WORKING PAPER

3-05

European R&D Strategy: impact and feasibility study for Belgium

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February 2005

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Responsible Editor Henri Bogaert
Legal Depot: D/2005/7433/6

This paper is part of the EUKLEMS project, funded by the European Commission, Research Directorate General as part of the 6th Framework Programme, Priority 8, "Policy Support and Anticipating Scientific and Technological Needs". The paper contains results from the NEMESIS model (http://www.nemesis-model.net). NEMESIS is a model co-financed by the European Commission and developed by the Federal Planning Bureau (Belgium), Laboratoire ERASME (France), Chambre de Commerce et d'Industrie de Paris (France) and ICSS/NTUA (Greece). The results that are mentioned come from the ERASME and CCIP teams' work. All errors and omissions remain ours.

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Executive summary

Following the Lisbon strategy designed to transform the European economy into the most competitive and dynamic knowledge-based society, the Barcelona Summit quantified one of the available instruments to reach this ambitious objective by fixing the amount of resources which have to be devoted to R&D by 2010, at 3% of the European GDP.

What could be the implications of the Barcelona objective in terms of the main economic variables for Belgium and the EU? What are the needs for human capital to reach this objective? How are these needs covered by the current trends in the supply of qualified labour in Belgium? These are the main questions analysed in the present working paper.

The NEMESIS simulation allows to quantify the positive impact of the intensification in R&D efforts under the conditions of the Barcelona objective. At the macroeconomic level, it demonstrates an important positive impact on long-term economic growth, foreign trade and employment, as well as on productivity for every European country. However, at the sectoral level, structural changes occur and some sectors end up as net losers from this European common strategy.

The accounting exercise based on economic forecasts reveals that the 3% objective seems feasible in Belgium. The results show that the current efforts in R&D investment have to be at least maintained and at best intensified up to 2010. Indeed, the necessary annual average growth rates in R&D expenditure and in demand for R&D personnel are slightly higher than those recorded between 1993 and 2001, but equivalent to those of the last few years. Furthermore, the trends observed in the supply of human resources do not seem to be problematic.

However, the analysis is less positive at the regional level. Recently, the Walloon and Flemish regions have individually adopted the 3% objective. The regional estimates indicate that this target seems to be more difficult to reach for the Brussels-Capital Region. As a consequence, it is of major concern that the regional and federal authorities plan their future efforts in close consultation, in order to achieve the Barcelona objective at the national level.

I Introduction

Following the Lisbon strategy designed to transform the European economy into the most competitive and dynamic knowledge-based society, the Barcelona Summit quantified one of the available instruments to reach this ambitious objective by fixing the amount of resources which have to be devoted to R&D by 2010, at 3% of the European GDP. These efforts are considered as the major step to fill the gap in R&D investment between the EU and its main competitors, mainly the US and Japan[1]. A corollary of this objective is the acknowledgement that scientists and researchers are the backbone of the New Economy. Now, ageing population, but also the fact that science seems to have become an increasingly unpopular subject with students, have raised fears that we could run out of required human capital. The EU estimates that it will need 700 000 new researchers to meet its commitment concerning R&D. The problem has become more difficult by the increasing demand for researchers outside Europe and the net outflow of Science and Technology (S&T) human resources from Europe to the United States is expected to continue. Indeed, the US National Science Foundation projects that some 2.2 million new jobs in science and engineering will be created in the US over 2000-2010[2].

Such concerns are not exactly new and over the last half-century, numerous alarms have sounded about looming shortages of scientists. Back in 1945, Vannevar Bush[3], Director of the US Office of Scientific Research and Development, warned that: "there is thus an accumulating deficit of trained research personnel which will continue for many years. The deficit of science and technology students who, but for the war, would have received bachelor's degrees is about 150 000. The deficit of those holding advanced degrees […] has been estimated as amounting to about 17 000 by 1955 in chemistry, engineering, geology, mathematics, physics, psychology, and the biological sciences. With mounting demands for scientists both for teaching and for research, we will enter the post-war period with a serious deficit in our trained scientific personnel." More recently, in 1989, the US National Science Foundation warned that, by 2006, America's production of scientific skills at university level would fall short by hundreds of thousands. Currently, some voices raise doubts on the feasibility of the Barcelona objective by lack of skills available in the European economies.

What could be the implications of the Barcelona objective in terms of the main economic variables for Belgium and the EU? What are the needs for human capital

1. The yearly gap between European and American R&D expenditure reached more than 120 billion euro in 2000, 80% of which was due to lower R&D investment by firms in Europe. There is an even wider gap between the EU and Japan in terms of R&D intensity, since Japan devotes 3% of its GDP to R&D, as underlined by the Commission in its communication "More research for Europe Towards 3% of GDP", September 2002.
2. Cervantes (2003).
3. Bush (1945).

to reach this objective? How are these needs covered by the current trends in the supply of qualified labour in Belgium? These are the main questions analysed by this working paper. Therefore, this paper constitutes a new step in the better understanding of the innovation process, after the working papers devoted to the theoretical impacts of innovation[4], the description of the innovation system[5] and the sectoral and regional innovation indicators[6].

After a brief overview of the theoretical links between R&D, innovation and productivity in the second section, the consequences of the increase in R&D efforts on competitiveness, employment, growth and public finances are quantified by using the study of Erasme and the CCIP with the macroeconomic European model NEMESIS in the third section. The main advantage of this model is that it takes into account the positive externalities of the R&D expenditure made abroad on the Belgian economy. The fourth section is devoted to an accounting exercise designed to translate the objective of 3% of GDP by 2010 in the number of scientists and other persons active in R&D and to compare these needs to the potential supply of qualified labour force by the Belgian educational system. Finally, the last section concludes and underlines the challenges in terms of economic policy.

4. Kegels, van Overbeke and Van Zandweghe (2002).
5. van Overbeke (2001).
6. Biatour (2004) and Fiers (2005).

II Links between R&D, innovation, productivity and growth

The growth rate of an economy can result from growth of labour utilisation and growth of labour productivity. Under the assumptions of the growth accounting theory, it is possible to identify three main sources of labour productivity gains: capital deepening (growth of the capital/labour ratio), the improvement in labour quality and total factor productivity (TFP) growth. TFP growth reflects greater overall efficiency in the use of labour and capital due to innovation. Empirically, in the absence of perfect statistical measures of the capital stock and the labour force qualifications, TFP also includes quality improvement of capital and labour as well as the other measurement errors.

Innovation is widely recognized as a major source of long run economic growth. Different types of innovations exist, which can have an effect on economic performance in several ways:

- Technological process innovation, which corresponds, according to the OSLO Manual[7], to the adoption of technologically new or significantly improved production methods, including methods of product delivery. These methods may involve changes in equipment or production organisation, or a combination of these changes, and may be derived from the use of new knowledge.
- Technological product innovation, which comprises technologically new and improved products.
- Organisational innovation, which consists in the introduction of significantly changed organisational structures, the implementation of advanced management techniques and the implementation of new or substantially changed corporate strategic orientations.

Innovations introduced in the production process or in the organisation (disembodied technological progress) will generate economic growth mainly by their effect on TFP growth. Technological innovations can also be incorporated in the production factors (embodied technological progress) and generate a productivity growth. On the other hand, product innovations will generate a growth of demand. In the absence of hedonic price indices, the effect of improvement of quality products is not statistically measurable. Transmission of innovation in economic performance is far from immediate and expected positive effects on economic growth are rarely observed in the short term.

7. This OECD Manual is the foremost international source of guidelines for the collection and use of data on innovation activities in industry.

Innovation is therefore a broad concept, which largely depends on the level of R&D activities, even if R&D is not the only source of innovation[8]. R&D expenditure is frequently used as a measure of innovative capability because it is more easily measurable. Many authors have empirically proved the existence of a strong relation between R&D and output or productivity growth. In summary, Nadiri (1993) suggested that the output elasticity of R&D is situated between 10% and 30% at the firm level and between 8% and 30% at the industry level. In their more recent survey, Mohen and Mairesse (1999) situated the elasticity of R&D at a firm level between 5% and 30%.

Research performed in a sector or in a firm has an impact not only on the sector or firm's productivity and output, but also on those of other sectors. This existence of R&D externalities is widely recognized in the literature and is based on the quasi-public good character of technological knowledge[9]. Griliches (1979) distinguished two categories of externalities or spillovers: rent spillovers and knowledge spillovers. The first category arises when inputs are purchased at a price that does not totally reflect the quality improvements included in the inputs, preventing the complete appropriation of the innovation rent by the innovator. This situation is due to the fact that the innovator cannot exercise perfect price discrimination. The productivity gains are then passed on to the sector using the input. Therefore, this kind of spillovers is always embodied in economic transactions, such as the purchase of investment goods, intermediate inputs or patents (Van Pottelsberghe, 1997).

