European Science and Technology Observatory

Impact of Technological and Structural Change on Employment:

Prospective Analysis 2020

Background Report

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Institute for Prospective Technological Studies

About the IPTS

The Institute for Prospective Technological Studies (IPTS) is one of the eight institutes of the Joint Research Centre (JRC) of the European Commission. It was established in Seville, Spain, in September 1994.

The mission of the Institute is to provide techno-economic analysis support to the European decision-makers, by monitoring and analysing science and technology related developments, their cross-sectoral impact, their interrelationship in the socio-economic context and future policy implications, and to present this information in a timely and logical fashion.

Although particular emphasis is placed on key science and technology (S & T) fields, especially those that have a driving role and even the potential to reshape our society, important efforts are devoted to improving the understanding of the complex interactions between technology, economy and society. Indeed, the impact of technology on society and, conversely, the way technological development is driven by societal changes are highly relevant themes within the European decision-making context.

In order to implement this mission, the Institute develops appropriate contacts, awareness and skills for anticipating and following the agenda of the policy decision-makers. In addition to its own resources, the IPTS makes use of external advisory groups and operates a network of European institutes (ESTO) working in similar areas. These networking activities enable the IPTS to draw on a large pool of available expertise, while allowing a continuous process of external peer review of the in-house activities.

The interdisciplinary prospective approach developed by the Institute is intended to provide European decision-makers with a deeper understanding of the emerging S & T issues, and is fully complementary to the activities undertaken by other JRC institutes.

About the ESTO network

The European Science and Technology Observatory (ESTO) was formally constituted by the Institute for Prospective Technological Studies in February 1997 as a 'technology watch' network. The ESTO network comprises 34 institutions with experience in the field of scientific and technological assessment at national level, representing the vast majority of European think-tanks.

ESTO members share responsibility for supplying the IPTS with high-quality, up-to-date scientific and technological information drawn from all over the world, facilitated by the network's broad presence and wide range of contacts. Developments are examined from a socio-economic perspective, identifying breakthroughs and trends which may require action at a European level. Activities are targeted at policy-makers and decision-makers within the European S & T sector, in particular the Commission, but information is also available to a wider audience, such as the Member States, non-governmental organisations (NGOs) and industry.

Currently, ESTO is engaged in the following activities:

- contributing to the monthly *IPTS Report;*
- developing specific prospective projects intended to act as a trigger for in-depth studies;
- building thematical networks allowing ESTO and the IPTS to provide rapid responses to specific requests from European decision-makers;
- fostering the continuous expansion of the ESTO network and the involvement of new members in activities.

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Study for the Committee on Employment and Social Affairs of the European Parliament

IPTS – ESTO

Edited by P. Christidis, H. Hernandez and J. Lievonen

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IPTS–ESTO

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Preface

This study was commissioned by the Committee on Employment and Social Affairs of the European Parliament following a request by its Chairman Mr Michel Rocard in a communication sent to Commissioner Philippe Busquin in July 2000. The Commissioner responded positively and requested that the JRC/IPTS carry out the work. An interim working document was presented to the Committee co-ordinators in May 2001 and the work was completed in November 2001.

The study examined the role of technology in the economy of the EU and its impacts on employment. IPTS applied a combination of qualitative and quantitative analyses, in collaboration with the European Science and Technology Observatory (ESTO) network and with Prof. Robert Solow (Nobel prize, MIT) as an external advisor. The starting point of the work in this study was the Technology and Employment Maps of the IPTS FUTURES project, which identified the main emerging technological developments and their implications for employment respectively. The potential impact of these technologies on productivity growth and consumption patterns was estimated using theoretical and empirical evidence. These estimates were used as input by two established simulation models in order to quantify the impact of these technological developments in terms of economic growth and employment under various alternative technology policy scenarios.

The study results reinforce the argument that technological development stimulates economic growth and employment generation in the EU. Technology policy is one of the keys for achieving the objectives of economic, social and environmental policy, and a valuable instrument to reach the goals of the ‘Knowledge-based Society’ as defined in the Lisbon Summit.

One of the main findings of the study suggests that a limited increase in R&D spending can lead to a considerable increase in GDP and employment levels provided that certain complementary measures are implemented. Since new technologies are often accompanied by structural changes, concerted policy actions are necessary in order to exploit the full potential of new technology and ensure that the whole society can share the benefits. In particular, policy measures in the areas of education and training, labour laws and regulations, and incentives for innovation and investment are of special importance.

Whilst IPTS is grateful for the help and inputs received from its various partners and other European Commission services (DG EMPL, DG ECFIN, DG ENTR, DG TREN, DG RTD), responsibility for the report’s content rests solely with the JRC and the Institute. The views expressed herein do not necessarily represent those of the European Commission.

Seville, March 2002

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Executive summary

1 Introduction

This report presents the results of an IPTS-ESTO study on the impacts of technical change on employment in Europe in 2000-2020. The study has been prepared at the request of the Committee on Employment and Social Affairs of the European Parliament.

The aim set out for this study was to show how changes in technology can affect employment in the EU Member States over the next twenty years. The work was carried out in response to the following five questions:

1. Which sectors of the economy will offer the best prospects for growth and job creation?
2. Which technologies will have significant impacts on those sectors?
3. What kinds of skills will be required in those sectors and technologies?
4. What will be the impact of emerging technologies on the organisation of work and job profiles?
5. What would be the impact of selected innovation and technology policy strategies under different socio-economic conditions?

Answers to these questions have been developed on the basis of technology foresight analyses, computer simulations with two large-scale economic models and qualitative analyses. The combination of these approaches represented an innovation that was made possible by the collaborative relationships developed by IPTS with research organisations participating in the European Science and Technology Observatory (ESTO) network and individual high-level European experts.

The scope of this study is limited to the indirect, time-lagged links that can be found between research and development (R&D) policy and employment, but we have to recognise that employment is not the only concern in R&D and innovation policies, which foster the development of beneficial new technologies and their diffusion in society. That is why when assessing the full potential of new technologies, technical change and technology policy, considerations other than employment have to be taken into account as well. These considerations include those related to environmental issues, quality of life, health, social equality, gender issues, public safety, and defence. Technical change has some bearing on all of these issues, often solving major problems but sometimes raising secondary problems that need to be addressed.

2 The methods of the study

Three different sets of methods were brought together for the purpose of the study. The starting point was *technology foresight analysis* in which the Technology Map developed in the FUTURES Project of IPTS was applied. In the context of this study, three general-purpose technologies (information and communication technology, biotechnology and nanotechnology) covered by the FUTURES project have been identified as likely to represent the main impetus for technological change on employment over the next twenty years. The employment effects of these general-purpose technologies are enhanced by future developments in technologies specifically designed for and often limited to particular industries.

The potential impacts of advances in general-purpose technologies and sector-specific technologies on productivity growth and consumption patterns were estimated on the basis of past trends, available theoretical and empirical evidence, results from other relevant studies, and additional expert advice. In future studies it may become possible to apply more formal methods in the production of such estimates. In the current study the judgement of economic experts was an invaluable resource. The expert estimates of consumption and productivity coefficients were used as inputs in two well-established large-scale *economic models*. GEM-E3 model is a global economic model based on the general-equilibrium principle, while ASTRA is a system-dynamics model focusing on the European economy. These models represented the second set of methods applied in the study.

While the simulations with the two models were being completed, a third team of experts launched *qualitative analyses* on the skills, work-organisation and innovation policy implications of technical change. These analyses confirmed the expectation that in the labour market technical change favours highly skilled people and that technical change often is associated with changes in work organisation. In the case of organisational changes, highly qualified people tend to be winners while unskilled workers face a larger danger of losing jobs. Another clear threat to the jobs of the unskilled workers is the globalisation of economies, particularly in the manufacturing sector. As technologies spread to newer industrialising countries, jobs may be threatened by cheaper imports from such countries.

3 Policy scenarios as a tool of analysis

The level of employment in an economy is affected by a great variety of factors that include consumption demand, real wages, tax-like costs imposed on employers, labour productivity, competitiveness, education, training systems, the relative shares of declining and expanding industries in the economy, the investment climate, and cyclical factors. Changes in technology affect many of these factors directly or indirectly, and therefore different technology policies can be expected to lead eventually to different levels of employment. A full analysis of the employment impacts of changes in technology and technology policy would require taking into account technological and social factors simultaneously, but the tools at the disposal of the economist do not currently allow this. In the current study a set of scenarios was used to depict differences in technology policy. The policy differences studied were comparatively small, consisting of differences in the sectoral allocation of assumed increases in R&D and innovation expenditures in the EU economy.

The policy differences were depicted by using four scenarios that were designed to reveal the long-term employment impacts of such small differences in the sectoral allocation of additional R&D and innovation expenditures. The policies that involved increased R&D and innovation were assumed to affect labour productivity and the consumption of goods produced in different sectors of the economy. Changes in productivity were assumed to conform to an empirical finding according to which R&D efforts tend to improve labour productivity following a certain elasticity relationship. Changes in consumption patterns are assumed to take place mainly when the increase in R&D and innovation expenditures is directed towards advanced technologies. The consumption assumption can be justified as reflecting an R&D-driven proliferation of new products and as a small shift of consumption demand for goods from more traditional sectors.

In what follows each of the policy scenarios will be presented in brief. The long-term employment outcomes of the scenarios at the level of the aggregate EU economy as well as sectoral and regional levels will be reviewed in the next two sections.

The *Baseline Scenario* was based on the assumption that the current patterns in R&D and innovation policies, consumption and labour productivity would be continued. R&D and innovation expenditures as a proportion of GDP would stay at about the current level in all regions of the EU. As a result, productivity growth for each sector was assumed to continue at its current rate. The Baseline Scenario defined a reference with which the impacts of increased R&D and innovation expenditures could be compared. In the Baseline Scenario public and private R&D and innovation expenditures were assumed to be increased by 1.5 % each year.

The effects of additional increases in publicly and privately funded R&D and innovation efforts in Europe were shown in the three alternative policy scenarios. In each of these scenarios an equal annual increase in the share of total innovation expenditures of the EU GDP was assumed. The alternative policy scenarios were similar to each other in that they involved an equal overall increase in innovation and R&D expenditures, and consequently an equal overall increase of 0.5 % in labour productivity in the EU economy. The alternative policy scenarios differed from each other in the way the increase in R&D and innovation expenditures was distributed across the sectors of the EU economy. As the productivity response of each sector differed, reflecting among other things the pace of technical development in the sector, the overall employment impacts of the scenarios also differed from one another.

In the *Uniform Scenario* R&D spending was increased uniformly, at an equal growth rate, in all of the modelled sectors of the EU economy. Because of the uniform pattern of growth in R&D and innovation expenditures, the rate of labour productivity growth could be assumed to be uniform across the sectors.

In the *Diversified Scenario* the increase in R&D and innovation expenditures was allocated to sectors that already demonstrate strong performance at least on a regional basis, and therefore could be said to enjoy a comparative advantage of one kind or another in the EU economy. Sectors targeted for increases in R&D and innovation expenditures and consequently labour-productivity improvements were chemicals, equipment manufacturing, transport equipment, food industry and various services. The four main regions of the EU economy were assumed to follow different paths of productivity improvement, with each region strengthening its high-performing sectors.

