor on the sectoral level.

6.2.2.5. Coincidence of different types of lines

In the complete graph 13151 of the 14918 project-lines relate to RTD Framework programmes financed by the EU. These projects are labelled pre-competitive as they are often more close to basic research than to development, production or marketing of new products or to the introduction of new processes. This is reflected in the large participation of research institutes and higher education institutions in the EU Framework programmes (58.7% in the 2nd Framework, 61.8% in the 3rd Framework (see *The European Report on Science and Technology Indicators 1994*, p. 225)). With respect to innovation the ´near-market´ EUREKA projects and the technological agreements contained in the MERIT-CATI database provide in this respect more relevant information, albeit that they only account for 1156, respectively 104, of the 14918 projectlines.

With regard to the pre-competitive RTD-lines it is - particularly because of the relatively recent character of the phenomenon of joint European R&D projects ([36]) - interesting to analyse the extent to which they coincide in the global graph with EUREKA- and CATI-lines and how often they precede these lines in time. The 'linear' causal model of innovation would lead us to expect that near-market co-operation between firms would follow an earlier phase where this co-operation follows the more loose and informal channels of pre-competitive research, and not the other way round. From the evaluation of EUREKA, quoted in the *European Report on Science and Technology Indicators 1994,* we learn however that 'The original policy conception of a 'pipeline model', whereby pre-competitive EC projects are followed by nearer-market EUREKA projects has not materialised to date. Rather there has emerged a complex picture in which involvement in EC programmes could either precede or follow a EUREKA project'. Peterson comes to similar conclusions on the nature of the relation between EUREKA and EU's RTD programmes, based on two attitudinal surveys of EUREKA participants (Peterson, 1993). In our graph only 36 Belgian firms (on a total of 626) appear both in at least one RTD project and at least one EUREKA project and there is a coincidence of 256 EUREKA and CORDIS lines. The RTD projects in the area of Information Technology and Telecommunications (ESPRIT, ACTS, RACE, TELEMATICS) by far coincide the most with EUREKA in these disciplines with 234 lines where other technological disciplines account for only 22 coinciding lines. This is not all too surprising, given the importance of Information Technology and Telecommunications both in the EU Framework programmes and EUREKA. Nevertheless there seems to be a disproportional coincidence between RTD and EUREKA lines in these disciplines. Of the 256 CORDIS lines 149 (58.2%) precede EUREKA lines ([37]). Moreover, involvement in some specific RTD programmes seems even more often to precede involvement in EUREKA projects (e.g. 74 of 88 ESPRIT lines precede EUREKA lines). So in our graph the 'pipeline model' *to a certain extent* seems to be materialised, especially for those projects in the area of IT and Telecommunications.

Meeusen and Dumont (1997a,b) also analysed the coincidence of project-lines with personal

[36] A sequence analysis looses meaning as the period in which joint projects have been set up grows longer. The reason is a 'demographic' one : R&D initiatives set up between two partners which are in a mature stage will be more often coexistant with new initiatives between the same partners as time proceeds.
[37] The observed difference between 149 lines where RTD Framework projects precede EUREKA projects and 107 where the opposite is true or RTD and EUREKA projects started in the same year, is statistically significant (compared to a 50-50 proportion) at a level of 99 %.

lines . Most of the actors in the 'strong line' set ([38]) are actors who are involved in relatively many joint projects. The results of the strong line analysis do not support the idea that personal influence becomes more important as R&D co-operation moves closer to direct market applicability. On the other hand we find it difficult to believe that personal influence would be more often instrumental in obtaining 'easy' government subsidies for more or less noncommittal research, than in making strategic choices with respect to the development of new products and the entry on new markets. A possible explanation for the low number of strong lines in near-market contexts might be the fact that non-equity agreements seem to become more important than equity agreements, especially in high-technology industries (Duysters, 1996; Hagedoorn and Narula, 1996), and that these kind of agreements are less likely to result in 'interlocking directorates' than equity agreements.

6.3. Clusters in the National Innovation System

6.3.1. Concepts and methodologies of cluster approaches

In studies dealing with innovation clusters and cluster-based policies a wide variety of cluster definitions and concepts is used. A clear distinction must be made between cluster approaches using traditional cluster analysis techniques to detect objects that are similar or proximate as to some relevant characteristic(s) (i.e. cluster-analysis in the traditional, statistical, sense), and those approaches that focus on relationships between actors or groups of actors (firms, sectors, branches) in networks. Another distinction concerns the level of aggregation used in the analysis ([39]). Meeusen and Dumont (1997a) contains a more detailed analysis and theoretical underpinning of the graphtheoretical cluster approach used to detect clusters in the 'Belgian' R&D network.

6.3.2. Cliques and micro-clusters of R&D co-operation

In what follows we specialise the rather loosely defined concept of 'cluster' to the graph-theoretical concept of 'clique'. N-Cliques can be defined as subgraphs of which all points are linked with one another through a path with maximal length equal to n in a way that no point outside the subgraph has the same quality.

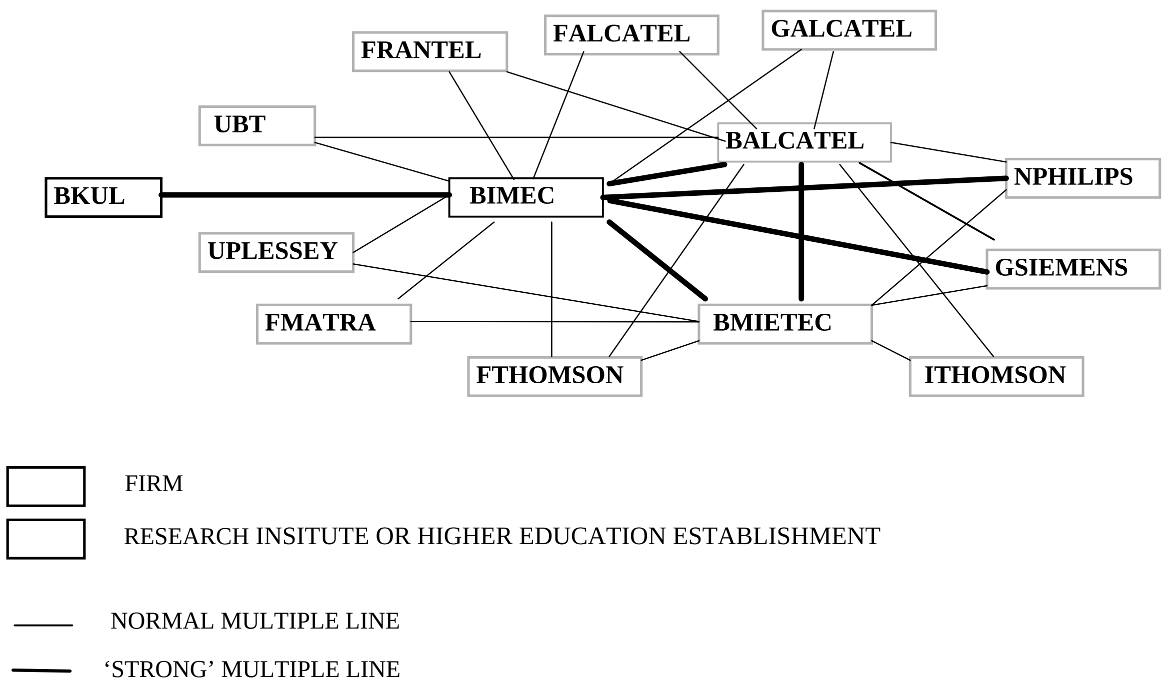
The detection of n-cliques poses some problems for the complete graph due to the size of the graph and programme limitations with respect to central memory. In order to reduce computational complexity the multiplicity of lines was taken into account. For the complete graph 1-cliques could be detected from a multiplicity level of 8 onwards. The subgraph at multiplicity level 8 (containing all actors inter-linked by at least 8 lines) has 4 components. The largest contains 56 actors and 108 multiple lines. At the multiplicity level of 12 two components remain. The largest contains 35 actors and 53 multiple lines. At the multiplicity level 8 there are

[38] A 'strong' line is defined as a project-line which coincides with a 'personal' line created by an interlocking directorate.
[39] 'Clusters' is also a term which sometimes is used in a a-prioristic, non-analytical, context. An example is the cluster-concept used by the Flemish regional government, which considers (and in a number of cases, finances) clusters as formal organisations of firms in a particular industrial sector or active in the same field, formed on a voluntary basis, and taking care of co-ordination and advisory tasks with respect to product and process innovation on behalf of its members (see Debackere and Vermeulen (1997) who place this cluster-concept in a more general perspective).

20 1-cliques, 3 of which contain 4 actors and 17 contain 3 actors. Although the result of a straightforward detection procedure for the complete graph, i.e. without having introduced any bias in the methodology as to specific technological disciplines, the 20 cliques without exception are generated by RTD projects related to *IT or Telecommunications* and are themselves highly linked to one another.
The dominance of links related to Information Technology and Telecommunications clearly reflects the dominance of these disciplines in the EU Framework programmes, and to a lesser extent in EUREKA and MERIT-CATI and the relative specialisation of Belgian actors.
With regard to the distinction between R&D and innovation it is worthwhile to notice that the dominance of IT is less outspoken in near-market projects (EUREKA) and in technological alliances (CATI) than in pre-competitive EU projects, and that the number of strategic IT alliances in which Belgian partners are involved is relatively low, both in absolute and relative terms, compared to other countries (see also Hagedoorn and Narula (1996)).

In Figure 6.1, which can be seen as the core of the 'Belgian' international R&D network, the interlinkage of the cliques is shown. All actors (except foreign education establishments) appearing in at least one clique are shown with their links in the cliques. The thick lines are 'strong' lines (projectlines backed up by a personal link between the actors). The central triangle IMEC, Alcatel Bell and Alcatel Mietec consists of these strong lines. The multiple line (46 projects) between IMEC and Philips (NL) and the multiple line (42 projects) between IMEC and Siemens (DE) are also backed up by a personal link.

Figure 6.1 : Interlinkage of the cliques in the complete graph (multiplicity ≥ 8)



The density of the network is underestimated as existing links between foreign actors are not considered.
It was found that the density of the *IT and Telecommunications* related networks in EU projects increased over time (see Meeusen and Dumont (1997a)). An analysis on the level of some specific technological areas can be found in Meeusen and Dumont (1997a,b).

6.4. Knowledge spillovers in R&D co-operation

Within the scope of endogenous growth theory the interest in technology spillovers as a source of economic growth has increased considerably in recent years. Further progress in this area is in Griliches view essentially to be expected from a more accurate definition of 'the changing multi-dimensional space of technological opportunities' (Griliches (1992), p. S44). Griliches clearly makes the distinction between two notions of R&D spillovers. He qualifies spillovers to be 'embodied' if they relate to the purchase of goods and services. 'Disembodied spillovers' are seen by Griliches as '... ideas borrowed by research teams of industry i from the research results of industry j. It is not clear that this kind of borrowing is particularly related to input purchase flows' (ibid., p. S36), and are considered in Griliches view to be more significant. Unfortunately computing 'embodied' spillovers is easier and more straightforward than it is for 'disembodied' spillovers, since in the study of the former type of spillovers use can be made of methods borrowed from more or less traditional input-output analysis. The study of the intra- and intersectoral aspects of R&D co-operation may offer a useful alternative.
In what follows we will propose a method to calculate intra- and intersectoral knowledge flows, based on the data on R&D co-operation between Belgian firms in EU RTD and EUREKA projects and in technological agreements (MERIT-CATI). The method indirectly measures 'disembodied' knowledge flows between firms co-operating in R&D projects. The basic hypothesis is that the number of joint co-operation links between firms is a proxy measure for the underlying knowledge-flows.
We constructed an asymmetric matrix of intra- and intersectoral knowledge flows. The asymmetry was obtained by hypothesising that in R&D projects more knowledge flows from the main contractant - often the technologically more advanced partner - to other contractants than the other way round, whereas knowledge flows between 'normal' partners are assumed to be balanced. Furthermore, we assumed knowledge flows to be inversely related to the total number of participants in each project or agreement. In this way we account for the importance of 'intimacy'. The hypothesis that in joint R&D projects as a rule more knowledge flows from the main contractor to another partner than the other way round is open for discussion. The results that followed should therefore be interpreted with care.

We performed our analysis at the NACE 2-digit level, due to insufficient data for an analysis at a more disaggregated level. So, for example, if a Belgian firm belonging to NACE sector 32 is the main contractant in a project or agreement that involves 5 partners of which one is another Belgian firm belonging to NACE 72, we assume a knowledge flow of 0.4 (2/5) from NACE 32 to NACE 72 and a knowledge flow of 0.2 (1/5) from NACE 72 to NACE 32 whereas if none of the firms is the main contractant both knowledge flows equal 0.2. The knowledge-flows between firms and non-firms are not integrated in the matrix, nor the flows between Belgian and foreign firms. The matrix is given in Table 6.3.

The column sums account for the total amount of knowledge flowing towards a given sector and the row sums account for the knowledge flowing out of the given sector. Overall intersectoral spillover measures per sector are calculated as the amount of knowledge flowing from a given sector to the other sectors (SpillOut), and from the other sectors to the given sector (SpillIn) (see also Den Hertog et al. (1995)). Apparently overall intersectoral spillovers are high for all sectors, with exception of NACE 17 (Textiles), which reveals that co-operation occurs more between sectors than within sectors, even at a rather high level of aggregation. It also reveals that co-operation between 'national' *competitors* in international R&D projects and technological agreements, which can be traced on the main diagonal of the matrix, is rather limited, although, as pointed out by Griliches (1992), data for this kind of analysis should ideally be collected at business-unit level rather than on firm level. In our analysis major R&D-active firms which are competitors for some of their activities span several sectors, even at the 2-digit level used.

The matrix of intra- and intersectoral knowledge-flows can in our view be used to test the significance of innovation megaclusters detected on the basis of input-output tables of intersectoral flows of capital goods and technology. If it is the intention to analyse innovation clusters by means of client-supplier relations, R&D projectlines can be used as a filter to eliminate redundant lines, or at least to discriminate between 'R&D supported' and client-supplier lines of 'embodied' technological flows. As co-operation seems to occur more between than within industries, and firms within sectors can be expected to be more technologically related than firms from different 2-digit sectors, the relationship between spillovers and proximity is probably not a clear-cut, monotonically increasing one.

The advantage of the proposed matrix is therefore that it does not depend on any distance measure, but calculates knowledge flows in a rather straightforward manner. The intra- and intersectoral elements might be used as weights for the computation of within and between industry 'disembodied' R&D spillovers.

In the obtained matrix, diffusion can be measured for each sector as the logarithm of the row sum related to the column sum (see Den Hertog et al. (1995)). In the line of Pavitt (1984), science-based sectors can be expected to be characterised by 'positive' diffusion and supplier-dominated sectors by 'negative' diffusion. NACE 15 (*Food & Beverage*), NACE 74 (*Other services to firms*), NACE 32 (*Electronic Equipment*) and NACE 25 (*Rubber and Plastic Products*) have a positive diffusion index. When accounting for the number and magnitude of intersectoral flows NACE 32 in particular diffuses a lot of knowledge to other sectors, as measured in Table 6.3. NACE 33 (*Instruments and Office Machines*), NACE 31 (*Electrical Machines*) and NACE 64 (*Telecommunications*) have, in our definition, the highest negative diffusion index.

For each sector the last column in Table 6.3 gives the share of national links for each sector. With exception of NACE 28 (*Metal Products*) and NACE 29 (*Machinery*) this share is fairly low. With data on the sector classification of foreign firms a more dense and revealing matrix could be computed which would allow the study of intra- and intersectoral knowledge flows on an international level, and international 'disembodied' spillovers could then be computed.

Table 6.3 : Matrix of intra- and intersectoral knowledge flows in R&D co-operation

	15	17	24	25	26	27	28	29	31	32	33	34	36	45	64	70	72	73	74	**Total**	**Spill-Out**	**DIFF**	**INT**
NACE15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.33	0	1.33	1.00	0.2	0.14
NACE17	0	3.27	0.07	0	0	0	0	0.05	0	0.07	0	0	0.05	0	0	0	0	0	0.05	3.56	0.08	0	0.18
NACE24	0	0.07	0	0	0	0	0	0	0	0.07	0	0	0	0	0	0	0.04	0.11	0	0.29	1.00	-0.14	0.05
NACE25	0	0	0	0	0	0	0.12	0	0.5	0	0	0	0	0	0	0	0.2	0	0.06	0.88	1.00	0.03	0.22
NACE26	0	0	0	0	0.55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.55	0.00	0	0.07
NACE27	0	0	0	0	0	1.23	0.27	0.07	0	0.6	0.03	0	0	0	0	0	0	0	0.46	2.66	1.00	-0.06	0.15
NACE28	0	0	0	0.12	0	0.27	0.92	0.27	0	0	0	0	0	0	0	0	0	0	0.65	2.23	0.59	-0.05	0.48
NACE29	0	0.05	0	0	0	0.07	0.27	0	0.25	0.2	0	0	0.05	0	0	0.33	0	0	0.19	1.40	1.00	-0.03	0.29
NACE31	0	0	0	0.25	0	0	0	0.25	0	0.24	0	0.06	0	0	0.14	0	0	0	0	0.94	1.00	-0.18	0.12
NACE32	0	0.07	0.07	0	0	0.6	0	0.4	0.49	1.64	0.5	0	0.17	0.18	0.86	0	0.67	0	0.18	5.83	0.72	0.11	0.06
NACE33	0	0	0	0	0	0.03	0	0	0	0.25	0	0	0	0	0	0	0	0	0	0.28	1.00	-0.28	0.11
NACE34	0	0	0	0	0	0	0	0	0.06	0	0	0	0	0	0	0	0	0	0	0.06	1.00	0	0.04
NACE36	0	0.05	0	0	0	0	0	0.05	0	0.17	0	0	0	0	0	0	0	0	0.05	0.32	1.00	0	0.08
NACE45	0	0	0	0	0	0	0	0	0	0.18	0	0	0	0	0	0	0	0	0.05	0.24	1.00	0	0.33
NACE64	0	0	0	0	0	0	0	0	0.14	0.45	0	0	0	0	0.13	0	0	0	0.13	0.85	0.85	-0.17	0.07
NACE70	0	0	0	0	0	0	0	0.16	0	0	0	0	0	0	0	0	0.2	0	0	0.36	1.00	-0.17	1
NACE72	0	0	0.04	0.4	0	0	0	0	0	0.47	0	0	0	0	0	0.2	1.32	0	0.17	2.59	0.49	-0.03	0.07
NACE73	0.83	0	0.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.05	1.00	-0.14	0.17
NACE74	0	0.05	0	0.06	0	0.86	0.92	0.25	0	0.18	0	0	0.05	0.05	0.13	0	0.33	0	0.34	3.22	0.89	0.14	0.14
Total	0.83	3.56	0.4	0.83	0.55	3.05	2.49	1.49	1.44	4.53	0.53	0.06	0.32	0.24	1.25	0.53	2.76	1.44	2.33				
Spill-In	1	0.08	1	1	0	0.6	0.6	1	1	0.64	1	1	1	1	0.9	1	0.52	1	0.94				

In a similar way as in Table 6.3 a matrix of intra- and interregional knowledge flows within Belgium can be computed (Table A.6.6 ; see also Meeusen and Dumont, 1998). This matrix reveals that scale effects are also relevant on the regional level as the largest Belgian region, Flanders, is more 'self-reliant' (in this particular context of R&D co-operation) than Brussels and Wallonia. Somewhat surprisingly, Flanders has a negative diffusion index whereas Wallonia and Brussels have positive indices, which would mean that more knowledge flows from the smaller regions to the largest region than the other way round. Again of course this result is conditional upon the definition which is adopted of the direction of the knowledge spillovers (main contractor to partner). Furthermore the three indexes are close to 0 and therefore do not indicate significant differences.

6.5. The Belgian R&D network in an international context

If R&D co-operation, on the national and international level, has increasingly become an important feature of economic development this certainly holds true for small firms and small countries. Table 6.4 shows the total number of collaborative links within each country as a percentage of the total number of links for the 3rd EU Framework programme. Large countries clearly have a larger share of links within their borders: Spearman's rank correlation between country size and share of collaborative links is significant at the 10 % level (EC (1994) and own calculations). Belgium has the lowest degree of links within its borders (see also Steurs and Cortese (1993)). Greece is an outlier. For all countries the shares of collaborative links within the country appeared to have risen when the results for the 3rd Framework Programme are compared to those of the 2nd.

With regard to the analysis of participation of EU countries in RTD projects we followed the method used by Lichtenberg when he evaluated the participation in the ESPRIT program. Lichtenberg (1996) computed cross-country regressions of the logarithm of the number of participating organisations on the logarithm of population and the logarithm of GDP (in Purchasing Power Parities) separately, and a model with both independent variables combined. He found that the number of organisations is more closely related to a country's population than to its GDP. The residuals of the model with both independent variables show those countries with a relatively high (positive residual) or a relatively low (negative residual) number of participating organisations.

Table 6.4 : Share of collaborative links within a country as a percent of its total number of links (3rd Framework Programme)

Country	%
Greece	14.9
France	14.5
GB	14.0
Germany	13.6
Italy	12.9
Spain	9.1
the Netherlands	8.5
Denmark	8.1
Portugal	7.4
Belgium	7.1

Source: EC (1994, appendix)

Instead of using the total number of organisations of each country we used its total number of prime contractors, hereby also measuring the ability of the actors of a country to act as project leader. In RTD programmes the role of project leader is mostly assumed by large firms and SMEs mostly participate as associate partners (EC (1994), p. 232). We used each country's 1992 GDP measured in current international prices (Penn World data). Furthermore, contrary to Lichtenberg, we included an intercept in the regression equation. Its apparent significance in 5 of the 8 equations suggests that there is a structural effect not accounted for by population or GDP. For all RTD-projects given by the CORDIS database the number of prime contractors is related to a country's GDP, albeit only at the 90 % level of significance, and not to its population, controlling for its GDP. This conclusion holds true for most of the specific programmes.

For ESPRIT, contrary to the findings of Lichtenberg on the total number of participating organisations, the number of prime contractors is significantly related to a country's GDP and not to its population, again controlling for its GDP. The coefficients for all RTD programmes (CORDIS) and for the major RTD programmes are shown in appendix A.6.2. The residuals are ranked in decreasing order. Positive residuals indicate a high number of prime contractors, given the country's size, whereas a negative residual indicates that a country has a comparatively low number of prime contractors relative to its size.

We also computed cross-country regressions for participation in EUREKA with the total number of projects as dependent variable. Again we find that the number of EUREKA projects is significantly related to the GDP of a country and not to its population. The UK is the only country with positive residuals for all RTD programmes that were considered. Belgium has negative residuals for BRITE/EURAM, JOULE/THERMIE and also for EUREKA, and positive residuals for all other RTD programmes and for overall RTD participation. The high number of Belgian prime contractors relative to Belgium's size might partly be caused by the fact that the European Commission has its seat in Belgium. Indeed, Lichtenberg suggested that the intensity of involvement of countries in ESPRIT projects might significantly depend on their distance from Brussels.

For the complete CORDIS database the 4 countries with the highest positive residuals are Belgium and 3 of its neighbouring countries. For specific RTD programmes and for EUREKA this seems less outspoken. Germany has, with exception of one RTD programme (RACE), only negative residuals. Although these results at first glance seem to yield a relatively positive picture about Belgian participation, Steurs and Cortese (1993) and EC (1994) reveal that this high participation is mainly due to universities and research institutes, and that Belgian *firms* have a low participation degree compared with the EU average.

We also performed a hierarchical cluster analysis with data on prime contractors for 10 major RTD subject index codes for a group of 11 countries and found 3 important clusters. A first cluster consists of the UK, France, The Netherlands and Belgium with especially Belgium and the UK having a very similar distribution over the subject codes. The countries of the first cluster, relative to other countries, highly participate in *agriculture*, *biotechnology* and *medicine*. A second cluster is composed of Germany, Italy and Spain with relative strength in *materials technology*, *aerospace technology* and *electronics*. The third cluster is composed of Greece, Denmark, Portugal and Ireland with relative strength in *environmental protection* and *renewable sources of energy*. The first 2 clusters to a large extent coincide with the 2 scientific clusters detected by Archibugi and Pianta (1992, p. 99)

France, Germany, Great Britain and the Netherlands for the 2nd EU Framework Programme, and France, Germany, Great Britain and Italy for the 3rd Framework Programme were in decreasing order of importance the most significant partners for Belgian organisations (*The European Report on S&T Indicators 1994*, p.248). In Table A.6.7 we show the number of lines between Belgian companies and foreign organisations. Germany, France, Great Britain, Italy and the Netherlands are the main countries in terms of the number of collaborative links in the complete graph, as well as for all RTD programmes combined (CORDIS). The ranking for EUREKA and MERIT-CATI is somewhat different (e.g. Spain as the 3rd country for EUREKA and Great Britain as the main country for MERIT-CATI).

In order to get a more precise view on technological collaborative patterns as transpiring through the configurations of joint R&D projects, we computed the relation of a foreign country's collaborative links with Belgian companies in a technological area or programme to the overall number of collaborative links with Belgian companies in that specific area or programme. We refer to this measure as the Revealed Comparative Preference (RCP), as to some extent it reveals the preference of Belgian companies to co-operate with organisations of a given country in a given technological area or programme compared to the overall distribution of collaborative links.

In Table A.6.7 the RCP is computed for all collaborative links in CORDIS, EUREKA and MERIT-CATI. In Table A.6.8 the RCP is computed for all main links, proceeding from the directed graph, i.e. the graph consisting only of the directed lines going from main contractors to the partners. The RCP measure apparently varies less between countries for the 'pre-competitive' RTD projects (RCP close to 1) than for the 'near-market' EUREKA projects or technological agreements contained in CATI. Apparently the closer to the market the more outspoken the preference of Belgian companies for partners from certain countries. In Table A.6.9 we computed the RCP for all links of Belgian companies with foreign partners for major RTD programmes. These programmes were classified in technological areas. The RCP of links in these areas are reported in Table A.6.10.