The second category of spillovers -knowledge spillovers- results from a transfer of knowledge from a firm or a sector to another, by the diffusion and circulation of ideas and concepts. Poor patent protection, inability to keep innovations secret, reverse engineering[10], technical meeting and mobility of (R&D) personnel (Levin et al., 1987) are possible channels of knowledge spillovers. Those spillovers are not necessarily related to economic transactions, since it is possible that two industries that do not buy much from each other, but that are working on similar fields, benefit from each other's research. However, it is assumed that the existence of knowledge spillovers is closely related to the 'technological proximity' between industries (Griliches, 1992).

These externalities are not limited to domestic borders. Due to the globalisation, the international diffusion and absorption of knowledge have become recurring and increasing characteristics of the world economy. The literature on international R&D spillovers usually finds empirical evidence of the effects of international knowledge diffusion on productivity growth. Although only a small part of research is done at the industry level, Verspagen (1997), Vuori (1997), Jacobs et al. (2002) and Frantzen (2002) found evidence of international R&D spillovers at sector-level, by using a trade related weighting matrix. Van Pottelsberghe and Guellec (2001) also showed significant international R&D spillovers, with foreign R&D stocks based on a patent proximity matrix. As shown by Coe and Helpman (1995) and confirmed by many others, the more open an economy is to international trade, the stronger effect on domestic productivity the

8. This is particularly true for the service activies in which innovation is not only generated by R&D personnel but also by commercial staff.
9. Knowledge is a non-rival good (consumption does not reduce the available quantity) and a partially non-excludable good (it is partially impossible to exclude others from the consumption of the good).
10. Reverse engineering is the process of recreating a design by analysing a final product and its components.

foreign R&D is supposed to have. Coe and Helpman (1995) obtained for Belgium an elasticity of total factor productivity with respect to foreign R&D of 0.26 for 1990 (with a sample of 21 countries of OECD and Israel). No other OECD country from this study showed a higher TFP elasticity with regard to its foreign R&D stock.

Due to the existence of R&D externalities, the private rate of return to research is below the social rate of return that reflects the total benefits from R&D, including the indirect effect on other industries. This means that the investments made by individual firms do not allow to reach the socially optimal level of investments. This potential underinvestment problem justifies the intervention of government[11]. Public authorities can stimulate business R&D with the help of two main policy instruments: direct subsidies and fiscal incentives. They can also develop incentives to promote collective research activities, which would allow participants to take externalities into account. Summarizing several econometric studies, Mohnen (1996)[12] estimates that the social rate of return to R&D exceeds private rate of return by 50 to 100% on average.

11. Traditionally, government intervention is also justified by a second market failure: the high degree of risk embodied in R&D activities which makes external financing more difficult to obtain.
12. Cited in Le Bas C., van Pottelsberghe de la Potterie B. (2002).

III Economic impact in Belgium and Europe of investing 3% of GDP in R&D - Case study with the NEMESIS model

With the NEMESIS model, a "3% scenario" that meets the Barcelona requirements is built. This scenario is then compared to a baseline scenario that is computed by prolonging the trend observable "before Barcelona". This comparison allows us to analyse the consequences of innovation on competitiveness, employment, growth and international trade in Belgium and in Europe.

A. Methodological framework

NEMESIS is a macroeconometric model[13] covering 30 sectors in 16 European countries[14]. It is particularly well suited for studying the impact of the 3% objective for R&D as, contrary to many other applied models, technical progress is endogenous. Indeed, inside NEMESIS, R&D expenditure is interdependent between sectors and increases the stock of the variable called "knowledge". The stock of knowledge gives rise to innovations that can be of two types: process innovations or product innovations[15]. Process innovations result in higher productivity, while product innovations result in a better product quality. Both kinds of innovations generate an improvement of firms' economic performance and therefore create more profit. By this process, firms are incited to undertake R&D expenditure.

The sectoral dimension of the model is also important for two reasons. First, research intensity is very unequally spread over the different sectors. Secondly, the reaction to an increase in R&D will be different according to the nature of the sector[16].

Although NEMESIS has many advantages for this study, the fact that the model does not include any financial coverage, such as an endogenous exchange rate or interest rate, is a drawback. For example, a change in the structure of trade between Europe and the rest of the world would probably imply a shock in the exchange rate evolution. Or inside Europe, any shift in the inflation rate usually

13. More details about the model can be found on the Nemesis website: http://www.nemesis-model.net.
14. EU15 plus Norway.
15. Although the model takes into account innovation, it does not include "organisational innovation". It may therefore underestimate innovation, mainly in services sectors.
16. As we will see below, even if they have the same initial intensity of R&D, two sectors will not respond in the same way to an increase in research. For example, the impact will be different for consumption or investment sectors.

implies changes in interest rates. Because of this lack of financial coverage, those mechanisms and their impact on other variables are not taken into account in the model.

Since the 3% scenario is compared to a baseline scenario[17], the assertions hereafter are an answer to the question of what will change if we achieve the 3% objective in 2010. Numbers given hereafter must therefore be interpreted as the difference between the two scenarios.

1. R&D assumptions

The Barcelona objective consists in reaching, on average in Europe, an investment level in R&D equivalent to 3% of GDP in 2010. In the model, this goal is translated with different constraints. First, the average intensity of 3% must be reached in 2010, which is the primary objective. Moreover, it seems plausible that this increase will not be done in one step and that countries will start their effort now in order to achieve the objective by 2010. It is thus imposed that R&D intensity increases linearly in every country from 2002 and until Europe reaches an average of 3% in 2010. Another assumption concerns the extent of the effort for each country. There are great differences in the current level of investment in research between southern and northern countries of Europe, the latter investing more in research. However, the Lisbon Council set as an objective to make the whole of Europe more competitive. Every country should therefore participate in this common effort. To translate this fact, in addition to the 3% target, a relative convergence objective is set: southern countries like Greece (lowest R&D intensity with 0.67% of GDP in 2000) will slowly catch up with countries like Sweden (higher intensity with 4.27% in 2001) but if the average R&D intensity will be 3%, all countries will not be at the same level in 2010. However, the initial level of R&D in Belgium[18] is such that, in this scenario, Belgian R&D intensity reaches 3% in 2010.

The scenario also takes into account the period after 2010. We assumed indeed that after reaching the level of 3%, other targets are set for 2030 and for 2050 at 3.5 and 4% respectively. In fact, through those new targets, it is implicitly assumed that once research starts producing its positive effects, a dynamic is created: the need for raising R&D intensity becomes increasingly recognised and firms invest more by themselves.

The 3.5% intensity on average in Europe is therefore assumed for 2030 but with more convergence than in 2010[19]. Finally, in 2050, it is assumed that all countries reach the intensity of 4% (absolute convergence).

17. In the baseline scenario, the R&D intensity is assumed to be constant.
18. For Belgium, in the model, R&D starts from a non-updated intensity of 1.82% in 2002 rather than the current official intensity of 2.17%.
19. Since convergence in 2030 is still relative, European countries do not have the same R&D intensity. Belgium reaches an intensity of 3.53%.

2. Other assumptions

The other main assumptions of this scenario are the following:

- Based on recent literature, the elasticity of the knowledge stock on economic performance, usually called β, is calibrated at 0.075 in 2002[20]. According to the learning-by-doing theory, the impact of R&D, and therefore of knowledge, on economic performance becomes bigger as research increases. As a consequence, after the simulation of this scenario, β reaches gradually 0.124 in 2030 for Europe as a whole. However, this elasticity is different for every country according to its own characteristics.
- A higher R&D intensity will probably generate higher productivity gains. Those gains will in turn create more value added that can be shared between enterprises and workers. We make the assumption that one third of the productivity gains are redistributed to workers and that the rest is kept by the firms.
- R&D financing: on average in Europe, almost the whole increase in R&D effort is realised by the private sector and only 0.16% of the supplementary effort is financed by the public sector. This assumption is made in order to meet the goal of two thirds of the total European R&D expenditure financed by the private sector. However, in Belgium, public and private sectors have roughly the same effort to make since nearly 2/3 of R&D is financed by the private sector.
- Implementation of R&D: 70% of the supplementary effort of R&D is realised by the private sector and the 30% remaining are made by the public sector.
- A possible way of increasing R&D investment would be to raise public orders of R&D intensive goods to private firms. However, in the scenario presented here, the R&D targets are met without any supplementary public order.

Some of these assumptions, like the value of β or the redistribution of productivity gains, may be subject to discussion. Therefore, a sensitivity study that modifies some parameters of the model is carried out in part D.