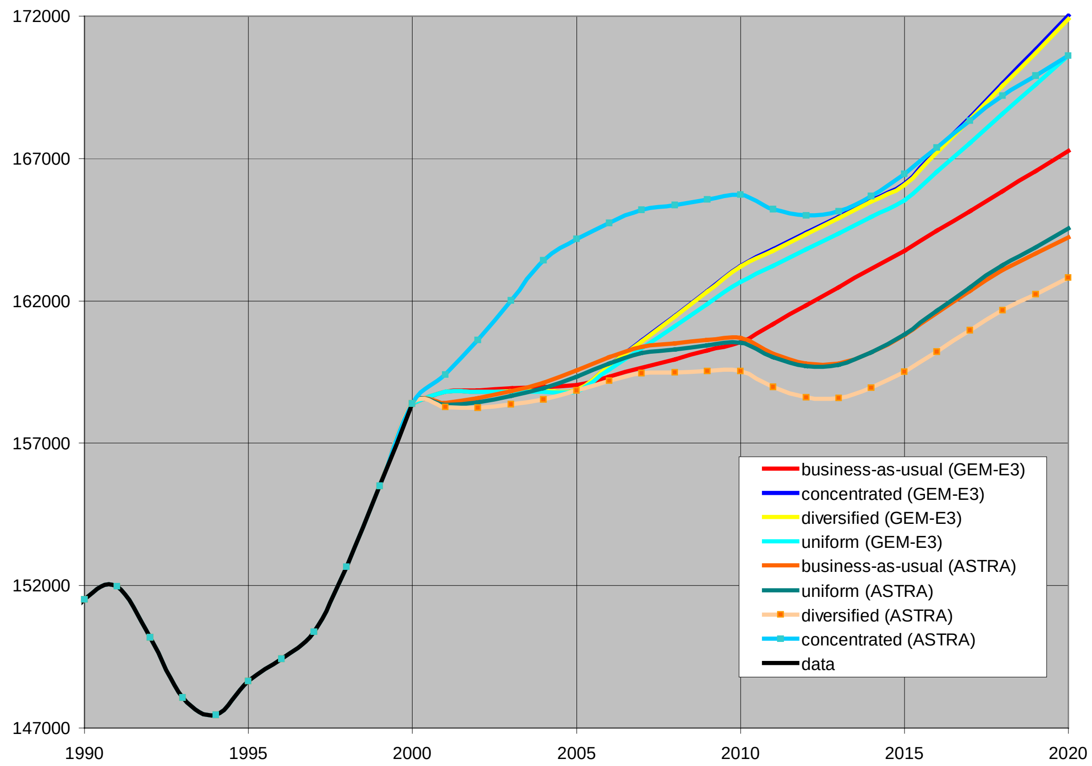
In the *Concentrated Scenario* the increases in R&D and innovation expenditures were concentrated on advanced technologies (electronics, telecommunications, genetic engineering, nanotechnology, aeronautics & space applications). The sectors affected were those that rely heavily on these technologies, and included electronic equipment, services, high-tech manufacturing, transport equipment and chemicals. In these sectors the competitiveness of the EU was expected to improve as the strategies of the competitors were assumed to remain unchanged in this as in the other scenarios. However European sectors that are not technology-intensive would probably lose some of their relative competitiveness. Given the pervasiveness of technologies targeted for increased R&D and innovation spending, new products were assumed to emerge in this scenario at a more rapid pace than in the other scenarios. That is why an increase of 1 percentage point was assumed to take place in 2010 and 2020 in the share of consumption demand for health and medical care, transport and communication, recreational services and miscellaneous goods and services. However, there was a parallel decrease of 1 percentage point in the consumption of food, beverages and tobacco; clothing and footwear; gross rent, fuel and power; furniture, furnishing and household operation. As in other alternative policy scenarios, an overall acceleration in annual productivity growth of about 0.5 percentage points was assumed relative to the Baseline Scenario. In this scenario the sectors in which labour productivity growth would take place were electronics, trade and transport, other market services and non-market services.

4 The results of policy scenario simulations at the EU level

One of the main findings arising from the simulations is that improvement in labour productivity induced by technical progress does not seem to threaten the aggregate level of employment in the EU economy. In fact both of the models foresee positive long-term growth rates in European employment in all of the scenarios. Moreover there are good reasons for believing that the simulation results represent the lower boundaries of the employment impacts that can be expected to result from increases in R&D and innovation expenditures. This is because the models cannot take into account the effects of intersectoral and international capital investments. The impacts of investment would probably increase the differences between the scenarios, increasing the positive employment effects that were observed in scenarios involving added R&D and innovation expenditures in sectors that take advantage of high technologies.

Another observation that can be made is that the differences between the employment outcomes of the scenarios were more pronounced in the ASTRA model than in the GEM-E3 model. While in general the ASTRA model seems to draw a more sluggish picture of the EU economy than the GEM-E3 model, the ASTRA model simulations results were more optimistic about the responsiveness of the EU economy to technology policies focusing on high technology. A closer analysis of the reasons for this difference would reveal that the role of consumption – *i.e.* success in the development of new attractive products – is of paramount importance for the realisation of positive employment outcomes. Figure 1 shows how the paths of employment levels tended to converge towards a comparatively high level in the GEM-E3 simulations, while the results of the ASTRA model dispersed more widely. The GEM-E3 model was considered to be a more consistent tool for our purposes.

Figure 1. The level of EU labour demand between 2000 and 2020 in the different scenarios (thousands of full-time job equivalents, GEM-E3 and ASTRA simulations).



In the GEM-E3 simulations the Baseline Scenario produced the smallest increase in the level of employment by the year 2020, amounting to 5.6 % or 9.2 million jobs. The increase would set the elasticity of employment with respect to GDP growth to about 0.1, which would be comparable to what was observed in the period 1980-1995. The low responsiveness of employment to GDP growth over these years has been a key characteristic of the EU-15 countries compared to the United States. The Uniform Scenario results in lower employment levels than the two other scenarios that involve increases in R&D and innovation expenditures. The *aggregate* employment outcomes of the Concentrated and Diversified Scenarios are almost equal in the GEM-E3 simulations. Given the comparative robustness of the GEM-E3 simulations, it could be concluded that at the European level the employment outcomes of R&D and innovation policies emphasising high technology would be almost the same as those focusing on industries that already have demonstrated their competitive strengths.

5 The simulation results at the sectoral and regional level

The simulations of sector-specific impacts show that among the major sectors of the economy services will be the most important source of new jobs in Europe. This is not surprising, since the service sector already is a leading provider of employment, and for more than two decades most of the new jobs in Europe have been created in that sector. Agriculture and many other activities of primary production can be expected to continue to shed jobs. Employment in manufacturing industry peaked in Europe about 20 years ago, but the simulations suggest that there is potential for employment creation in some branches of the industry.

Figure 2 illustrates the importance of the service sector in employment creation in Europe. In all of the scenarios the sectors that dominate new job creation include two large service-related sectors: *Other services and construction* and *Trade and transport*. *Non-market services* do not perform quite as well, and in the Concentrated Scenario a decline is projected for employment in this sector. Also manufacturing offers some employment-creation potential. Significant increases in employment are also to be expected in *Other manufacturing products* and *Other equipment goods*.

Figure 2. Changes in sectoral employment in the different scenarios in 2020 (thousands of full-time job equivalents; GEM-E3 simulations).