We finally performed a hierarchical cluster analysis with the data given in Table A.6.9 supplemented with RCP data on co-operation in EUREKA. We found 3 major clusters of countries with similar RCP patterns of co-operation with Belgian actors. Germany and the Netherlands have the most similar RCP pattern and form the first cluster. They have high RCPs for CRAFT and Materials (EUREKA) and low RCPs for ECLAIR and COST. A second cluster is composed of Italy, Denmark and Spain with high RCPs for COST and RACE and low RCPs for DRIVE and JOULE/THERMIE. The third cluster consists of France, the UK and Greece with high RCPs for JOULE/THERMIE and low RCPs for COST, CRAFT and RACE. Portugal, Switzerland, Ireland and Sweden are somewhat isolated at the outside of the central group composed of these 3 clusters.

6.6. Conclusion

In this early phase of the research on the network of R&D co-operation at least one thing became abundantly clear, and comes for that matter – in the light of previously published research - as no surprise for those studying national innovation systems. The (international) network aspects of R&D activities are very pronounced and 'markets and hierarchies' are obviously transcended.

We cannot, of course, but realise that the shape of the network that we find gives a somewhat biased view of national innovation systems. Because in the last decade the EC selected a number of S&T fields which they considered of being of growing importance in terms of international competitiveness and future growth potentiality, heavy emphasis was placed in the EU Framework programmes on fields such as Information Technology, Telecommunication, New Materials, Bio-engineering, new forms of energy etc. The result is of course a R&D co-operation network in which the highest connectivity can be found in precisely these fields. Should we therefore not consider to put more weight on the information contained in databases of the MERIT/CATI type, since they do not reflect this bias resulting from governmental policy ?

The following conclusions emerged:

1. The network of R&D collaboration involving Belgian actors (firms, research labs and institutions of higher education) showed to be highly connected. Two subsets of domestic actors with the highest (weighted) degree centrality could be distinguished: on the one hand firms active in the IT field, and on the other hand universities and interuniversity research laboratories also active in the IT technological discipline. Another important subset consisted of foreign multinationals active in the field of IT and telecommunication. This feature of the network was confirmed by the analysis of so-called clique-configurations.
2. Simple crosstabulations revealed that in the set of R&D active firms, those that participate in international R&D projects or agreements were not significantly more innovative than those that did not participate in any such project or agreement.
3. The study of the coincidence of project-lines indicated that partnerships between firms in the pre-competitive sphere only to a limited extent continued in more near-market projects.
4. The matrix of intra- and interregional and international knowledge flows as implicit in R&D partnerships reveals that scale effects are as relevant on the regional level as on the international level: the largest Belgian region, Flanders, is more 'self-reliant' (in this particular context) than Brussels and Wallonia.

5. A hierarchical cluster analysis with data on prime contractors for 10 major RTD subject index codes for a group of 11 countries yielded 3 important clusters. A first cluster consists of the UK, France, The Netherlands and Belgium with especially Belgium and the UK having a very similar distribution over the subject codes. The countries of the first cluster, relative to other countries, highly participate in *agriculture*, *biotechnology* and *medicine*. A second cluster is composed of Germany, Italy and Spain with relative strength in *materials technology*, *aerospace technology* and *electronics*. The third cluster is composed of Greece, Denmark, Portugal and Ireland with relative strength in *environmental protection* and *renewable sources of energy*.
6. The closer to the market the more outspoken the preference of Belgian companies for partners from certain countries.

7. The technological performance

7.1. Introduction

The amount of R&D expenditures is the most commonly used indicator to appreciate the technological position of countries. Yet, large differences exist among countries in their allocation of R&D expenditure. Some countries devote more effort to fundamental research while others are more oriented towards applied research and experimental development. Further, all other things being equal, the innovative character of R&D expenditures can also be expected to vary from one country to an other. Finally, the amount of R&D expenditures is an input measure. A main question is to know how to measure the outcome of inventive activity. In other words, efforts in the field of R&D are only important as far as they yield results in terms of innovation. But this type of argument should be driven home to its logical conclusion: in its turn innovation is only important as far as it leads to tangible results with respect to what is really economically important: a high income per capita and its fair distribution, therefore good performance in terms of economic growth and, especially for a small open economy like Belgium, international competitiveness.

Patent and scientific publication data are the most common output indicators to measure technological and scientific activities. A double advantage of patent data is that they can be broken down by technological classes and provide internationally comparable information. They are also a main form of codified information. Their main disadvantages are well-known: not all inventions are patented or patentable and the propensity to patent differs greatly across technological classes ([40]). With regard to bibliometrical indicators, only a subset of world publications are contained in the available databases, and there is a bias in favour of English-language publications. Yet, these shortcomings are generally considered not to affect substantially the relevance of this type of data.

A third, more indirect and also less commonly used, type of output-indicator of innovation in the broader sense can derived from trademark data. The usefulness of this indicator has recently been brought to the attention by Meeusen and Rayp (1998).

In what follows we first go deeper into the matter of three - first level - output-indicators: patents (our main focus of attention), publications and trademarks. At the end of this chapter we turn to the second level output indicators and study the relation between innovative performance and economic performance.

[40] For the relevance of patent statistics as an indicator of the output of Science and Technology activities, see for instance Bound et al. (1984), Basberg (1987), Glisman and Horn (1988) or Griliches (1990).

7.2. Patents

Despite its limits, patents appear to be a relevant indicator for studying the impact of inventiveness on the economic environment, and for tracing the interactions and technology flows across sectors and among countries. Recent studies show that the productivity achieved by a firm depends on both its own research effort and the accessible knowledge from other firms. This aspect of the analysis of patents as a knowledge flow is not covered in this chapter. The data used hereafter bear on Belgian patent applications at the European and US patent offices over the period 1978-1995.

The identification of Belgian patents is based on applicants and not on inventors. This choice is not without consequences on the analysis because for Belgium the number of patents based on the applicant criterion only represents three quarters of the number of patents based on the inventor criterion. Such an observation indicates that the Belgian NIS depends to an important extent on strategies developed by foreign multinationals.

7.2.1. The Belgian positioning inside the European Union

The Belgian propensity to patent is inferior to the European average. The indexes of the number of Belgian patent applications per capita comparative to the average for the European Union (EUR15 = 100) were equal to 61, 63 and 65 for the periods 1981-1985, 1986-1990, 1991-1995 respectively (the indexes are measured on the basis of EPO data). While the index is increasing over time, we observe that Belgian firms on the basis of this criterion appear less innovative than average. It is worth recalling in this context that Belgium is one of the richest countries of the European Union, its GDP index being equal to 113. So, Belgium appears to be more a technology user than a technology producer.

As the index of patents per capita is equal to the product of the index of R&D expenditure per capita with the index of R&D productivity, the smaller Belgian propensity to patent can partially be explained by taking these components into account. On the one hand, the index of Belgian R&D expenditure per capita comparative to the European average is equal to 89 (91 for business R&D exependitures). On the other hand, the R&D productivity index as measured by the ratio of patent applications on R&D expenditures is equal to 74. Consequently, a relatively large part of the observed gap cannot be explained by lesser R&D expenditures. Actually, the low R&D productivity index apparently plays a larger role than low R&D intensity. However, as the measure of the propensity to patent is based on the applicant criterion, a correction has to be made with respect to the part of patents which have to be attributed to Belgian inventors but whose registration is not applied by the Belgian subsidiary of the multinational company. When such a correction is made, we obtain a Belgian propensity to patent roughly comparable to the European average ([41]).

What can we conclude from this global glance at the Belgian technological performance ? A possible hint is that the Belgian index of manufacturing employment comparative to the

[41] The use of patent data per applicant leads to an index of patents per capita equal to 65, to an index of R&D per capita equal to 88 and a R&D productivity index equal to 74. When the patent data per inventor are used instead of applicant, the indexes are respectively equal to 87, 88 and 99.

European average, which is equal to 89, reveals a less important weight of manufacturing activities in the Belgian economy. It is however worth underlining that this lesser performance is compensated by a higher productivity index equal to 110. The lesser Belgian propensity to patent comparative to the European average is for one part explained by the lower R&D expenditures (one third of the gap) and for the other one by the behaviour of some multinational firms which repatriate the research results (two third of the gap). Consequently, the question stands whether specifically Belgian firms are less innovative than their European competitors and how the national innovation system is under the dependence of foreign decision centres. In the light of the manufacturing employment index, another point deals with the adequacy of the Belgian S&T policy to valorise efficiently the innovative potential of the country to develop new market niches ([42]). To address this question we need to deepen our understanding of the Belgian innovation system in order to identify what are the particularities differentiating Belgium from other European countries.

7.2.2. Patenting activities of firms

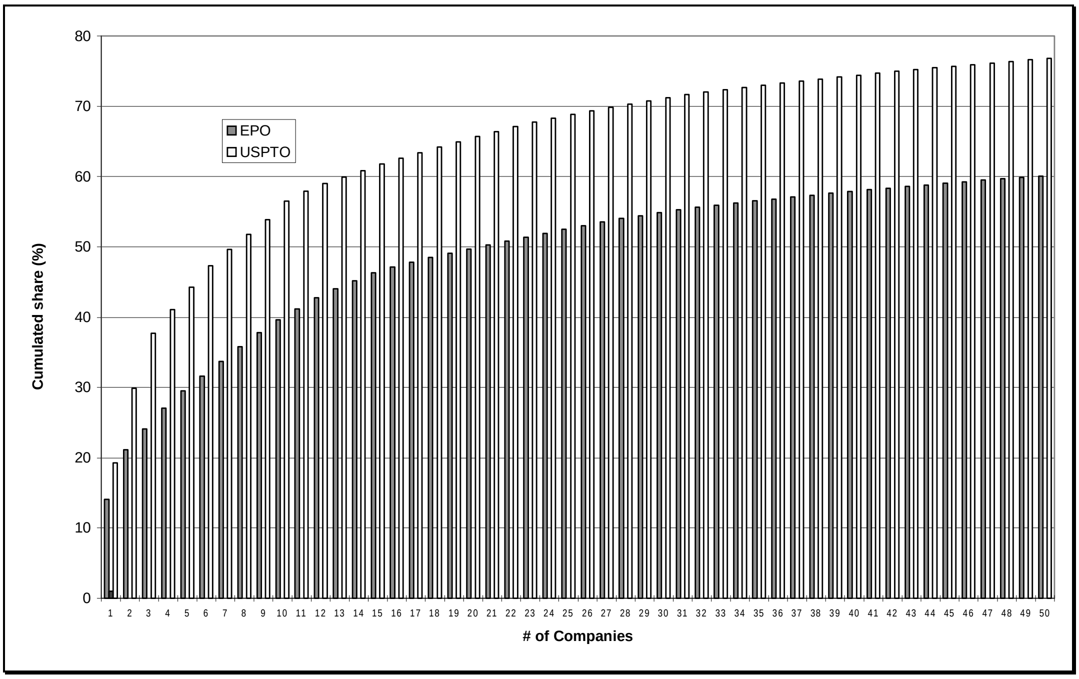
Figures 7.1 and A.7.1 shed some light on the patenting activities of the top 50 Belgian firms. As can be observed this activity is quite concentrated. Indeed, in terms of European patents, the two firms which have applied for the highest number of patents hold respectively 14 percent and 7 percent of the total number of patents applied by Belgian applicants over the period 1978-1995. In terms of US patents, these shares are even higher (19 and 11 percent respectively). The cumulated share of US patents of the top 50 Belgian firms is about 75 percent against 60 percent for European patents. This shows that it are mainly the largest firms that patent outside the European market.

Table 7.1 gives the list of the 20 first companies which account for 50 percent of Belgian patents. As can be seen, three companies, Agfa-Gevaert, Solvay-Interox and Janssen Pharmaceutica concentrate 25 and 38 percent of patent applications at the EPO and the USPTO respectively. Globally, we can observe that the Belgian patent activity is highly dependent upon a few companies. A second weakness of the Belgian patent activity is that a significant number of these companies are subsidiaries of foreign multinationals. This is particularly the case for Agfa-Gevaert, Janssen Pharmaceutica and Alcatel-Bell, which account for more then 20 percent of all Belgian applications. Consequently, not only the Belgian patent activity is low in comparison to other countries, but it is also highly dependent upon a few foreign multinational companies. Interestingly, the first three patenting firms are the same in terms of both European and US patents as can been seen from Table A.7.1. However, 8 firms to be found in the ranking of the European patent top 20 firms are not present in the corresponding US ranking.

The high dependency of the Belgian innovation system on foreign multinationals could be an important explanation of its lesser propensity to patent.

[42] The relevance of the question becomes higher if Belgium is compared with other countries of the central part of the European Union instead of the European average.

Figure 7.1 : Cumulated distribution of the number of patent applications (EPO & USPTO, 1978-1996)



Sources: EPO and USPTO databases; own calculations

Table 7.1 : Top 20 firms in terms of European and US patent applications (EPO & USPTO, 1978-1996)

Rank	EPO	C%	USPTO	C%
1	Agfa-Gevaert	14.3	Agfa-Gevaert	19.3
2	Solvay-Interox	21.5	Solvay-Interox	29.9
3	Janssen Pharmaceutica	24.5	Janssen Pharmaceutica	37.7
4	**Alcatel/Bell Telephone**	27.5	Picanol	41.1
5	Picanol	30.0	Bekaert	44.3
6	Raychem	32.2	**Glaverbel**	47.3
7	Bekaert	34.3	Raychem	49.6
8	**Ford New Holland**	36.4	**Staar**	51.8
9	Centre de Recherches Métallurgiques	38.5	Centre de Recherches Métallurgiques	53.9
10	ACEC	40.3	Fina Research	56.5
11	Fina Research	41.9	UCB	58.0
12	**Procter & Gamble**	43.2	**Metallurgie Hoboken-Overpelt**	59.0
13	**Monsanto Europe**	44.4	**Confiserie Leonidas**	59.9
14	**Pumptech**	45.6	**Dow Corning**	60.9
15	**Cockerill Sambre**	46.4	Fabrique National Herstal	61.8
16	**Smithkline Biologicals**	47.2	ACEC	62.6
17	**GB Boucherie**	47.9	**Champion Spark Plug Europe**	63.4
18	Fabrique National Herstal	48.6	Michel Van de Wiele	64.2
19	Michel Van de Wiele	49.2	**Esselte Dymo**	65.0
20	UCB	49.8	**Texaco Belgium**	65.7

Note: C% = cumulative share; bold names of companies in only one of the top 20 ranking
Sources: EPO and USPTO databases; own calculations

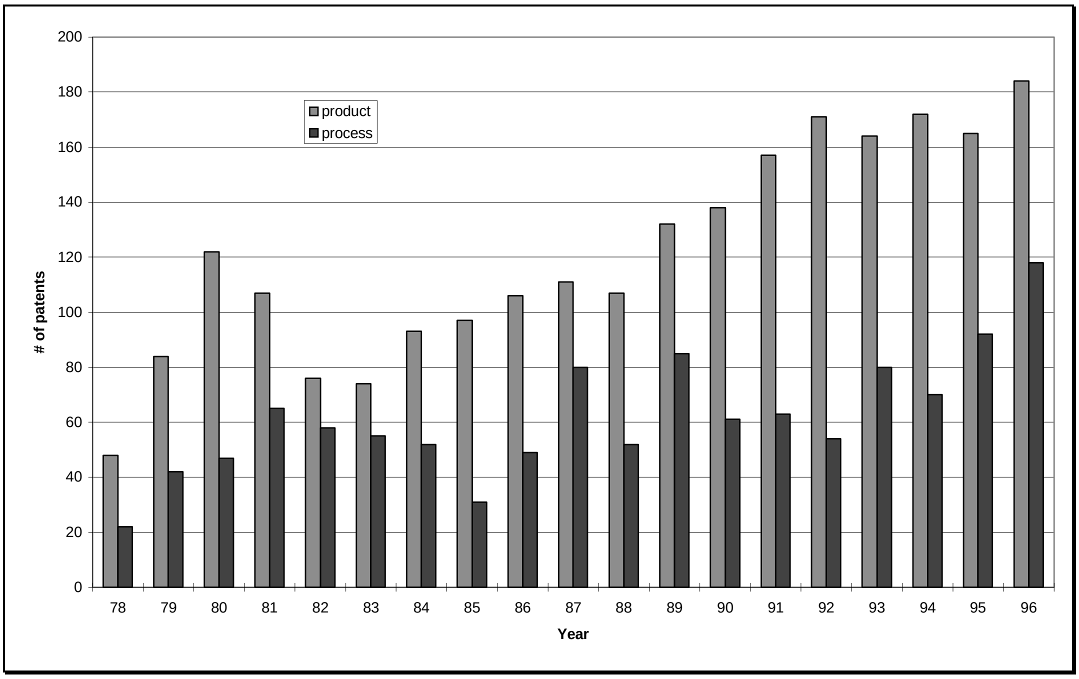
Indeed, on the one hand, there is the hypothesis that Belgian subsidiaries are specialised in the local adaptation of products and processes developed, in the first place, in foreign headquarters of multinationals. On the other hand, a significant part of their R&D output could be hoarded by head-offices. These points deserve some further investigations in order to understand correctly the Belgian NIS.

7.2.3. Product and process oriented US patents

Technological change can be defined in several ways. For instance, it is common to distinguish process innovation from product innovation. The former is related to the discovery of a new production process, while the latter is associated with the invention of a new product. The distinction is important because it is often suggested that the private rate of return seems greater for processes than for products (Mansfield (1977,1988)).

Innovation-counts by means of patent-data allows one to appraise the orientation of the Belgian NIS. A logometric analysis on the basis of the summary of each patent applied at the USPTO has been realised. Each time that the word ‘process’ or/and ‘method’ were found, the patent was assigned to a process innovation. Figure 7.2 indicates that on average 1/3 of the total number of patents over the period are process patents. The distribution of patents between these two categories does not seem to change over time. Also, it can be observed that the time pattern of both kinds of patents is unsynchronised. One explanation may be that each time a product innovation is generated, it takes a varying time to implement a method to produce it.

Figure 7.2 : Patent distribution by category (product and process oriented US patents)



Source: USPTO database; own calculations

7.2.4. Patenting activities of universities, RTOs and government authorities

Table 7.2 shows the number of EPO patent applications by public research institutes, universities, private non profit organisations and government authorities. As can be seen the patenting activities of these institutions is once again quite concentrated ([43]). Indeed, three institutions out of 33 hold 52.7 percent of the total number of patent applications by these institutions.

A second emerging fact from the table is the relatively low propensity to patent of universities and public research institutes in comparison to the funds engaged in R&D activities and as compared to private business firms. Given the more scientific nature as well as the aims and the functions of the research activities undertaken by such institutions, patent statistics may not be well suited to assess the output of their activities. Hence, other indicators such as the number of scientific papers and their citations may be more relevant here.

Table 7.2 : Patents applied by public institutions, universities and government (EPO, 1978-96)

	PUBLIC INSTITUTIONS (I), UNIVERSITIES (U), GOVERNMENTS (G)	NPA	C%
I	Centre de Recherches Métallurgiques	126	35.3
I	Interuniversitair Microelektronica Centrum	35	45.1
G	La Région Wallonne	27	52.7
I	Leuven Research & Development	23	59.1
I	Stichting REGA	22	65.3
I	S.C.K/C.E.N.	19	70.6
U	Université Catholique de Louvain	16	75.1
I	International Institute of Cellular and Molecular Pathology (ICP)	16	79.6
I	Vlaamse Instelling voor Technologisch Onderzoek (V.I.T.O.)	14	83.5
G	Etat belge, Services de Programmation de la Politique Scientifique	13	87.1
U	Rijkuniversiteit Gent	10	89.9
U	Université Libre de Bruxelles	9	92.4
U	Université de Liège	4	93.6
I	Société de Recherches et de Développement Industriel (SOREDI)	2	94.1
I	Institut d'Enseignement Spécial, Atelier Protégé les Erables	2	94.7
I	Institution pour le Développement de la Gazéification Souterraine	2	95.2
I	Wetenschappelijk en Technisch Centrum van de Belgische Textielnijverheid (Centexbel)	2	95.8
I	Miscellaneous	15	100.0
	TOTAL	357	

Note: NPA = number of patent applications; C% = cumulative share
Sources: EPO database; own calculations

[43] A similar observation has been found for private business firms.

7.3. Differences in regional profiles

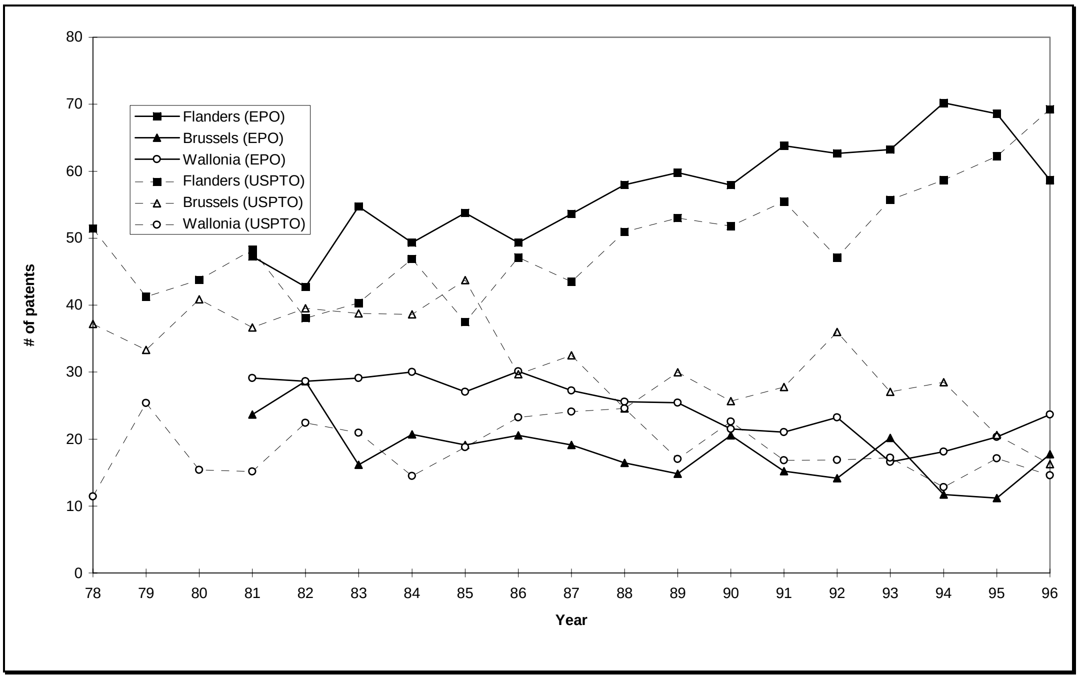
Increasingly, regional technology initiatives are inducing important changes in national innovation systems, especially in a country like Belgium. The adequate targeting of S&T policies at the different spatial decision levels in terms of effectiveness, priorities and complementarities is vital to reinforce the capacity to cope with increased technological competition and its economic consequences. Indeed, S&T policies are not spatially neutral ([44]). The spatial structures are not only central in the innovation process but innovation is also a spatial process in itself. Innovation appears to be less the product of individual firms than the result of the agglomeration of technological infrastructure in specific places. In this regard, the technological infrastructure of a region strengthens the innovation potential and influences the location of firms. The proximity between industries and academic research centres is also a significant source of productivity benefits ([45]). Furthermore, spillovers are intrinsically linked to location factors. Consequently, in order to assess properly innovation dynamics it is essential to grasp the regional context.

As a federal country, a large part of the Belgian S&T policy is now the responsibility of the three regions, Flanders, Wallonia and Brussels as well as the French-speaking Community ([46]). Yet, the federal government can still take initiatives regarding international agreements or specific scientific fields going beyond the concerns of a single region or 'community'.

Figure 7.3 gives a view of the distribution of European and US patents among the three Belgian regions: Flanders, Brussels and Wallonia. On the whole, Flanders, with about 60 percent, has the highest share in both patent offices over the period 1978-1995. Moreover, this share in terms of European patents has increased from about 48 percent in 1981 to 58 percent at the end of the period. For US patents, this increase is even larger. Conversely, the shares of the two other regions, Brussels and Wallonia, have decreased over the same period. However, these figures have a somewhat different pattern according to the patent office considered. Indeed, for European patents the decline is relatively similar in both regions and seems to be stabilised at the end of the period. In terms of US patents, the share of Brussels has fallen from 40 percent in 1978 to less than 15 percent in 1996, while Wallonia's share is stable over this period. This last observation may be mainly explained by the increase in the propensity to patent of Flanders.

[44] For a discussion see Jaffe, Trajtenberg and Henderson (1993) as well as Audretsch and Feldman (1993).
[45] See for instance Jaffe (1989).
[46] Strictly speaking also the Flemish Community can be said to be partly responsible for S&T policy, but on the administrative and political level the Flemish Community is merged with the Flemish Region.

Figure 7.3 : Number of patent applications by region (EPO and USPTO, 1978-1996)



Sources: EPO and USPTO databases; own calculations

With regard to the patent distribution at the district level it appears that the number of patent applications is highly concentrated in a few districts: Antwerpen and Brussels, the two most important Belgian districts in terms of economic activities, concentrate together respectively 46.4 and 54.2 percent of the total number of European and US patents over the period 1978-1996. They consequently can be viewed as the most innovative Belgian areas, if we take patents as a measure.