B. Impact in Belgium

1. At the macroeconomic level

a. First stage: moderate effect due to external deficit[21]

During a first stage that lasts until about 2010, the supplementary growth in Belgium matches the growth of R&D expenditure. The macroeconomic impact is shown in Figure 1. R&D intensity has increased from 1.82% in 2002 to 3% in 2010 while GDP is 1.17% higher than in the baseline. It thus corresponds to a unit

20. Econometric studies such as Mohnen (1990), Mairesse and Sassenou (1991), Griliches (1992), Nadiri (1993) or Cameron (1998) suggest a range from about 0.05 to 0.2 for the value of β.
21. Please note that, as described by the assumptions, the results that are mentioned below are in case Europe as a whole reaches the 3% objective, and not only Belgium.

multiplier of R&D on GDP, meaning that one percent of GDP spent on R&D increases GDP by 1%. In fact, the expansionary impact of increased R&D expenditure is offset by two phenomena, which explain this low value. First, during this period, maturation lags, which are about 3 years for private research and about 5 years for public research, are such that productivity increases to a very small extent: total factor productivity only increases by 0.73%. Secondly, the bad results of foreign trade before 2010, as explained below, prevent GDP from growing faster than R&D expenditure.

Nevertheless, the higher GDP generates a rise in employment and real income. Employment rises by 1.15% and real disposable income by 2.33%. Until 2009, the raise in employment is higher than the increase in GDP, which may seem curious from a macroeconomic point of view[22]. In the scenario, this phenomenon can be explained by the fact that expenditure in R&D consists to a large extent in human resources.

Moreover, every component of domestic demand increases. In particular, the rise of consumption by 1.92% in 2010, and which is due to a better employment situation and higher real incomes, plays an important role. Total investment also increases by 1.65%.

Concerning price evolution, it is different from a classical Keynesian expansionary policy in which states raise their expenditure to boost the economy. In our scenario, enterprises need to increase their prices in order to finance their additional R&D. As a consequence, inflation becomes higher than in the case of a simple expansionary public policy. There are therefore two causes for the higher inflation: higher demand and the financing method of R&D. However, from 2009 onwards, productivity gains start offsetting the cost of R&D and prices decrease.

During this first period, the higher demand, together with the price increase, worsens Belgium's global foreign trade balance: extra-European exports decrease by 0.29% in 2010 while extra-European imports increase by 1.55%. Nevertheless, the case of intra-European trade is different: since Belgium already has a higher research intensity than Europe as a whole, it has less efforts to make to increase R&D, and inflation increases less in Belgium. Consequently, Belgium improves its intra-European position until 2010[23]. However, the improvement inside Europe is smaller than the deficit of extra-European trade and in total, Belgium's global trade balance worsens.

b. Stage 2: higher growth due to innovation

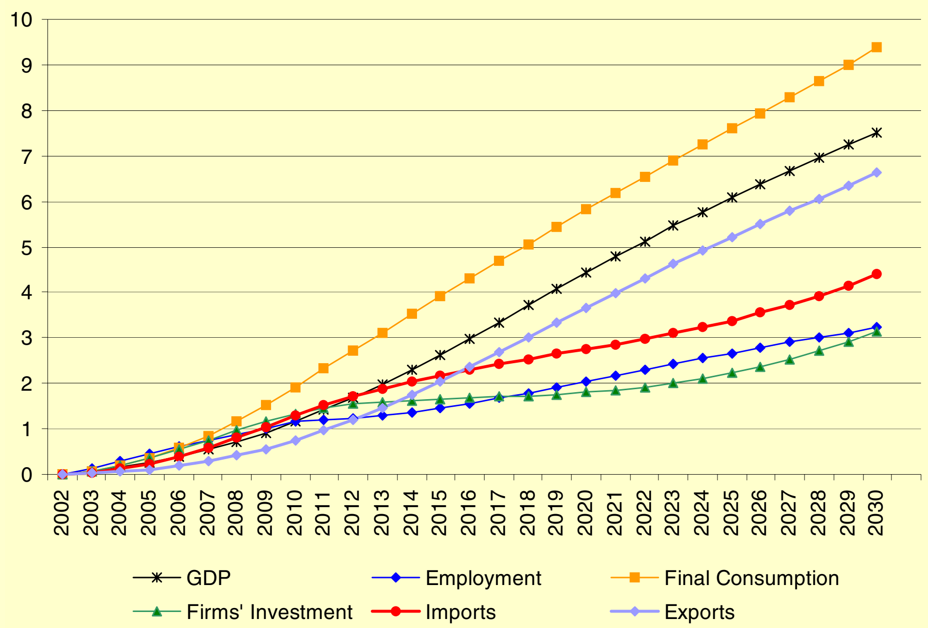
Beyond 2010, R&D will fully produce its impact on the two kinds of innovation: total factor productivity, that was higher by 0.73% in 2010, grows by 5.47% in 2030 while product quality improvement goes from 1.74% in 2010 to 9.53% in 2030. Growth is now pushed forward thanks to lower costs (and thus lower prices) and better quality. Despite slight inflationary pressures due to limitation of the labour force at the end of the simulation period, GDP rises by 7.52% in 2030. The multiplier of R&D on GDP is now equal to 4.3. Furthermore, this increase is based on value added but does not include the welfare improvement of consumers due to the better product quality. The increase in demand is mainly driven by two

22. Usually, employment follows GDP with a certain lag.
23. Belgian intra-European imports increase but intra-European exports increase to a larger extent.

components: consumption and foreign trade. Consumption goes up (by 9.38% in 2030) because prices are lower but also thanks to the better quality. Indeed, in the model, a price decrease based only on higher productivity would not have been sufficient to push the growth up.

On the other hand, business investment rises at a much lower pace (3.13% in 2030) because of productivity gains.

FIGURE 1 - Macroeconomic impact in Belgium of increasing R&D intensity in Europe to 3% in 2010 and to 3.5% in 2030[a]



a. In % deviation w.r.t. the baseline.

Moreover, and contrary to the first stage, the foreign trade balance for Belgium fully benefits from productivity gains and improves to a large extent. In fact, the situation is the opposite of the one at the first stage. Productivity increases compared to non-European countries and thus, the extra-European trade situation improves. However, after 2010, since the average European countries have invested more in R&D than Belgium, productivity gains are also higher in those countries and as a consequence, Belgium's competitiveness and intra-European trade deteriorate. However, in fine, the global situation of foreign trade improves in Belgium.

In the same way, employment only increases by 3.23%, which is much lower than the GDP growth of more than 7%. In fact, this negative aspect is due to the impact of R&D. Indeed, R&D improves labour productivity by 5.21% and thus, higher production is not completely reflected in higher labour demand. Moreover, newly created employment stands mainly in R&D.

TABLE 1 - Main macroeconomic results for Belgium

	2010	2030
GDP	+1.17%	+7.52%
Total Employment	+41 000	+155 000
Final Consumption	+1.92%	+9.38%
Total Investment	+1.65%	+2.97%
Imports	+1.29%	+4.39%
Exports	+0.75%	+6.62%
Total Factor Productivity	+0.73%	+5.47%
Consumption Prices	+0.43%	-13.06%

Employment is in number of jobs and budget balance is in GDP percentage points.

Results are given in % deviation w.r.t. the baseline.

2. At the sectoral level: transformation of the industrial structure

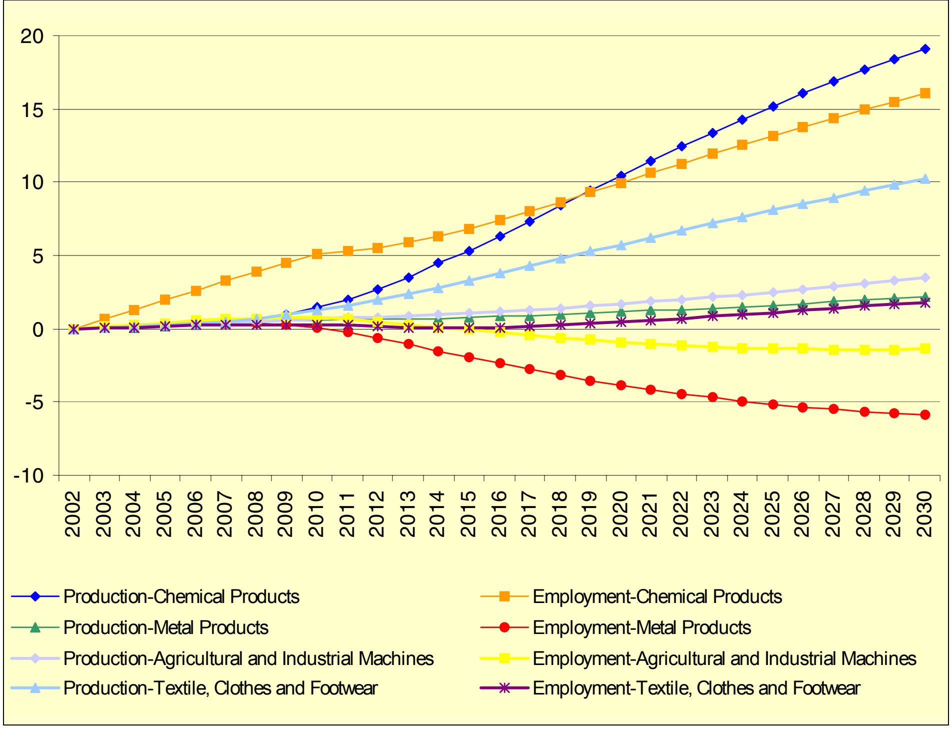
The 3% policy in Europe will considerably change the way the different production sectors contribute to Belgian economic growth. From a "consequences" point of view, four groups of sectors could be distinguished: intensive R&D sectors, intermediary goods sectors, investment goods sectors and consumption goods and services sectors. Figure 2 shows the behaviour of one representative sector for each group.