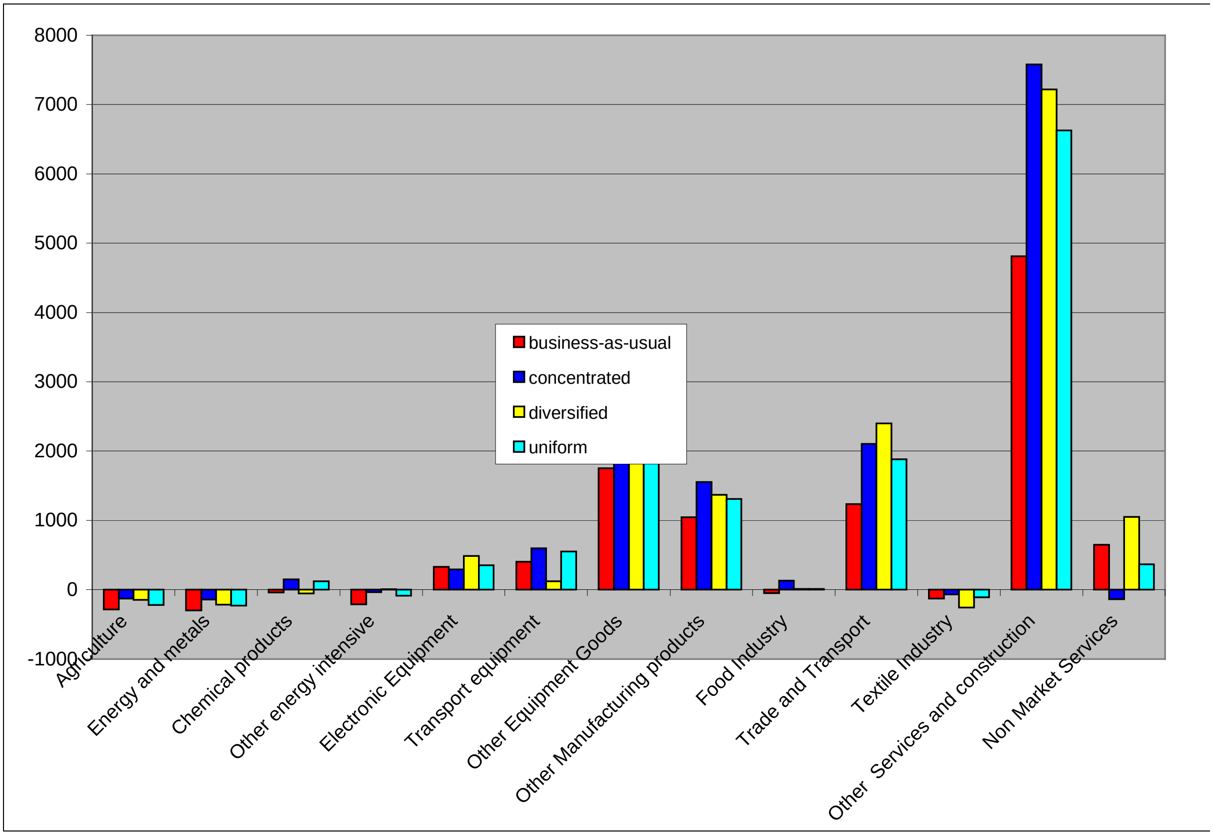


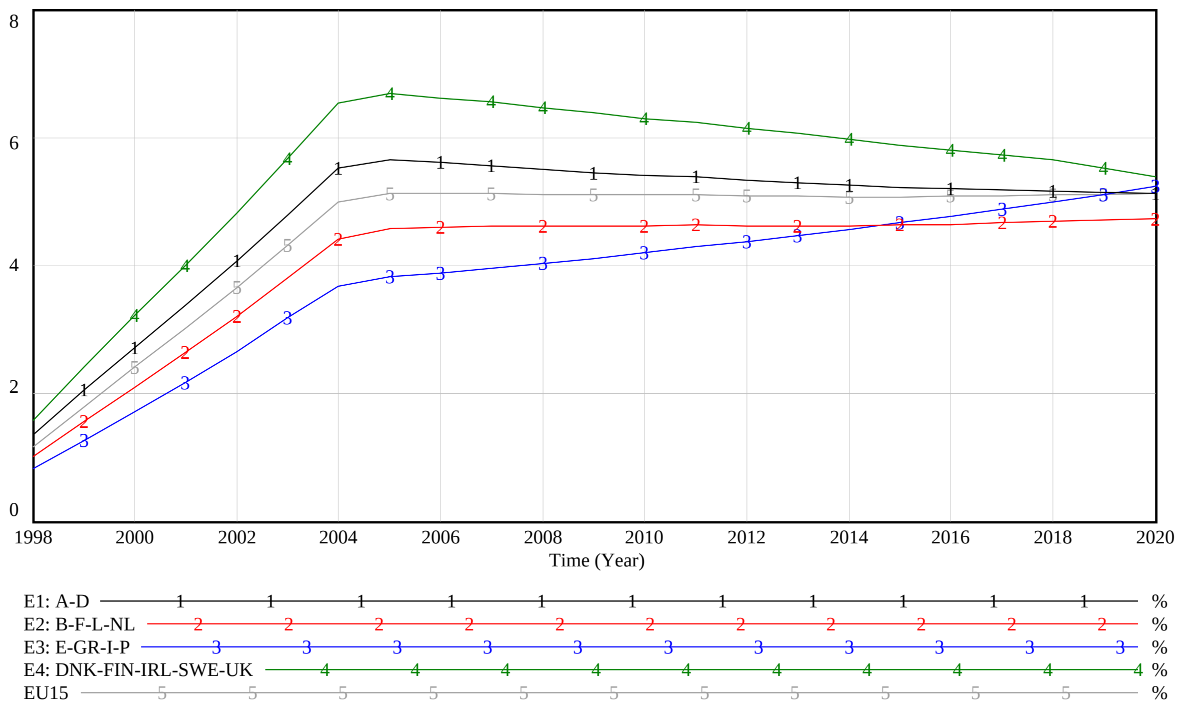
Figure 2 also shows what kinds of differences emerge between scenarios in the GEM-E3 simulations. The Concentrated Scenario produced the best employment outcomes for almost all of the sectors. The exceptions were *Non-market services*, *Trade and transport*, and *Electronic equipment*. For these sectors the highest employment levels were achieved in the Diversified Scenario. In many but not all sectors the 'business-as-usual' or the Baseline Scenario would result in the lowest levels of employment. Surprisingly, the Concentrated Scenario would produce the lowest employment increase for the *Electronic equipment* sector. On the whole that sector, often considered to be a leading sector in employment creation, is not expected to create many additional jobs as the impact of labour productivity growth in the sector is likely to be high even in comparison with the growing demand for the products of the sector.

Let us now turn to the regional results. In the ASTRA model the EU economy is divided into four subregions:

- E1: Austria, Germany (A-D);
- E2: Belgium, France, Luxembourg, Netherlands (B-F-L-NL);
- E3: Spain, Greece, Italy, Portugal (E-GR-I-P);
- E4: Denmark, Finland, Ireland, Sweden, United Kingdom (DNK-FIN-IRL-S-UK).

The impacts of the scenarios differed slightly from region to region due to differences in regional composition of industries, which influenced the extent to which labour productivity responded to the changes in R&D and innovation spending. Figure 3 shows the regional pattern of employment that emerged in the Concentrated Scenario. The consumption-related increase in employment was particularly strong in the Germany-Austria region and the weakest in the Mediterranean region of Spain, Greece, Italy and Portugal.

Figure 3. Employment in the main regions of the EU in the Concentrated Scenario in 1998-2020 (percentage difference from the Baseline Scenario; ASTRA simulations).



In ASTRA simulations the aggregate employment outcomes of the Uniform and Diversified Scenario were worse than those of the Baseline Scenario. The outcomes are particularly bad for the Northern European region of Denmark, Finland, Ireland, Sweden and the UK. The results of the ASTRA model remind us that the development of conditions favourable for employment creation in Europe will take energy and determination.

6 Technologies having the most significant impacts on employment

Employment at the national or the EU level can be affected noticeably maily by technologies that have become widely diffused in the economy, and that is why the employment impact of one of the emerging general-purpose technologies, nanotechnology, is estimated to remain small over the period covered in this study. However, a lack of highly-qualified experts in nanotechnology could significantly reduce the growth and employment-creation potential of the European economy towards the late 2010s, a crucial period during which the first economically significant nanotechnology advances may be commercialised. In contrast the employment impact of ICTs and biotechnology can be expected to be significant and positive.

Among the background assumptions of the economic simulations that were carried out in this study were those related to the impacts of technical change on labour productivity and consumption. In what follows we shall show which kinds of developments in sector-specific technologies can be expected to affect employment in the different sectors of the economy. However, it has to be kept in mind that in many sectors technical change will not be the main driver of changes in productivity, consumption demand and employment. One such sector is agriculture. There a mixture of protective and subsidising measures has a determinate impact on international competition and employment.

Sector-specific technologies affect employment by themselves or in combination with general-purpose technologies. Table 1 shows what kinds of developments can be expected to take place in various sectors of the economy. The table presents the sectors as they are grouped in the ASTRA model. In many of these sectors the role of general-purpose technologies will be to augment the sector-specific technologies and to make possible integration with external products and services.

Table 1. Factors influencing competitive conditions and sector-specific technologies in various sectors of the EU economy by the year 2020.

Sectoral and non-technological factors affecting employment in these sectors	New sector-specific technologies expected to be adopted in widespread use by 2020
1. *Agriculture, forestry and fishery*. The opening of the EU to international competition, product quality and health issues may affect employment more strongly than technical change.	Gene technology; biotechnological treatment of waste products; new vaccines
2. *Energy, water, mining products, crude oil*. Environmental considerations and related changes in costs and taxation can be expected to increase the rate at which more labour intensive and decentralised power- and heat-producing technologies are adopted in Europe.	Methane from urban and farming waste; biomass, wind energy and solar cells; fuel cells in heat and power production; clean methods of producing energy from fossil fuels; biotechnical methods in water purification and waste water treatment; robots and solution mining.
3. *Chemical, mineral, plastic and petroleum products*. Cost competition and development of new speciality products are the main modes of competition.	Biocatalysts (enzymes); biopolymers; conductive polymers; environmentally-friendly processes; products related to medicine and health care.
4. *Ferrous and non-ferrous ores and metals*. Cost-efficient recycling methods could create new jobs while labour-saving production technologies and cost competition tend to reduce overall employment.	Ultra-pure steel; recycling technologies; durable and strong high-temperature alloys, low-cost titanium; new casting methods.
5. *Steel products, machinery, transport equipment*. Global overcapacity tends to intensify cost competition.	Integration of ICT functionalities into existing products; fuel cells in automotive applications; recycling; micro- and nanometre-scale components.
6. *Electrical, optical goods, office and data processing, toys*. New products and services expected to create more jobs than are lost as a result of productivity enhancement.	Continued progress in processor, memory, software and networking technologies.
7. *Textiles, clothing, paper, wooden goods*. Process improvements tend to reduce the number of jobs. Design a significant success factor.	Enzymatic modification methods; new design opportunities from combinations of old materials with new materials and constructions.
8. *Food, beverages, tobacco*. Health issues, subsidy and taxation policies important factors.	Technologies related to health, hygiene, product preservation and packaging.
9. *Building and construction*. Increased international competition; the importance of building standards and systems.	Information technologies for building-management systems; productivity enhancements in the construction of large-scale infrastructures; technologies for maintenance and repair tasks.
10. *Services for repair, wholesale and retail, transport, communication*. Increased international competition and productivity enhancement in services.	Continued rapid progress in the performance of fibre-optic networks as well as in communication and collaboration software.
11. *Other market services*. International competition, standardisation, cost competition.	Communication networks, identification methods, service and e-commerce software systems.
12. *Non-market services, education, healthcare*. The public sector has a leading role in setting the level of demand and product specifications.	Preventive health care; DNA-diagnostics; biocompatible implants; e-learning.

A detailed presentation of the sector-specific technologies that are expected to have a significant effect on employment by the year 2020 is given in Annex 1 of this report.

7 Issues related to labour supply, skills and work organisation

While at the starting point the differences between our scenarios were relatively small, the scenarios can be interpreted as reflecting not only the weights given to different sectors of the economy in R&D and innovation spending but also differences in general policy. For instance, the Concentrated Scenario reflects a focused drive to excel in high technology, and that pursuit would be commensurate with measures that would emphasise free international trade and rely on the highest achievers in education, research and technology policy. In the Diversified Scenario the additional R&D and innovation expenditures would be invested in industries that have already proven themselves successful in Europe. Therefore there would be less structural change in the European economy, and protective measures would not contradict the general purpose of focusing on the existing strengths of Europe. While in the Concentrated Scenario the risk is that the technological goals will not be achieved at competitive cost levels, in the Diversified Scenario the risk is that the well-established industries are already near to the peaks of their technological cycles and will not grow at a rapid pace in the future, but will soon start to shed employment as their foci increasingly turn from product competition to cost competition. In the Uniform Scenario the additional innovation resources are distributed between all of the sectors, and therefore the impact on individual sectors is even less than in the other scenarios. Moreover, some of the additional innovation resources will go to sectors where the prospects for technological innovation and productivity improvement are few.

While our simulations for the year 2020 concern the demand for labour, it is necessary to have a look at factors affecting *labour supply* to see if mismatches between supply and demand will be in the offing. These factors include declining birth rates, growing numbers of the elderly in the population, increasing immigration rates to the EU-15 countries, declining weekly and/or yearly working hours, and changing patterns of part-time work.

Among the economic determinants of labour supply are the changing composition of households and changing levels of employment of adult women. In past times, the latter have acted as to some extent a kind of 'reserve army', but with rapidly rising levels of female education, allied with structural changes in the nature of work, the participation of women in the labour force is increasingly crucial. For the participation of both women and men, changes in wages, earnings and incomes, together with the effects of changing levels of employment and unemployment, can be expected to have significant impacts. The degree to which the supply of labour can be expected to be able to adjust itself to the different levels of demand described in the demand-side quantitative analyses becomes a key issue, especially in the Concentrated Scenario that emphasises the need for high skills.

One variable on the supply side is particularly liable to be influenced by changing demand conditions, and that is the migration of labour. Traditionally this has been seen as conditioned by both 'supply-push' of poor employment expectations in the source countries and 'demand-pull' of strong employment expectations in the receiving countries. Currently many of the immigrants are highly trained, thus alleviating skill shortages; but past experience such as that for the USA. in the early twentieth century shows that this can be succeeded by a phase in which immigrants fuel the supplies of unskilled labour, with totally different impacts on assimilation and social concerns about exclusion. The accession of eastern European countries to the EU may generate a similar reversal (and it was precisely these countries a century ago which helped do the same for the US immigration).

Demographic and economic factors will have impacts on the composition of the workforce. Apart from the gender issue, the age composition is also a key problem, with the impact of falling birth rates in recent times bound to lead to an ageing population in the EU-15 countries, and a lack of young people equipped with new skills. Similarly changes in the length of the working week, such as the 35-hour week currently being introduced in France, will evidently affect the supply relative to demand (assuming that there is no commensurate fall in annual earnings); also changes in number of days taken as holidays can provide some adjustment.