Table 7.3 gives the levels of concentration and diversity of innovativeness in terms of European patents across the Belgian districts, provinces and regions. The figures A.7.2 to A.7.4 also give some complementary illustrations. It follows from these figures that if Antwerpen and Brussels are the two main Belgian patenting districts with respectively 25 and 18 percent of patent applications, the two main Walloon innovative districts are Liège and Charleroi with respectively 7 and 6 percent of patent applications. All the other districts have a share which is less than 5 percent, except Turnhout (a district contiguous to Antwerpen) with 5 percent. Ieper has an innovativeness index similar to the one obtained for Antwerpen. There is however no direct link between the wealth of districts and their innovativeness. While Ieper has a high innovativeness index, its GDP per capita (average for the period 1981-1993) is less than the one observed for Gent and Hasselt the innovativeness indices of which are low.

If we turn to the link between innovativeness concentration and innovativeness diversity (measured by the number of innovative firms or individuals in terms of patents), Brussels is characterised by a higher innovativeness diversity than Antwerpen. Ieper is to a large extent dependent on a small number of innovators. Liège, the Walloon part of the Brabant province and Turnhout are characterised by an equilibrated distribution of patents among innovators.

If we look at the technological concentration measured by the variation coefficients among technological classes ([47]), we observe that Antwerpen is characterised by a higher concentration of patent applications in some technological classes ([48]) than Brussels. The two main Walloon districts, Liège and Charleroi, benefit also from a more diversified technological activity.

Table 7.3 : GDP-, Patents- and Innovators per Capita; Technological Concentration

Abbreviation	Districts PROVINCES **REGIONS**	GDP per Capita	Patents per Capita	Innovators per Capita	Technological Concentration
ANT	Antwerpen	142	269	134	4.2
MEC	Mechelen	86	30	61	3.4
TUR	Turnhout	99	134	114	4.9
	ANTWERPEN	122	193	116	3.5
HAL	Halle-Vilvoorde	80	53	88	3.3
LEU	Leuven	77	102	64	3.0
	VLAAMS BRABANT	79	75	77	2.3
HAS	Hasselt	114	34	63	2.8
MAA	Maaseik	84	20	62	3.6
TON	Tongeren	63	32	72	3.0
	LIMBURG	93	30	65	2.2
AAL	Aalst	70	43	45	3.0
DEN	Dendermonde	74	38	60	3.2
EEK	Eeklo	73	42	73	5.0
GEN	Gent	121	42	77	3.0
OUD	Oudenaarde	91	24	63	3.5
SNI	St-Niklaas	93	76	136	3.0
	OOST VLAANDEREN	95	46	77	1.9
BRU	Brugge	111	108	72	7.8
DIX	Diksmuide	78	35	109	5.9
IEP	Ieper	83	277	81	8.9
KOR	Kortrijk	99	139	87	2.6
OOS	Oostende	102	18	48	3.3
ROE	Roeselare	103	88	99	6.0
TIE	Tielt	102	94	265	2.4
VEU	Veurne	122	29	89	5.5
	WEST VLAANDEREN	101	110	94	3.6
NIV	BRABANT WALLON	74	141	141	2.7
ATH	Ath	65	22	50	5.0
CHA	Charleroi	81	128	60	3.0
MON	Mons	76	30	66	2.4
MOU	Mouscron	78	42	144	2.9
SOI	Soignies	71	12	31	4.3
THU	Thuin	58	36	54	5.8
TOU	Tournai	77	36	69	3.5
	HAINAUT	75	62	62	2.1
HUY	Huy	114	36	127	2.9
LIE	Liège	95	114	119	1.7
VER	Verviers	89	60	134	2.3
WAR	Waremme	64	13	42	8.6
	LIEGE	93	87	119	1.5
ARL	Arlon	84	94	27	5.6
BAS	Bastogne	82	41	87	5.7
MAR	Marche-en-Famenne	88	11	43	8.1
NEU	Neufchâteau	86	22	61	5.1
VIR	Virton	76	26	57	4.6
	LUXEMBOURG	83	39	54	3.4
DIN	Dinant	78	7	42	4.8
NAM	Namur	81	46	68	2.6
PHI	Philippeville	64	43	100	5.2
	NAMUR	78	37	67	2.3
	VLAAMS GEWEST	101	102	90	2.1
BXL	**BRUSSELS**	158	181	205	2.0
	REGION WALLONNE	81	72	87	1.6
	BELGIUM	100	100	100	1.4

[47] The data on which these figures are based are not corrected for the distinction between headquarters and R&D centres.
[48] The main explanation is the high propensity of Agfa-Gevaert to patent in some technological classes.

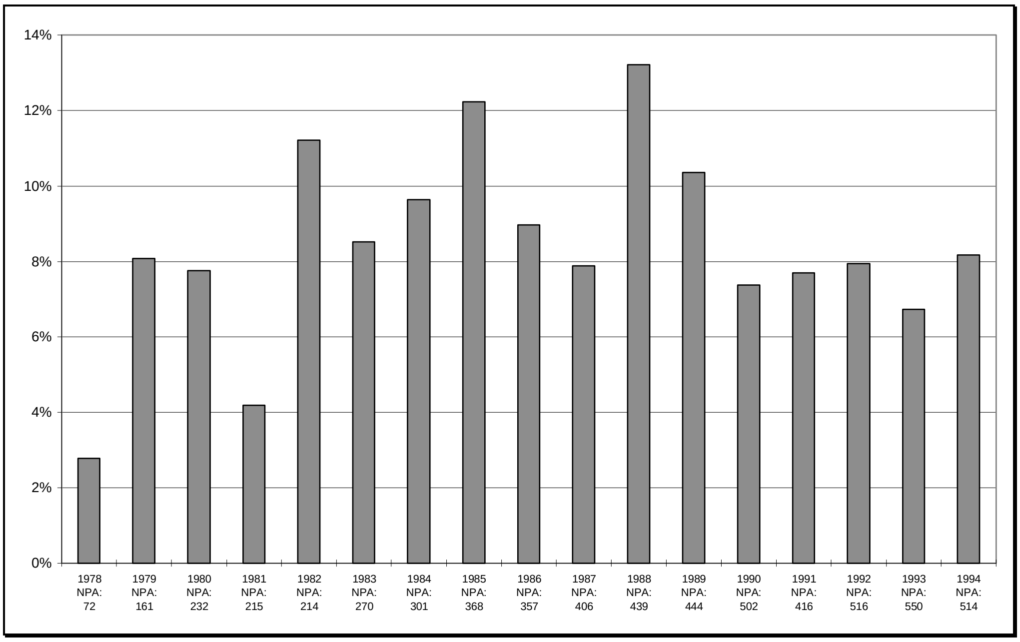
7.4. Co-patents

Quoting Archibugi and Pianta (1992) ([49]), '*the internationalization of technology and the growing sectoral specialization of the activities of countries and firms have led, over the last decade, to a new pattern of cooperation in innovative activities both across borders and among different institutions, namely research centres, industry and government agencies*'. The purpose of this section is to look at the behaviour of Belgian actors with regard to S&T collaborative activities in the field of patents. More precisely, we turn our attention to the output of the Belgian co-operative activities as measured by co-patenting activities. Before examining more carefully these figures it is worth recalling briefly what are the main theoretical arguments in favour of S&T collaborations. The main advantages associated with technological co-operation ([50]) are the possibility to share the risks of S&T activities, a better access to the funds necessary to finance them, and the ability to take advantage of economies of scale and of scope. In addition joint S&T activities allow firms to benefit from complementary knowledge bases and eliminate the duplication of resources allocated to such activities.

Figure 7.4 reports the share of co-patent applications with respect to the total number of patents filed to the EPO over the period 1978-1994. On average 10 % of patents are co-patent applications. Compared to France, whose economy is less open than Belgium, this share is somewhat lower ([51]). Hence the success of Belgian technological collaborations as measured by patents may be questioned. Yet, among the co-patents deposited, two out of three imply on average a foreign co-applicant. It will be noted that this proportion tends to be accentuated in time and is higher than in France where one co-applicant on two is a foreign one.

[49] p. 12.
[50] See Kamien et al. (1992) or Geroski (1995).
[51] 15 % over the period 1980-1989 (Duguet, 1994).

Figure 7.4 : Share of co-patent applications (EPO, 1978-1994)



Note: NPA = number of patent applications
Sources: EPO database; own calculations

Figure 7.5 : Foreign co-applicants: share by country

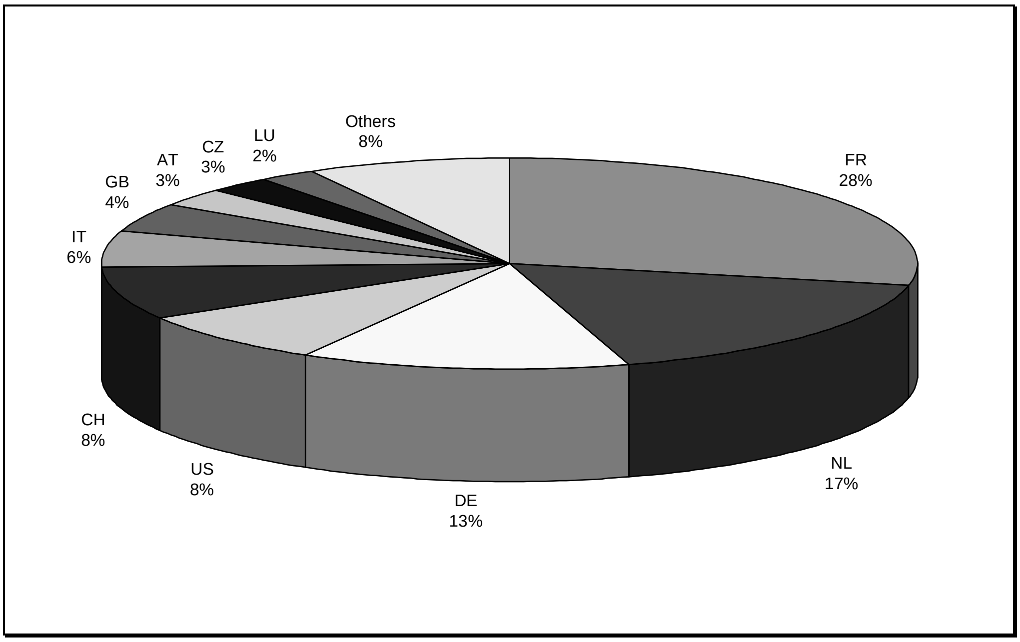


Figure 7.5 exhibits the share of foreign co-patent applications with Belgium. The four largest shares represent a total of 71%. With the exception of the United States, these countries, i.e. France, the Netherlands and Germany, are neighbours of Belgium. Hence, technological collaborations in terms of co-patenting appears to be rather spatially confined.

The number of co-patents involving Belgian and foreign public institutes, universities and governments whose list is given in Table A.7.1 represents a small amount of total patenting, i.e. about .9%, and of the total of co-patents, i.e 12%. The 'Centre de recherche metallurgique' holds the largest number of co-patents, i.e. 8 out of 47. About one fifth of co-applicants are universities and 8 out of 47 are foreign institutes.

7.5. Technological specialisations and Technological Revealed Comparative Advantage

The evaluation of the technological capacity of a country with a view on its economic performance becomes increasingly important for political decision-makers. This section analyses the technological fields in which Belgium is specialised, or has revealed comparative advantages as compared to the European Union. For this purpose, the European patent statistics are used. Table 7.4 indicates the main technological classes in which Belgium is specialised in terms of EPO patents and according to the International Patent Classification (IPC). On the whole, it appears that innovative activities are quite concentrated.

Moreover, this concentration has intensified in the more recent years. Indeed, the top IPC classes represent 40.3 percent of total patents over the sub-period 1981-1985 against 52.4 percent for 1991-1995. *Instruments* and particularly *photography* (G03) are characterised by the highest shares in all three sub-periods. Furthermore this share has more than doubled in the last sub-period. Over the period, *organic compounds* (C08) and to a lesser extent *biochemistry* (C12) and *packing* (B65) have become more important while *agriculture* (A01), *health* (A61) and *measurement instruments* (G01) have relatively declined.

The bottom part of Table 7.4 shows the TRCA ([52]) indexes. A value less than one of this index of specialisation means that Belgium holds a smaller share in its patent distribution for the concerned technological class than its world counterpart. The IPC classes have been ranked in decreasing order of the performed value taken by this index for each of the three sub-periods. The TRCA indexes shed some light on the relative advantages of Belgium with respect to its existing technological capability. Over the whole period, personal articles (in particular *brushwares* (A46)) and textiles (*weaving* (D03), and *ropes* (D07)) represent the activities for which Belgium has the highest TRCA. In the more recent sub-period, four new IPC classes entered the top 10: instruments (*photography* (G03)), *printing* (B41), *agriculture* (A01) and metallurgy (*electrolytic processes* (C25)). In the later sub-period, it appears that among the twenty first classes only three high-tech classes are identified as Belgian specialisations: *photography* (G03), *inorganic chemistry* (C01) and *biochemistry* (C12).

[52] In order to compute the TRCA index, the IPC classification at the two digit level is used. It should be noted that an alternative more aggregated classification has also been retained. The results obtained do not contradict the findings of Archibugi and Pianta (1992) in their study of the technological specialisation of advanced countries.

Table 7.4 : Relative share of top IPC classes and Technological Revealed Comparative Advantage (TRCA) - EPO

	1981-1985			1986-1990			1991-1995		
Rk	IPC	%	C%	IPC	%	C%	IPC	%	C%
1	photography	5.6	5.6	Photography	6.6	6.6	photography	12.6	12.6
2	agriculture	5.4	11.0	organic chemistry	6.1	12.7	printing	6.0	18.6
3	organic chemistry	5.3	16.3	weaving	5.0	17.8	transmission	5.8	24.4
4	medical, hygiene	4.4	20.7	Agriculture	4.7	22.4	organic compounds	5.6	30.0
5	packing; storing	4.1	24.7	organic compounds	4.6	27.0	organic chemistry	5.2	35.1
6	measuring instruments	3.5	28.2	medical, hygiene	4.1	31.1	agriculture	4.1	39.2
7	heating	3.1	31.4	Biochemistry	3.6	34.7	biochemistry	3.6	42.8
8	organic compounds	3.1	34.5	measuring instruments	3.5	38.2	packing; storing	3.4	46.2
9	building	3.0	37.5	packing; storing	3.0	41.2	medical, hygiene	3.2	49.4
10	oils, deterg., candles	2.8	40.3	Mining	2.9	44.1	measuring instruments	3.2	52.6
11	engineering	2.8	43.1	Building	2.5	46.5	weaving	3.0	55.6
12	plastics	2.5	45.6	electric elements	2.2	48.7	engineering	2.3	57.9
13	electric power	2.1	47.7	Plastics	2.0	50.8	dyes; paints	2.2	60.1
14	electric elements	2.1	49.8	Engineering	2.0	52.8	processes, apparatus	2.2	62.4
15	domestic articles	2.0	51.8	domestic articles	2.0	54.8	plastics	2.1	64.5
16	sport, games	1.9	53.7	processes, apparatus	2.0	56.8	electric elements	1.9	66.4
17	processes, apparatus	1.6	55.2	Heating	1.8	58.6	building	1.8	68.3
18	weaving	1.5	56.7	Transmission	1.8	60.3	computing	1.8	70.1
19	vehicles	1.5	58.2	combustion apparatus	1.7	62.0	domestic articles	1.3	71.5
20	transmission	1.5	59.7	oils, deterg., candles	1.7	63.7	electric power	1.3	72.7
	IPC	%	TRCA	IPC	%	TRCA	IPC	%	TRCA
1	brushware	0.9	11.7	weaving	5.0	21.0	ropes; cables	0.4	16.3
2	ropes; cables	0.2	7.4	ropes; cables	0.5	20.3	weaving	3.0	12.3
3	oils, deterg., candles	2.8	5.6	Brushware	0.7	7.9	brushware	0.5	8.3
4	weaving	1.5	5.6	Sugar industry	0.2	6.0	Sugar industry	0.1	6.8
5	explosives	0.3	5.4	Instruments	0.1	5.1	photography	13.0	4.8
6	machines; engines	0.9	4.6	Mining	2.9	4.9	printing	6.0	3.8
7	cleaning	0.1	3.9	Metallurgy	1.4	3.9	metallurgy	0.9	3.7
8	Sugar industry	0.2	3.6	combustion apparatus	1.7	3.8	saddlery; upholstery	0.0	3.3
9	heating	3.1	3.6	Heating	1.8	3.7	Agriculture	4.1	3.0
10	Agriculture	5.4	3.0	heat exchange	0.9	3.5	electrolytic processes	0.7	2.7
11	metallurgy	1.3	2.9	oils, deterg., candles	1.7	3.1	mining	1.1	2.3
12	sport, games	1.9	2.8	Photography	6.6	3.1	weapons	0.4	2.1
13	photography	5.6	2.6	electrolytic processes	1.4	3.1	butchering	0.3	2.0
14	building	3.0	2.3	spraying, atomising	0.1	2.9	sewing	0.2	2.0
15	heat exchange	0.8	2.3	Agriculture	4.7	2.9	building	1.8	1.9
16	weapons	0.8	2.3	Headwear	0.1	2.8	Inorganic chemistry	1.1	1.9
17	ammunition	0.5	2.3	Drying	0.2	2.7	casting	0.8	1.7
18	life-saving	0.4	2.2	hydraulic engineering	0.9	2.6	baking	0.2	1.7
19	hydraulic engineering	0.9	2.2	saddlery; upholstery	0.0	2.4	biochemistry	3.6	1.5
20	Constructions	0.8	2.2	Weapons	0.7	2.4	dyes; paints	2.2	1.5

Notes: rk = rank; % = share; C% = cumulated share

$$TRCA_{ib} = \left(n_{ib} \Big/ \sum_i n_{ib} \right) \Bigg/ \left(\sum_j n_{ij} \Big/ \sum_i \sum_j n_{ij} \right)$$

where $n_{ij}(b)$ is the number of patents of country j (Belgium) in the jth technological class.

7.6. Scientific publications

If patents can be viewed as a main indicator of innovative output in industry, publications are often considered a good indicator of the innovative effectiveness of the higher education system. Table 7.5 shows that Belgium is in a favourable position in three scientific fields: clinical medicine, biomedical research and physics. These scientific specialisations roughly correspond to the main technological specialisations found in the analysis of patents. Yet, a slow but real degradation of the number of scientific publications is observed with reference to the European evolution: the Belgian share of international publications at the world level is decreasing while the European one is increasing. In 1993, the index of the number of publications is 7% inferior to the European average. Taking into account the observed shortage on the labour market of scientists and engineers in Belgium, the country however appears to perform relatively well. Finally, it is worth noting that, despite its small size, Belgium has a broad distribution of its efforts across fields of science (Archibugi and Pianta (1992)).

An explanation of the shortfall in the publication index is the increasing international collaboration in which Belgian teams are involved. When not corrected for co-publications, the Belgian position with respect to the European Union average is around 10% higher than the average. Both the citation and co-citation indexes confirm the increase as well as the scope of the degree of internationalisation of the Belgian scientific research. As shown in Table 7.5 Belgian scientists have a high propensity to collaborate with foreign colleagues. Presently, around 44% of Belgian scientific papers are the results of a collaboration with a foreign scientist. The Belgian propensity to collaborate with a foreign team is twice as big as the European average. Finally, the citation index gives clues as to the quality of Belgian research since the value of the index is increasing over time and about 30% higher than the European average.

Table 7.5 : Scientific Publications

Publications by Scientific Fields (% EUR15)	1981	1985	1990	1993	Index 1981	Index 1993
Clinical Medicine	2.9	2.5	2.8	2.7	103	100
Biomedical Research	3.0	2.9	3.2	3.1	107	115
Biology	2.3	2.7	2.7	2.5	82	93
Chemistry	2.7	2.7	2.1	2.2	96	81
Physics	2.9	2.5	2.6	2.7	103	100
Mathematics	3.3	2.8	2.5	2.5	117	93
Engineering	2.1	2.1	2.5	2.4	75	89
Universe Sciences	2.5	2.9	2.3	2.0	89	74
Total (% EUR15)	2.7	2.7	2.6	2.5	96	93
EUR 15 (% world)	29.2	30.1	30.3	32.5	-	-
Publication index	112	113	110	109		
Citation index	121	128	126	133		
Co-publication index	-	-	-	217		

Note: Index = 100*value of the variable per inhabitant divided by the EUR15 ratio.
The indexes by scientific fields are corrected for co-publications.
Source: First & Second European Report on S&T Indicators

7.7. Trademarks

In sections 7.2 to 7.5 we measured innovative activities by looking at patents deposited in an international context. Yet, patenting decisions are conditioned by commercial considerations about the costs and (expected) benefits of the protection of an innovation offered by the patent, i.e. its adequacy as a strategy against imitation. This is generally regarded as sector and country specific and implies that patenting remains an imperfect and biased indicator of innovation. Geroski (1995), who finds a rather weak relationship between directly measured innovation and patenting in the UK, confirms this. Moreover, though patenting is an aspect of commercial strategy, it reflects more the *intention* of the commercial exploitation of an innovation rather than the *extent* to which this is effectively done. Technological innovation is not identical with commercial innovation and excelling in the first doesn't imply straightforward success in the latter. A technological successful firm might easily fail in its efforts to commercialise its potentially superior goods.

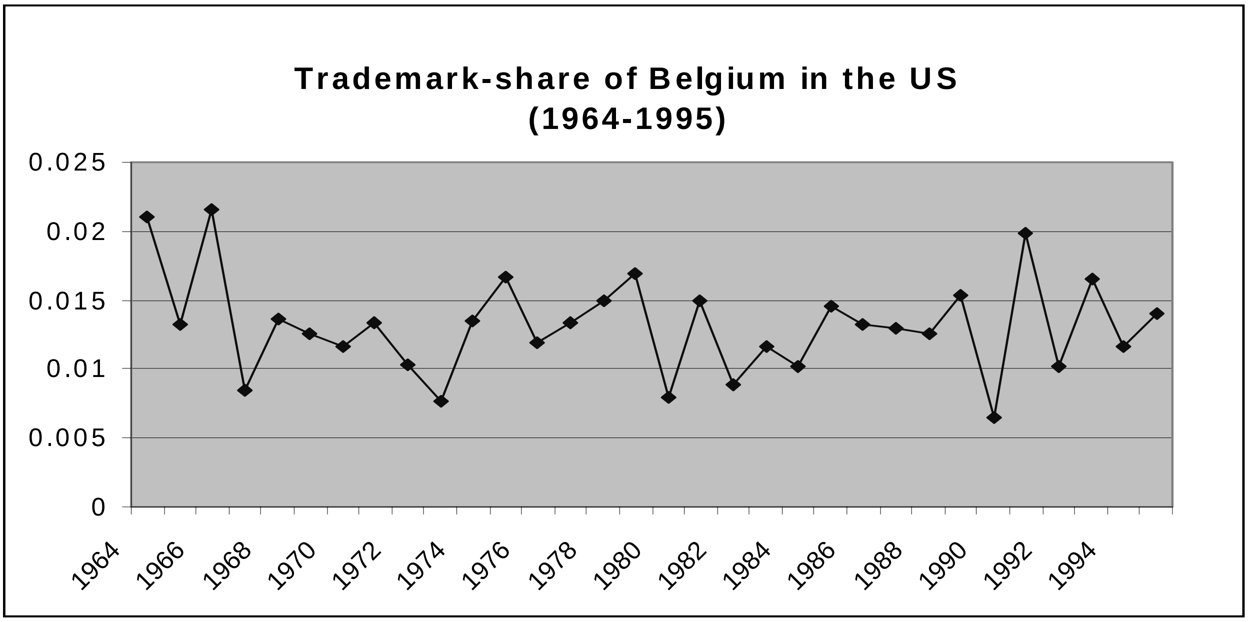
In assessing the importance of innovation for economic competitiveness, we therefore tried to improve the measure of innovation traditionally used, by complementing it with an indicator of commercial innovativeness and the efforts of firms in selling their goods abroad. Though potentially affected with similar sins as the patent measure, we retained the national shares in the foreign trademark applications in the US as a statistical proxy of commercial innovativeness. The rationale for this is that if a firm is prepared to start a relatively lengthy and costly procedure in order to protect a brand-name on the US market, it presumably will also be willing to spend a considerable amount of marketing-efforts to introduce the brand on that market. We assume that the application for trademarks is linked to the final output of innovative activities insofar as these result in new products rather than in quality upgrading of existing types of products. This implies that the combined use of patent and trademark statistics could give an indication of the importance of the expansion of product variety and of quality upgrading.

Simple correlations may illustrate this point. Correlating the patent and trademark shares in the US for the countries considered in the sample (Belgium, but also Germany, France, the Netherlands, Italy, Denmark, Sweden, Finland, Canada and Japan) for each year from 1970 to 1990, we found, as expected, mostly high positive values for contemporaneous correlations and for different lag specifications (we considered a lead of patent applications of three, four and five years). However, a striking feature of the time-series of the correlation coefficients is the observed quasi monotonical decline in the period examined. Whereas values around .9 are typical for the first years of the seventies, the correlation coefficient does not exceed .4 at the end of the sample period. Part of this decrease is apparently explained by the singular position of Japan. Repeating the calculations correcting for this, the decline of the correlation is limited to .3 and remains significant (at a 10 % level) for all years of the sample. We have no testable explanation to offer for this rather unexpected and systematic phenomenon. Insofar as the correlation between patents and trademarks gives some indication of the relative importance of expanding product variety versus quality upgrading in innovation, the result could point to an increasing weight of the latter, since one then might expect these increases in product variety to be less than completely matched by increased patenting which possibly preceded. Another phenomenon which might (tentatively) explain the looser connection between patenting and trademarking is the possible increased importance of process as compared to product innovation.

Trademark-shares may also be regarded as a measure of 'commercial innovation' in the narrow sense, i.e. innovative activities or the parts thereof that do not require technological breakthroughs. The number of trademark applications may indeed be an important indicator of sales and marketing activities that reflect the commercial dynamism of firms.