- Intensive R&D sectors[24]: except for Transport equipment, every Belgian sector of this group experiences a relatively strong growth. For example, by 2030, Chemical production rises by 19% and Electrical goods[25] production increases by 14.67%. On the other hand, employment grows, but at a much lower speed because of the productivity gains due to R&D (16.03% for chemical products and 4.33% only for electrical goods). Product quality improves and market shares increase.
- Intermediary goods sectors[26]: improvement of total factor productivity of the client-sectors has a negative effect on the demand for this type of products. Furthermore, the relatively low content of R&D in intermediary goods only leads to a moderate price decrease and a small quality improvement. As a consequence, demand for intermediary goods is weak, production rises slowly and employment decreases.
- Other investment goods sectors[27]: because of the poor intensity of R&D in those sectors, productivity and quality gains are limited and thus, as for intermediary goods sectors, investment goods sectors do not increase as much on average as other sectors. For example, production of Agricultural and industrial machines only increases by 3.45% in 2030 while employment decreases compared to the baseline.
- Consumption goods and services sectors[28]: those sectors benefit at the same time from the increase in the R&D effort, from higher real wages and

24. Chemical products, Office machines, Electrical goods and Transport equipment.
25. Electrical goods are electric motors, generators and transformers, electricity distribution and control apparatus, insulated wire and cable, accumulators, primary cells and primary batteries, electric lamps and lighting equipment and other electric equipment.
26. Ferrous and non-ferrous metals, Non-metallic mineral products, Metal products, and Rubber and plastic.
27. Investment goods that are not included anywhere else, in other words, Agricultural and industrial machines, Other manufactures and Construction.
28. Food, drink and tobacco, Textiles, clothes and footwear, Paper and printing products, Lodging and catering and transport services.

more generally, from higher household purchasing power and from the quality effect. Consumption is therefore one of the main components of the faster growth in Belgium, but also in the rest of Europe. Many sectors raise their production by more than 7%, while some sectors such as Textile and Lodging and catering even increase their production by more than 10%. Employment is also pushed up, particularly in the transport sector, with for example a 6.4% increase in Air and sea transport.

FIGURE 2 - Production and Employment in some representative sectors for Belgium in % deviation w.r.t the baseline



C. Results for Europe

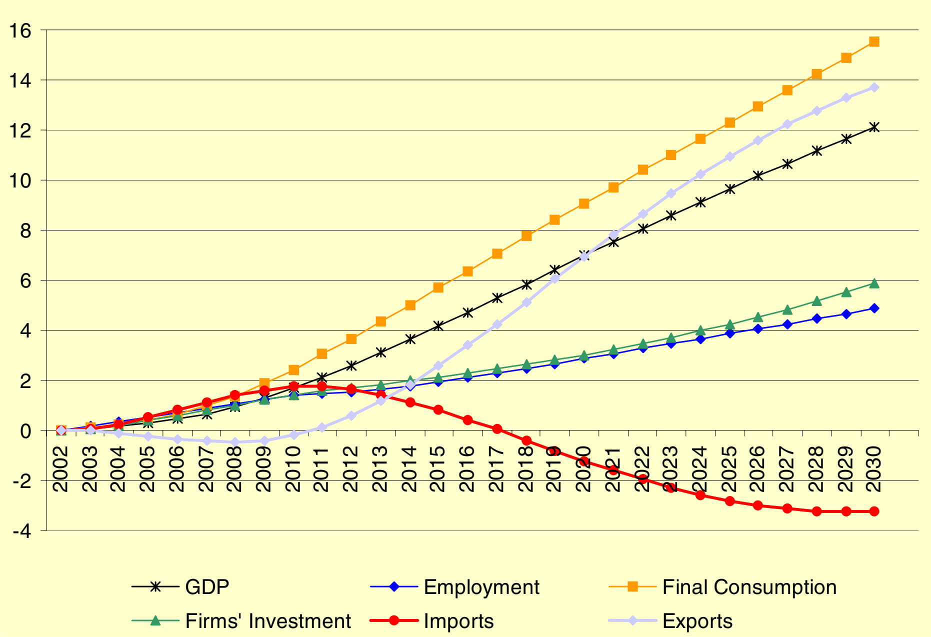
1. At the macroeconomic level

Overall, mechanisms are the same for every European country as for Belgium. Even if there are differences between countries because of their own characteristics, the more efforts countries have to make, the bigger the impact on the economy. The extent of the efforts will determine which countries become more or less competitive compared to the other European countries. As on average Europe currently has a slightly lower R&D intensity than Belgium, the efforts to make until 2010 and even until 2030 are therefore a little bigger than for Belgium, and the impact will be bigger.

At the beginning of the simulation period, the expenditure will be more important for countries that have low R&D levels such as Greece, Italy, Portugal or Spain. As a consequence, those countries will have a faster GDP growth but, as already explained, because of the increasing price level, they will also lose competitiveness compared to the countries that have little efforts to make. In a second stage, when R&D will have produced its effect on productivity, competitiveness will improve relatively more and finally, countries with a low level of R&D at the beginning will catch up the best countries like Sweden, Finland, Denmark or Germany.

Concerning Europe as a whole, GDP rises by 1.70% in 2010, mainly due to the Keynesian multiplier effect of higher R&D expenditure[29]. After 2010, productivity gains become significant and in 2030, production is increased by 12.14%. The positive effect of one percent of GDP spent on R&D is therefore equal to 1.5% of GDP in 2010 but to 7.4% in 2030[30]. In the same way, employment gains 1.39% in 2010 and 4.87% in 2030. At first, investment in R&D has an inflationary impact through its cost included in the prices, the higher pressure on the labour market and the higher demand. Inflation worsens price competitiveness in Europe with respect to the rest of the world. Indeed, Figure 3 shows that exports are below the baseline until 2011, while imports are higher until 2017. Nevertheless, as in Belgium, once R&D produces its effect, competitiveness improves, exports go up and imports fall relatively to the baseline, despite the higher European demand that grows by more than 20%.

FIGURE 3 - GDP and its components in Europe in % deviation w.r.t the baseline



29. This effect was cancelled in Belgium because of its high degree of openness and the bad results of the trade balance, but for Europe, trade balance has less impact and the multiplier effect is less affected.
30. For comparison, the European Union Economic Review 2003 estimates the multiplier of R&D at 9.1 after 10 years and 17.7 in the long run.

TABLE 2 - Main macroeconomic results for some European countries and Europe

	R&D expenditure	GDP	Total Employ-ment	Final Consumption	Total Investment	Imports	Exports	TFP	Consumption Prices
2010									
Sweden	+11.89%	+0.79%	+0.31%	+1.10%	+0.73%	+0.64%	+0.71%	+0.37%	+0.51%
Belgium	+70.16%	+1.17%	+1.15%	+1.92%	+1.65%	+1.29%	+0.75%	+0.73%	+0.43%
France	+47.69%	+1.18%	+1.25%	+1.62%	+2.23%	+1.64%	+0.65%	+0.63%	+0.94%
Greece	+389.08%	+6.26%	+3.10%	+8.29%	+4.23%	+3.52%	+0.22%	+2.71%	-0.77%*
Europe	+72.30%	+1.70%	+1.39%	+2.44%	+1.83%	+1.74%	-0.20%	+0.80%	+0.44%
2030									
Sweden	+11.43%	+3.67%	+1.24%	+3.64%	+1.54%	+4.25%	+6.95%	+2.19%	-10.67%
Belgium	+115.51%	+7.52%	+3.23%	+9.38%	+2.97%	+4.39%	+6.62%	+5.47%	-13.06%
France	+75.76%	+7.06%	+2.86%	+8.85%	+5.91%	+5.51%	+10.70%	+3.53%	-13.66%
Greece	+852.51%	+49.84%	+15.49%	+62.74%	+24.06%	+16.58%	+18.47%	+15.84%	-30.61%
Europe	+122.97%	+12.14%	+4.87%	+15.53%	+6.87%	-3.22%	+13.72%	+5.00%	-16.17%

*: this number may seem contrary to what we said; in fact, prices start decreasing earlier (in 2009) in Greece than in the other countries.
Results are given in % deviation w.r.t. the baseline.