The skills of the labour force are a crucial factor. Technical change and globalisation seem to favour employment for highly skilled workers in Europe. Workers who remain low-skilled will continue to face high unemployment rates. Skills related to rapidly advancing technologies of wide application will be in high demand in the labour market. From the point of view of the economy, skills related to entrepreneurship are also important since they will help to create new jobs.

It can be expected that certain skills will be in high demand over the next two decades. These skills relate to general-purpose technologies, which in our study comprise information and communication technologies (ICTs), biotechnology and nanotechnology. These technologies may be applied in a widening range of industries in the future, and that is why skills related to them will be highly valued, as can already been seen in the worldwide shortage of software engineers. Application skills in software are needed in all efforts involving the development of new ICT products and services. The first phases of increased demand for biotechnology and nanotechnology skills are likely to concern demand for people who have research qualifications in these fields, but there too there is expected to be a shift to application skills. While highly educated specialists will constitute only a small proportion of the total workforce, their significance to the national economies of Europe is likely be much higher. It is the responsibility of highly-trained specialists to carry out and manage critical phases of R&D, where success can lead to the emergence of important new products and job opportunities through such applications.

Among the new sectors of the economy that can be expected to emerge over the next two decades is that of preventive medicine. As the origins of various medical conditions are becoming understood at the molecular level, it is likely that ways will be found that will at least reduce the probability of individuals developing these conditions. A proportion of such individuals should be willing to invest time and resources for preventive treatments that can be provided either by public health care or private sector. At the same time, the numbers of people requiring medical attention can be expected to grow, not only because of the ageing of population but also because the number of people who survive serious illnesses but require continued medical support is going to grow. Tissue engineering is one of the fields of medical technology that can be expected to make great strides over the next two decades. For all these reasons the demand for workers in the health-care sector can be expected to continue to grow.

It is the task of an entrepreneur to organise the skills of the labour force and the production technologies so as to achieve profitability in commercial operations. *The organisation of work* and job profiles are influenced by a number of factors. One of them is the use of information and communication technologies. The Internet makes it possible to reorganise interactions with companies' suppliers and customers. Experience from previous generations of ICTs and automation technologies shows that their full productivity benefits can be realised only if organisational changes are carried out to instigate self-managing teams, decentralise decision making, reduce layers of management, and empower employees to make critical decisions together with suppliers and customers. While ICTs make collaboration increasingly seamless, the protection of the companies' key information assets is going to need heightened attention and may also result in additional changes in work organisation.

The link between skills and technologies has major implications for workplace organisation. Concerns about virtual workplaces, teleworking and related issues are widespread. The effects to date have been quite ambiguous in terms of conditions of work – sometimes improving them for employees, though on many other occasions perhaps degrading them. Nevertheless, technology is not the only factor that influences the outcome on work organisation. Some of the trends may be dictated by economic necessity. In health care, for instance, it may become necessary to find ways to increase the productivity of costly investments in modern equipment and facilities. That could involve the introduction of additional working shifts in operating theatres and supporting departments. The outcomes will, as in other fields, depend on the balance or imbalance between labour supply and demand, and the impact of technological change on any such imbalances.

8 Conclusions

The fact that training reduces the likelihood of unemployment among individuals and improves their position in the labour market stresses benefits that accrue to society from improving the qualifications of the labour force. The need to achieve a general improvement in skill levels among the working population is of the highest concern. Another suggestion that emerges from the qualitative analyses carried out in this study is that in the future education resources should be refocused towards fulfilling the skill requirements that will be created by the expected diffusion of the general-purpose technologies (information and communication technologies, biotechnology and nanotechnology). Employment prospects in Europe would also be enhanced by a wider dissemination of entrepreneurship skills. Another challenge for the future is how to foster 'partial employment' for individuals for whom full employment is not (temporarily or permanently) possible. Technology has some bearing on this, since ICTs make it easy for people to work at home or in specially designed office-cubicle hotels. Policy issues related to changing work organisations concern enabling flexible changes in work organisation and job profiles while at the same time safeguarding employees' employment prospects and dignity. Building trust and encouraging initiative are likely to be more cost-effective strategies than resorting to confrontational styles of management.

The results of the quantitative simulations show that technology and innovation have a positive role in fostering economic growth and employment. Emerging technologies accelerate economic growth and are likely to lead to the creation of new jobs. The models suggest that this can be achieved with the highest likelihood when the benefits of productivity increases of technical change are distributed widely in the economy even if their sources become more concentrated, and when labour supply is responsive to higher wages and growing demand for high skills.

Even a comparatively small increase in innovation expenditures tends to increase economic growth and employment in the long term. The mechanism assumed to work here is that a relatively small initial increase in public funding leads to increases in private R&D outlays and improvements in labour productivity. Labour productivity leads to increased wages and, together with increasingly attractive new products, boosts the consumption of goods in the targeted sectors as well as overall consumer demand in the economy. Equitable distribution of the economic gains resulting from improvements in productivity therefore seems to help to sustain demand and employment. In the simulations carried out the employment effect of increased consumption is always larger than the labour-saving effect of productivity increases.

The best prospects for the EU emerge in various fields of high technology (Concentrated Scenario) and those sectors of the economy in which the EU already has established a strong competitive position (Diversified Scenario). Moreover, even if the additional R&D and innovation expenditures are divided more or less evenly across the sectors (Uniform Scenario), an improvement in growth and job opportunities is likely to ensue.

The fact that the impact of technological change also depends on changes in consumption and investment (within sectors) suggests that fiscal and monetary policies can play an important role in the overall policy mix. Measures that increase R&D can be complemented by others that assist the diffusion of new products, services and production methods; perhaps more general macroeconomic policies encouraging consumption and investment are not without merit as well. Seen in the context of the overall goals of the EU, innovation policies can be a key instrument enhancing employment, as well as growth and structural change.

The main results of the study can be summarised as answers to the five questions set out for the project.

1. Which economic sectors will offer high growth potential and quality jobs? The majority of new jobs that will be created during the next 20 years are expected to be in the area of services. More than three-quarters of the new jobs in the EU will probably be in trade and commerce, business services, healthcare, entertainment and recreational services, tourism and catering services, education, transport and logistics services, and construction. Jobs in these sectors are expected to provide increased real wages and an improved overall job quality, aided by the expected developments in information and communication technologies and organisational improvements in the workplace.

2. Which technologies will have a significant impact on those sectors? Obviously sector-specific technologies will have important employment and job-quality implications, but it is the general-purpose technologies that will be the main drivers of technical change. Information and communication technologies, biotechnology and nanotechnology are rapidly evolving fields and will remain so during the next twenty years or so. They will form numerous combinations with sector-specific technologies enhancing productivity and creating opportunities for the emergence of new products, services and enterprises.

3. What kinds of skills will be required to match the needs of those sectors and technologies? It will be important to ascertain the availability of highly-trained experts in the general-purpose technologies. Acute shortages can be expected of people who can combine expertise in both information technology and biotechnology and of those who can combine expertise in both automation technology and nanotechnology. Europe will also need strong management and entrepreneurial skills in order to take full advantage of opportunities for job creation that arise as a result of technical change.

4. What will be the impact of emerging technologies on the organisation of work and job profiles? In the past the full benefits of new information and communication technologies have been obtained only after organisational changes such as the instigation of self-managing teams and decentralised decision-making have been carried out, and employees have been empowered to make critical decisions together with suppliers or customers. Biotechnology and nanotechnology will affect production processes more directly than organisational practices, but their application in health care and elsewhere in the economy is likely to require new organisational and regulatory arrangements.

5. What would be the impact of selected policy strategies (industrial and technological) under different socio-economic conditions? The overall success in employment creation depends on the coherence of the policy mix that can be achieved in changing socio-economic and competitive conditions. Attention needs to be devoted not only the development of new technologies but also to their diffusion. Education, labour-market, fiscal, monetary and social welfare policies all have an impact on final employment outcomes. Technology policy variations considered in our study can also be seen as expressions of more comprehensive policy strategies. Our Concentrated Scenario might be seen as a manifestation of a drive that emphasises high technology, and by necessity globalisation. The Diversified Scenario is compatible with more inward and even protectionist attitudes. The Uniform Scenario tries to favour everyone but offers relative benefits only to sectors in which the prospects for technical change are poor.

1 Trends in employment and technology

1.1 Introduction

Since the early 1970s the Member States of the European Union have suffered from high rates of unemployment, while in the United States, with which the performance of the EU is often compared, the main problem has been a decline of wages of low-educated workers in real terms. One possible interpretation is that in fact both the EU and the United States are facing a common problem of an oversupply of unskilled labour. In Europe trade unions and minimum wage regulations have succeeded in protecting the pay, but not the jobs. In the United States pressures in labour market have led to the sacrifice of the wage levels while leading to better employment prospects.

A possible policy would be to instigate measures that would increase labour productivity. In the EU increased productivity could make it possible to create more jobs without having to cut wages. In the United States increased labour productivity could make it possible to raise wages without the threat of higher unemployment and inflation. However, the employment impacts of productivity enhancement depend crucially on the growth in demand for goods and services in the domestic and international markets.

The scope of this study is limited to innovation policy, and many of its instruments can have significant impacts on productivity in the long run. Innovation policy consists of technology policy, the main aim of which is to foster the development and diffusion of new technologies, and other measures that encourage the creation of new innovations and enterprises in the economy. The most obvious instrument of technology policy is the level of public funding for research and civilian technology development (R&D). It is customary to compare countries' R&D expenditures as a percentage of GNP. Private R&D is included in these comparisons, and is probably more relevant from the point of view of employment than public R&D expenditures. Technology policy measures can and do affect private R&D expenditures. Public R&D financing tends to increase private R&D expenditures.

The instruments of innovation policy measures include direct and indirect public support for emerging science- and technology-based companies; measures affecting intellectual property rights; regulations on university-industry collaboration; measures boosting networking arrangements between enterprises and research groups; and measures supporting international R&D collaboration. One of the themes that is considered in the study is whether economic and employment benefits of R&D can be increased by focusing on particular fields of technology that seem to offer the best economic opportunities.

The emergence of new companies and industries that rely on exploitation of R&D efforts depends on the availability of the necessary skills. There is little hope of success, if education fails to supply people with sufficient qualifications. Consequently, one of the tasks of the study is to estimate what kind of education efforts will be required to supply sufficient expertise in those fields of technology that seem to offer the best economic potential.

In Europe recent statistics illustrate the importance of technical change for economic growth and employment. It has been estimated that technological progress and investment in ICTs have contributed 0.5 to 0.7 percentage points to the annual EU GDP growth of about 2.5 % since 1995 (EC 2001a). In the United States the positive impact has been even greater, since the country has been able to take advantage of its leadership in processor and software technologies.

In industrialised countries employment is affected by a great number of transient phenomena, such as seasonal fluctuations and business cycles. In the long run probably the most significant changes in employment are brought about by productivity and innovation. Productivity tends to grow over time and by itself alone reduces the demand for labour and other inputs per each unit of output. However, improved productivity reduces the costs of goods or services supplied and therefore increases their demand, thus tending to compensate for at least a part of the job losses. Innovation brings about new products, services, enterprises, and even industries, that create new jobs, though this may come at the cost of job losses amongst the less innovative sectors and companies.