The link between 'commercial innovation' in the narrow sense and marketing efforts was again further explored by simple correlations. Ideally for this, we would need data on the marketing efforts of firms abroad (i.e. their efforts in promoting and selling goods on foreign markets), but these do not seem to be available. Usual breakdowns of marketing data (which are anyway of rather recent date) neither include the nationality of the spending firms nor the origin of the amounts spent. Assuming a positive relationship between commercial dynamism on the home and foreign markets, we used data on total advertising expenditure on national markets as a proxy, after relating it to GDP (Euromonitor, 1982-1993). Correlating these data with the foreign trademark applications in the US for all countries considered (except the US) gave always positive, though usually not statistically significant annual correlation coefficients for the period 1982-1990. Correlation centers around .4, but can be as low as .3. Neither lagging the trademark shares, nor excluding Japan seem to matter. The choice of the US for the computation of the trademark-shares is the same as for patents: an important market, an expensive and therefore significant application procedure, and the availability of long time-series.

Figure 7.6



Source: WIPO

Figure 7.6 shows that the level of trademarking by Belgian firms as measured by the OECD trademark-share in the total of trademarks deposited in the US remained more or less constant over the period considered. On average the Belgian share in the total of foreign trademarks deposited in the US was approximately 1.45 % in the period from 1991 to 1995. In relative terms with respect to the size of the population however, Belgian firms deposit about only half of the deposits in comparison to their Dutch neighbours, and consistently less than the firms in most of the other OECD countries.

7.8. Technological performance and economic performance

The performance of countries is measured in the first place by very basic economic indicators like the level and evolution of per capita income, the relative inequality of the distribution of income, the unemployment rate, the degree of indebtedness towards the rest of the world, etc. For very open economies like Belgium one of the main determinants of these basic variables is the share in world trade and its evolution. As it happens the Belgian market share in OECD exports of manufactured goods, although still high compared to the size of the country, shows a marked decline since the beginning of the seventies: from about 6.5 % in the early seventies to 5.5 % in the early nineties. A number of studies have been carried out in order to explain this phenomenon.

Five potential candidate-determinants of the evolution of the export share can be identified:

1) relative price or cost according to whether firms operate as price-makers or price-takers ; relative unit labour cost can be used as a proxy for the price variable (in the first case), or as an indicator of gross profit margins (in the second) ;
2) relative quality, indirectly measured by such S&T variables as the proportion of R&D outlays to output or as the share of patent applications in the US ;
3) relative marketing efforts, indirectly measured by the share of trademark applications in the US ;
4) relative ‘capacity to deliver’, measured by relative capacity use in industry ;
5) ‘reputation’, as measured indirectly by the lagged value of the market share.

Meeusen and Rayp (1995, 1998) report on the results of the estimation of an error-correction model and a hysteresis model of OECD export-shares of the manufacturing sector for different OECD countries, and conclude that for most countries studied labour cost per unit of output only plays a relatively minor role. For Belgium the labour cost variable does not even appear in both specifications which are finally estimated. For all countries, but especially for Belgium, the technological proxy variables (patents and trademarks) are shown to be the most decisive ones: the patent share and/or the trademark share variables turned out to be statistically significant. For Belgium, the UK, the USA and Japan even both variables were significant. They also show that there is a remarkable consistency with respect to the lag structure of the patent-share and trademark-share variables. The patent-lag with respect to export-shares is nearly always 5 years for the countries where this variable was significant. The same consistency holds for the trademark-lag: the lag is nearly always 2 and/or 3 years. The details of the results for the estimation of the hysteresis of OECD export-shares are in appendix A.7.8.

7.9. Conclusion

Some important conclusions can be made from the analysis of patent and trademark applications of Belgian firms, and from the number of publications by Belgian scientists as - 'first level' - output indicators of its national innovation system. They can be summarised as follows:

1. The Belgian propensity to patent and patent productivity are largely inferior to the European average. The specific industrial base and the high degree of dependence of the Belgian NIS to foreign companies could to a large extent explain this weak performance. Indeed, a more thorough analysis of the patent applications has shown that Belgian R&D centres which are part of domestic branches of foreign multinationals operate in the context of a larger research policy of these companies, which results in the 'repatriation' of the 'Belgian fruits' of their R&D activities.

2. The Belgian technological revealed advantages are mainly concentrated in technological classes linked to medium- and low-tech manufacturing industries (except for instruments). About fifty percent of patents are concentrated in about 10 technological classes out of 118.

3. The Belgian R&D system is to a large extent oriented towards product innovation. About two thirds of the patents are mainly associated with new products, a ratio which is compatible with the observations from CIS data.

4. At the regional level, two districts concentrate a large part of Belgian patent applications: Antwerpen and Brussels. Among Walloon districts, Charleroi and Liège, the main industrial districts, as well as the Walloon part of the Brabant province appear the most innovative ones in patent terms. Yet, there is a significant gap of innovativeness between these three Walloon districts on the one hand, and the two main Belgian innovative areas on the other. This gap should not however be overestimated since the data for Antwerpen are affected by the very high propensity to patent of the Agfa establishment in that town.

5. With regard to the scientific position of Belgium, the indicators reveal a number of publications and co-publications higher than the European average and an increase in the internationalisation of the teams. The main fields of specialisation are clinical medicine, biomedical research and physics. Furthermore, despite its small size, Belgium is characterised by a broad distribution of its efforts across fields of science

6. Trademark-shares may be regarded as a measure of 'commercial innovation' in the narrow sense and reflect the commercial dynamism of firms. In relative terms with respect to the size of the population, Belgian firms deposit about only half of the deposits in comparison to their Dutch neighbours and consistently less than the other OECD countries.

On the 'second level' of results, i.e. with respect to the relation between technological pertformance and economic performance, econometric evidence showed that the economic performance of Belgium as expressed in the (adverse) evolution of the OECD trade-share of the manufacturing sector can mainly be explained by technological determinants.

8. Conclusions

The text of this pilot study, although by its very nature focussing on the systemic as opposed to the 'linear' aspects of the relations between science, technology, R&D, innovation and economic performance, has a linear structure. We studied the institutional setting first, continued with the 'inputs' in the technological system, and concluded with an examination of the technological 'outputs' that can be identified. We shall structure the text of this concluding chapter accordingly, and look successively at the historical background and institutional setting (section 8. 1), the inputs in the NIS (8.2), co-operation and diffusion aspects (8.3), and the outputs of the NIS (8.4).

8.1. Historical background and institutional setting

Belgium is a country with a highly educated and industrious population and is located in the economic centre of Europe. These are important advantages. In order to understand properly the specificity of its NIS one has however also to take account of three major characteristics of this country which cannot from all points of view be considered as beneficial: its *early* industrial development following the lead of Great Britain, its geographical location on horseback of the Latin and Germanic culture and its small size.
The first factor explains why the technological orientation of the national innovation system has until relatively recently been mainly in the direction of traditional industrial activities: metallurgy, chemicals, textiles. Belgium has only tried to enter R&D activities in the new high tech fields when other countries, which had started their industrial revolution with some delay, had already gained, through the 'dialectics of progress', a perhaps decisive headstart advantage. The same industrial mismatch explains partly why the government has had great difficulties in making corrections, and modernising the NIS. When at the end of the seventies many West European countries, as a result of a number of concurring adverse circumstances, were coping with the consequences of an excessive government debt, Belgium was more affected than neighbouring countries because, among other things, it was in the midst of a process of 'restructuring' the traditional industries. This 'restructuring' unfortunately was not very effective since it mainly took the form of continuously subsidising failing enterprises without much future perspectives. The snowball effects on the government budget which ensued later on prevented that the necessary funds could be raised to re-orientate the technological bias of the NIS. The particular circumstance that the industrial crisis hit the South of the country harder than the North added only to the gravity of the situation. This brings us to the second factor.

It is fair to say that on a continent like Europe, where quarrels and wars between different nationalities have dominated history for as long as one cares to remember, and continue to do so until this day, the cultural and linguistic differences between the Dutch-speaking part of the population in the North of Belgium and the French-speaking part in the South have remained manageable. But at the same time the management of these differences proved to be far from easy and has deflected the attention of politicians for too long a time, at the expense of other urgent problems like the implementation of an adequate S&T policy.

In 1989, and again in 1993, in an effort to solve the problems between the two linguistic 'communities' once and for all, the country was reshaped into a federation in which the authority on a large set of policy matters was given to the regions (Flanders, Wallonia and Brussels) and the 'communities' (Dutch-speaking, French-speaking and German-speaking). S&T policy was one of these matters, the authority on education having already been regionalised at an earlier stage. It is probably more than a coincidence that around the same time also in other countries regions gained more authority in different matters.
The implications of this regionalisation for the adequacy of the NIS have been twofold.
On the one hand, the implicit decentralisation has undeniably had an activating effect. Freed from the burden of the debt service, which continues to be carried by the federal government, the regional governments are now in a position to set out and implement clear targets in the S&T field and to make available the necessary budgetary means. It should be said that in relative terms the Flemish government, also as a result of less strict budgetary conditions, has put a higher priority on S&T policy objectives and formulated these objectives in a clearer way (e.g. the creation of a number of interuniversity research labs in high tech disciplines, the establishment of new, largely autonomous, bridging institutions like IWT etc.). There are however clear signs that the Walloon regional government is now moving in the same direction, and a catching-up process is underway.
On the other hand, activating as the regionalisation of R&D policy may have been, it might be argued that it runs in the opposite direction of what is observed on a larger European scale where centralisation, knitting together of R&D initiatives, merging of national into supranational financial funds, scale enhancement etc. are on the agenda. In other words, *if* (but of course *only if*) a small country size would constitute a handicap on the international technological scene, then regionalisation only makes this handicap greater. This brings us to the third factor.

The question of the economic advantages and disadvantages of small countries on world markets is an intricate one. But if we confine ourselves to technological aspects, it can scarcely be denied that the disadvantages dominate the advantages. Small countries acting on their own cannot reach minimum scale in terms of the financial means necessary to initiate important research projects in many high tech disciplines, in terms of the volume of human capital that one needs, in terms of the size of the markets that one wants to have access to for the final output of the R&D project, etc.
Small countries therefore have no other choice than to specialise in a few technological disciplines and to accept the inherent risk that goes with specialisation, or to open the borders to allow foreign multinational corporations to dominate the domestic technological scene through inward FDI and takeovers of domestic firms. Both scenarios were followed in Belgium. Especially the second strategy seems to a certain extent to have mortgaged the development of the NIS in the direction of high tech disciplines, since there is some evidence that the R&D in many Belgian labs is confined to narrow niches and/or its results are largely 'repatriated' to foreign headquarters of multinational corporations.
A 'modern' alternative for minimum efficient scale however, in principle at least, is technological networking. When in the eighties the European Commission started its Framework Programmes, small countries, among which Belgium, indeed engaged proportionally more in international R&D co-operation than the larger ones. Time will tell if networking in actual

practice constitutes a substitute for minimum scale, and more in particular if entering pre-competitive R&D networks by firms of small countries will ultimately be translated in forms of market-oriented co-operation in which partners from small countries play a significant role. The heavy accent on networking that one finds in the Belgian NIS explains the importance of bridging institutions, in terms of their numbers, their relatively early development, and in terms of the mediating role in the formation of cross-border networks that they play.

8.2. Inputs in the NIS

We first look at efforts in the field of R&D and the creation of human capital at the global, i.e. macro-economic, and industrial level, and after that discuss R&D intensities observed at firm level.
At this global and industrial level the following conclusions could be made:

- The relative R&D efforts in Belgium are relatively low compared to most other OECD countries. Especially the share of government R&D in total R&D outlays has been insufficiently high in the recent past. A catching-up process is underway in some of the regions. The business sector is by far the largest financing source and the largest R&D active sector in the Belgian economy. The services industry relies much more than the manufacturing industry on outside funding of intra-muros expenditures and more precisely, on funds from abroad and from the government. The services industry has also a higher propensity to finance extra-muros R&D.

- High tech and medium-high tech industries account for only 8% of the total value added created by the whole business sector (including services), but use 71% of total business R&D resources. The qualification level of total R&D personnel is much higher in the services industry than in the manufacturing industry. However, the manufacturing industry relies ten times more on R&D personnel than the services industry.

- There is a marked trend towards the regionalisation of S&T policies and a reduction of the role of the federal authority. Furthermore, the functional distribution of public budget allocations varies substantially across regional authorities, which implies a different regional behaviour regarding the organisation of their respective innovation systems.

- Despite a favourable positioning with regard to the total number of graduates, Belgium is suffering from an insufficient number of graduates in natural and applied sciences. This deficit can be considered as a mismatch of the higher education system. The important role played by Belgians in international human capital mobility witnesses the high degree of openness of Belgium comparative to other European countries.

At firm level the following conclusions could be drawn:

- On the basis of an OSTC-sample of R&D-active firms we found that three-quarters of the intramural R&D budget is spent on the ‘development’ of new products and processes, and only one quarter on ‘research’ sensu stricto. About two-thirds of the total R&D efforts is allocated towards the innovation of new products, and R&D activity is found to be rather labour intensive. With regard to 'firm size' we found that *in the set of R&D-active firms* the smallest and largest firms are relatively more research-oriented, the latter also being more product-oriented. For the 'research vs. development' and the 'product vs. process' distinctions we found relatively big interindustry differences. Both the *chemicals* and the *iron & steel ferrous metals* industry were, relatively spoken, much more research-oriented, the latter being also predominantly process-oriented. Rather surprisingly, we notice that the high tech industries spend the smallest percentage of their total intramural R&D budget on research as opposed to development. They are also strikingly product-oriented.

- In global terms, and again within the set of R&D-active firms, the quantitative approach gives evidence of a '*less-than-proportional'* relationship between R&D efforts (and therefore, indirectly, innovativeness) and firm size, which stresses the importance of R&D-active SMEs within the National Innovation System.

8.3. Diffusion and co-operation

International trade, inward and outward FDI flows, and technology payments are three important channels which may foster the international diffusion of technology. The most salient observations can be summarised as follows:

- The analysis of all three indicators has shown that Belgium relies substantially on research activities from abroad.

- Technology payments, i.e. the extent to which Belgium takes advantage of foreign technology, have increased during the eighties and stayed quite stable in the early nineties. During the whole period, the US was the main destination of technology payments. Next in order of importance come four neighbouring countries: the UK, the Netherlands, Germany and France, which received about half of the technology payments to foreign countries. Technology receipts and inward and outward FDI have also substantially risen in the late eighties, and their geographical distribution is comparable to those of technology payments. From the early eighties to the early nineties, the most noticeable change in their geographical distribution was the strong reduction of the US share to the advantage of neighbouring countries.

- The geographical distribution of the various channels of technology diffusion shows that technology transfers are facilitated by *(i)* geographical proximity, *(ii)* technological endowments, and *(iii)* the size of the countries where the technology originates from.

- The analysis of its trade specialisation pattern shows that Belgium, statically speaking, is specialised in declining commodity classes. Yet, in a dynamical sense, companies are generally moving into classes with growing importance. With regard, specifically, to high-level technology commodities the position of Belgian firms is however declining. This is caused, simultaneously, by a loss of shares, a 'wrong' specialisation pattern and a 'wrong' adaptation pattern.

Co-operation in the field of R&D has received particular attention because of its diffusion implications. The following conclusions emerged:

- Among the main actors involved in R&D collaborations with Belgian firms, Belgian universities, foreign firms and customers account for more than 45% of the whole of collaborations. These collaborations predominate in the chemical and electrical industries as well as in the technology services supplied to firms. The R&D collaborative pattern is rather different across Belgian regions: Flemish firms are more directed towards other foreign and domestic firms and suppliers, while in Wallonia, firms do more co-operate with institutions located upstream the innovation process, i.e. universities and public RTOs.

- The network of R&D collaboration involving Belgian actors (firms, research labs and institutions of higher education) showed to be highly connected. Two interlinked subsets of domestic actors with the highest (weighted) degree centrality could be distinguished: on the one hand firms active in the IT field, and on the other hand universities and interuniversity research laboratories also active in the IT technological discipline. Another important subset consisted of foreign multinationals active in the field of IT and telecommunication. This feature of the network was confirmed by the analysis of so-called clique-configurations.

- Simple crosstabulations revealed that in the set of R&D-active firms, those that participate in international R&D projects or agreements were not significantly more innovative than those that did not participate in any such project or agreement.

- The study of the coincidence of project-lines indicated that partnerships between firms in the pre-competitive sphere only to a limited extent continued in more near-market projects.

- The matrix of intra- and interregional and international knowledge flows, as implicit in R&D partnerships, reveals that scale effects are as relevant at the regional as at the international level: the largest Belgian region, Flanders, is more ‘self-reliant’ (in this particular context) than Brussels and Wallonia.

- A hierarchical cluster analysis with data on prime contractors for 10 major RTD subject index codes for a group of 11 countries yielded 3 important clusters. A first cluster consists of the UK, France, The Netherlands and Belgium with especially Belgium and the UK having a very similar distribution over the subject codes. The countries of the first cluster, relative to other countries, highly participate in *agriculture, biotechnology and medicine.* A second cluster is composed of Germany, Italy and Spain with relative strength in *materials technology, aerospace technology and electronics.* The third cluster is composed of Greece, Denmark, Portugal and Ireland with relative strength in *environmental protection* and *renewable sources of energy.*

- The closer to the market the more outspoken the preference of Belgian companies for partners from certain countries.

8.4. Outputs of the NIS

Some important conclusions can be made from the analysis of patent and trademark applications of Belgian firms, and from the number of publications by Belgian scientists as - 'first level' - output indicators of its national innovation system. They can be summarised as follows:

- The Belgian propensity to patent and patent productivity are largely inferior to the European average. The specific industrial base and the high degree of dependence of the Belgian NIS on foreign companies could to a large extent explain this weak performance. Indeed, a more thorough analysis of the patent applications has shown that Belgian R&D centres which are part of domestic branches of foreign multinationals operate in the context of a larger research policy of these companies, which often results in the 'repatriation' of the 'Belgian fruits' of their R&D activities.

- The Belgian technological revealed advantages are mainly concentrated in technological classes linked to medium- and low-tech manufacturing industries (except for instruments). About fifty percent of patents are concentrated in about 10 technological classes out of 118.

- The Belgian R&D system is to a large extent oriented towards product innovation. About two thirds of the patents are mainly associated with new products, a ratio which is compatible with the observations from CIS data.

- At the regional level, two districts concentrate a large part of Belgian patent applications: Antwerpen and Brussels. Among Walloon districts, Charleroi and Liège, the main industrial districts, as well as the Walloon part of the Brabant province appear the most innovative ones in patent terms. Yet, there is a significant gap of innovativeness between these three Walloon districts on the one hand, and the two main Belgian innovative areas on the other. The importance of this gap should not however be exaggerated since the data for Antwerpen are influenced by the very high propensity to patent of the Agfa establishment in that town.

- With regard to the scientific position of Belgium, the indicators reveal a number of publications and co-publications higher than the European average and an increase in the internationalisation of the teams. The main fields of specialisation are clinical medicine, biomedical research and physics. Furthermore, despite its small size, Belgium is characterised by a broad distribution of its efforts across fields of science.

- Trademark-shares may be regarded as a measure of 'commercial innovation' in the narrow sense and reflect the commercial dynamism of firms. In relative terms with respect to the size of the population, Belgian firms deposit about only half of the deposits in comparison to their Dutch neighbours and consistently less than the other OECD countries.

On the 'second level' of results, i.e. with respect to the relation between technological and economic performance, econometric evidence showed that the economic performance of Belgium as expressed in the (adverse) evolution of the OECD trade-share of the manufacturing sector can mainly be explained by technological determinants.

8.5. Policy implications

The efficiency of the Belgian NIS could be improved by targeted actions in several complementary directions. The proposals fall in three main categories. First, maintaining and expanding the knowledge base as the main support to economic growth. Second, ensuring the adequacy of S&T policy instruments with socioeconomic choices and other policies implemented to promote these choices. Third, thinking about efficient bridges between the absorptive capacity, the transfer capacity and the creative capacity in order to improve the socioeconomic returns of the knowledge base.

If we turn to the first type of actions which concern the maintain and the expansion of the knowledge base, the following points should be stressed:

- In the medium term, the public gap in R&D expenditures might lead to a weakening of the Belgian technological base. Considerable efforts should continue to be devoted to adjust the R&D intensity to the European average. As technology is at the source of absolute advantages, it is of first importance to anticipate any process of deterioration of the technological base. A high level of university research (which is itself conducive to high-level teaching) and an efficient public technology infrastructure are prerequisites to business R&D in efficient conditions. Any disturbance of the equilibrium could produce cumulated negative effects which will be difficult to correct afterwards (hysteresis effects).

- The low participation of Belgian enterprises to international strategic alliances, as opposed to pre-competitive joint R&D projects, contrasts with the dynamism of Belgian organisations in European R&D networks. In other words, there seems to be an insufficient valorisation of the S&T potential in economic terms. Public authorities should design programmes aimed at deepening and completing the acquired knowledge with a special stress on downstream capabilities such as manufacturing and commercialisation capabilities.

- The difference of patenting activities as shown by the distinction between applicants and inventors suggests that there might be an important leak-out of the fruits of innovative outcomes, which calls for specific public actions in order to better internalise them. The inability of the government to reap the economic returns of domestic R&D leads to an indigenous brain drain. In a world of increased international interdependence, both regional and federal governments should think about the best way of stimulating national spillovers.

- As shown by the measures of revealed technological advantages, the country remains strongly dependent on low and medium tech industries. Public efforts should therefore be directed towards targeted high growth market niches. What is however at least as important is the ability of mature industries to adopt and to assimilate the products of R&D-intensive industries. Once more, investments in public research infrastructure and human capital are likely to be more profitable than subsidies to industrial R&D.

With regard to the second type of actions which deal with the formulation and implementation of S&T policies:

- There are certainly some important grounds for a strengthening of the complementarity between actions implemented by the Federal State and the 'federated' entities, as well as for a better co-operation among 'federated' entities, in order to achieve the necessary critical mass in some research fields and to avoid duplication of research projects and the perverse effects of unnecessary technological competition.

- It would be useful to improve the fine-tuning of the S&T policy mix (e.g. direct subsidies vs. favourable fiscal regimes, diffusion and adoption policies besides supply policies) in order to boost the leverage effect of public intervention. The stress should at least as much be put on technological assimilation and adaptation than on technological advance.

- There is also a need to develop efficient tools for assessing the effectiveness of S&T instruments as well as the results of S&T policies. Public interventions have to be adapted to the needs of research institutions. It is vital to apprehend correctly what disables the innovation propensity and the valorisation process of innovativeness and to concentrate efforts on the resolving of bottlenecks.

Last but not least, the observed mismatches between the components of the distribution power attract attention on the need to improve the links between the creative, transfer- and absorptive capacities in the following fields:

- Despite the fact that Belgium benefits from a favourable positioning for some scientific and technological indicators (patents as measured by inventors, pre-competitive research and publications in some scientific fields), it appears to face high difficulties to bridge the gap between its technological performance and the economic valorisation of results (patents as measured by applicants, strategic alliances and publications in applied sciences). Existing and newly to be created bridging institutions operating as transfer technology and diffusion centres and interweaving institutions should strive to correct these institutional failures.

- The significant deficit of Belgium regarding the number of graduates in natural and applied sciences and the bad scores revealed by OECD studies on interest in science studies in Belgian schools is a clear signal that there is something wrong in the absorptive process of knowledge. Appropriate measures should be implemented in order to improve both accessibility and receptivity to knowledge. More fundamentally, one should recognise the premonitory signals that an adverse process of lagging behind in the technological field is in gestation.

In this study the efforts have been concentrated on the more prominent characteristics of the Belgian NIS. The hope is that the analytical background given here can serve to deepen some specific points in future studies. Indeed, some important questions remain unanswered which merit further investigations. Among them, we can point to the following ones.

- To what extent is the institutional setting that has been described adapted to face the challenge of the knowledge-based economy ? Is the policy mix of instruments well adapted to the new chain-linked model of innovation or is it still too much based on the linear system of innovation ?

- Why does the country benefits from a good scientific base but at the same time suffers from disadvantages when we confront its technological base and economic performance in the manufacturing industry ? The relative decrease in the positioning of Belgium when we go downstream from the channels of its participation to pre-competitive research networks to near-market research and strategic alliances indicates that there are bottlenecks that are worth identifying and removing.

- In the present study, the stress has been essentially put on the components of both the creative and transfer capacities of the knowledge base. Yet, some of the mismatches observed have their roots in the deficiencies of the absorptive capacity. Among other things, there is a need to improve our understanding of institutions, to extend the analysis of R&D data in the direction of data on innovation in the strict sense, and to identify the most appropriate means for improving the absorptive capacity.

- An important dimension insufficiently covered in the analysis is human resources development. Education and training are main channels of knowledge transmission and are main components of the NIS, not only as an input to the R&D process, but also as a means to convert technological change into economic growth and job creation. In the framework of the present study the education and training system has been considered as exogenous but in the future some efforts should certainly be devoted to examine its interconnections with the NIS.

At the eve of the 21st century, the regional governance of the Belgian NIS is radically changing the institutional characteristics of the country. But even if regions and 'communities' seem to be evolving in different directions, they remain largely conditioned by the Belgian historical background. There are definitely a number of tasks that 'federated' entities are able to accomplish more efficiently than the federal state, just as there are other tasks that the federal state can satisfy in a more appropriate way as these tasks transcend regional spaces. Science and technology, and more generally knowledge, have no frontiers.