2. At the sectoral level

At the sectoral level, every country will improve its competitiveness towards the rest of the world. However, inside Europe, countries that already have a good R&D level, like Sweden (or Belgium to a lesser extent) will see their competitiveness deteriorate.

Production of sectors with a high degree of R&D will particularly depend on their research effort compared to the effort made by sectors from other European countries. Production rises in every country but with the smallest scope in Sweden, Finland, Denmark or Germany. On the other hand, production rises much more in Greece, Italy, Portugal or Spain, where R&D increases relatively the most. This evolution might be illustrated by the Electrical goods sectors. Production of this sector remains almost unchanged in Sweden (+0.3% in 2030) while it increases by 28.7% in Greece[31]. Other sectors with a high level of R&D have a similar evolution. However, at the national as well as at the European level, productivity gains prevent employment from growing as much as production.

31. For Belgium, increase is about 15%.

FIGURE 4 - Sectoral comparison in Europe in 2030: production and employment in % deviation w.r.t the baseline[a]

a. Graph for Belgium, The Netherlands and Germany can be found in annex A.

For intermediary goods and investment goods sectors, which are illustrated respectively by Ferrous and non-ferrous metals, and by Agricultural and industrial machines, the mechanism is the same as the one explained for Belgium. Internal demand decreases because, in general, innovation is insufficient to compensate for competitiveness gains from the client-sectors and to significantly increase the level of production and employment. Furthermore, some countries which improve their competitiveness relatively less, lose market shares in Europe. These market losses are not always fully compensated for by the increase in competitiveness outside of Europe. In those countries, the structure of foreign trade by zone (intra and extra-European) will lead the evolution of the trade balance of every intermediary goods and investment goods sector. On the other hand, countries with a low initial R&D level that improve competitiveness to a larger extent, manage to develop production and employment.

Among the non-intensive R&D sectors, consumption goods and services sectors are the ones that improve their relative situation most. Those sectors benefit from higher household wages that result from, on the one hand, the better economic growth and, on the other hand, the redistribution to the employees of one third of productivity gains. However, for this type of goods, illustrated by the Textile, clothing and footwear sector, the extent of the impact depends more on the evolution of households' purchasing power than on sectoral and national productivity gains.

D. Sensitivity of the results to different assumptions

As we said before, some of the assumptions that were made in the scenario, like the value of β or the redistribution of productivity gains, may be subject to discussion. In order to see how the model behaves with different parameters for those variables, six other scenarios have been simulated. These scenarios and their results are detailed in annex B. To summarize, increasing the elasticity of the knowledge stock on the economic performance implies a bigger impact of R&D on production than in the initial scenario. Therefore, R&D intensive sectors gain more competitiveness and finally, production and employment are also higher[32]. If the elasticity is decreased, the opposite result is obtained.

When productivity gains are not redistributed to workers, GDP and employment are higher than in the initial scenario, where a third of productivity gains are distributed. Although household demand is weaker, this negative demand effect is compensated for by higher competitiveness gains and by a substitution effect in favour of labour.

When R&D is financed by the public sector, GDP growth is higher thanks to a lower inflationary impact. However, this result is quite limited since the model does not include the negative impact of budget deficit on interest rates and economic agents' behaviour. Public orders of R&D intensive goods also have a more positive impact than the initial scenario. Nevertheless, it is not possible to reach the 3% threshold with public orders only and, as a consequence, the private sector still has to finance 2/3 of the supplementary effort.

32. Employment is higher than in the initial 3% scenario thanks to higher growth, however, to a lower extent than production because of productivity gains.

IV Feasibility of the Barcelona objective in Belgium

After the economic impact assessment of the 3% policy, this section is devoted to analysing the needs for financial and human resources in Belgium in order to reach the Barcelona objective. The political measures to achieve this objective are, however not analysed. The study covers the national as well as the regional level in case of a static approach without a policy change.

A. Current situation of R&D in Belgium

Most Member States have decided to reach the Barcelona objective at the national level. It is the case of Belgium, which adopted the 3% objective in July 2003[33].

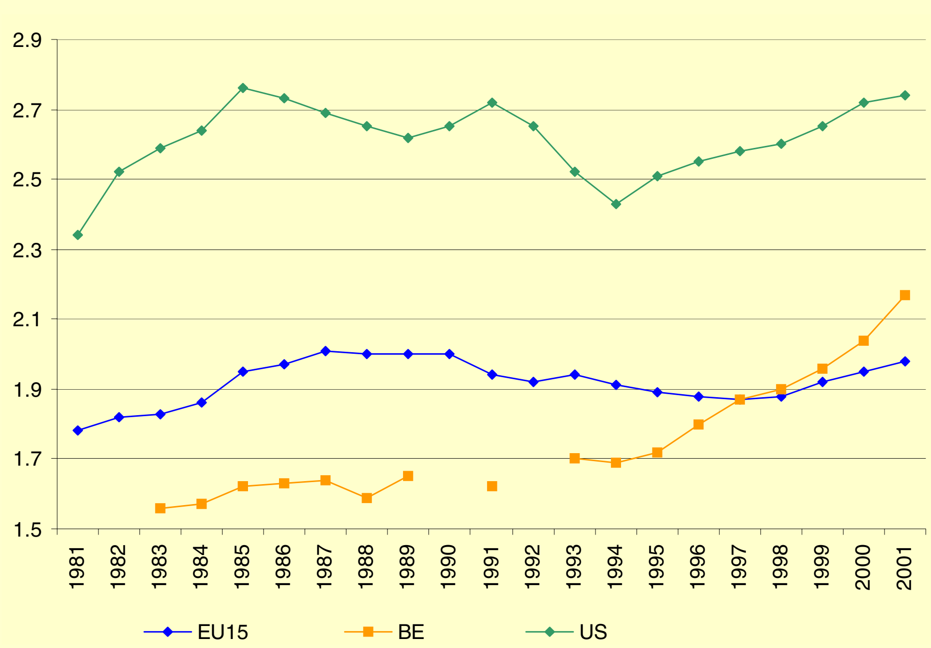
In Belgium, in 2001, R&D expenditure reached 2.17% of GDP, which is above the European average (1.98% in EU15) and above nine of the other Member States of the EU15. However, this expenditure is lower than the expenditure of the United States (2.74% of GDP), Sweden (4.27%), Finland (3.40%), Germany (2.51%), Denmark (2.40%) and France (2.23%).

Since 1995, R&D investment in Belgium has strongly grown (growth of 0.45 percentage points during the 1995-2001 period against 0.09 in the EU15 and 0.23 in the US). It has increased each year by a number of percentage points higher than in the EU15 and the US (Figure 5). This growth allowed Belgium to make up for lost time compared to the European average and to do better since 1998. In 2000 and 2001, efforts in Belgium became even more intense.

Among countries reaching a high level of R&D in 2001 (higher than the European average), Denmark, Finland and Sweden have also known, during recent years, a strong growth of their R&D expenditure in percentage of GDP. In addition, as already mentioned, Finland and Sweden have already passed the 3% threshold. On the other hand, in France, with a level close to that of Belgium, R&D expenditure in percentage of GDP has shown a downward trend, these last eight years.

33. Governmental declaration and agreement (2003).

FIGURE 5 - Evolution of R&D expenditure in Belgium, EU15 and US, as % of GDP



Source: Eurostat - R&D statistics (October 2004).

Since 1980, subsequent institutional reforms have given the primary jurisdiction over scientific research, education and innovation to Belgium's Communities and Regions. Federal authorities nevertheless still hold some competences, such as the fiscal incentives for R&D. According to the last available data on R&D expenditure, regional differences are considerable in Belgium. In 2001, the R&D investment level as a percentage of GDP reaches approximately 1.29%, 2.49% and 2.11% in the Brussels-Capital Region, the Flemish Region and the Walloon Region respectively. During recent years, the different regional public authorities in Belgium have put in place various policy measures to increase R&D efforts in line with the Barcelona objective[34].