We shall start this review of long-term trends in employment by noting that over the last few years employment in the European Union has increased, partly as a result of favourable international growth conditions. Between 1995 and 2000 the rate of employment increased from 60 % to 63.3 % in the EU, while unemployment declined from 10.7 % to 8.2 %. At that level the rate of the EU unemployment was almost twice as high as in the United States and in Japan. In the Accession Countries the rate of unemployment was increased in the year 2000 and exceeded 12 %. In July 2001, the seasonally-adjusted unemployment rate remained at 7.6 % in the EU as a whole, the same level as a year before. The lowest unemployment rates were reported in the Netherlands (2.3 %) and Luxembourg (2.5 %), while the highest numbers came from Spain (13.0 %) and Finland (9.0 %) (EC 2001a). After the terrorist attacks in the United States in September 2001, the growth prospects of the world economy have declined and there is an increased need for policies that would encourage employment.

1.2 Trends in employment

1.2.1 Employment trends in the major sectors of the economy

One of the most significant long-term trends in employment concerns the loss of jobs in primary production, i.e., in industries such as agriculture, fishing and minerals production. Only 4.5 % of the EU working population were occupied in agriculture in 1999 (EC 2001a).

An intriguing question is whether employment in secondary production – consisting of manufacturing and chemical industries – is facing a permanent decline in Europe. In 1999, industry employed 29.8 % of EU workers. Many factors related to technical change and globalisation have already reduced the demand for production workers in industrialised countries. The negative overall impact is somewhat ameliorated by the fact that higher productivity makes it possible for companies to pay higher wages for the remaining workers. Similarly industrial plants that have relocated to low-wage countries usually create valuable job opportunities in these countries. There is also a process of structural change going on in manufacturing companies. They are concentrating on their core competencies and have started to buy from outside some of the services that were once provided within the company. This process has not only increased the size of the service sector in the economy but has also underlined the growing importance of services for the efficiency and competitiveness of the manufacturing sector.

The tertiary or service sector of the economy is doing well in terms of employment, representing 65.6 % of all jobs in the EU in 1999. The leading position of the service sector as a source of employment is the outcome of forces that have shaped industrialised economies for decades. In 1996 it was estimated that 18 million new service-sector jobs had been created in the EU since the early 1980s, while a combined reduction of 13 million jobs had taken place in industry and agriculture (EC 1996). Since then the relative importance of the service sector as a provider of new jobs has become even more significant. Between 1995 and 2000 net job creation in the EU economy almost exactly equalled growth of employment in the service sector. The net creation of jobs amounted to 10 million jobs in the Member States, while the service sector was responsible for a net increase of 9.8 million jobs. The number of new jobs in industry (0.9 million) was not sufficient to compensate for job losses in agriculture (1.1 million). In the Accession Countries job losses in agriculture and manufacturing are expected to continue, while the relatively underdeveloped service sector will need more workers in the future (EC 2001a).

In order to develop a more detailed picture on long-term trends, we shall turn to calculations presented by von Tunzelmann (1999). These calculations show trends in three regions of western Europe (West Europe, North Europe and South Europe) in five broad sectors of the economy: agriculture, mining, manufacturing, infrastructure and services. 'Infrastructure' covers the activities of gas, electricity and water supplies, transport and communication services, and construction, i.e. certain parts of what are called 'marketed services'. The calculations cover the period 1950 to 1995.

The share of agriculture in total output (and employment) was throughout highest in the Mediterranean countries of South Europe, but even there fell from around 23 % of output in the early 1950s to about 4 % by the mid-1990s. In North Europe it fell from around 10 % of output to under 3 %, but in West Europe it fell faster, from about 15 % to under 2 % of total output.

The share of manufacturing held fairly stable at around 35 % of total output in western Europe until the beginning of the 1970s, then its share in total output fell fairly monotonically to about 25 % by 1995. In North Europe the decline ('deindustrialisation') started earlier and was on a greater scale. South Europe was still catching up in the 1950s, from a starting point where the share was about 10 percentage points lower than the rest of western Europe; but once it succeeded in catching up by the mid-1970s, its share of manufacturing in total output also stagnated. In terms of absolute numbers employed in manufacturing, both West Europe and North Europe reached their maxima in 1970, with West Europe having grown much faster up to that point. The numbers employed in manufacturing in South Europe reached their maximum in 1980, though the decline thereafter was much smaller than in the other two regions.

The share of 'infrastructure' remained stable throughout in all three regions. The remainder of services and distribution rose from under one-third of total output in the early 1950s to over one-half by the mid-1990s.

In all three regions, labour productivity in agriculture throughout was only about half of that in the economy as a whole, so the transfer of labour out of agriculture – which was fastest in South Europe – reaped intersectoral productivity gains. Labour productivity in manufacturing, perhaps contrary to intuition, was about average for the economy in all regions, as was labour productivity in infrastructure (the latter with some regional variations). But productivity in the remaining services was well above average in both West Europe and South Europe (not in North Europe), hence the continuing shift of gravity from manufacturing to services after 1970 also had a positive intersectoral effect.

Between 1995 and 2000 the largest numbers of jobs within the EU service sector were created in occupations related to health care, education and social work. These occupations were responsible for more than 40 % of the 9.8 million new service sector jobs. More than 25 % of the new jobs concerned general business services and around 10 % computer and related services. The structural change in employment can be seen more clearly when comparing employment growth rates. The highest growth rate was recorded in occupations that are related to information technology and involve high levels of education. Employment in 'computer and related services' grew more than 13 % (1 million jobs) in 1995-2000, while the net growth rate of jobs in general business services was 6 % (2.5 million jobs). The number of jobs in education, health and social work increased by 2.1 % (4 million jobs). It has been estimated that 1.5 million jobs were created in the high-tech sector of the European Union in 1995-2000 (EC 2001a).

Historically business services have been the most rapidly growing group of service occupations. Business services comprise professional, computer, technical, marketing, leasing and renting, labour recruitment, operational and other services, but exclude real estate services as well as R&D services. Between 1980 and 1994 employment in business services grew at an average annual rate of 5.5 %, more rapidly than in any other sector of the economy during that time (EC 1998). The rapid sustained employment growth rate in business services suggests that in this field there may exist a continued potential for job creation that has not been exhausted yet. Some support for this claim can be found by looking at what has happened in the United States. In 1998 it was estimated that in the EU the value added by business services equalled 72 % of the value added from manufacturing industry and was six times that from agriculture. In the United States the value added from the business services was even higher, amounting to 106 % of that from manufacturing industry (EC 1998). Therefore it is quite possible that in Europe employment in this sector will continue its rapid growth at least in the near future.

While the employment outlook is brighter in services than in other major sectors of the economy, there are risks as well. They relate mainly to technical change and globalisation. In the service sector the main impact of information and communication technologies has been so far focused on the quality of services rather than on labour productivity. ICTs, the Internet in particular, make it possible for service providers and users to transcend the boundaries set by time and place. Making banking, booking, ordering and governmental services available on the Internet enhances the quality of these services significantly for that segment of the population that has easy access to the Internet. At the same time, information technologies have the capability to induce large numbers of job losses in service occupations that involve tasks that can be performed more efficiently or conveniently by relying on self-service systems, automation, or communication networks. The technological potential for such productivity enhancement is evident in low-skill occupations in the banking sector and various administrative tasks in both the private and public sector.

Skills required in human interaction may save many of the jobs of low-paid and low-skilled workers in social services, health care and personal services. In fact, as a result of on-going demographic, social, life-style, and cultural changes the demand for labour in these job categories may increase. Technical change plays a secondary role in these occupations, whereas it has a much more important role in service occupations requiring high skills and offering high pay. New service sector jobs requiring high skills and paying high wages are expected to emerge at least in business services, R&D, software, human resource development as well as various consulting and marketing services (IPTS 1999; EC 1998).

So far most service sector enterprises have not been subjected to international competition. This may change in the future as a result of the increasing sophistication and convenience of information and communication technologies (ICTs). These technologies facilitate the provision of knowledge- and skill-intensive services not only regionally, but nationally and internationally as well. International trade in services is supported by liberalisation and globalisation of the economy and the General Agreement on Trade in Services. The fact that demand for services increases as incomes grow bodes well for employment in the sector, but one of the risks involved is that advances in communication may lead to productivity increases that will eventually reduce the growth rate of jobs in business services. Most of the low-paid service sector jobs will, however, continue to rely on local demand with little international competitive pressures and only incremental changes in technology. In relation to their turnover, small and medium sized enterprises (SMEs) can be expected to require more services than their large counterparts.

Another important trend in the EU labour market is the rising average skill level of the workforce. Between 1995 and 2000 the proportion of the EU workforce having attained less than secondary education fell by 8 percentage points to 28 %. In all industrialised countries workers having low levels of education face a higher risk of unemployment. More than 40 % of the unemployed in the EU are low-skilled, *i.e.*, they have had less than upper secondary level education. Skills and education are particularly important for women, since the employment rate of low-skilled women was only 38 % in 2000. Industries relying on low-skilled workers tend to use well-established technologies and produce goods that usually have no significant technological competitive advantages. The risk of job losses in such companies is high, while companies that invest in new technologies need workers with skills that are not possessed by many of the unemployed. In the year 2000 about a quarter of the EU labour force had attained tertiary education level and almost 70 % had at least secondary education. However, there were wide differences among the Member States (EC 2001a).

1.2.2 The importance of productivity

In the long run it is the productivity of labour, more than anything else, that determines the level of welfare in a society. Labour productivity indicates how much effort is needed in the production of a certain level of output. Improvements in labour productivity translate themselves into increases in wages, reductions in the need for labour in the production of a set level of output, reductions in prices, consequent increases in demand, and therefore increases in the demand for labour. This beneficial cycle has been a major cause of the rise in living standards since the beginning of historical time. In economics unemployment directly caused by improved productivity is less important than productivity, since the problems associated with unemployment could (in theory) be solved by redistributing those increases in welfare that accrue from higher productivity. Technical change (broadly interpreted) is a major source of improvements in productivity.

The vital importance of labour productivity becomes evident when studying long-term trends in the welfare of industrialised nations. During the last few centuries increasing productivity has brought about immense improvements in welfare in Europe, and technological development has been one of the main factors that has contributed to the productivity increase. Income per capita roughly doubled between the years 1500 and 1800 in Western Europe, representing a growth rate of 25 % per century. Since the year 1800 the growth rate has been about 500 % per century. Industrialisation has been the single most important cause behind the 20-fold acceleration of the growth rate (Maddison 1991). Industrialisation increased the productivity of labour and capital, and in 1992 a typical worker in a rich industrialised country was 20 or 30 times more productive than an average worker in the poorest countries (Prescott 1997: 1).

In economic theory it is easy to see a difference between a case in which labour productivity improves as a result of movement along a production function and another in which a similar improvement is achieved as a result of change in technology, *i.e.*, a shift in the production function. However, in practice it is difficult to distinguish between the two phenomena. Increases in the productivity of labour are usually associated with investments in human capital (education) or physical capital, such as machinery or computers. Investment and education are key factors affecting labour productivity. Technical change often takes the form of investment in production capital, and the productivity of capital investments in turn often depends on the success of employee training.