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Appendices

FIGURE A.2.1 : BELGIAN INSTITUTIONAL PROFILE :
Federal Authorities

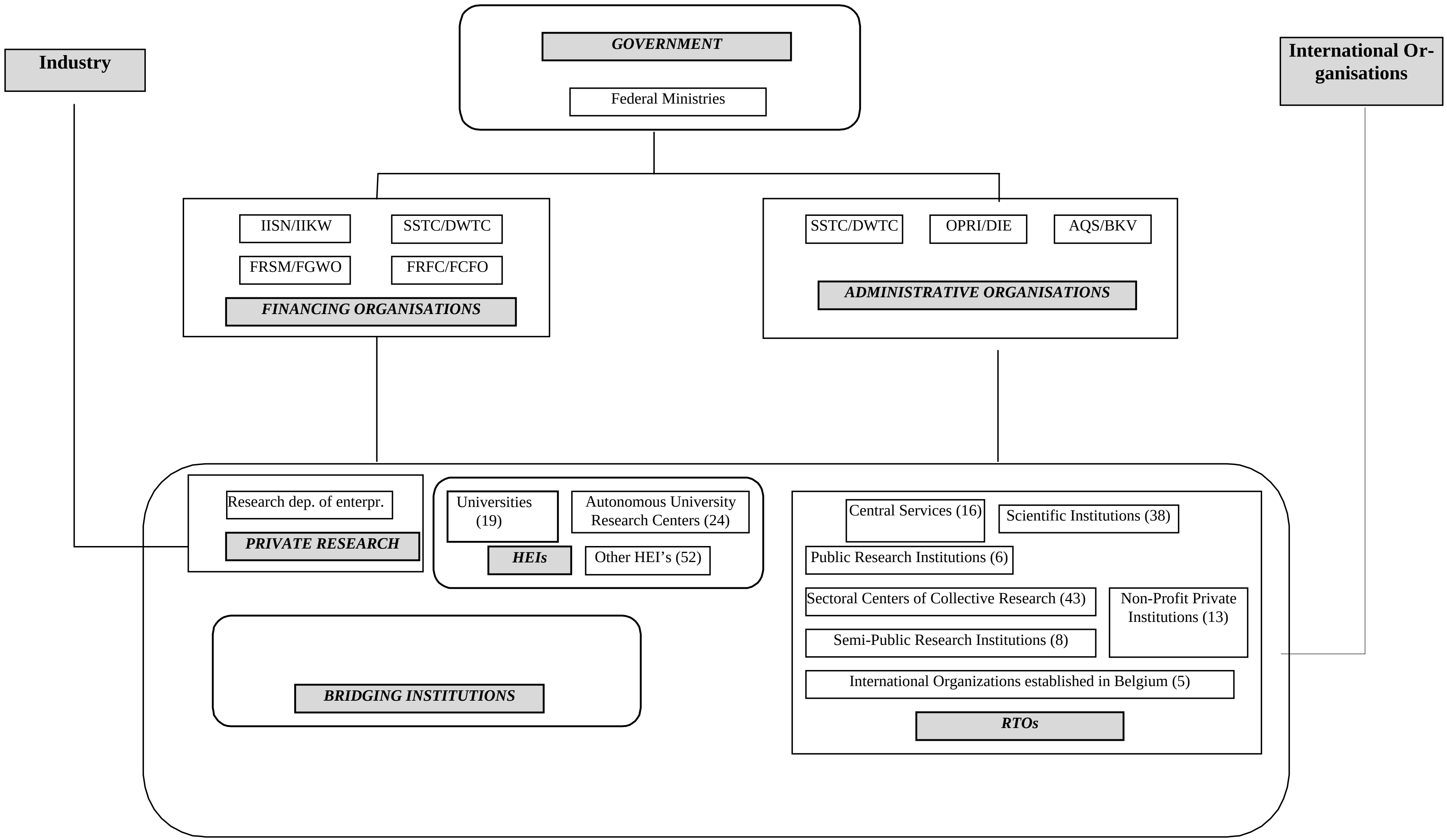


FIGURE A.2.2 : BELGIAN INSTITUTIONAL PROFILE
Region of Brussels-Capital

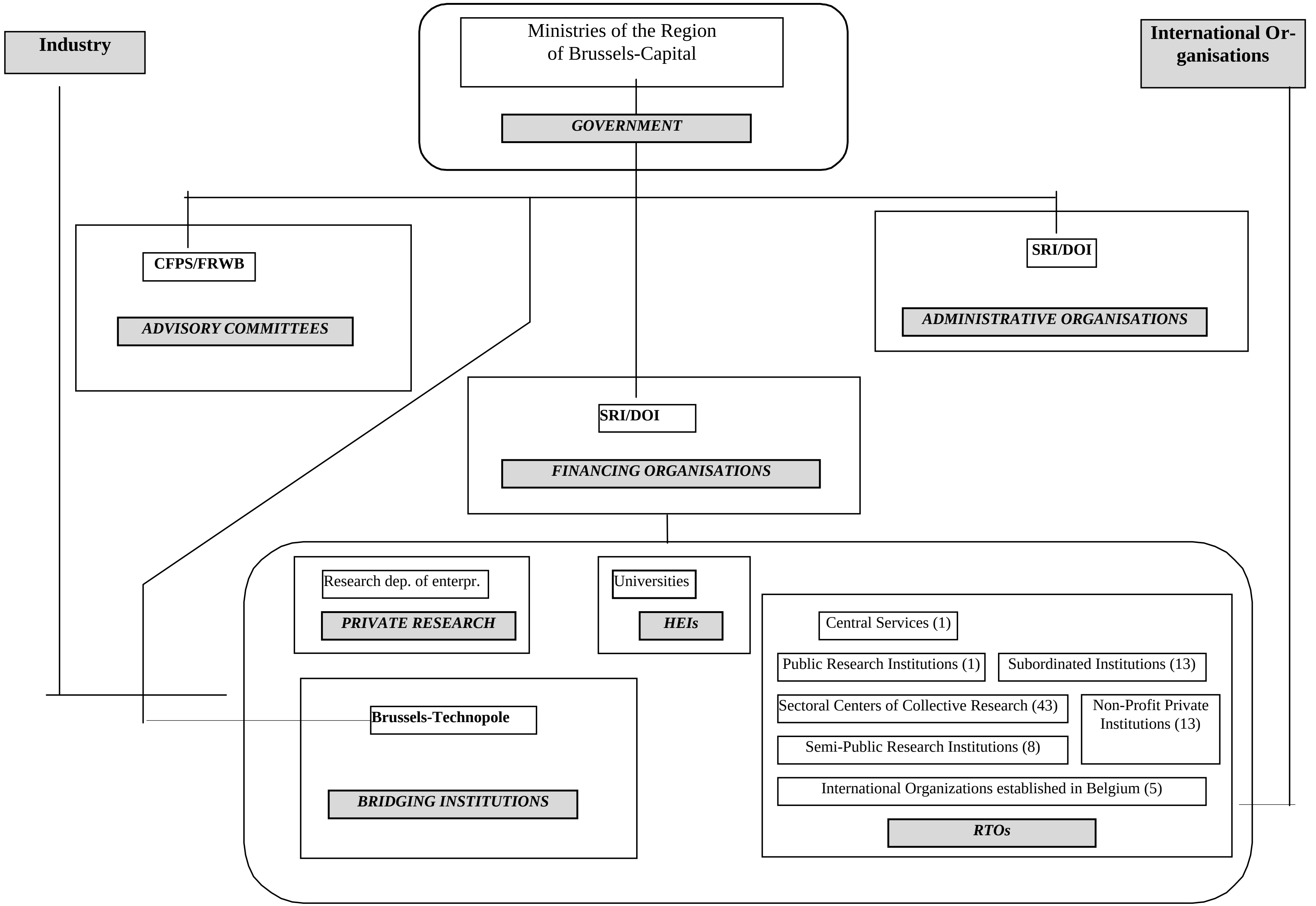


FIGURE A.2.3 : BELGIAN INSTITUTIONAL PROFILE
Flemish Community

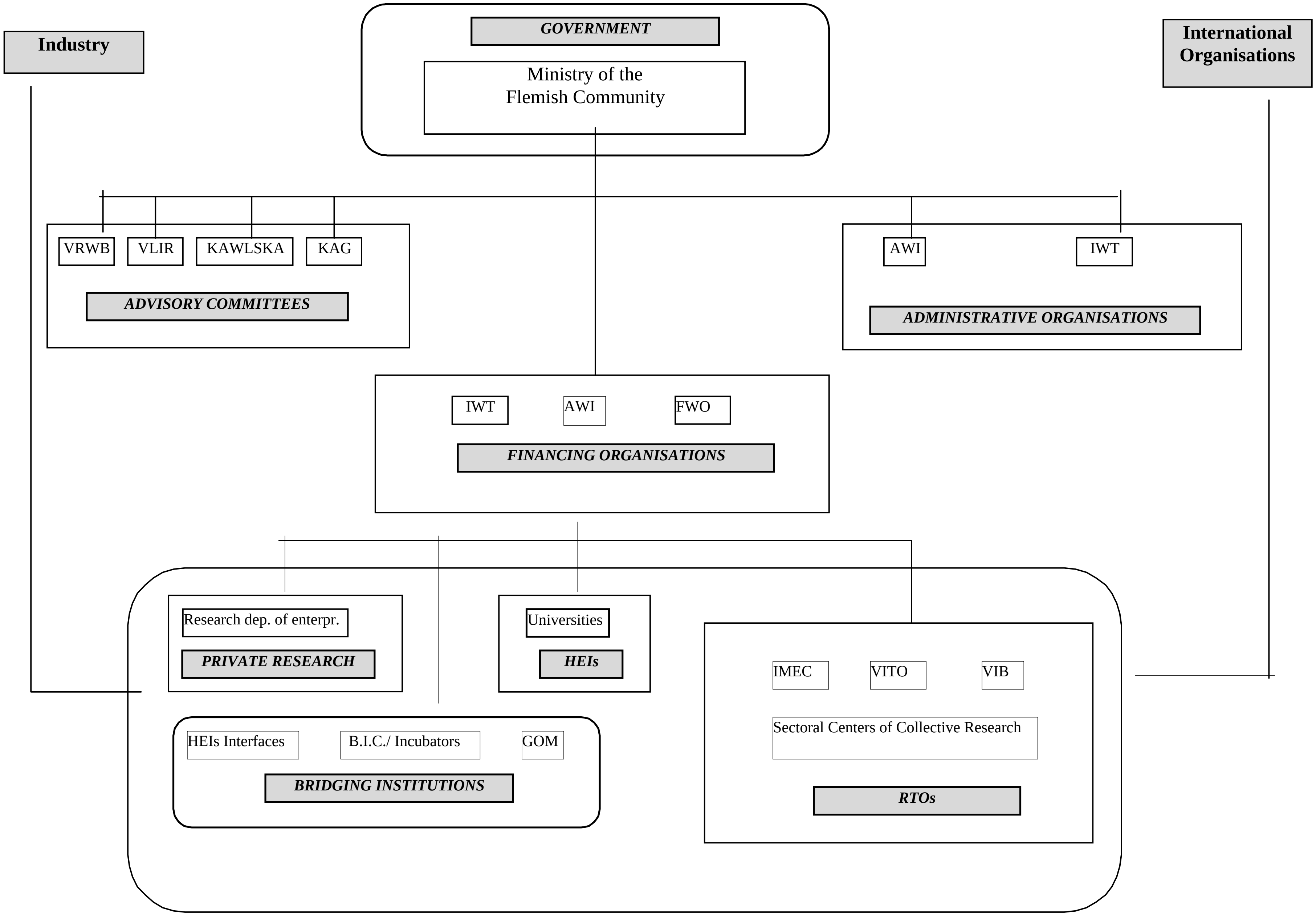
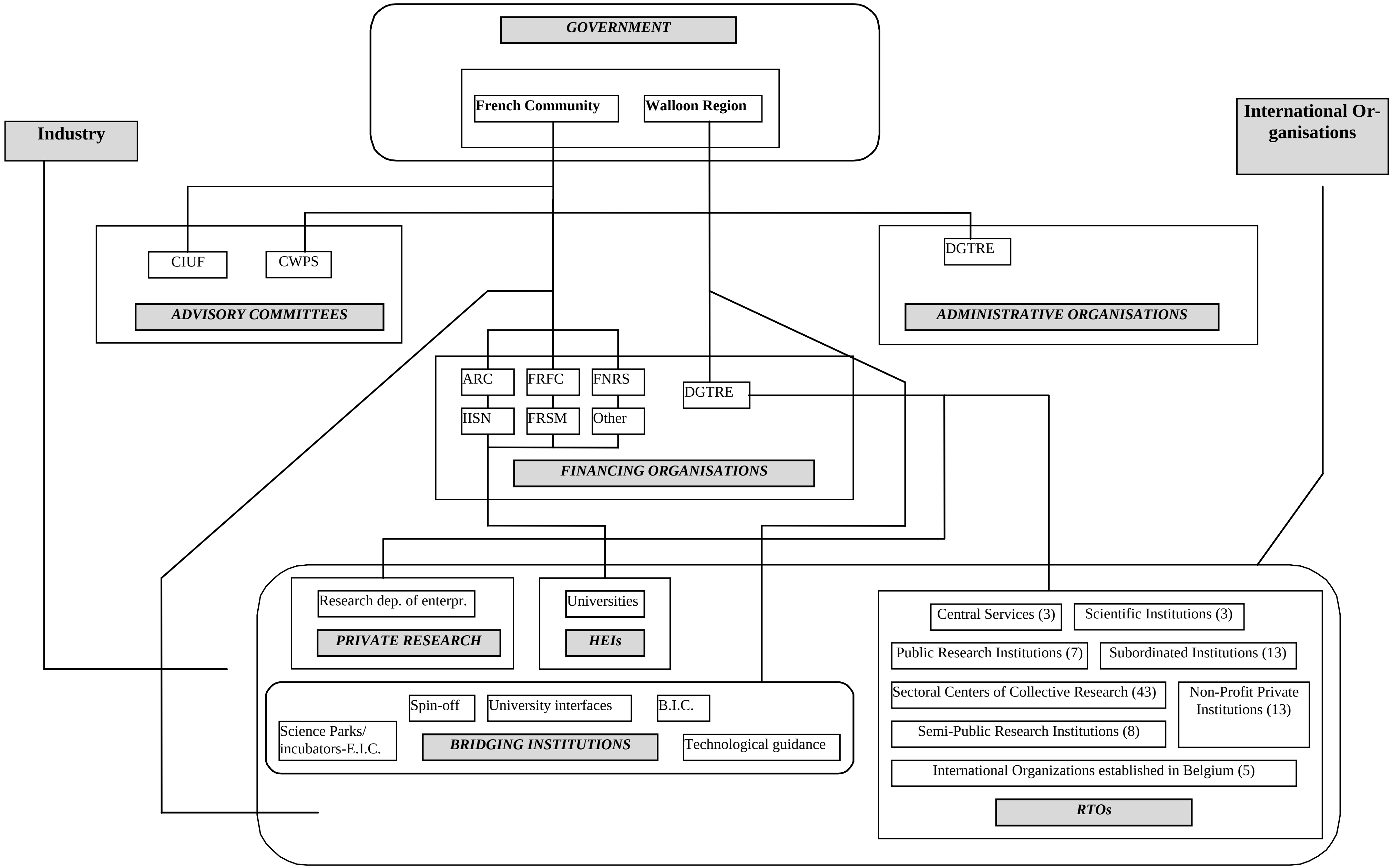


FIGURE A.2.4 : BELGIAN INSTITUTIONAL PROFILE
Walloon Region and French Community



Appendix 2.1 : Belgian Universities, autonomous university research centres and Sectoral Centres of Collective Research

Belgian universities		
Ecole Royale Militaire / Koninklijke Militaire School	ERM/KMS	F.S.
Faculté des Sciences Agronomiques à Gembloux	FSAGX	W
Faculté Polytechnique de Mons	FPMS	W
Faculté Universitaire Catholique à Mons	FUCAM	W
Faculté Universitaire de Théologie Protestante / Universitaire Faculteit voor Protestantse Godgeleerdheid	FTP/FPG	F.S.
Facultés Universitaires Notre-Dame de la Paix à Namur	FUNDP	W
Facultés Universitaires St.-Louis à Bruxelles	FUSL	B
Katholieke Universiteit Brussel	KUB	B
Katholieke Universiteit Leuven	KUL	F
Limburgs Universitair Centrum	LUC	F
Universitair Centrum te Antwerpen	RUCA	F
Universitaire Faculteiten St.-Ignatius te Antwerpen	UFSIA	F
Universitaire Instelling Antwerpen	UIA	F
Université Catholique de Louvain	UCL	W
Université de Liège	ULG	W
Université de Mons - Hainaut	UMH	W
Université Libre de bruxelles	ULB	B
Universiteit Gent	UG	F
Vrije Universiteit Brussel	VUB	B
Autonomous university research centres		
Alitech vzw		F
Association our la Recherche Avancée en Microélectronique et Integration de Systèmes	ARAMIS	W
Babbage Institute for Knowledge and Information Technology		F
Born-Bunge Stichting v.z.w.		F
Centre d'Etudes Wallon de l'Assemblage et du Contrôle des Matériaux cewac		W
Centre International de Recherches et d'Information sur l'Economie Publique, Sociale et Coopérative	CIRIEC	W
Centre Interuniversitaire pour les Etudes de la Consommation Privée		W
Centre Universitaire de Charleroi		W
Centrum voor Andragogisch Onderzoek		B
Centrum voor Ontwikkelingspsychologie		F
Dr. L. Willems Instituut vzw		F
Fondation Universitaire Luxembourgeoise	FUL	W
Fruitteeltcentrum		F
Hoger Instituut voor de Arbeid		F
Institut de Science Politique		B
Institut International de Chimie-physique - Solvay		B
Institut National Interuniversitaire des Silicates et des Matériaux	INISMA	W
Institut Universitaire pour l'Etude du Judaisme - Martin Buber		B
Instituut voor Biotechnologie vzw		F
International Institute of Cellular and Molecular Pathology - aibs	ICP	B
Interuniversitair Centrum voor Micro-electronica	IMEC	F
Ontwikkelings- en Oriëntatiecentrum		F
Politologisch Instituut		F
Prins Leopold Instituut voor Tropische Geneeskunde te Antwerpen	ITG	F

Source: OSTC, 1997

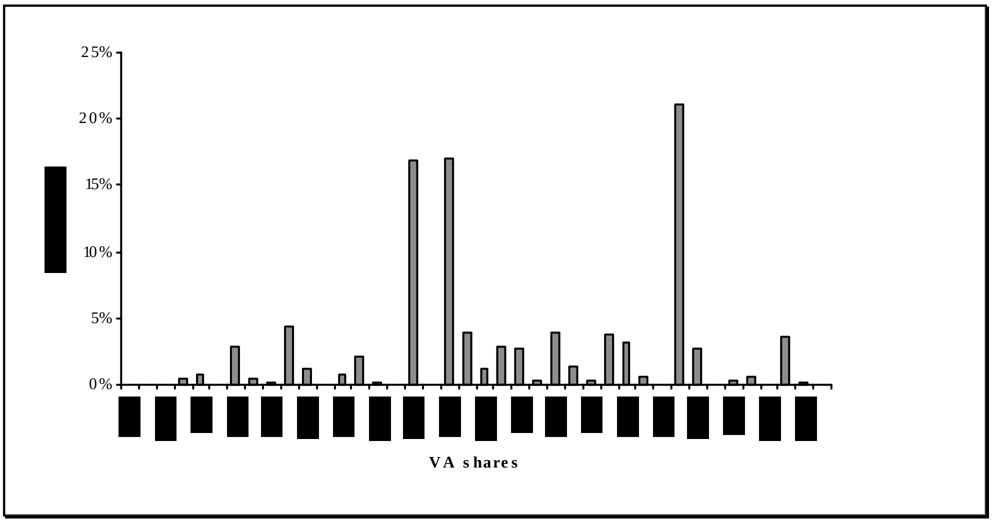
Note: F.S. = Federal State, B = Brussels-Capital Region, F = Flemish Community, W = Walloon Region / French-speaking Community

Appendix 2.1 : Belgian Universities, autonomous university research centres and Sectoral Centres of Collective Research (con't)

Sectoral Centres of Collective Research		
Association royale des gaziers belges / koninklijke vereniging van belgische gasvaklieden	ARGB / KVBG	F.S.
Bedrijfsvoorlichtingsdienst voor de tuinbouw in de provincie antwerpen		F
Belgisch centrum voor technologisch onderzoek van leidingen en toebehoren	BECETEL	F.S.
Centre belge d'etude de la corrosion / belgisch studiecentrum voor corrosie	CEBELCOR / CEBELCOR	B
Centre belge d'etude et de documentation de l'eau	CEBEDEAU	W
Centre d'essais 'profruit'		W
Centre d'essais horticoles du hainaut		W
Centre de recherche de l'institut belge de la soudure / onderzoekcentrum van het belgisch instituut voor lastechniek	IBS / BIL	F.S.
Centre de recherche et de controle lainier et chimique	CELAC	W
Centre de recherche scientifique et technique de l'industrie des fabrications metalliques / wetenschappelijk en technisch centrum van de metaalverwerkende nijverheid	CRIF / WTCM	B
Centre de recherche scientifique et technique de l'industrie diamantaire / wetenschappelijk en technisch onderzoekscentrum voor diamant	CRSTID / WTOCD	F.S.
Centre de recherches de l'industrie belge de la ceramique / centrum voor wetenschappelijk onderzoek der belgische keramische nijverheid	CRIBC / CWOBKN	W
Centre de recherches metallurgiques / centrum voor research in de metallurgie	CRM / CRM	W
Centre de recherches routieres / opzoekingscentrum voor de wegenbouw	CRR / OCW	B
Centre de recherches, d'essais et de controles scientifiques et techniques pour l'industrie textile	CRECIT	W
Centre de selection bovine		W
Centre national de recherches scientifiques et techniques pour l'industrie cimentiere / nationaal centrum voor wetenschappelijk en technisch onderzoek der cementnijverheid	CRIC / OCCN	B
Centre scientifique et technique de l'industrie textile belge / wetenschappelijk en technisch centrum van de belgische textielnijverheid	CENTEXBEL / CENTEXBEL	B
Centre scientifique et technique de la construction / wetenschappelijk en technisch centrum voor het bouwbedrijf	CSTC / WTCB	F.S.
Centre technique de l'industrie du bois / technisch centrum der houtnijverheid	CTIB / TCHN	B
Centre technique et scientifique de la brasserie, de la malterie et des industries connexes / technisch en wetenschappelijk centrum voor de brouwerij, de mouterij en aanverwante nijverheden	CBM / CBM	B
Centrum voor toegepaste biologie	CTB	F.S.
Comite voor onderzoek op de bewaring van tuinbouwprodukten van het verbond van belgische tuinbouwveilingen		F.S.
Demonstratiebedrijf - tongeren		F
Innovatie- en incubatiecentrum - kul	I&I	F
Innovatie- en incubatiecentrum - ug	I&I	F
Institut belge de l'emballage / belgisch verpakkingsinstituut	IBE / BVI	B
Institut de recherche des revetements, peintures et encres / researchinstituut voor bekledingen, verven en inkten	CORI / CORI	W
Institut du transport routier / instituut voor wegtransport	ITR / IWT	B
Institut royal belge pour l'amelioration de la betterave / koninklijk belgisch instituut tot verbetering van de biet		F.S.
Institut scientifique du verre / wetenschappelijk instituut voor het glas	INV / NIG	W
Laboratoire belge de l'industrie electrique / belgisch laboratorium van de elektriciteitsindustrie	LABORELEC / LABORELEC	F.S.
Nationale proeftuin voor grootfruit		F.S
Opzoekingsstation van gorsem / opzoekingsstation van gorsem		F.S.
Proefbedrijf der noorderkempen		F.S.
Proefbedrijf voor witloof		F.S.
Proefcentrum voor de sierteelt (boomkwekerij/snijbloemteelt/bloemisterij)	PCS	F.S.
Proefstation voor de groententeelt		F.S.
Provinciaal onderzoek- en voorlichtingscentrum voor land- en tuinbouw		F
Provinciaal proefcentrum voor groenteteelt - oost-vlaanderen		F
Service de controle des medicaments de l'association pharmaceutique belge / dienst voor geneesmiddelenonderzoek van de algemene pharmaceutische bond		B
Service pedologique de belgique / bodemkundige dienst van belgie		F.S.
Vlaamse rundveeteeltvereniging		F

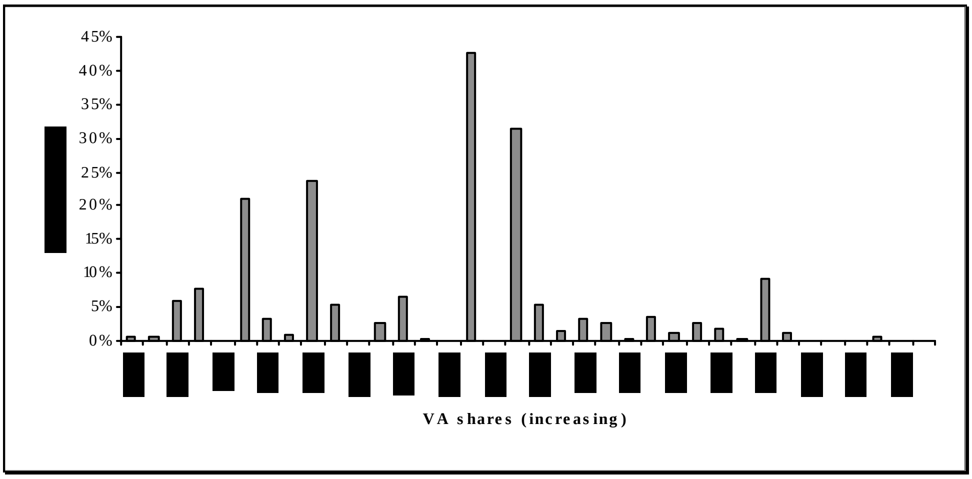
Source: OSTC, 1997 ; *Note:* F.S. = Federal State, B = Brussels-Capital Region, F = Flemish Community, W = Walloon Region / French-speaking Community

Figure A.3.1 : Value added shares and R&D shares in the Belgian industry, 1995



Source: Table 3.2; the industries are ranked from the lowest to the largest share in total industry value added.