B. Methodological framework

To judge the feasibility of the Barcelona objective in Belgium, it is necessary to evaluate the financial resources in millions of euros and the human resources in full time equivalents to be reached in 2010. This evaluation is realised by using the economic forecasts for 2010 obtained with the HERMES model, which has developed by the Federal Planning Bureau. HERMES is a macrosectoral model aimed to establish medium-term projections for the Belgian economy. The advantage of this model, compared to NEMESIS used in the previous section, is that HERMES is totally adapted to the characteristics of the Belgian economy, frequently updated to take into account most recent statistical information and used to provide several official reports[35]. However, using HERMES has the

34. Regional Development Plan - Priority 12 (Brussels-Capital Region, 2001), Flemish Innovation Pact (Flemish Community, 2003), Future Contract for Wallonia - updated version (Region of Wallonia, 2002), Future Charter for the Wallonia-Brussels Community (French-speaking Community, 2002).
35. Federal Planning Bureau (2004).

drawback that the effects on GDP of the increase in growth of R&D expenditure needed to reach targeted 3% in Belgium and in the other countries during the 2001-2010 period, are not taken into account. Therefore, this exercise amounts to a static approach, with no policy change.

From the GDP forecast at current prices for 2010, the necessary monetary level of R&D expenditure to reach the 3% objective is calculated. This total level of R&D expenditure is then used to deduce the volume of human resources that should be necessary in the R&D activities in 2010.

The evaluation of data at current prices is preferable since the objective and R&D data are established at current prices.

In order to judge the importance of the effort, the growth in R&D expenditure and R&D personnel to realise on the 2001-2010 period will be compared with the performances observed during the 1993-2001 period[36].

C. Needs in financial and human resources to reach the 3% objective in 2010

1. Needs in financial resources

a. Total R&D expenditure

In Belgium, R&D intensity accounted for 2.17% of GDP in 2001, which corresponds to an amount of R&D expenditure of 5 514.5 million euros (current prices). From the economic forecasts obtained with the HERMES model[37], we can evaluate the necessary evolution of the R&D expenditure in euros at current prices to achieve the Barcelona objective. It results that R&D expenditure will have to increase by an annual average rate of 7.7% until 2010 to realise the objective. It will have to reach 10 739.7 million euros in 2010, which corresponds to almost twice the expenditure in 2001.

In nominal terms, the efforts necessary to reach the 3% objective are relatively close to the ones realised on the 1993-2001 period, during which R&D expenditure has grown by 7.2% per year on average. However, the efforts are smaller than the ones observed during the 1995-2001 period, which corresponds to a period of strong growth of R&D expenditure in Belgium (annual average growth of 8.0%).

36. 1993 has been chosen because it is the first year available after the change of methodology to collect R&D data.
37. According to the HERMES model, GDP at current prices has been estimated at 357 990.7 million euros in 2010, which corresponds to an average annual GDP growth rate (in current prices) of 3.9% for the period 2001-2010 (with an average annual growth rate of the GDP deflator of 1.9%), compared to 4.0% annually for the 1993-2001 period (with a GDP deflator of 1.5%).

TABLE 3 - R&D expenditure *(at current prices)*

	1993	2001	2010 Objective
R&D in % of GDP	1.70%	2.17%	3.00%
R&D in million euros	3 154.5	5 514.5	10 739.7

Source: Belgian Federal Science Policy Office (2004), own calculations.

b. R&D expenditure by source of funds, by sector of performance and by economic activity

R&D expenditure can be divided by source of funds: Business enterprises, Government, Private non-profit sector, Higher education sector and Abroad. In Belgium, Business enterprises financed 64.3% of the total R&D expenditure in 2001, which is slightly below the two-third objective set for 2010 at the Barcelona Council, but considerably above the European average. Foreign funds play also an important role in the financing of the Belgian expenditure. Consequently, the share financed by the public authorities is lower than in the majority of Member States.

In Table 4, the R&D expenditure estimated for 2010 is divided between the different sources of funds. It rests on the assumption that Business enterprises finance 2/3 of the total R&D expenditure and that the other sectors finance the remaining part according to the same distribution as in 2001. It appears that Business enterprises will have to increase their expenditure by 8.1% per year on average while other sectors will have to increase their expenditure by 6.9%. These growth rates are higher than the ones observed during the 1993-2001 period for all the sectors, with the exception of the sector Abroad. Consequently, support from the Government will play an important role to reach the Barcelona objective. In 2001, 19.6% of the total R&D expenditure financed by the Government was devoted to business enterprises as direct financing, 61.5% to higher education sector (direct funds and General University funds) and 18.6% to realise R&D activities in public institutions. Fiscal incentives for R&D are not counted in the total government expenditure.

TABLE 4 - R&D expenditure by source of funds *(current prices)*

	1993		2001		Objective 2010		Average annual growth	
	Million euros	% total	Million euros	% total	Million euros	% total	1993-2001	2001-2010
Business Enterprises	2 097.6	66.50%	3 546.1	64.31%	7 159.8	66.67%	6.78%	8.12%
Government	742.2	23.53%	1 182.2	21.44%	2 150.2	20.02%	5.99%	6.87%
Private non-profit sector	12.6	0.40%	19.8	0.36%	36.0	0.33%	5.81%	6.87%
Higher Education sector	69.1	2.19%	117.0	2.12%	212.8	1.98%	6.81%	6.87%
Abroad	233.0	7.39%	649.4	11.78%	1 181.0	11.00%	13.67%	6.87%
TOTAL	3 154.5	100%	5 514.5	100%	10 739.7	100%	7.23%	7.69%

Source: Belgian Federal Science Policy Office (2004), own calculations.

Total R&D expenditure can also be divided between the four sectors that perform R&D: Business enterprises, Government, Private non-profit sector and Higher education. As in most Members States, Business enterprises perform the largest share of the R&D expenditure in Belgium. This share is higher than the average share performed by enterprises in the EU.

Table 5 provides R&D expenditure by sector of performance for 2010. It is based on the assumption that total R&D expenditure will be distributed in the same way as in 2001. All sectors will have to increase their R&D performance by 7.7% on average per year. This growth is higher than during the 1993-2001 period in the Higher education sector, in the Private non-profit sector and slightly higher than in the Business enterprises sector.

TABLE 5 - R&D expenditure by sector of performance *(current prices)*

	1993		2001		Objective 2010		Average annual growth	
	Million euros	% total	Million euros	% total	Million euros	% total	1993-2001	2001-2010
Business Enterprises	2 260.1	71.65%	4 062.2	73.66%	7 911.4	73.66%	7.60%	7.69%
Government	157.9	5.00%	330.9	6.00%	644.4	6.00%	9.69%	7.69%
Private non-profit sector	44.1	1.40%	61.9	1.12%	120.6	1.12%	4.35%	7.69%
Higher Education sector	692.4	21.95%	1 059.5	19.21%	2 063.3	19.21%	5.46%	7.69%
TOTAL	3 154.5	100%	5 514.5	100%	10 739.7	100%	7.23%	7.69%

Source: Belgian Federal Science Policy Office (2004), own calculations.

Under the assumption that in 2010, Business enterprises R&D expenditure will be distributed between the different activity sectors in the same way as in 2001, the highest levels of expenditure will be reached in the chemical industry (36.8% of total business enterprises expenditure), and more specifically in the pharmaceutical industry, and in the manufacture of electronic equipment (radio, television and communication, 17.5% of business expenditure). R&D expenditure is indeed strongly concentrated in high and medium-high technology manufacturing[38] and in knowledge-intensive high-technology services[39] (72.8% of business expenditure)[40].

38. NACE Rev 1.1 codes 24, 29 to 35 (Eurostat).
39. NACE Rev 1.1 codes 64, 72 and 73 (Eurostat).
40. For more information, see Biatour (2004).