While most productivity studies have concentrated on labour productivity, it has to be kept in mind that between countries and industries there are large differences in the productivity of capital as well. Sectoral differences in productivity of capital can be expected to affect rates of return to capital investment in these sectors. Historically rates of return have been much higher in the United States than in Europe, and consequently the United States has attracted large amounts of investment capital from other parts of the world, including Europe. A recent study compared capital productivity in the United States, Germany and Japan in automotive production, electric utility, food processing, retailing, and telecommunications in the early 1990s (Borsch-Supan 1998). It was shown that in Germany and Japan the productivity of capital was about two-thirds of the level achieved in the United States. Only in the Japanese auto industry and in German retailing was capital productivity on a par with the corresponding industries in the United States. In our simulation models we cannot take into account the international movements of investment capital, but it is likely that they would sharpen the differences that are now observed between our scenarios.

The productivity of all factors used in the economy is called multi-factor productivity (MFP) or total factor productivity (TFP). This quantity is derived as a residual and thus comprises the productivity effects of not only known but also unknown factors. Following an interpretation given by Robert Solow in the 1950s, it is widely believed that increases in multi-factor productivity result mainly from improvements in technology. However, MFP comprises not only the consequences of technical change but also productivity impacts from all other potential sources, such as changes in government policies, education and training, health care, physical infrastructures, and social infrastructures. Multi-factor productivity can be regarded as a measure of an economy's overall efficiency – its cleverness in organising work and exploiting innovations (Easterly and Levine 2000).

Individual technologies, however clever, have little impact on multi-factor productivity of a whole economy. The daily lives of inhabitants of industrialised countries were thoroughly transformed by successive waves of innovations during the 19th and 20th centuries, but the contrast with the patterns of multi-factor productivity is striking. For instance, in the United States multi-factor productivity increased at an average annual rate of 0.77 % between 1870 and 1913. The productivity growth rate increased to 1.60 % between 1913 and 1972, during a period when such radical innovations as the electric motor, internal combustion engine, petrochemicals, plastics, modern pharmaceuticals, radio and TV were diffused throughout the American economy. The growth rate of multi-factor productivity declined to 0.62 % between 1972 and early 1996 (Gordon 2000: 51). It is only natural that the introduction of the personal computer in the 1980s and the rapid growth of the use of the Internet in the 1990s have had only a small initial impact on national productivity statistics. Modern advanced economies comprise a great number of economic activities, and individual technologies can have little impact on the overall growth rates, until they become diffused across a wide range of uses ('general purpose').

Productivity growth is one of the most important determinants of long-term sustainable economic growth. In a study of ten OECD countries it was found that about 42 % of average GDP growth across the countries during the 1970s and 1980s resulted from growth in multi-factor productivity, about 37 % from increases in capital input, and about 21% from labour input (Sakurai *et al.* 1997). The contribution of MFP was more than 60 % of GDP growth in the Netherlands, Denmark, the UK, France and Italy. In Germany and Japan it was about 30-40 % of GDP growth. In Australia, Canada and the United States the contribution of MFP was only 10-30 % of GDP growth, reflecting higher growth rates of labour and capital inputs in these countries. The contribution of labour was negative in the Netherlands and Denmark, reflecting declines in the productivity of labour. The contribution of capital was highest in Japan (50 %) and Germany (43 %). Thus it can be argued that about 40 % of the recent increases in our living standards result from multi-factor productivity, and one of its major components, in turn, is technical change.

1.2.3 The impacts of innovation on productivity

As labour productivity is a major determinant of our economic well-being, it is of paramount interest to know which policy instruments, if any, can lead to improvements in productivity. International studies have shown that labour productivity is influenced by such factors as the openness of countries to competition, education and training, investment in production capital, innovation, and technological change. In recent years important insights into factors affecting productivity growth have been achieved as a result of an approach known as the economics of technological change (Dosi *et al.* 1988). The approach takes advantage of technology indicators in explaining productivity improvements and economic growth. In what follows we shall concentrate on one factor that has been shown over and over again to have a considerable impact on productivity. This factor is research and development, or more precisely, R&D expenditures.

Let us start by noting the importance of product innovations. Table 2.1 presents past trends in labour productivity in the manufacturing industry. The industry has been divided into two sectors, in one of which technical change manifests itself mainly in product innovations and in the other in process innovations. According to the figures presented in the table, in Europe the growth rate of labour productivity was in the 1970s and 1980s higher than in the early 1990s. Higher productivity growth rates prevailed in industries that relied on product innovation than in industries dominated by process innovations.

Table 1.1. Performance of product and process innovation based industries

	Productivity growth Avg. annual rates of change				**Share of product innovation industries**		**Employment growth** in total manufacturing	
	1975-1989		1989-1994		In manuf. value added		(avg. annual change)	
	Product	Process	Product	Process	1975	1994	1975-1989	1989-1994
United States	3.78	2.37	3.48	0.59	45.9	56.5	0.51	-1.01
Japan	6.33	2.50	1.39	-0.36	40.8	60.3	0.47	0.33
Germany	2.30	1.84	0.99	2.56	48.1	54.3	-0.37	-1.63
France	3.87	2.79	1.88	1.89	43.5	49.7	-1.60	-1.59
United Kingdom	3.76	3.43	1.69	1.32	49.0	54.5	-2.32	-1.62
Italy	5.44	4.65	2.12	2.87	40.8	43.7	-0.70	-2.07
Europe 4	3.59	2.94	1.41	2.17	46.0	51.0	-1.18	-1.72
G6	4.35	2.66	2.20	0.96	44.9	55.5	-0.24	-0.93

Source: Pianta 2001.

In the past industries dominated by product innovation have expanded everywhere, but at markedly different rates. In 1975 these industries accounted for 45 % of manufacturing value added of the G6 countries; twenty years later their share had reached 55 %. The largest increase took place in Japan (from 41 to 60 %), followed by a 10 percentage point increase in the United States and a 5 percentage point increase in Europe. The fact that Europe has relied more on process innovations than other industrialised regions of the world has had serious consequences in terms of employment.

The picture that emerges of European manufacturing industries is that technological change seems to be dominated by labour-saving process innovations embodied in new investment. The substitution of older production equipment often leads to a decrease in labour demand. One of the long-term problems of Europe is a high share of capital-intensive process-innovating industries, in which technical change manifests itself in unemployment. There is an urgent need to foster the development of product-innovating industries that would achieve higher rates of growth in turnover and employment.

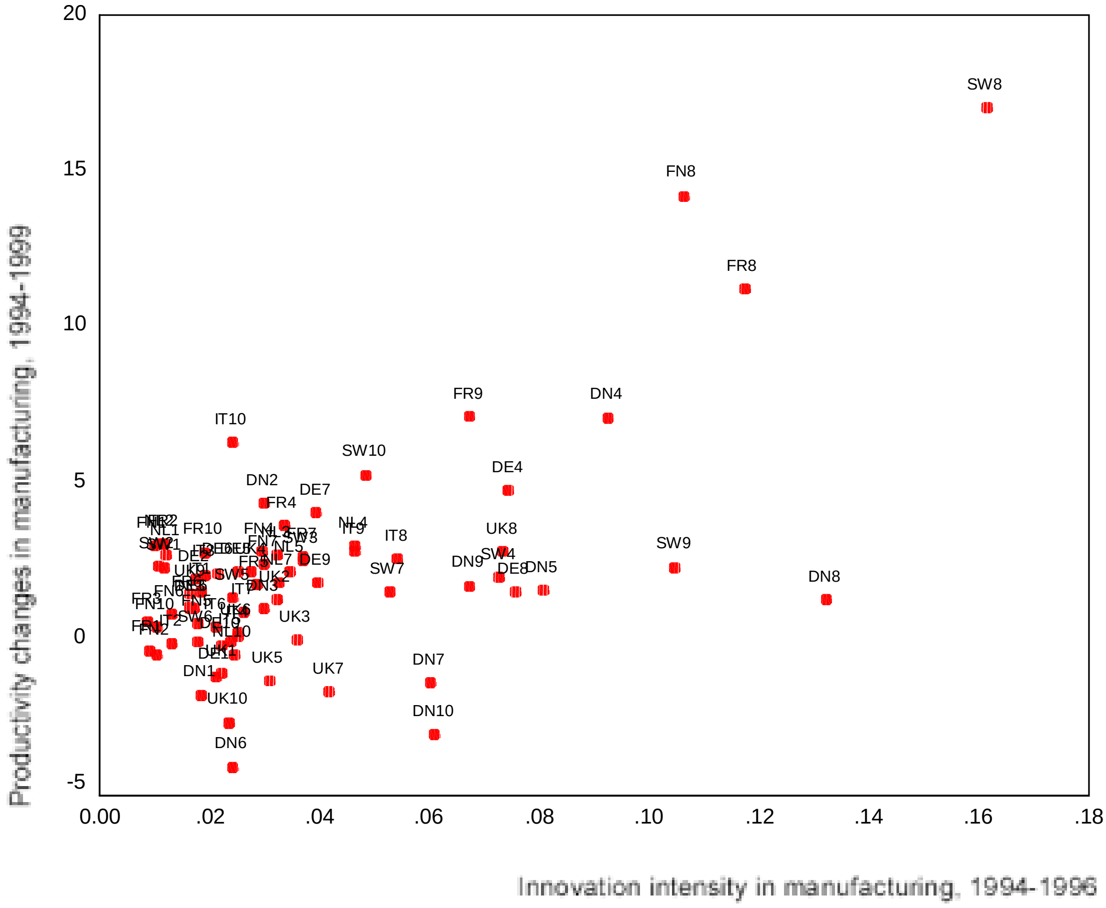
In quantitative simulations carried out in our study innovation policies are assumed to affect directly the rates of productivity and consumption in Europe. This is not an unreasonable assumption. In the economics of technological change R&D expenditures are often used directly as a proxy for technical change, and most empirical studies point out that there is a connection between R&D expenditures and productivity. The first regression analyses linking R&D with labour productivity were carried out as long ago as the 1950s by Terleckyj (1958) and were followed by Griliches (1964) and Mansfield (1965). By 1995 more than 150 econometric studies on the impacts of R&D and productivity had been carried out (Mairesse and Mohnen 1994). In most of these studies innovation activities were assumed to produce what is known as R&D capital, a stock of knowledge that gradually depreciates if it is not replenished by new R&D efforts. Reviews of this literature have been prepared by Griliches (1995), Nadiri (1993) and Fagerberg (1994). Models exploring the links between R&D and productivity have been applied to firm, industry and country data using both cross sectoral and time series approaches.

While labour productivity is in the long term an important determinant of our standard of living, labour productivity is in turn influenced by advances in technology, in particular the diffusion of new technologies. An overwhelming body of evidence shows that both the firms performing technology development (i.e., R&D) and society at large derive considerable economic benefits from their investments in R&D. Often the returns for R&D are found to exceed the returns for other types of private investment.

In a survey of more than 60 international studies it was found that annual returns of between 20 % and 30 % were obtained for private industrial R&D. Estimates of social rates of return averaged about 50 % (Nadiri 1993). The high rate of social returns for R&D means that the productivity benefits of R&D carried out in a certain sector eventually diffuse throughout the economy, albeit with a delay. In one study it was found that indirect productivity increases in industries purchasing capital and intermediate inputs from industries conducting R&D were higher than those derived by the industries that actually conducted the R&D (Terleckyj 1980: 376). Transmission of new technologies across national borders is also an important source of productivity improvements (Grossman and Helpman 1991). If a government or a public R&D funding agency aims at obtaining a high social rate of economic return for R&D expenditures, then it usually tries to stimulate R&D in industries that are on the verge of commercialising new technologies. Social rates of return up to 270 % have been reported in the case of computer-tomography scanners for R&D carried out in the 1980s (Trajtenberg 1990). Needless to say, such high returns are probably no longer possible in that particular industry since it has grown more mature.