Figure A.3.2 : Value added shares and R&D intensities in the Belgian industry, 1995



Source: Table 3.2; the industries are ranked from the lowest to the largest share in total industry value added.

Table A.3.1 : Evolution of intra-muros R&D investments of firms, by industrial sectors, 1981-1995

(Constant (1981=100) prices: GDP deflator)

	1981	1985	1991	1995	1995
Indices, 1981=100					BEF Mio
Agriculture	**100**	**100**	**239**	**161**	**249**
Mining	**100**	**159**	**392**	**5**	**7**
High and medium-high tech industries	**100**	**133**	**144**	**140**	**59581**
Drugs	100	123	184	282	14235
Chemicals (excl. drugs)	100	111	137	108	17563
Non electrical machines	100	131	148	87	3293
Electrical machines + electronics + instruments + office m.	100	152	128	132	20726
Motor vehic. + other transport	100	211	224	207	3764
Medium-low and low tech industries	**100**	**96**	**110**	**108**	**13227**
Rubber and plastic products	100	84	98	294	2450
Stone, clay & glass	100	50	78	48	1104
Other manufacturing	100	60	90	222	381
Food, beverage and tobacco	100	109	145	151	2292
Textile, clothing, and leather	100	87	91	68	1007
Wood, paper and furniture	100	118	131	90	595
Iron & Steel and non ferrous metals	100	125	137	100	3150
Metal products	100	99	95	106	2248
Total manufacturing industry	**100**	**125**	**136**	**133**	**72810**
Construction	**100**	**195**	**89**	**148**	**514**
Total services	**100**	**88**	**68**	**147**	**9939**
Total	**100**	**121**	**129**	**134**	**83519**

Sources: Service Inventaire Statistique, SSTC May 1994; SSTC June 1997, provisional data for 1995. A different census methodology has been used for the year 1985; extrapolated data for 1991. GDP deflator: OECD; own calculations.

Table A.3.2 : Intra-muros R&D investments in the Belgian industry by firm size, 1994-1995

(BEF Mio)

Firms' size (employment)	**1994**	**1995**	**1994=100**	**Shares 1995**	**Cumulated shares**
0-9	1 040	1 369	131,6	1,64%	100,00%
10-19	1 539	1 620	105,3	1,94%	98,36%
20-49	5 528	5 812	105,1	6,96%	96,42%
50-99	6 695	7 092	105,9	8,49%	89,46%
100-199	5 305	5 381	101,4	6,44%	80,97%
200-499	7 906	9 065	114,7	10,85%	74,53%
500-999	9 109	10 251	112,5	12,27%	63,67%
plus de 1.000	41 054	42 929	104,6	51,40%	51,40%
TOTAL	**78 175**	**83 519**	**106,8**	**100,00%**	

Source: SSTC, June 1997, and own calculations.

Table A.3.3 : R&D employees in the Belgian industry by firm size, 1994-1995

(Full time equivalent)

Firms' size (employment)	**1994**	**1995**	**1994=100**	**Shares 1995**	**Cumulated shares**
0-9	686	799	116,5	3,58%	100,00%
10-19	700	653	93,2	2,93%	96,42%
20-49	2 084	2 185	104,8	9,80%	93,49%
50-99	2 064	2 093	101,4	9,39%	83,69%
100-199	1 728	1 683	97,4	7,55%	74,31%
200-499	2 215	2 322	104,9	10,42%	66,76%
500-999	2 174	2 338	107,5	10,49%	56,34%
plus de 1.000	9 885	10 223	103,4	45,85%	45,85%
TOTAL	**21 536**	**22 294**	**103,5**	**218,09%**	

Sources: SSTC-DWTC, June 1997; and own calculations.

Table A.3.4 : Public budget allocations to R&D and scientific and technological activities: Institutional and functional destination, 1989

INSTITUTIONAL DESTINATION	Belgium	Federal Author.	BXL-Capital Reg.	Flemish Reg.+Com.	French Com.+ Walloon Reg.
100. HIGHER EDUCATION	13760	530.4		6640.9	6588.2
Higher Education Institutions	11496	530.5		5738.6	5227.3
Universities' research funds	650			357.5	292.5
Financial transfers to universities	1613.1			544.7	1068.4
200. SCIENTIFIC INSTITUTIONS	4963.1	3557		832.6	573.6
Departmental services	2793.1	2503.2		196.3	94.2
Academies	53.2	15.3		8.5	29.5
Other Research Institutes	2116.2	1038.4		627.8	450
INIEX-ISSEP	*218.4*				*218.4*
IRE -'Institut National des Radio-Eléments'	*253.4*	*21.8*			*231.6*
CEN - 'Centre d'études de l'énergie nucléaire'	*844.3*	*821.3*		*23*	
'Institut belge de normalisation'	*24.8*	*24.8*			
'Institut géotechnique de l'Etat'	*1.2*	*0.6*		*0.6*	
'Vlaamse Instelling voor Technologisch onderzoek'	*478.2*			*478.2*	
'Interuniversitair Centrum voor Micro-Electronica'					
Sectorial Collective Research Centres	*296*	*170*		*126*	
'Vlaamse interuniversitaire instelling voor Biotechnologie'					
300. MISCELLANEOUS BUDGET ALLOCATIONS TO R&D	885.9	284.7		240.4	360.8
R&D Credits	422.7	273.5		69.9	79.3
S&T activities Credits	463.3	11.2		170.5	281.6
400. PROGRAMMES AND ORGANISATIONAL SYSTEMS OF R&D	3955.9	1510.6	30	619.4	1795.9
R&D programmes and projects (subsides and refundable loans)	2446.3	1192.3	30	5.5	1218.5
ARC ('Actions de Recherche concertées')	611.6	1.3		335.7	274.6
PAI ('Pôles d'Attraction interuniversitaire')	317	317			
FRFC ('Fonds de la Recherche fondamentale collective-initiative ministérielle')	208.1			86.3	121.8
Specialisation grants	372.9			191.9	181
500. FUNDS FOR UNIVERSITY and BASIC RESEARCH	4030.9	350.3		2288.4	1392.2
FNRS (	1729.9			1211.9	518
Fonds de la Recherche fondamental collective (FRFC)-initiative chercheurs	751.7			416.4	335.3
Institut interuniversitaire des Sciences nucléaires (IISN)	745.5	149.1		328	268.4
Fonds de la Recherche scientifique médicale (FRSM)	780	201.2		318.3	260.5
Collège interuniv. d'Etudes doctorales dans les Sc. du management (CIM)	23.8			13.8	10
600. FUNDS FOR INDUSTRIAL AND APPLIED RESEARCH	4908.2	2616.3	383	1908.9	
Industrial and agricultural research	925	841	84		
Research in Agriculture	*841*	*841*			
Pre-competitive industrial research	*84*		*84*		
IWT (subsides and refundable loans)					
Funds for supporting enterprises R&D	2920.5	1775.3	299	846.2	
Prototypes (refundable loans)	*2721.5*	*1775.3*	*100*	*846.2*	
'Fonds de rénovation industrielle' - 4th mission (refundable loans)					
'Fonds pour aide aux entreprises' (refundable loans)	*199*		*199*		
'Fonds tot bevordering van het industrieel onderzoek in Vlanderen' (subsides and refundable loans)					
'Fonds voor Preventie en Sanering inzake Milieu en Natuur'	*1062.7*			*1062.7*	
INTERNATIONAL ACTIONS	6472.1	6212.5		255.9	3.7
Programmes and organisations related to Space	3516.2	3453.3		62.9	
Other international programmes	2667.5	2470.8		193	3.7
Funds for co-operation and development	288.4	288.4			
TOTAL	38976	15062	413	12786	10715

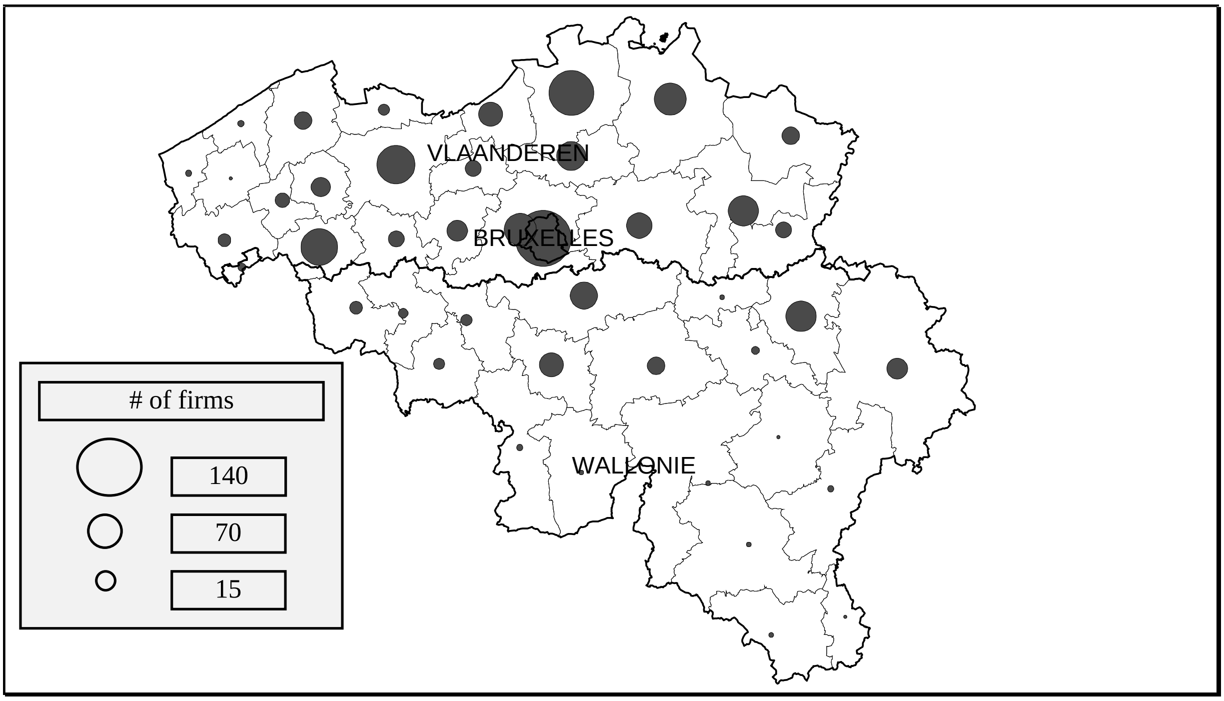
Source: Commission Coopération Fédérale, Groupe de concertation CFS/STAT, October 1996 (FEBEDET)

Table A.3.5 : Public budget allocations to R&D and scientific and technological activities: Institutional and functional destination, 1996

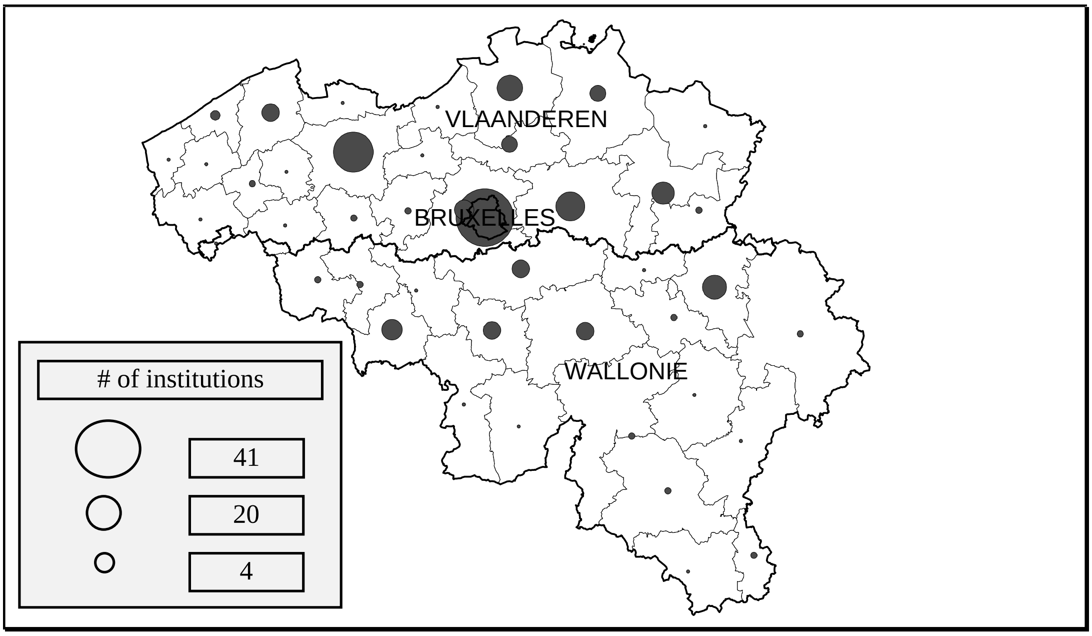
INSTITUTIONAL DESTINATION	Belgium	Federal Author.	BXL-Capital Reg.	Flemish REG.+Com.	French Com.+ Walloon Reg.
100. HIGHER EDUCATION	**18309.6**	**693.3**		**9467.1**	**8149.2**
Higher Education Institutions	15528.7	693.3		7952.3	6883
Universities' research funds	946.5			570.8	375.7
Financial transfers to universities	1834.4			943.9	890.5
200. SCIENTIFIC INSTITUTIONS	**7994.9**	**4157.7**	**2.5**	**3303.2**	**531.5**
Departmental services	3394.1	2943.5		425.6	25
Academies	46.4	9.3		7.1	30
Other Research Institutes	4554.4	1204.9	2.5	2870.6	476.5
INIEX-ISSEP	*336.5*				*336.5*
IRE -'Institut National des Radio-Eléments'	*36.9*	*36.9*			
CEN - 'Centre d'études de l'énergie nucléaire'	*870.8*	*870.8*			
'Institut belge de normalisation'	*26.3*	*26.3*			
'Institut géotechnique de l'Etat'					
'Vlaamse Instelling voor Technologisch onderzoek'	*645*			*645*	
'Interuniversitair Centrum voor Micro-Electronica'	*980.9*			*980.9*	
Sectorial Collective Research Centres	*538*	*270.9*	*2.5*	*124.6*	*140*
'Vlaamse interuniversitaire instelling voor Biotechnologie'	*1120*			*1120*	
300. MISCELLANEOUS BUDGET ALLOCATIONS TO R&D	**1881.9**	**661.1**		**870.1**	**350.7**
R&D Credits	1402.1	585.4		723.9	92.8
S&T activities Credits	479.8	75.7		146.2	257.9
400. PROGRAMMES AND ORGANISATIONAL SYSTEMS OF R&D	**7518.5**	**2607.8**	**134.6**	**1640.8**	**3135.3**
R&D programmes and projects (subsides and refundable loans)	4912.3	1755.3	134.6	557.9	2464.5
ARC ('Actions de Recherche concertées')	956			601.4	354.6
PAI ('Pôles d'Attraction interuniversitaire')	812	812			
FRFC ('Fonds de la Recherche fondamentale collective-initiative ministérielle')	130.5	40.5			90
Specialisation grants	707.7			481.5	226.2
500. FUNDS FOR UNIVERSITY and BASIC RESEARCH	**4960.2**	**486.1**		**2627.1**	**1847**
FNRS (	3554.9	140		2553.6	861.3
Fonds de la Recherche fondamental collective (FRFC)-initiative chercheurs	370				370
Institut interuniversitaire des Sciences nucléaires (IISN)	460.8	152.8			308
Fonds de la Recherche scientifique médicale (FRSM)	556.7	193.3		64.2	299.2
Collège interuniv. d'Etudes doctorales dans les Sc. du management (CIM)	17.8			9.3	8.5
600. FUNDS FOR INDUSTRIAL AND APPLIED RESEARCH	**3413.7**	**424.6**	**258**	**2731.2**	
Industrial and agricultural research	1844.3	407.5	140		
Research in Agriculture	*407.5*	*407.5*			
Precompetitive industrial research	*140*		*140*		
IWT (subsides and refundable loans)	*1296.8*			*1296.8*	
Funds for supporting enterprises R&D	1061.4	17.1	118	926.3	
Prototypes (refundable loans)	*95.1*	*17.1*	*78*		
'Fonds de rénovation industrielle' - 4th mission (refundable loans)					
'Fonds pour aide aux entreprises' (refundable loans)	*40*		*40*		
'Fonds tot bevordering van het industrieel onderzoek in Vlanderen' (subsides and refundable loans)	*926.3*			*926.3*	
'Fonds voor Preventie en Sanering inzake Milieu en Natuur'	508.1			508.1	
INTERNATIONAL ACTIONS	**9251.2**	**9187.3**		**60.4**	**3.5**
Programmes and organisations related to Space	6162.8	6162.8			
Other international programmes	3088.4	3024.5			3.5
Funds for co-operation and development				60.4	
TOTAL	**53330.1**	**18218**	**395.1**	**20699.8**	**14017.2**

Source: Commission Coopération Fédérale, Groupe de concertation CFS/STAT, October 1996 (FEBEDET)

Map A.3.1 : The distribution of R&D firms across Belgian districts



Map A.3.2 : The distribution of research centres across Belgian districts
(Public institutions, University centres, and research centres)



Map A.3.3 : The distribution of documentation centres and libraries across Belgian districts

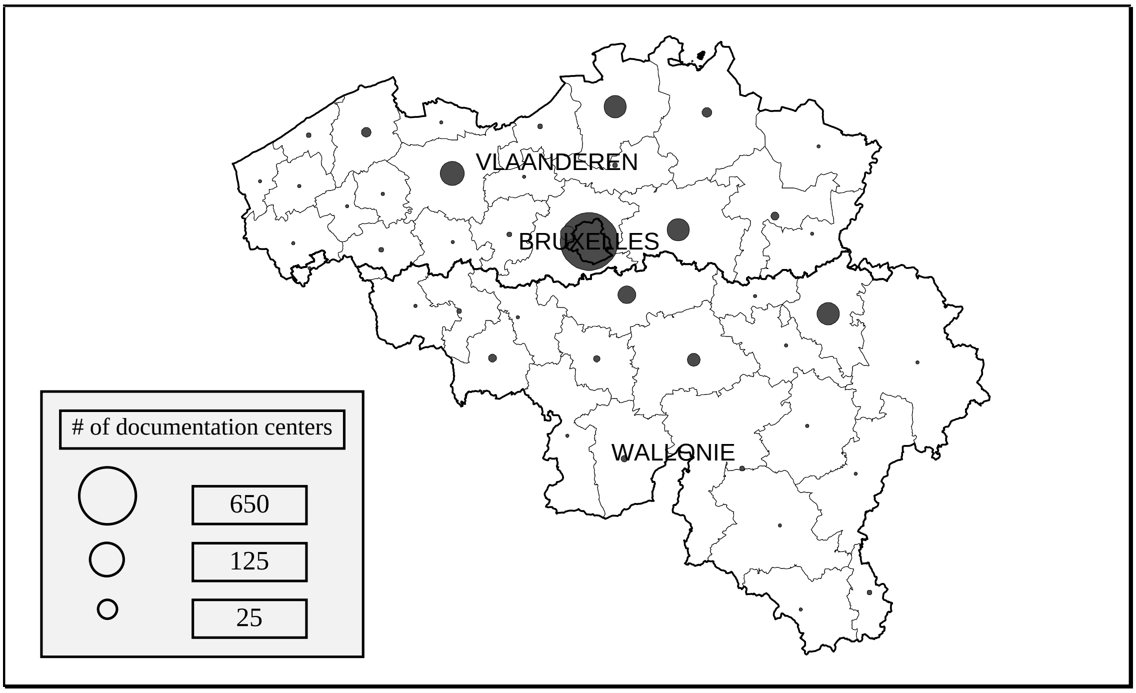
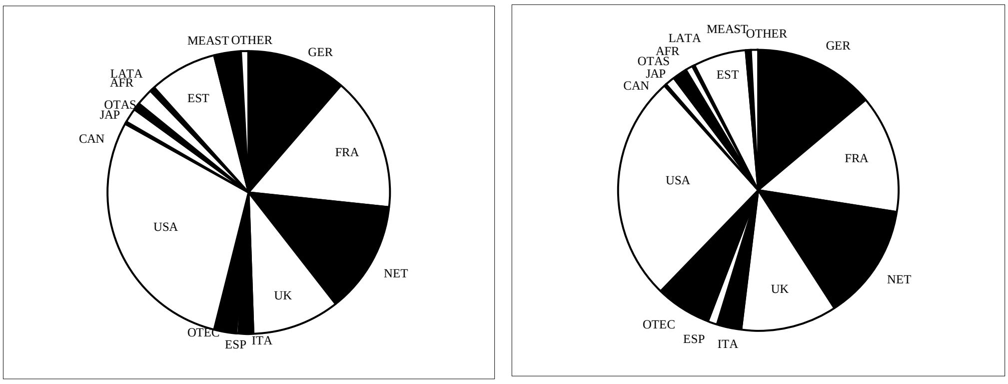


Table A.5.1 : The channels of international technology transfer

role of the ‘origin’ country:	**ACTIVE**	**PASSIVE**
Direct	Inward foreign direct investments* Foreign technology payments* R&D joint-ventures Foreign R&D investments	Human capital mobility Technology sourcing* Imitation - Re-engineering
Indirect	Trade*	Technical publications

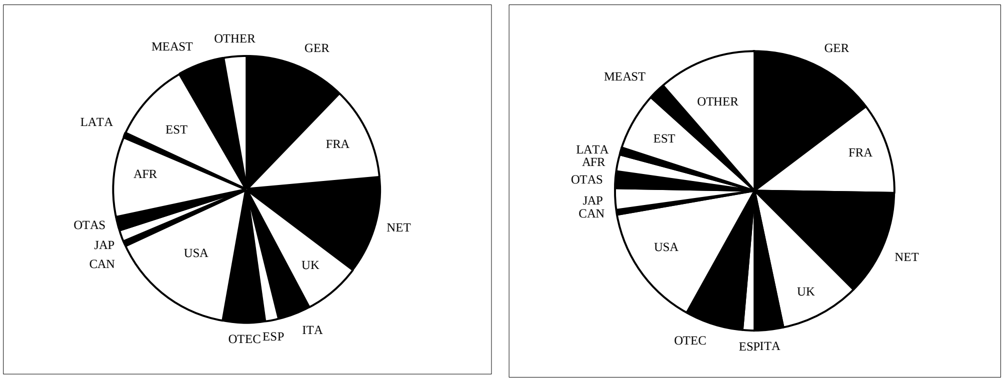
* indicates the channels that are to be analysed in this chapter

Figure A.5.1 : Technology payments by country of origin, 1983-85 (left) and 1993-95 (right)



Sources: Banque Nationale de Belgique, own calculations

Figure A.5.2 : Technology receipts by country of destination, 1983-85 (left) and 1993-95 (right)



Sources: Banque Nationale de Belgique, own calculations.

Table A.5.2 : The Belgian technology balance of payments by geographical areas in billions of BEF, average for the early eighties and the early nineties

	1983-5	1993-5		1983-5	1993-5
GERMANY	-490	353	CANADA	96	-90
FRANCE	-2844	-3163	JAPAN	-273	1385
NETHERL.	-1364	-1167	OTH. ASIA	365	271
UK	-1981	-2104	AFRICA	3457	915
ITALY	819	503	LAT. AM.	-33	410
SPAIN	703	310	EASTERN	309	471
OTH. EUR.	905	65	MID. EAST	900	1175
USA	-8491	-11335	OTHER	894	9429
			TOTAL	-7	-2

Source: Banque Nationale de Belgique.