c. R&D expenditure by Region

TABLE 6 - R&D expenditure by Region[41] *(current prices)*

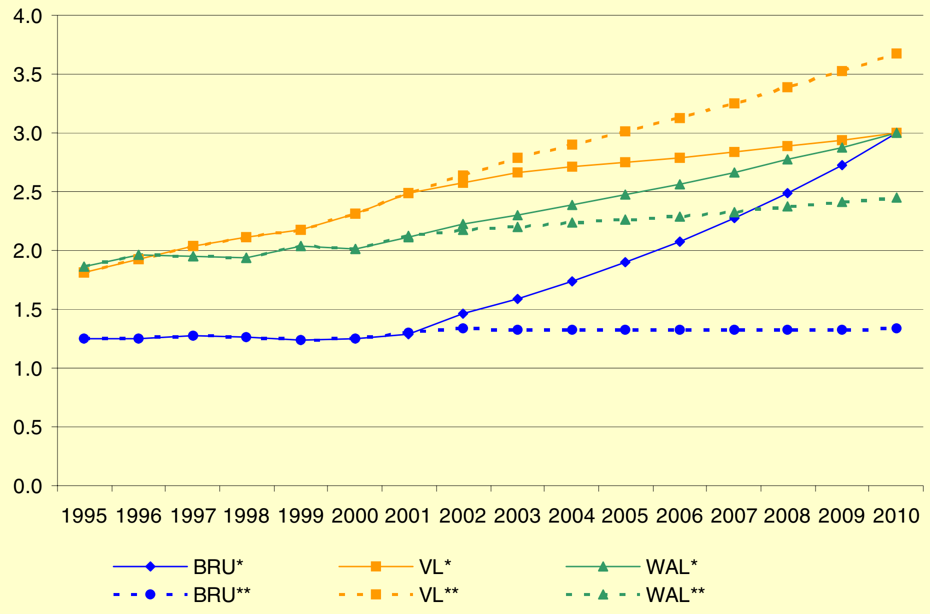
	1993		2001		Objective 2010		Average annual growth	
	Million euros	% of GDP	Million euros	% of GDP	Million euros	% of GDP	1993-2001	2001-2010
Brussels-Capital Region	453	-	629	1.29%	2 041	3.00%	4.19%	13.97%
Flemish Region	1 884	-	3 617	2.49%	6 143	3.00%	8.49%	6.06%
Walloon Region	818	-	1 267	2.11%	2 535	3.00%	5.63%	8.07%
Belgium	3 155	1.7%	5 515	2.17%	10 740	3.00%	7.23%	7.69%

Source: Belgian Federal Science Policy Office (2004), own calculations.

Under the assumption that each Region will meet the 3% target, Belgium as a whole would also reach the Barcelona objective in 2010. But could this objective be reached by each of the three Regions? In view of the annual average growth rates of the previous period (1993-2001), an annual average growth rate of 6.1% and 8.0% respectively between 2001 and 2010 seems to be realistic for both the Flemish and the Walloon Region. However, the estimates in Table 6 show that an R&D-intensity of 3% of GDP by 2010 could be more difficult to reach for the Brussels-Capital Region, since this would require an annual average growth rate of 14.0% until 2010. Indeed, the level of R&D expenditure in Brussels is currently lower than in the two other regions. This situation is mainly explained by the economic structure of Brussels, which is more turned towards the tertiary sector, traditionally less R&D-intensive, and by the presence of many head offices, which perform their R&D in the other regions. BERD[42] and HERD[43] forecasts until 2005, produced by the Belgian Federal Science Policy Office, have also shown that such a growth rate would not be observed in Brussels over the next four years[44]. It is therefore relatively clear, that if the Flemish and Walloon Region will not exceed the 3%-target in 2010, the overall Belgian R&D intensity level will not reach the Barcelona objective. As a consequence, supplementary efforts should be made, both at regional and federal level, to be in line with the European target. Under the assumption that the average annual growth rate of total R&D investments of the previous periods (1993-2001) would also hold between 2001 and 2010, only the Flemish Region would fulfil the 3% objective (Figure 6).

41. Due to the fact that communities are competent for education, no official regional data exist on higher education expenditure in R&D (HERD) in Belgium. As a consequence, the parts of the Brussels' higher education institutions in the HERD of both the Flemish and French-speaking Community have to be estimated. To this end we redistribute those expenditures to the Regions on the basis of the part of the Brussels universities in the R&D-related working budgets of universities. Over the whole period this part is estimated for the Flemish and French-speaking Community respectively at 14% and at 30%. Forecast regional GDP data are obtained by applying the regional shares of total value added, on the national GDP forecast for the period 2003-2010, as given by HERMES. The forecasts of the regional shares in value added originate from a regional module of the HERMES model.
42. Business enterprises R&D expenditure.
43. Higher education R&D expenditure.
44. According to the forecasts of the Federal Science Policy Office, the annual average growth rate, for the BERD and the HERD in the Brussels-Capital Region, which represent approximately 85% of total R&D expenditure, would not exceed 5% until 2005.

FIGURE 6 - R&D-intensity in the Belgian regions in order to meet the 3% target - (% of GDP)



* Under the assumption that the 3% objective will be met by 2010.

** Under the assumption that the annual average growth rates of the previous period (1993-2001) will also hold between 2001 and 2010.

Source: Belgian Federal Science Policy Office (2004), own calculations.

2. Needs in human resources

a. Total R&D personnel

Total R&D expenditure is composed of labour costs, other current expenditure (operating costs) and capital expenditure. In 2001, 56.1% of the total R&D expenditure in Belgium was devoted to labour costs, 33.4% to operating costs and 10.6% to investments. Under the assumption that the distribution of R&D expenditure by type of costs will be the same in 2010 as in 2001, labour costs will amount to 5 935.0 million euros, at current prices, in 2010.

In 2001, total R&D personnel in Belgium amounted to 55 949 full-time equivalents (FTE). This means that the average cost of a person (at full time) belonging to the R&D personnel was 55 260 euros. If the average annual growth rate of the nominal per capita labour cost during the 2001-2010 period, estimated with the HERMES model, is applied[45], an average cost of 72 654 euros per person is obtained for 2010. Then, the number of R&D personnel will reach 82 876 full-time equivalents in 2010, which corresponds to an average annual growth of 4.5% or 2 992 FTE (26 927 additional FTE on the whole period 2001-2010). However, we should bear in mind that in the forecasts, the effect on GDP of an increase in the R&D effort in Belgium and in the other countries, during the 2001-2010 period, is not taken into

45. This rate is estimated at 3.09%.

account. The pressure on the highly-educated labour market is not taken into account either.

The comparison of these results with those observed during the 1993-2001 period seems to suggest that the effort in terms of human capital in order to meet the Barcelona objective is feasible. Indeed, during the 1993-2001 period, R&D personnel increased on average by 5.4% per year or 2 395 FTE. The growth required in absolute terms is higher than the one recorded during the 1993-2001 period, but lower than the one observed during the last three years.

TABLE 7 - Total and average costs of R&D personnel *(current prices)*

	1993	2001	2010 Objective
Costs of R&D personnel (euros million)	1 768.6	3 091.7	6 021.3
R&D personnel (FTE)	36 786	55 949	82 876
Average costs per person (euros)	48 076.0	55 259.7	72 654.1

Source: Belgian Federal Science Policy Office (2004), own calculations.

b. R&D personnel by occupation

R&D personnel is composed of researchers, technicians and other supporting staff. According to the Frascati Manual[46], these three types of personnel can be defined as follows:

- Researchers are "professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned". Researchers are generally expected to have university degrees[47].
- Technicians are "persons whose main tasks require technical knowledge and experience in one or more fields of engineering, physical and life sciences or social sciences and humanities. They participate in R&D by performing scientific and technical tasks involving the application of concepts and operational methods, normally under the supervision of researchers". Technicians generally have diplomas of higher education (non-university level)[48].
- Other supporting staff includes "skilled and unskilled craftsmen, secretarial and clerical staff participating in R&D projects or directly associated with such projects". The majority of the supporting staff has a diploma of secondary education. This category includes also managers and administrators dealing with financial and personnel matters and general administration linked to R&D. These people can have university degrees.

In 2001, 57.6 % of total R&D personnel in Belgium are researchers, 26.9% are technicians and 15.5% are supporting staff. If the distribution of total R&D personnel between the different types of R&D personnel will be the same in 2010[49], we obtain the results presented in Table 8.

46. This OECD manual contains the proposed standard pratice for surveys on research and experimental development.
47. Levels 5A and 6 of ISCED 1997.
48. Level 5B of ISCED 1997.
49. This assumption respects the observed evolution of the proportion of researchers and seems credible for the two other categories.

According to this distribution, the 82 876 full time equivalents constituting the R&D personnel in 2010 will be composed of: 47 751 researchers, 22 275 technicians and 12 850 supporting staff. That means that the number of each type of personnel will have to increase by 4.5% per year on average during the 2001-2010 period. In terms of average annual growth rate, the effort to make during the coming period is less important than the one realised during the previous period for the researchers and for the technicians. In terms of staff, it appears that the number of researchers (in FTE) will have to increase by 1 724 per year on average, the number of technicians by 804 and the number of supporting staff by 464. With the exception of technicians, these growth rates are higher than those recorded during the previous period. However, comparable growth rates were already observed during some of these last years.

TABLE 8 - R&D personnel by occupation in FTE

	1993	2001	2010 Objective
Researchers	20 831	32 237	47 751
Technicians	7 178	15 038	22 275
Other	8 777	8 675	12 850
Total R&D personnel (FTE)	36 787	55 949	82 876

Average annual growth rate	1993-2001	2001-2010
Researchers	5.61%	4.46%
Technicians	9.68%	4.46%
Other	-0.15%	4.46%
Total R&D personnel (FTE)	5.38%	4.46%

Source: Belgian Federal Science Policy Office (2004), own calculations.

c. Graduates

In 2001, 62.1% of R&D personnel owned a university-level diploma[50], 18.1% a higher education diploma of non-university level[51] and 19.8% another diploma, which reflects the important role played by highly educated labour force.