Total innovation expenditures are a broader concept than R&D outlays. Innovation expenditures comprise R&D expenditures (usually less than half of the total) as well as expenditures related to product design, engineering, marketing and innovation-related investment. Figure 1.1 depicts the varying relationships between innovation intensities (ratio of total innovation expenditures to sales in a sector) and productivity growth rates in ten industries of eight EU countries between 1994 and 1999. The strong sector-specificity of the innovation-productivity relationship should be carefully noted, although there is a broad positive association between the overall innovative efforts and the productivity performance. The best productivity growth rates were seen in electronics industries in Northern Europe as well as chemicals and pharmaceuticals industries in several other EU countries. In most countries traditional industries exhibit low rates of innovation and productivity growth.

Figure 1.1. Productivity growth and innovation intensity in ten European industries in 1994-1999.



Countries: Germany, France, Italy, the UK, the Netherlands, Denmark, Sweden and Finland.

The sectors are an aggregation of ISIC Rev.3 classification and include:

1. Food, Beverages and Tobacco products (15-16)
2. Manufacture of Textiles, Dressing, Luggage, Footwear (17-19)
3. Manufacture of Wood, Paper and Publishing and Printing (20-22)
4. Manufacture of Coke, Chemicals products Refined Petroleum products (23-24)
5. Manufacture of Rubber, Plastic and other Non-Metallic Mineral products (25-26)
6. Manufacture of Basic Metals and Metal products (27-28)
7. Manufacture of Machinery (29)
8. Manufacture of Electrical, Office, Precision Machinery and Communication Equipment (30-33)
9. Transport Equipment (34-35)
10. Recycling (36-37)

It should not be forgotten that it is the diffusion of new technologies in an economy that is the basis of the realisation of the benefits of technical change. In fact a considerable part of the R&D carried out by companies is actually designed to facilitate the adoption of new technologies. This is an especially significant feature of R&D carried out in small countries. An OECD study estimated that technology diffusion can account for more than half of the growth in total factor productivity. The impact of technology diffusion was stronger during the 1980s than 1970s and was especially notable in the service sector (OECD 1996:37).

1.2.4 The impact of technical change on employment

The net employment impacts of new technologies depend on their effects on the supply of and the demand for labour. On the supply side, new technologies increase productivity and, subsequently, the production capacity. On the demand side, new technologies increase the attractiveness of products having new features, in some cases even supplied at lower prices. Moreover, completely new kinds of products may be developed, prompting consumers to increase spending on them until a point of saturation is reached. Technical change makes it possible to increase productivity both by improving the efficiency of production processes and by increasing the value of the products, thus raising the value added per each unit of labour and capital.

Various compensation mechanisms mediate the impacts that productivity-augmenting innovations have on employment and productivity. Product innovations tend to improve employment, but the net effect depends on the extent to which new products replace existing products in the marketplace. Although process innovations usually involve the displacement of workers, they may also reduce unit costs of production and – in a competitive market – this effect is translated into decreasing prices that stimulate demand and employment. In a concentrated oligopolistic market decreasing costs are more likely to be translated into higher profits and wages depending on the bargaining power of trade unions, but even in this case aggregate demand and employment may be increased.

It is possible to discern altogether six compensation routes that alleviate the labour-saving effects of technology-induced productivity enhancements (see Vivarelli 1995; Vivarelli and Pianta 2000):

- via new machines (more jobs in the capital sector)
- via decreases in prices (the number of new jobs depends on the degree of competition)
- via new investments (the delay depends on the expectations of entrepreneurs)
- via new consumption (the technological rent is partially appropriated by wages)
- via new products (welfare vs. substitution effect)
- via a decrease in wages (labour market adjustment triggered by technological unemployment that has a negative effect on aggregate demand)

The actual difference between the labour-saving effects of on-going process innovations and the employment-creating impacts of product innovations varies considerably according to prevailing conditions of competition, price and wage rigidities, investment climate, and so on. Moreover, new technologies differ as to their propensity to create employment opportunities. For instance, the introduction of the automobile had a much higher effect on labour demand than the diffusion of the home computers.

Evidence from the United States suggests that firms using advanced technologies pay higher wages, offer more secure jobs, and increase employment more rapidly than other plants. Technology is found to contribute to the creation of high-quality jobs. Advanced-technology firms hire workers with higher skills and pay them better wages (even when taking into account the skill level). At the firm level there is a positive relationship between technology and employment (see Entorf and Pohlmeier 1990; Blanchflower, Millward and Oswald 1991; Van Reenen 1997; and Smolny 1998). However, these results cannot necessarily be generalised to the industry level.

A positive correlation between technology and employment at the firm level may be associated with overall job losses at the sectoral level. While leading innovators may increase their market shares and employment, other companies may be forced to cut labour or leave the market altogether. Hence, microeconomic studies can lead to the conclusion that innovation is good for a given innovative firm and for its employment, but say little about the overall relationship between a given technology and employment. For this purpose attention has to be turned to sectoral and aggregate studies. That is the level to which we pay most of our attention in this study.

At a sectoral level, the positive relationship between new technology and productivity growth still appears, although is not as strong as at the firm level. Contrary results have also emerged. In a study of 21 manufacturing sectors in five European countries from 1989 to 1994, employment changes were positively correlated with growth in demand, output (value added and exports) and product innovations, while the overall technological intensity had a negative effect. These results suggested that in Europe the dominant impact of innovation was that related to processes and productivity rather than to new products and employment-creation (Pianta 2000, 2001).

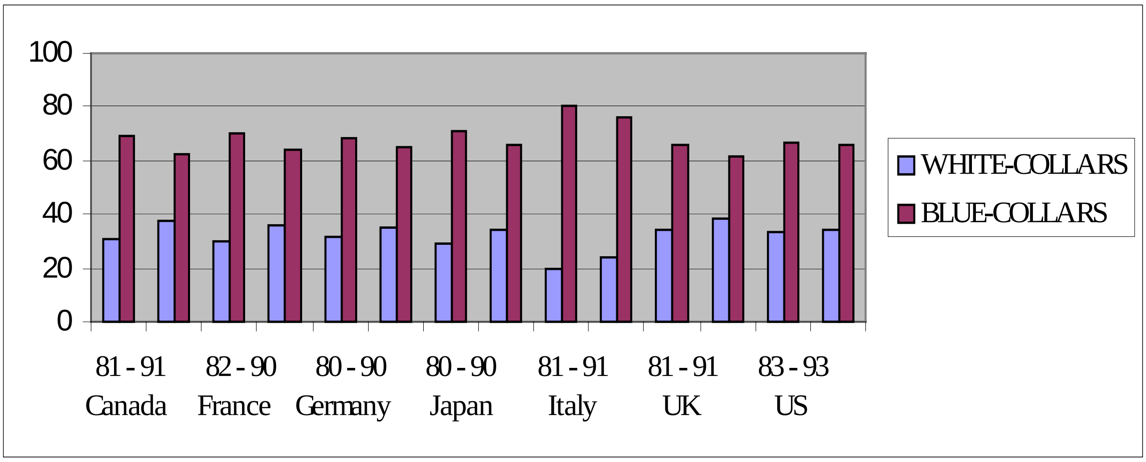
In the service sector the prospects are more promising. New technologies have led to the birth of entirely new occupations in the sector, and the shift in demand from tangible goods to intangible goods and knowledge-intensive services has spurred a virtuous circle between supply and demand in the sector. While services are not immune to labour-saving process innovations, so far information and communication technologies have had a positive overall impact on employment in this sector (Evangelista and Savona 1998; Evangelista and Perani 1998).

1.3 Trends in skills

Over the last decade the demand for skilled labour seems to have increased in Europe at a faster pace than its supply. As a result, skilled workers find employment more easily and are better paid than the unskilled (Nickell and Bell 1995), but there are national and sectoral differences. Technical change is one of the factors prompting employers to demand higher skills from their workers. That is why it is said that technical change is skill-biased. In continental Europe the skill bias has contributed to higher unemployment among the unskilled workers (Machin and Van Reenen 1998), while in the United States and – to a lesser extent – in the United Kingdom the bias has affected the wage differentials between the skilled and unskilled (Krueger 1993; Autor *et al.* 1998). It seems that there has been a growing skill bias in manufacturing industries, although recent patterns are in debate, while more evidence on the existence of the bias is emerging from the service sector as well (OECD 1998).

In manufacturing employment, the share of blue-collar workers is declining, while that of white-collar workers is growing. In the United Kingdom the employment of blue-collar workers has decreased at a faster pace than white-collar workers. In the United States, high-skilled white-collar employment has been increasing at a much faster pace than that of low-skilled white-collar workers and blue-collar workers. Figure 1.2 depicts these trends in the G-7 group of countries.

Figure 1.2. Shares of white-collar and blue-collar workers in manufacturing employment in the G-7, per cent.



Source: Calculations based on OECD data (1998).

It is generally believed that one of the main reasons for the labour-force upskilling is the non-neutrality of technological change. Historically, till the middle of the nineteenth century, technical change exhibited a negative skill-bias, as craft-skilled artisans were forced to become unskilled employees carrying out simplified tasks in factories (Acemoglu 2001). New skills were however needed in new activities (von Tunzelmann 2000). By the early 20th century, Goldin and Katz (1998) find evidence of complementarities between technology and new skills in the manufacturing industries of the United States. The complementarity seems to reflect the introduction of continuous production, and was reinforced by the diffusion of electric motors that made unskilled factory labour redundant.

The existence of the skill bias has been largely supported by empirical studies carried out in Europe and the United States. Machin and Van Reenen (1998) studied the phenomenon in the manufacturing industry of seven countries over the period 1973–1989. It emerged that the relative demand for skilled workers was positively linked to R&D expenditure.

Concerning the United States Berman *et al.* (1994) analysed the dynamics of 450 branches of manufacturing industry in the 1980s. Their cross-sector econometric analysis related the shift in employment structure to R&D expenditure and investment in computers. This result was proved to be statistically significant in almost all sectors. In another study a positive relationship was also found to exist between R&D and skilled labour (Dunne *et al.* 1996). The use of the most advanced industrial technologies (CAD, numerically controlled machines, robots) has been shown to be associated with workers having high qualifications (Doms *et al.* 1997). The skill-biased nature of R&D and innovative investments is also evident in the chemical industry (Adams 1999).

In Canada a connection between several different measures of technology and the growing demand for skilled workers has been shown to exist both in manufacturing and in service industries (Gera *et al.* 1999). In the United Kingdom a positive correlation has been observed between skilled labour and R&D intensity, the number of innovations, as well as the use of computers (Machin 1996). The link between investment in computers and the presence of skilled (white-collar) labour was confirmed by Haskel and Heden (1999).

The hypothesis of skill-bias in technical change has been supported in studies carried out in other countries, but the evidence obtained has been less robust than in North American and British industries.

In France the diffusion of new technologies was found to explain only 15 % of the changes in labour demand between 1970 and 1993 (Goux and Maurin 2000). These results were confirmed by Mairesse *et al.* (2001), who also observed that a negative relationship existed between ICT technologies and low-skilled workers.