Figure A.5.3 : The imperceptible net effect of inward FDI

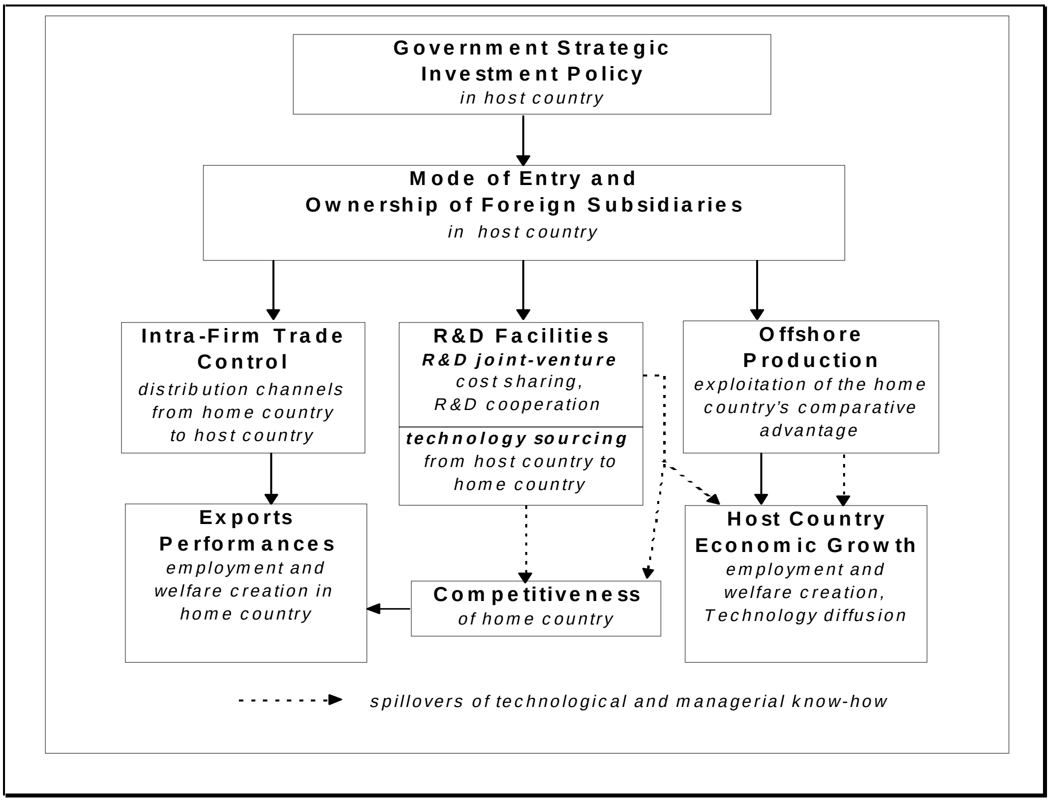
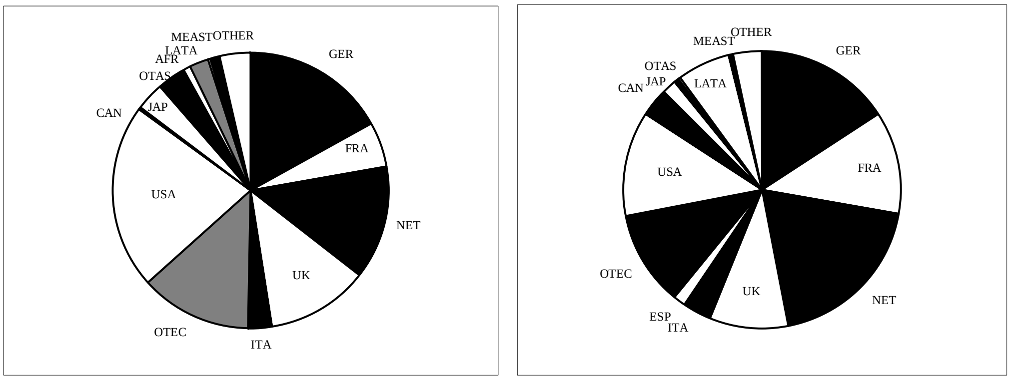
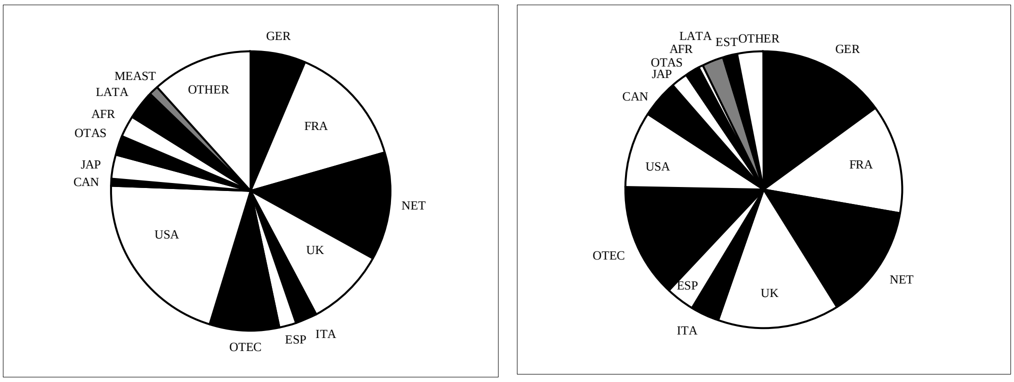


Figure A.5.4 : Inward foreign direct investments, receipts by country of origin, 1983-1985 (left) and 1993-1995 (right)



Sources: Banquet Nationale de Belgique, own calculations.

Figure A.5.5 : Outward foreign direct investments, payments by country of destination, 1983-85 (left) and 1993-95 (right)



Sources: Banque Nationale de Belgique, own calculations

Table A.5.3 : Trade Balance, RCA and Constant Market Share effects of leading-edge commodities Belgium-Luxembourg (1991-1995)

		EXP-IMP (1000 US $)	EXP/IMP 91	EXP/IMP 95	RCA 91	RCA 95	CMS Analysis			
							OVERALL	SHARE	COMPOSITION	ADAPTATION
591	Agricultural Chemicals	606429	0,62	2,96	1,46	5,41	5,38	6,72	-0,34	-0,99
541	Pharmaceutical products	796682	1,08	1,26	2,98	3,33	5,78	4,76	0,87	0,15
516	Advanced Organic chemicals	-131116	0,48	0,81	2,54	3,01	0,53	0,98	-0,36	-0,09
778	Advanced electrical machinery	375457	1,17	1,25	2,06	1,51	-1,79	-4,10	3,00	-0,70
718	Nuclear, water, wind power engines	-32118	0,28	0,65	0,32	0,98	0,30	0,47	-0,05	-0,11
764	Telecommunications equipment	258309	1,08	1,17	1,10	0,95	0,22	-1,36	1,74	-0,16
524	Radio-active materials	19506	1,21	1,48	0,39	0,76	0,03	0,49	-0,23	-0,23
874	Advanced measuring instr.	-209978	0,58	0,75	0,74	0,74	-0,80	0,32	-1,06	-0,05
752	Automatic data processing machines	-838484	0,42	0,63	0,56	0,71	3,68	2,91	0,57	0,20
714	Turbines and reaction engines	13408	1,23	1,05	0,73	0,67	-1,26	-0,10	-1,19	0,03
774	Medical electronics	-126047	0,76	0,50	0,76	0,62	-0,45	-0,21	-0,27	0,04
871	Advanced optical instruments	-46548	0,29	0,48	0,31	0,34	0,07	0,04	0,03	0,00
792	Aircraft & spacecraft	-317167	0,64	0,53	0,63	0,31	-8,04	-5,34	-5,24	2,54
776	Semi-conductor devices	-363881	0,38	0,57	0,16	0,16	1,64	0,18	1,35	0,10
Total		**4452**	**0,79**	**1,00**			**5,28**	**5,75**	**-1,19**	**0,73**

Source: UN (1996), own calculations (Data on SITC classes 575 and 891 not available for Belgium)

Table A.5.4 : Trade Balance, RCA and Constant Market Share effects of high-level technology commodities Belgium-Luxembourg (1991-1995)

		EXP-IMP (1000 US $)	EXP/IMP 91	EXP/IMP 95	RCA 91	RCA 95	CMS Analysis OVERALL	SHARE	COMPOSITION	ADAPTATION
277	Adv. industrial abrasives	-26773	0.84	0.81	2.60	2.94	-0.06	0.02	-0.08	-0.00
882	Photo and cinema supplies	1155388	2,87	3,29	2,39	2,47	-0,48	-0,13	-0,35	0,00
781	Motor vehicles for persons	10438121	2,04	2,41	1,90	2,01	-4,20	-0,34	-3,89	0,02
533	Pigments, Paints	512217	1,36	1,69	1,61	1,73	0,38	0,04	0,34	0,00
598	Miscellaneous Chemicals	578248	1,29	1,42	1,54	1,47	-0,27	-0,60	0,37	-0,04
663	Mineral manufactures	165569	1,15	1,34	1,35	1,35	-0,04	-0,10	0,06	-0,00
872	Medical instruments	58507	0,76	1,08	0,62	1,18	0,94	0,88	0,03	0,02
515	Heterocyclic Chemistry	-354662	2,65	0,70	2,21	1,13	-2,38	-2,41	0,06	-0,03
522	Rare Inorganic Chemicals	-8712	1,61	0,99	1,23	1,07	-0,80	-0,45	-0,43	0,08
761	TV and Video Equipment	384687	0,28	0,69	0,91	0,69	-0,77	-0,68	-0,13	0,04
266	Synthetic fibres	-70190	1,77	2,75	0,40	0,69	0,20	0,14	0,03	0,02
791	Railway vehicles	71464	0,87	1,70	0,54	0,68	0,02	0,08	-0,05	-0,00
737	Adv. metalworking equipment	-7566	0,52	0,97	0,67	0,66	-0,11	-0,06	-0,05	0,00
773	Electrical distributing equipment	46141	1,23	1,07	0,88	0,65	-0,17	-0,63	0,66	-0,20
726	Printing & Bookbinding	-761	0,44	1,00	0,30	0,64	0,41	0,50	-0,05	-0,05
531	Synth. colouring matter	-33951	1,02	0,88	0,61	0,63	-0,11	-0,02	-0,09	0,00
744	Mechanical handling	-180310	0,48	0,82	0,47	0,62	0,42	0,43	-0,00	-0,00
762	Radio-broadcast	33859	0,67	1,07	0,27	0,61	0,82	0,72	0,05	0,05
741	Heating, Cooling and eq.	68543	0,73	1,09	0,53	0,58	0,17	0,08	0,09	0,00
745	Other non-el. machinery	-225128	0,34	0,67	0,28	0,56	0,52	0,62	-0,05	-0,05
763	Sound & Video recorders	30487	1,04	1,09	0,28	0,43	0,26	0,31	-0,04	-0,02
772	Traditional electronics	-153158	0,60	0,86	0,34	0,40	0,59	0,23	0,32	0,04
873	Traditional measuring equipment	-36758	0,2	1,01	0,35	0,38	0,02	0,00	0,02	0,00
751	Office machines	1646	0,36	0,49	0,08	0,38	0,46	0,52	-0,01	-0,05
881	Phot. apparatus & machines	-40703	0,67	0,78	0,28	0,37	0,12	0,09	0,02	0,00
724	Textile & Leather machinery	-95265	0,68	0,81	0,37	0,37	-0,27	-0,08	-0,20	0,01
551	Essential oils, perfume	-24330	0,58	0,76	0,32	0,35	0,00	0,00	0,00	0,00
728	Advanced Machine tools	-122673	0,51	0,86	0,39	0,34	-0,32	-0,46	0,16	-0,03
727	Ind. food-processing machinery	-61562	0,42	0,55	0,34	0,32	-0,07	-0,03	-0,04	0,00
689	Precious non-ferrous. base metals	-27929	0,53	0,56	0,25	0,30	0,03	0,01	0,01	0,00
725	Paper & Pulp machinery	-106510	0,16	0,32	0,17	0,17	-0,05	-0,01	-0,04	0,00
759	Adv. parts for computers	-312237	0,69	0,63	0,27	0,15	-0,81	-1,05	0,44	-0,20
884	Optical fibres, contact	-85141	0,30	0,29	0,13	0,13	-0,00	-0,00	-0,00	0,00
Total		**11570558**	**1,30**	**1,33**			**-5.58**	**-2.36**	**-2.86**	**-0.35**

Source: UN (1996), own calculations (Data on SITC classes 542, 574, 731, 733, 735, 746 and 525 not available for Belgium)

Appendix A.6.1 : List of actors

LABEL	NAME	TYPE	NAT
BALCATEL	Alcatel Bell	IND	BE
BBARCO	Barco	IND	BE
BEEIG	European Renewable Energy Centers Agency	NCL	BE
BBELGACO	Belgacom	IND	BE
BEURDEV	European Development Centre	IND	BE
BIMEC	Interuniversity Micro-electronics Centre (IMEC)	ROR	BE
BKARMAN	Von Karman Inst. For Fluid Dynamics	ROR	BE
BKUL	Catholic University of Leuven	EDU	BE
BLMSINT	LMS International	IND	BE
BMIETEC	Alcatel Mietec	IND	BE
BPGS	Plant Genetic Systems	IND	BE
BSCK	Study Centre for Nuclear Energy	ROR	BE
BSOCBIO	Societe de Biotechnologie	IND	BE
BSOLVAY	Solvay	IND	BE
BUCL	Catholic University of Louvain	EDU	BE
BUG	University of Ghent	EDU	BE
BULB	Université Libre de Bruxelles	EDU	BE
BUNIVL	University of Liège	EDU	BE
BVITO	Flemish Institute for Technological Research (VITO)	ROR	BE
BVUB	Free University Brussels	EDU	BE
BWTCB	Scientific Technological Centre of the Forest Industry (WTCB)	ROR	BE
BWTCM	Scientific Technological Centre of the Metal Industry (WTCM)	ROR	BE
FALCATEL	Alcatel-Alsthom	IND	FR
FCEA	Commisariat a l'energie atomique (CEA)	ROR	FR
FCNRS	Centre National pour la recherche scienti-fique	ROR	FR
FMATRA	Matra Cap systemes	IND	FR
FRANTEL	France Telecom	IND	FR
FTHOMSON	SGS-Thomson	IND	FR
GALCATEL	Alcatel Sel AG	IND	DE
GFRAUN	Fraunhofer Gesellschaft	IND	DE
GSIEMENS	Siemens	IND	DE
ICSELT	Centro Studi e Laboratori Telecomunicazione	ROR	IT
ITHOMSON	SGS Thomson	IND	IT
NPHILIPS	Philips	IND	NL
UBT	British Telecommunications	IND	GB
UPLESSEY	Gec Plessey	IND	GB
VTT	Technical Research Centre of Finland (VTT)	ROR	FI

Appendix A.6.2 : *EU RTD-Projects and Country size*

MODEL:

$$\log(\text{number of prime contractors}) = C + \alpha \log(\text{Population 1992}) + \beta \ln(\text{GDP 1992}) + \varepsilon$$

COEFFICIENTS: (t-statistics between brackets ; * = 95 % ; ** = 99 %):

	CORDIS	ESPRIT	BRITE	RACE	JOULE	CRAFT	BCR 4
C	-11.38	-21.62 **	-17.59 **	-19.57	-24.39 **	-1.78	-48.78 **
	(-1.69)	(-3.09)	(-3.04)	(-1.47)	(-3.65)	(-.28)	(-3.20)
log (Pop.)	.960	-1.35	-1.18	-1.45	-2.25 *	.95	-4.22 **
	(-1.27)	(-1.73)	(-1.81)	(-.97)	(1.76)	(1.26)	(-2.48)
log (GDP)	1.46	2.03 **	1.72 **	1.87	2.60 **	-.19	4.76 **
	(2.03)	(2.73)	(2.79)	(1.31)	(3.64)	(-.27)	(2.94)

RANKING OF RESIDUALS:

CORDIS	ESPRIT	BRITE	RACE	JOULE	CRAFT	BCR 4
UK (+)	UK (+)	UK (+)	UK (+)	UK (+)	**BE (+)**	UK (+)
FR (+)	**BE (+)**	IE (+)	IE (+)	NL (+)	ES (+)	NL (+)
IE (+)	FR (+)	FR (+)	FR (+)	DK (-)	NL (+)	**BE (+)**
BE (+)	IE (+)	**BE (-)**	DE (+)	DE (-)	FR (+)	ES (+)
NL (+)	NL (-)	DE (-)	**BE (+)**	IE (-)	UK (+)	FR (+)
DE (-)	DE (-)	DK (-)	NL (-)	ES (-)	DE (-)	DK (-)
IT (-)	IT (-)	IT (-)	DK (-)	FR (-)	IE (-)	IE (-)
DK (-)	ES (-)	NL (-)	IT (-)	**BE (-)**	DK (-)	DE (-)
ES (-)	DK (-)	ES (-)	ES (-)	IT (-)	IT (-)	IT (-)

Appendix A.6.2. (continued) : *EUREKA Participation and country size*

MODEL:

$$\log(\text{number of projects}) = C + \alpha \log(\text{Population 1992}) + \beta \ln(\text{GDP 1992}) + \varepsilon$$

COEFFICIENTS: (t-statistics between brackets ; * = 95% ; ** = 99 %):

	EUREKA
C	-19.60 * (-2.37)
log (Population)	-1.63 (-1.76)
log (GDP)	2.09 ** (2.37)

RANKING OF RESIDUALS:

EUREKA
NL (+)
ES (+)
DK (+)
FR (+)
UK (-)
BE (-)
DE (-)
IE (-)
IT (-)

Table A.6.1 : Classification of Belgian companies according to size (# of employees and ranking by value added)

	#	%
NUMBER OF EMPLOYEES (n)		
n> 5000	14	2
5000> n > 1000	33	5
1000 > n > 500	26	4
500 > n > 250	35	6
250 > n > 100	50	8
100 > n > 50	43	7
50> n	425	68
NATIONAL RANKING BY VALUE ADDED		
TOP 100	34	5
TOP 500	74	12
TOP 1000	105	17
TOP 5000	178	28
TOP 10000	212	34
TOP 30000	271	43
NOT RANKED in TOP 30000	355	57

Table A.6.2 : Classification according to the % of projectlines in which firms of a given NACE sector are involved

SECTOR(NACE-bel)		% lines	# firms	%
Audio-, video- & Telecommunications	(32)	11.26	14	3,32
Informatics	(72)	6.71	50	11,85
Other business services	(74)	4.05	66	15,64
Post & Telecommunications	(64)	3.20	4	0,95
Textile industry	(17)	1.96	27	6,40
Research & Development	(73)	1.75	6	1,42
Metallurgy	(27)	1.71	17	4,03
Food & Beverages	(15)	1.69	20	4,74
Manufacture of metal products	(28)	1.50	28	6,64
Chemical industry	(24)	1.37	37	8,77
Machinery & Tools	(29)	1.25	37	8,77
Electrical machines	(31)	0.90	16	3,79
Manufacture of Other means of Transport	(35)	0.80	7	1,66
Medical & Optical instruments, Fine mechanics	(33)	0.73	10	2,37
Rubber & Synthetic materials	(25)	0.47	14	3,32
Agriculture	(1)	0.40	7	1,66
Furniture industry	(36)	0.38	5	1,18
Building industry	(45)	0.34	10	2,37
Manufacture of Non-metallic mineral products	(26)	0.33	11	2,61
Manufacture of Motor vehicles	(34)	0.29	4	0,95
Wholesale trade machinery	(51)	0.21	28	6.64
Rent & Sale of real estate	(70)	0.1	4	0,95
Total			422	100
Other or at present unknown			204	

Table A.6.3 : Relative Specialisation Index of Belgian participants in EU and EUREKA projects and in technological agreements

	RSI PR(C)	RSI PR (E)	RSI (EUREKA)	RSI (CATI)
Aerospace Technology	0.97	0.88	*	1.10
Information Technology	0.96	1.13	1.36	0.47
Telecommunications	0.93	1.26	0.64	1.64
Materials Technology	0.97	0.98	1.19	0.76
Biotechnology	1.28	0.78	0.94	1.31
Energy	0.90	1.01	0.54	*
Environmental Technology	0.95	0.88	0.88	*
Medical Technology	1.58	1.19	*	0.00
Transport	0.69	0.92	1.01	*
Robotics	*	*	0.82	0.27
Laser	*	*	1.82	*
Chemicals	*	*	*	3.28

RSI= $(NP_{i\ Bel} / NP_{Bel}) / (NP_i / NP)$
NP= Number of projects (agreements)
I= technological discipline
PR (C): Prime contractors in completed EU projects
PR (E): Prime contractors in ongoing EU projects

Table A.6.4 : Comparison of the overall number of companies and the number of companies in major NACE sectors represented in the SSTC repertory with the number of companies of the given sector in the graph

NACE	TOTNUM	NUMGR	%	TOTSHARE	GRSHARE	T/G	REP	% REP	REP/ GRSHARE
High-Tech	827	24	2.90	2.08	8.99	4.32	112	14.91	1.66
244	**99**	**5**	**5.05**	**0.25**	**1.87**	**7.52**	**26**	**3.46**	**1.85**
32	**177**	**12**	**6.78**	**0.45**	**4.49**	**10.09**	**41**	**5.46**	**1.21**
353	**38**	**3**	**7.89**	**0.10**	**1.12**	**11.75**	**5**	**0.67**	**0.59**
33	**513**	**4**	**0.78**	**1.29**	**1.50**	**1.16**	**40**	**5.33**	**3.56**
Medium-high	2546	56	2.20	6.41	20.97	3.27	223	29.69	1.46
24	**618**	**21**	**3.40**	**1.56**	**7.87**	**5.06**	**78**	**10.39**	**1.32**
29	**1152**	**17**	**1.48**	**2.90**	**6.37**	**2.20**	**84**	**11.19**	**1.76**
31	**480**	**15**	**3.13**	**1.21**	**5.62**	**4.65**	**46**	**6.13**	**1.09**
34	**296**	**3**	**1.01**	**0.74**	**1.12**	**1.51**	**15**	**2.00**	**1.78**
Medium-low	3924	27	0.69	9.88	10.11	1.02	124	16.51	1.63
23	**30**	**1**	**3.33**	**0.08**	**0.37**	**4.96**	**7**	**0.93**	**2.49**
25	**633**	**9**	**1.42**	**1.59**	**3.37**	**2.12**	**41**	**5.46**	**1.62**
26	**1204**	**7**	**0.58**	**3.03**	**2.62**	**0.87**	**41**	**5.46**	**2.08**
35(excl. 351,352)	**198**	**5**	**2.53**	**0.50**	**1.87**	**3.76**	**6**	**0.80**	**0.43**
351	**109**	**2**	**1.83**	**0.27**	**0.75**	**2.73**	**6**	**0.80**	**1.07**
36 (excl. 361)	**1750**	**3**	**0.17**	**4.40**	**1.12**	**0.26**	**23**	**3.06**	**2.73**
Low	8007	70	0.87	20.15	26.22	1.30	189	25.17	0.96
15	**3307**	**14**	**0.42**	**8.32**	**5.24**	**0.63**	**58**	**7.72**	**1.47**
16	**31**	**1**	**3.23**	**0.08**	**0.37**	**4.80**	**2**	**0.72**	**0.71**
17	**1276**	**24**	**1.88**	**3.21**	**8.99**	**2.80**	**46**	**6.13**	**0.68**
27	**255**	**13**	**5.10**	**0.64**	**4.87**	**7.59**	**24**	**3.20**	**0.66**
28	**3138**	**18**	**0.57**	**7.90**	**6.74**	**0.85**	**59**	**7.86**	**1.17**
Construction	19945	6	0.03	50.19	2.25	0.04	27	3.60	1.60
Services	4257	79	1.86	10.71	29.59	2.76	76	10.12	0.34
72	**4167**	**76**	**1.82**	**10.49**	**28.46**	**2.71**	**63**	**8.39**	**0.29**
73	**90**	**3**	**3.33**	**0.23**	**1.12**	**4.96**	**13**	**1.73**	**1.54**
TOTAL	39736	267	0.67	100.00	100.00	1.00	751	100.0	1.00

TOTNUM: Total number of companies belonging to this sector (National Bank Data Source) ; NUMGR: Number of this sector's companies represented in the graph
%: NUMGR/TOTNUM*100 ; TOTSHARE: TOTNUM/TOTAL TOTNUM*100 ;
GRSHARE: NUMGR/ TOTAL NUMGR*100 ; G/T: GRSHARE/TOTSHARE ;
REP: Total number of this sector's companies in the SSTC R&D repertory ; % REP: REP/TOTREP*100.