According to the available data (Table 9), the number of new graduates of tertiary education seems to increase every year[52]. If we consider that graduates of a certain year are hired the next year, we can observe that the new graduates in 2000 were sufficient to generate, within the R&D personnel, more than 3 000 new full time equivalents in 2001. These data seem to suggest that the new graduates of the next years will be sufficient to allow an average growth of 2 992 new full time equivalents per year. The necessary growth of the three types of R&D personnel seems also feasible. Indeed, to reach the Barcelona objective, 1 724 new researchers (in FTE) will have to be hired on average per year, 804 new technicians and 464 supporting staff (in FTE), which is relatively close to the number of new persons hired in 2001 from the new graduates in 2000. Furthermore, the number of university-level graduates, who are the most sought after, seems to grow faster

50. Level 5A of ISCED 1997 (first stage of tertiary education) and level 6 of ISCED 1997 (second stage of tertiary education).
51. Level 5B of ISCED 1997 (first stage of tertiary education).
52. Non-official data covering a longer period seem to confirm this trend.

than the number of non-university level graduates. Nevertheless, the effects of the ageing population must not be forgotten. From 2010 onwards, the baby-boom generation that was born after the war will reach retirement age. Consequently, new graduates could be even more in demand.

TABLE 9 - Additional R&D personnel and new graduates from higher education schools

	2000	2001	2002	Growth rate 2001-2002
Additional R&D personnel (in FTE), compared with personnel of the previous year:	3 399	3 085	-	-
- Researchers	120	1 906	-	-
- Technicians	2 391	807	-	-
- Other	888	372	-	-
Number of tertiary education graduates:	68 451	70 202	72 939	3.90%
- Non-university level (ISCED 5B)	36 377	36 179	37 303	3.11%
- University level (ISCED 5A and 6)	32 074	34 023	35 636	4.74%

Source: Belgian Federal Science Policy Office (2004), Eurostat - Education statistics (2004).

Among the new tertiary education graduates, scientists and engineers play an important role because they are probably those who contribute most to research and development. In Belgium, the growth of the number of scientists and engineers is slightly below the growth of the whole graduates group (Table 10). However, growth of the number of graduates is particularly high in physical sciences, which include chemistry, and in the field of computing (software development,…). The number of R&D personnel in these fields is very large in recent years. In the field of engineering, the class "engineering and engineering trades", which notably includes mechanics, metal work, electricity, electronic and telecommunications, experienced a lower growth than engineering as a whole. In 2001, a large number of R&D personnel worked in these fields. Finally, graduates in the field of health, who can also represent potential researchers for the very R&D-intensive pharmaceutical industry, increase by a lower rate than the total number of tertiary education graduates. Better data on graduates by level and field of education and by region, covering a longer period, would be necessary to evaluate more precisely the current trends and to anticipate deficits of students in some fields.

TABLE 10 - New graduates in science and engineering and in the field of health

	2000	2001	2002	Growth rate 2000-2001	Growth rate 2001-2002
Science and engineering	12 919	13 239	13 743	2.48%	3.81%
- Science	5 013	5 704	6 054	13.78%	6.14%
Including Physical sciences	746	942	1 144	26.27%	21.44%
Including Computing	1 858	2 349	2 813	26.43%	19.75%
- Engineering, manufacturing and construction	7 906	7 535	7 689	-4.69%	2.04%
Including Engineering and engineering Trades	5 502	5 026	5 200	-8.65%	3.46%
Health	10 419	9 984	10 368	-4.18%	3.85%

Source: Eurostat - Education statistics (2004).

V Conclusion

The NEMESIS simulation has quantified the positive impact of the intensification in R&D efforts under the conditions of the Barcelona objective. At the macroeconomic level, it has demonstrated a great positive impact on long-term economic growth, foreign trade, employment and productivity for every European country. However, at the sectoral level, structural changes occur and some sectors end up as net losers from this European common strategy. An important challenge for the public authorities will therefore be to implement policies designed to facilitate the sectoral mobility of capital and labour and, within the sector, to promote mobility from low qualified jobs towards knowledge-based activities. This conclusion underlines the growing importance of lifelong training and the unavoidable development of public support to this formation scheme. Furthermore, countries that have to increase their R&D effort to meet the Barcelona commitment relatively less will lose market shares at the intra-European level after 2010. Even if this loss is compensated for by the extra-European trade, Belgium should try to remain, in addition to the 3% objective, above the average European intensity.

The accounting exercise based on economic forecasts has revealed that the 3% objective seems feasible in Belgium. The results have shown that the current efforts in R&D investment have to be at least maintained and at best intensified up to 2010. Indeed, the necessary annual average growth rates in R&D expenditure and in demand for R&D personnel are slightly higher than those recorded between 1993 and 2001, but equivalent to those of the last few years. Furthermore, the observed trends in supply of human resources do not seem to be problematic.

Nevertheless, the analysis is less positive at the regional level. Recently, the Walloon and Flemish Regions have individually adopted the 3% objective. However, regional estimates show that this target seems to be more difficult to reach for the Brussels-Capital Region. As a consequence, it is of major concern that the regional and federal authorities plan their future efforts in close consultation, in order to achieve the Barcelona objective. The federal and regional authorities also have an important role to play to fulfil the increasing needs for skilled human capital. Therefore, they are confronted with the challenge to strengthen the policy measures efficiently, notably to increase the attractiveness of science and engineering among students, to improve the career possibilities of researchers, in particular in the academic world, to increase the participation of women in R&D-activities, to limit the 'brain-drain' of highly-skilled workers and to foster the mobility of R&D personnel between sectors and regions.

Finally, better data on demand for researchers and on the career paths of science graduates would also bring some objectivity to the debate. But there is no guarantee that this will lead to the convergence of predictions, given the importance of the variety of the assumptions concerning both direct and indirect impact of R&D on innovation, and starting on economic growth and employment. Therefore, there is still plenty of room for research in this field.

Annex A

The results of the simulation for Belgium, The Netherlands, France and Germany are given in the following figures.

Annex B

Case study with the NEMESIS model: other scenarios based on different assumptions

In addition to the 3% scenario, that has been built and detailed above, different scenarios have been created with the same increase in R&D but with different assumptions. There are six other scenarios that are explained hereafter. The results are detailed in the following table.

- V0,0: Initial 3% scenario with the assumptions detailed above.
- V1,0: Elasticity of knowledge stock on economic performance: from 0.075 in 2002 to 0.141 in 2030 (instead of 0.124 in the initial scenario).
- V2,0: Elasticity of knowledge stock on economic performance: from 0.075 in 2002 to 0.1 in 2030.
- V4,0: Splitting up of added value: 0% of the productivity gains are redistributed to workers.
- V5,0: Splitting up of added value: 100% of the productivity gains are redistributed to workers, added to the rise of real wages due to pressures on labour market.
- V0,1: Financing of R&D: None of the supplementary effort of R&D is executed by the private sector and the whole new R&D is financed by the public sector.
- V0,4: Increase in R&D is done partially through public order of R&D intensive goods. R&D increase is done only partially through public order because an "only public order" policy cannot lead to 3% of GDP since it would need an unrealistically high level of public expenditure.

TABLE 11 - Global results for Europe and Belgium of the different scenarios

		V0,0	V1,0	V2,0	V4,0	V5,0	V0,1	V0,4
Total Employment 2010	Be	41	42	37	45	32	45	65
	EU	2 084	2 197	1 714	2 185	1 808	2 365	2 867
Total Employment 2030	Be	155	210	105	185	94	220	263
	EU	10 007	15 222	5 720	11 077	7 971	13 867	17 105
GDP 2010	Be	1.17	1.26	1.11	1.17	1.14	1.73	1.58
	EU	1.70	1.78	1.77	1.69	1.67	2.29	2.47
GDP 2030	Be	7.52	9.65	6.64	7.84	6.82	9.71	9.84
	EU	12.15	16.28	10.89	12.65	11.14	15.20	15.81
Budget balance 2010	Be	0.13	-0.10	0.20	-0.02	0.47	-0.64	-0.96
	EU	0.13	0.00	0.41	-0.01	0.38	-0.81	-1.19
Budget balance 2030	Be	0.70	0.96	-0.12	-0.10	2.8	0.23	1.63
	EU	2.33	2.78	2.90	1.88	3.92	1.97	3.05

Employment is in thousands; GDP is in %, budget balance is in GDP percentage point.

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