Table A.6.5 : Average Centrality in the 15 main NACE sectors (2 digit)

NACE	Centrality	Mean Rank (Kruskal-Wallis)
32 (El. Equipment)	53.43 (71.13)	200.07
64 (Telecommunications)	42.40 (66.55)	189.20
73 (R&D)	22.20 (23.29)	159.90
72 (Informatics)	15.65 (14.85)	156.96
27 (Metallurgy)	14.88 (20.38)	148.84
24 (Chemicals)	11.93 (27.83)	106.22
15 (Food & Beverage)	11.82 (10.86)	143.55
28 (Metal products)	10.93 (9.07)	138.73
74 (Other services)	10.71 (9.97)	132.86
17 (Textiles)	9.48 (6.79)	130.37
29 (Non el. machines)	8.18 (9.44)	100.35
31 (El. machines)	7.08 (6.64)	101.50
25 (Rubber & Plastics)	6.00 (5.37)	93.06
33 (Instr. and office mach.)	5.80 (3.03)	101.10
26 (Stone, clay & glass)	5.00 (4.06)	83.95

Table A.6.6 : Matrix of intra- and interregional knowledge flows in R&D co-operation

FROM\ TO	FLANDERS	WALLONIA	BRUSSELS	ABROAD	TOTAL	SPILL	INTDIFF	DIFF
FLANDERS	90.15	8.66	17.69	439.92	556.4	0.23	.003	-0.03
WALLONIA	9.42	13.4	7.39	134.587	164.7	0.56	.003	0.00
BRUSSELS	18.58	8.03	15.61	211.66	253.8	0.63	.008	0.00
ABROAD	436.97	133.75	207.82		778.5		-.004	
TOTAL	555.12	163.84	248.51	786.167				
SPILL	0.24	0.55	0.62					

SPILL: number of lines outside the region/ total number of lines of the region
DIFF: Interregional diffusion: Log (row (total-abroad) / column (total-abroad))

Table A.6.7 : Collaborative links between Belgian companies and foreign partners and Revealed Comparative Preference (RCP)

COUNTRY	TOTAL	CORDIS	RCP	EUREKA	RCP	CATI	RCP
Germany	1309	1173	1.01	132	0.92	4	0.52
France	1230	1059	0.97	165	1.22	6	0.84
Great Britain	964	864	1.01	87	0.82	13	2.31
Italy	684	593	0.98	88	1.17	3	0.75
The Netherlands	585	490	0.95	84	1.30	11	3.22
Spain	524	428	0.92	96	1.66	0	0.00
Greece	266	260	1.11	6	0.20	0	0.00
Denmark	247	231	1.06	16	0.59	0	0.00
Portugal	203	198	1.10	5	0.22	0	0.00
Sweden	184	167	1.03	17	0.84	0	0.00
Ireland	140	138	1.12	2	0.13	0	0.00
TOTAL	**6336**	**5601**		**698**		**37**	

$RCP_{ij} = (NL_{ij}/NL_i)/(NL_j/NL)$
NL: Number of Collaborative Links between Belgian companies and foreign organisations
i : Country
j : Programme/Technological area

Table A.6.8 : Main collaborative links between Belgian companies and foreign partners and Revealed Comparative Preference (RCP)

COUNTRY	TOTAL	CORDIS	RCP	EUREKA	RCP	CATI	RCP
Germany	233	223	1.06	10	0.47	0	0.00
France	311	264	0.94	47	1.66	0	0.00
Great Britain	216	202	1.04	10	0.51	4	3.04
Italy	129	123	1.06	5	0.42	1	1.27
The Netherlands	146	107	0.81	36	2.70	3	3.38
Spain	97	89	1.02	8	0.90	0	0.00
Greece	43	43	1.11	0	0.00	0	0.00
Denmark	53	53	1.11	0	0.00	0	0.00
Portugal	40	38	1.05	2	0.55	0	0.00
Sweden	17	15	0.98	2	1.29	0	0.00
Ireland	30	30	1.11	0	0.00	0	0.00
TOTAL	**1315**	**1187**		**120**		**8**	

Table A.6.9 : Revealed Comparative Preference for the major RTD programmes

	ESPRIT	RCP	BRITE	RCP	CRAFT	RCP	JOULE	RCP	BCR 4	RCP	RACE	RCP	ACTS	RCP	TELEMAT	RCP
GERMANY	302	1,05	208	1,21	105	1,65	30	0,94	125	1,03	146	0,93	51	0,86	18	0,63
FRANCE	251	0,97	190	1,23	54	0,94	33	1,15	119	1,09	89	0,63	36	0,68	21	0,81
GB	253	1,21	110	0,88	6	0,13	41	1,77	107	1,21	103	0,91	38	0,88	24	1,15
ITALY	150	1,02	84	0,95	14	0,43	10	0,62	51	0,82	119	1,49	32	1,06	17	1,16
NETHERLANDS	98	0,85	54	0,78	54	2,11	7	0,55	55	1,13	67	1,07	24	1,01	8	0,69
SPAIN	112	1,09	48	0,78	14	0,62	5	0,44	30	0,69	72	1,29	24	1,13	16	1,56
GREECE	52	0,78	38	0,95	8	0,54	12	1,63	17	0,61	35	0,97	20	1,46	9	1,35
DENMARK	31	0,56	31	0,93	15	1,21	6	0,97	40	1,70	44	1,45	7	0,61	8	1,43
PORTUGAL	37	0,76	12	0,41	39	3,63	1	0,19	17	0,83	30	1,14	16	1,60	5	1,03
SWEDEN	33	0,80	39	1,58	0	0,00	4	0,88	10	0,58	14	0,63	5	0,59	7	1,70
SWITZERLAND	32	0,96	8	0,40	1	0,14	3	0,81	12	0,85	31	1,71	27	3,91	3	0,90
IRELAND	50	1,45	17	0,82	0	0,00	3	0,79	7	0,48	11	0,59	9	1,27	4	1,16
	1401		**839**		**310**		**155**		**590**		**761**		**289**		**140**	

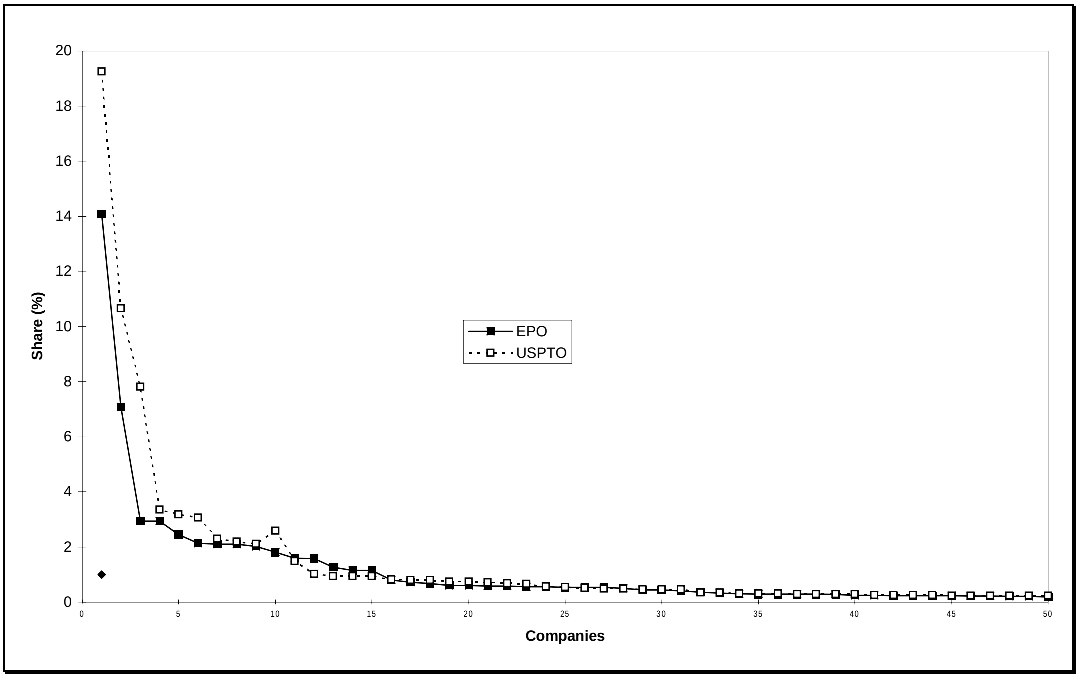
	AIR	RCP	DRIVE	RCP	NFS	RCP	ECLAIR	RCP	AERO	RCP	COST	RCP	BIOTECH	RCP
GERMANY	14	0,45	35	0,74	8	0,93	4	0,31	28	0,93	4	0,34	22	1,06
FRANCE	24	0,85	75	1,76	5	0,65	24	2,07	25	0,93	8	0,75	17	0,91
GB	20	0,87	18	0,52	7	1,12	9	0,96	23	1,05	2	0,23	22	1,46
ITALY	24	1,50	3	0,12	5	1,14	5	0,76	11	0,72	14	2,30	7	0,66
NETHERLANDS	19	1,50	19	1,00	3	0,86	3	0,58	17	1,41	4	0,83	8	0,96
SPAIN	20	1,78	18	1,06	2	0,65	9	1,95	8	0,75	6	1,41	12	1,62
GREECE	8	1,10	23	2,09	12	6,01	1	0,33	7	1,01	0	0,00	4	0,83
DENMARK	5	0,82	3	0,33	0	0,00	4	1,59	7	1,20	4	1,73	5	1,24
PORTUGAL	10	1,88	0	0,00	0	0,00	2	0,91	6	1,18	4	1,99	1	0,29
SWEDEN	2	0,44	29	4,27	0	0,00	0	0,00	6	1,40	7	4,11	0	0,00
SWITZERLAND	2	0,55	6	1,09	0	0,00	0	0,00	1	0,29	3	2,17	1	0,41
IRELAND	5	1,33	2	0,35	0	0,00	2	1,29	7	1,95	2	1,40	2	0,80
	153		**231**		**42**		**63**		**146**		**58**		**101**	

ESPRIT: Information Technology **BRITE**: Industrial technologies and advanced materials **CRAFT**: part of BRITE/EURAM oriented towards SMEs
JOULE: Non-nuclear energies/ Rational use of energies **BCR 4**: Measurement/ Reference materials **RACE- ACTS-TELEMATICS**: Telecommunications
AIR: Agro-Industrial research **DRIVE**: Transport/ Telecommunications **NFS**: Nuclear Fission Safety **ECLAIR-BIOTECH**: Agriculture/ Biotechnology
AERO: Aeronautics **COST**: Co-operation in Scientific and Technological Research

Table A.6.10 : Revealed Comparative Preference for the main technological areas of the EU Framework programmes

	IT	RCP	TELECOM	RCP	MATERIALS	RCP	ENERGY	RCP	BIOTECH	RCP	TOTAL
GERMANY	356	0,96	215	0,88	341	1,28	38	0,93	40	0,61	990
FRANCE	359	1,09	146	0,67	269	1,14	38	1,06	65	1,12	877
GB	302	1,14	165	0,94	139	0,73	48	1,66	51	1,09	705
ITALY	178	0,94	168	1,34	109	0,80	15	0,72	36	1,08	506
NETHERLANDS	127	0,87	99	1,02	125	1,18	10	0,62	30	1,16	391
SPAIN	133	0,98	112	1,24	70	0,71	7	0,47	41	1,71	363
GREECE	88	0,97	64	1,07	53	0,81	24	2,42	13	0,81	242
DENMARK	41	0,63	59	1,38	53	1,14	6	0,84	14	1,22	173
PORTUGAL	46	0,73	51	1,22	57	1,26	1	0,14	13	1,17	168
SWEDEN	66	1,23	26	0,73	45	1,17	4	0,68	2	0,21	143
SWITZERLAND	38	0,88	61	2,14	10	0,32	3	0,64	3	0,39	115
IRELAND	65	1,39	24	0,77	24	0,71	3	0,58	9	1,09	125
	1799		**1190**		**1295**		**197**		**317**		**4798**

Figure A.7.1 : Distribution of patent applications (EPO and USPTO, 1978-1996)



Sources: EPO and USPTO databases; own calculations

Figure A.7.2 : Number of patents at the district level

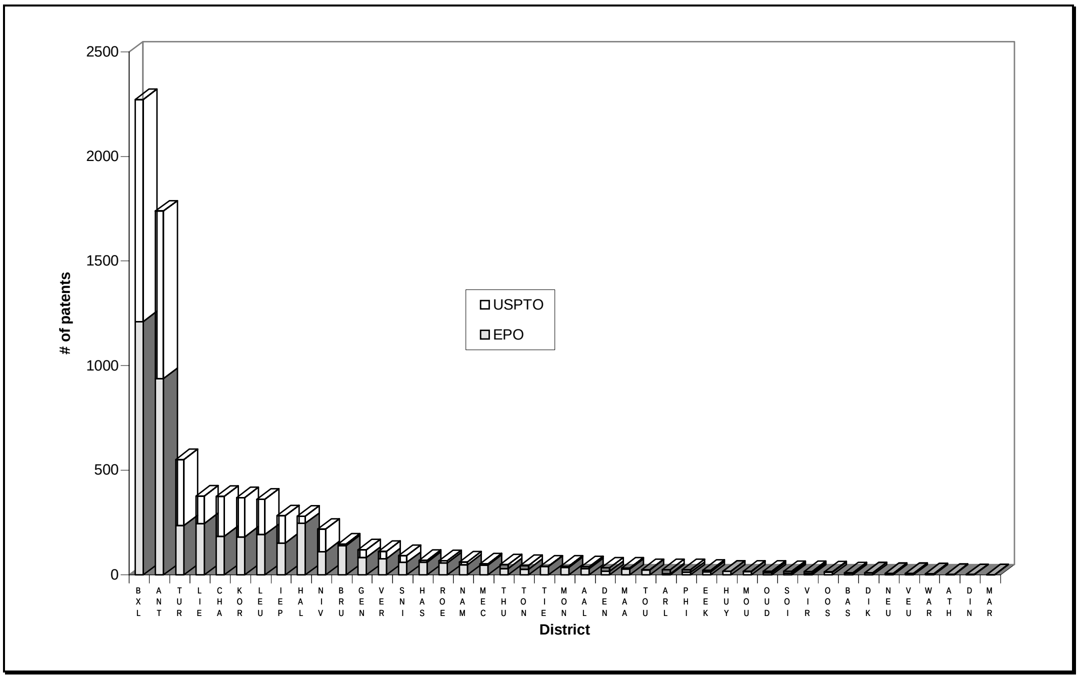


Figure A.7.3 : Concentration of Innovativeness and Wealth at the District Level (Belgium = 100)

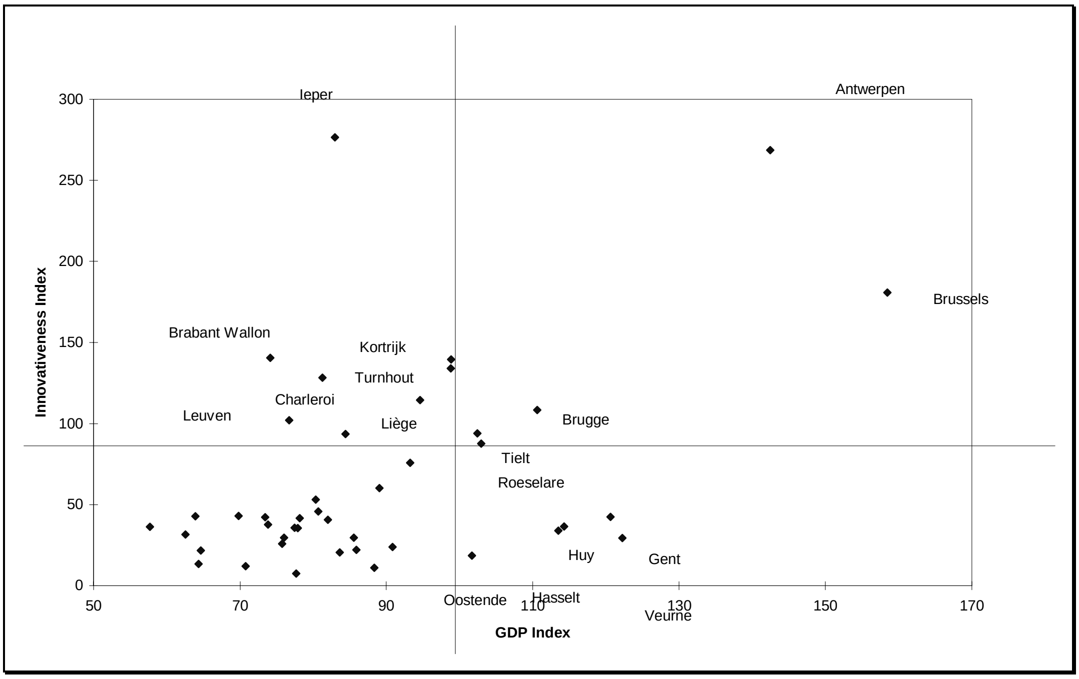


Figure A.7.4 : Concentration and Diversity of Innovativeness at the District Level (Belgium = 100)

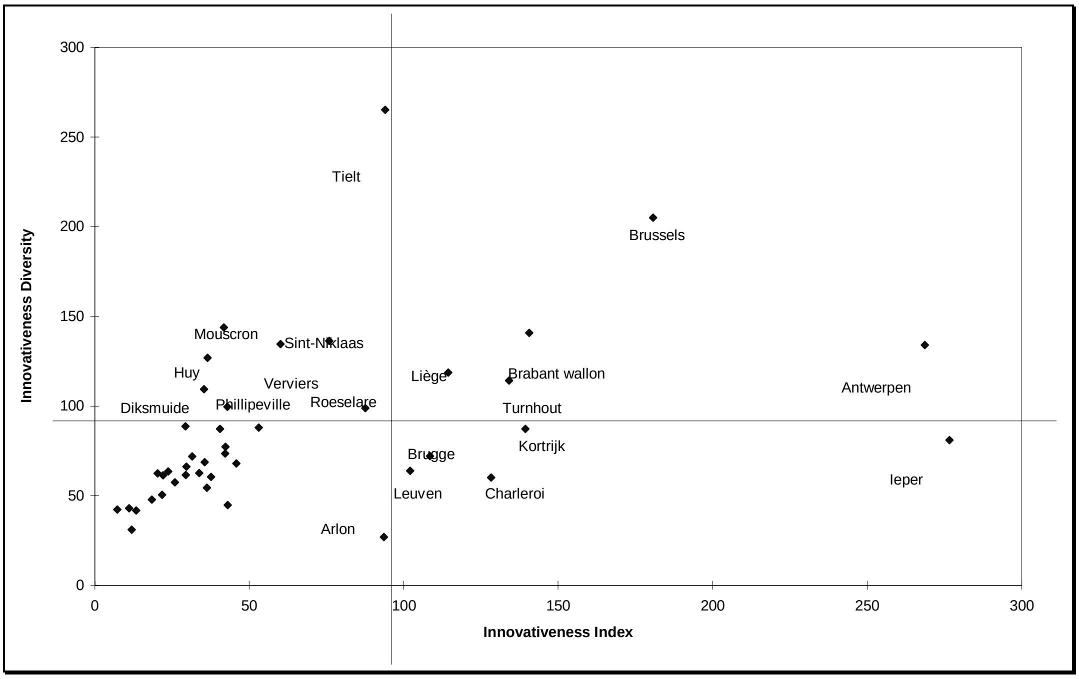


Table A.7.1 : Co-patents involving Belgian and foreign public institutes, universities and governments (1978-1994, EPO)

1st Co-applicant	ZIP	NPA	2nd Co-applicant	ZIP	3rd Co-applicant	ZIP	4th Co-applicant	ZIP
Belgian institutions								
INTERUNIVERSITAIR MIKROELEKTRONICA CENTRUM VZW	8900		BULCKE HYBRID TECHNOLOGY BVBA	3001	Siemens NV	8020		
CENTRE D'ETUDE ET DE DOCUMENTATION DE L'ENVIRONNEMENT(C.E.B.E.D.E.A.U.)	4000		PHENIX WORKS	4400				
CENTRE DE RECHERCHE DE L'INDUSTRIE BELGE DE LA CERAMIQUE	7000		INSTITUT NATIONAL INTERUNIVERSITAIRE DES SILICATES, SOLS ET MATERIAUX (INISMa)	7000				
CENTRE DE RECHERCHES METALLURGIQUES CENTRUM VOOR RESEARCH IN DE METALLURGIE	1040		KAWASAKI STEEL CORPORATION	JP				
CENTRE DE RECHERCHES METALLURGIQUES CENTRUM VOOR RESEARCH IN DE METALLURGIE	1040		COCKERILL SAMBRE SociÚtÚ Anonyme	4100	HOOGOVENS GROEP B.V.	NL	SIDMAR N.V.	9042
CENTRE DE RECHERCHES METALLURGIQUES CENTRUM VOOR RESEARCH IN DE METALLURGIE	1040	3	METALLURGIQUE ET MINIERE DE RODANGE-ATHUS Societe anonyme	LU				
CENTRE DE RECHERCHES METALLURGIQUES CENTRUM VOOR RESEARCH IN DE METALLURGIE	1040	2	ARBED S.A.	LU				
CENTRE DE RECHERCHES METALLURGIQUES CENTRUM VOOR RESEARCH IN DE METALLURGIE	4000		KAWASAKI STEEL CORPORATION	JP				
Centre scientifique et technique de l'Industrie textile belge en abrege 'Centexbel'	1040		**Centre Technique Industriel dit: INSTITUT TEXTILE DE FRANCE**	FR				
Centre scientifique et technique de l'Industrie textile belge en abrege 'Centexbel'	1040		'Santens' Societe de personnes a responsabilite limitee	9700				
LIMBURG UNIVERSITEIT CENTRUM	3590		**DR. L. WILLEMS INSTITUUT**	3590				
Gewestelijke Investeringsmaatschappij voor Vlaanderen N.V.	2000		Debremaeker, Egide Jozef	1502				
I N T R A D E L, Association Intercommunale de Traitement des Dechets de la Region Liegeoise	4400		PHENIX WORKS S.A.	4400				
IMEC Inter Universitair Micro-Electronica Centrum	3001		CAMECA	FR				
INTERNATIONAL INSTITUTE OF CELLULAR AND MOLECULAR PATHOLOGY (ICP)	1200		BOON, Thierry	1050				
INTERNATIONAL INSTITUTE OF CELLULAR AND MOLECULAR PATHOLOGY (ICP)	1200		BAXTER INTERNATIONAL INC.	US				
INTERUNIVERSITAIR MICRO-ELEKTRONICA CENTRUM VZW	3001		ADVANCED SEMICONDUCTOR MATERIALS, Naamloze Vennotschap	NL				
INTERUNIVERSITAIR MICROELEKTRONICA CENTRUM VZW	3001		**LIMBURGS UNIVERSITAIR CENTRUM**	3590				
KATHOLIEKE UNIVERSITEIT TE LEUVEN	3000		CORDOC V.Z.W.	9000				
L'UNIVERSITE DE LIEGE	4000	2	Liegeois, Jean-Marie	4654				
LA REGION WALLONNE	1050		**CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS)**	FR				
Leuven Research & Development V.Z.W.	3000	5	Collen, Desire Jose	3020				
Leuven Research & Development V.Z.W.	3000		SMITHKLINE BIOLOGICALS S.A.	1320				
RIJKSUNIVERSITEIT GENT	2610		N.V. Studiebureau O. de Konincks	9000	GEBRUDER SULZER AKTIENGESELLSCHAFT	CH		
NATIONALE BANK VAN BEL GIE N.V.	1000		AGFA-GEVAERT naamloze vennootschap	2640				
Openbare Afvalstoffenmaatschappij voor het Vlaamse Gewest	2800		Duivelaar, Patrick Gregory	NL				
Rega Stichting Vzw.	3000	11	**INSTITUTE OF ORGANIC CHEMISTRY AND BIOCHEMISTRY OF THE ACADEMIE OF SCIENCES OF THE CZECH REPUBLIC**	CZ				
Rega Stichting Vzw.	3000		**RICHTER GEDEON VEGYESZETI GYAR R.T.**	HU				
Rega Stichting Vzw.	3000		**CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS**	ES				
REGION WALLONNE representee par le Ministre des Technologies pour la R.W. dans ses attributions	1050		CHIRON CORPORATION	US				
RIJKSUNIVERSITEIT GENT	9000		**THE GENERAL HOSPITAL CORPORATION**	US				
UNIVERSITE CATHOLIQUE DE LOUVAIN	1348		**INSTITUT NATIONAL DE LA SANTE ET DE LA RECHERCHE MEDICALE (INSERM)**	FR	**FACULTE DES SCIENCES AGRONOMIQUES DE L'ETAT**	5031		
UNIVERSITE CATHOLIQUE DE LOUVAIN	1348		**INSTITUT NATIONAL DE LA SANTE ET DE LA RECHERCHE MEDICALE (INSERM)**	FR				
UNIVERSITE CATHOLIQUE DE LOUVAIN	1348		ISSI, Jean-Paul	1300	ALLEN, Gordon Derek	1050		
UNIVERSITE CATHOLIQUE DE LOUVAIN	1348		PLANT GENETIC SYSTEMS N.V.	1040				
Foreign entities								
BATTELLE MEMORIAL INSTITUTE	CH	3	SOLAGRO S.A.	1050				
Max-Planck-Gesellschaft zur F÷rderung der Wissenschaften e.V.	DE		**Deutsches Krebsforschungszentrum Stiftung des ÷ffentlichen Rechts**	DE	SMITHKLINE BEECHAM BIOLOGICALS s.a.	1330		
COMMISSARIAT A L'ENERGIE ATOMIQUE	FR		SOLVAY (Société Anonyme)	1050				
INSTITUT TEXTILE DE FRANCE	FR		DEPOORTERE GEBROEDERS	8791				
THE BOARD OF TRUSTEES OF THE MICHIGAN STATE UNIVERSITY	US		PLANT GENETIC SYSTEMS N.V.	1040				
THE GOVERNMENT OF THE UNITED STATES OF AMERICA c/o as represented by THE SECRETARY OF THE DEPARTMENT	US		SMITHKLINE BEECHAM BIOLOGICALS s.a.	1330				

Appendix A.7.8 : Results of the estimation of a hysteresis model of OECD trade-shares of the manufacturing sector (1970-1992)

Model:

$$\Delta Xsh_t = B_1(L)\ \Delta RelULC_t + B_2(L)\ \Delta PATsh_t + B_3(L)\ \Delta TMsh_t + u_t \quad .$$

Xsh , RelULC , PATsh and TMsh are the OECD trade-share, relative unit labour cost, the patent-share in the US and the trademark-share in the US respectively. $B_1(L)$, $B_2(L)$ and $B_3(L)$ are lag polynomials.

	RelULC	PATsh	TMsh	Wald χ^2	CRDW	LM-AR F-test	ADF(2)
BRD	-	.564 (5) (.357)	.126 (3) (.104)	5.443 (+)	1.48	.6938	-4.096 (*)
France	**-.028** (1) (.016) (+)	-	**.099** (3) (.040) (*)	9.382 (**)	1.51	2.0974	-6.023 (**)
Italy	**-.082** (1,2) (.021) (**)	-	**.129** (1) (.052) (*)	27.614 (**)	2.15	.4257	-6.302 (**)
Belgium	-	**4.199** (5,6) (1.887)(*)	**.770** (1,2) (.316) (*)	9.987 (**)	1.46	1.5602	-7.536 (**)
UK	-.020 (1) (.014)	**1.053** (3,4) (.441) (*)	**.072** (1) (.037) (+)	13.264 (**)	2.24	.2740	-6.829 (**)
Denmark	-.0021 (2) (.0014)	.444 (5) (.287)	**.117** (2) (.024) (**)	24.970 (**)	1.97	.1430	-4.967 (**)
USA	**-.044** (2) (.012) (**)	**.225** (5,6) (.103) (*)	**.246** (3) (.079) (**)	23.817 (**)	1.78	1.0721	-3.919 (*)
Japan	**-.139** (1,2) (.033) (**)	**.542** (3) (.181) (**)	**.420** (2,3) (.182) (*)	20.843 (**)	1.52	.8044	-6.305 (**)
Sweden	-.0045 (2) (.0028)	.213 (2) (.153)	**.176** (2,3) (.063) (*)	11.780 (**)	1.64	2.333	-4.574 (*)
Finland	**-.0062** (2) (.0022) (**)	**1.055** (5,6) (.586) (+)	.033 (2) (.032)	10.389 (*)	1.98	.8278	-5.542 (**)

[1] Standard errors of estimates between brackets ; **, *, + means 99%, resp. 95% and 90% statistical significance.
[2] The estimates are the sums $B_i(1)$ over the different lags of the coefficients in the final form of equation [3] ; the lags are given between brackets.