In German manufacturing companies the introduction of product and process innovations had a strong positive impact on the demand for university graduates (Falk 1999). In the service sector in Germany investments in information technology increased the demand for high-skilled workers and were associated with redundancies for the unskilled (Falk and Seim 1999). No statistically significant relationship was seen to exist between R&D and labour-force composition in a Spanish study (Aguirregabiria and Alonso-Borrego 2001).

In general, the skill bias of technical change seems to be a well-established finding. However, care should be taken in interpreting these results. Just as the early industrial phases of mechanisation and then electrification led from one established type of skill (craftsmanship) to another (machine-minding), so the skill-bias of recent times has especially favoured a third type. The machine-minding skills, often referred to as ‘motor skills’ (mainly using the hands, as in traditional manufacturing) are coming to be displaced by ‘cognitive skills’ (mainly using the brain, as in some new service sectors), and ‘interactive skills’ (in management and elsewhere). These displacements have had a dramatic impact on the relative earnings of employees over the past quarter-century - in particular, driving growing inequality, as in the USA (Howell and Wolff 1992; Wolff 1996).

Moreover, the cognitive skills required in the early stages of a new technology, such as at present needed in biotechnology and nanotechnology, come to be complemented over time by cognitive skills required to adapt and utilise these new technologies in myriad uses. The latter is now coming about in ICTs, for instance in relation to much software development. Such a pattern, of a shift in the balance from skills to produce new technologies to skills to make use of technologies, has been a regular phenomenon of past technological ‘revolutions’, such as the case of electrification to be discussed in a later section. It also underlies patterns towards the ‘fusion’ of new technologies. At several points in this report we refer to the likelihood of future acute shortages of those who can combine new areas of expertise, such as combing information technology with biotechnology, and combining automation technology with nanotechnology. These probable trends carry strong implications for educational policy, as will be described later.

The skill-biased nature of modern economic life is further reinforced by the globalisation of the economy and organisational changes instigated as a response to increased competition and technical change. The growth of international trade can lead to the relocation of activities involving unskilled workers to countries in which wages are low and the supply of unskilled people is abundant, while industrialised countries hold their comparative advantage – and jobs – in the production of skill-intensive goods. Feenstra and Hanson (1996), using a panel of 450 manufacturing industries (1972-1990), show how internationalisation can account for 30-50 % of the increase in the demand for skilled labour in the United States. Similarly it has been estimated that international trade is responsible for up to 30 % of the reduction of jobs for unskilled workers in developed countries (Wood 1994), although such figures have been disputed.

In Germany both ICTs and new organisational practices have been observed to have a negative effect on unskilled labour (Falk 2000). More evidence for the skill-biased nature of organisational change was gathered in a comparison of French and British firms (Caroli and Van Reenen 2001). In French manufacturing firms a reallocation of jobs from production to R&D and marketing seems to have taken place, again working in favour of white-collar workers and at the expense of blue-collar jobs (Thesmar and Thoenig 2000). In downsizing reforms of French firms developments of similar character have taken place (Caroli *et al.* 2001).

1.4 Trends in work organisation and job quality

The realisation of the productivity benefits of technical change often requires not only the acquisition of new skills by workers but also organisational changes in production. For instance, Hannan and Freeman (1977) treated firms as organisational entities subjected to adaptation to the environment and to selection by the market; only those firms that efficiently combine technology and organisation are able to survive and increase their market shares. Milgrom and Roberts (1990) push the analysis one step further and propose the presence of a super-additive production function where the combination of technology, organisation and skills can reveal important scale and scope economies. Caroli *et al.* (2001) represent these issues through a “black triangle” – technology, organisation and skills – which determines a company’s economic performance.

Turning the attention to the empirical evidence, among companies that have adopted information and communication technologies (ICTs) the best results have been obtained by those that also carried out organisational changes. The changes that were needed included the instigation of self-managing teams, decentralisation of decision making, reduction of layers of management, and empowerment of employees to make critical decisions together with suppliers and customers. One study shows a strong three-way complementarity between skills, technology and new organisational practices such as self-managing teams, teamwork and team building activities, all contributing to an upskilling of companies’ occupational structures (Bresnahan *et al*. 2002).

A gradual transformation is taking firms from rigid, Tayloristic organisations towards more flexible practices, which require higher skills. This phenomenon first appeared in the United States and has since expanded to Europe (OECD 1999). By 1992 more than 60 % of American companies covered in one particular study had already introduced such new working practices as just-in-time, total quality management, job rotation, or team work (Osterman 1994). In a survey carried out in ten European countries in 1996-1997 about one third of participating establishments reported that they had adopted such work practices (European Foundation for the Improvement of Living and Working Conditions 1997).

At the same time, these organisational changes imply a new variety of communication channels within the firm, aiming to balance new workers' autonomy with a more prescriptive approach in what is known as "controlled autonomy" (Coutrot 1996). Information and communication technologies play a crucial enabling role in management as well as in collaboration within and between organisations. In 1999 there were over 9 million workers in the European Union engaged in new working practices directly involving the use of networked technologies, unevenly distributed across Member States (Millard 1999). It has been suggested that in the future virtual organisations can engage suppliers, producers and customers in work processes on an as-needed basis. The anticipated results include reductions in cost and cycle time, and improved levels of quality and customer satisfaction (Crandall and Wallace 1995). Teleworking and teleconferencing can bring about savings in the costs of travel and office facilities (Black 1998).

Technology has also had some influence in making possible an increased segmentation of labour. Core or primary workers are offered stable careers, while secondary workers face a high rate of turnover with little career progression or training. The career-oriented, male-dominated core segment has seen job boundaries broken down, multi-skilling becoming the norm, and work organised into teams. They also carry a greater responsibility for operational decision-making. Meanwhile peripheral groups have increased in numbers in relation to the core. They include part-time and job-sharing employees as well as those who are on short-term or outsourcing contracts. Nevertheless there is evidence according to which 'job tenure', a measure of employment stability, either remained unchanged or increased during the 1990s in the labour markets of 12 out of 16 OECD countries. Even in occupations that are the most closely associated with the 'new economy', job tenure remained largely unchanged (ILO 2001). However, it is possible that employment stability will be eroded in the future, if economic conditions deteriorate.

The impact of technology on job satisfaction largely follows the lines of employee segmentation. The core workers have to cope with demands for longer hours of work and a blurring between work and leisure. Work in itself may have become more rewarding as the creation and use of knowledge have become an increased element of it. There is more freedom at work, because the necessity to be in a specified location at a certain time is reduced. On the margins of the labour market the new types of employment relationships often lead to increased stress and health problems. Problems related to safety at work are more common among the non-core employees and in low-skilled manual jobs. In a recent survey 30 % of the EU population were dissatisfied with their own work status. Unemployment, lack of job protection, low pay, and inflexible or atypical working hours were the main reasons (EC 2001a).

1.5 Trends in technology

What makes technical change important in terms of employment is not discoveries in the laboratory but new technologies that are adopted widely in the economy. This applies both to incremental innovations that induce improvements in products or processes and to radical new technologies that can lead to the development of entirely new products, enterprises and even industries. As we have already seen, successful exploitation of new technologies often requires changes in work practices and the acquisition new skills.

Incremental technical change is an almost continuous process going on in all sectors of the economy, including such traditional occupations as agriculture. From time to time, periods of more comprehensive technical turmoil are instigated by technical breakthroughs that open a wide variety of technical opportunities for commercial exploitation. A great number of new products come to be introduced to the market. Eventually, dominant technical designs emerge from the competition and become widely accepted as a common basis of commercial products. Examples of dominant designs include the basic structures of the passenger car and the PC. While it is often newcomer companies that first introduce technological turmoil into an industry, the winners in establishing dominant designs are often those well-established companies that know the needs of customers and have their trust.

In this chapter we shall look at expected technological developments that are likely to be of importance in terms of employment by the year 2020. In order to facilitate our analysis we shall divide the technologies into two groups. The first group consists of technologies that are the real engines of technical change: information and communications technologies (ICTs), biotechnology (including medicine) and nanotechnology. We shall call this group of three technologies 'general-purpose technologies'. They have the potential to influence developments in a number of industries and can bring about great improvements in productivity. The second group of technologies comprises those that are closely associated with particular industries and applications. Advances in these technologies are influenced by developments in general-purpose technologies and methods closely related to particular fields of application. We shall call this second group of technologies 'sector-specific technologies'.

1.5.1 General-purpose technologies

General-purpose technologies share a number of characteristics. Each of them has a wide potential for improvement and elaboration, applicability across a broad range of uses, products and processes, and strong complementarities with existing or potential new technologies (Lipsey *et al.* 1998). In addition to these features there are others as well that are common to the three general-purpose technologies.

The first additional shared characteristic of the three general-purpose technologies is that each of them has emerged as a combination of preceding technologies. ICTs came about as a result of a fusion of electronics hardware, theoretical ideas on programmable Turing machines, and communication technologies applied in the telephone industry. Biotechnology evolved as a merger of microbiology, biochemistry, medical sciences and industrial production technologies adapted from the chemical industry. Nanotechnology is gradually coming about as a result of efforts by scientists and engineers engaged in four separate disciplines:

microelectronics, photonics, biotechnology and chemistry. The defining feature of nanotechnology is the use of methods that operate on the scale of molecules.

The second additional common feature of these general-purpose technologies is that industries relying on them consume relatively small quantities of natural resources. Silicon produced from inexpensive sand is a good example. Methods of nanotechnology could reduce further the amounts of materials required in ICT devices. Similarly in biotechnology it is not the volume of materials that is important but their molecular composition and participation in complex processes that can be controlled by using gene technology or signalling molecules. The limits to growth in these fields of technology are not set by the availability of natural resources but by access to verified scientific knowledge and specialised skills.

The third additional shared feature of our general-purpose technologies is that they can confer great economic benefits on companies, regions and nations that develop dominant capabilities in their application. During the 1980s Japan enjoyed an astounding success as a result of its ability to take advantage of electronics and automation that were the most advanced fields of information technology in those days. In the 1990s the United States was able to achieve a dominant position in many areas of information and communication technology. All of the major industrial nations of today are now investing heavily in research capabilities related to biotechnology and nanotechnology, setting the stage for intense competition in the future.

The fact that the three general-purpose technologies have strong complementarities with existing or potential new technologies means that they can relatively easily form combinations with each other and sector-specific technologies. During the period reaching till the year 2020 it can be expected that, for instance, combinations involving information technology and biotechnology will become widely diffused in the European economy. Such combinations may include databases containing genetic information for diagnostic and predictive purposes. Combinations of biotechnology and nanotechnology can bring about, for instance, new diagnostic tools and lab-on-a-chip systems that can provide rapid information on patients' conditions without referral of samples to central laboratories. In 2020 widely used combinations of ICTs with nanotechnology may include electronic and optoelectronic components with features that are only a few molecules across.

Some similarities can be expected between the labour-market impacts of the three general-purpose technologies. First of all, skills related to these technologies can be expected to be in high demand over the next two decades because they can be useful in a wide range of industries. There is a close parallel with the current worldwide shortage of software engineers. The first phases of increased demand for specialised skills in biotechnology and nanotechnology are likely to focus on research qualifications in these fields. Acute shortages can be expected of people who can combine expertise in both information technology and biotechnology and of those who can combine expertise in both automation technology and nanotechnology. While highly educated specialists will constitute only a small proportion of the total workforce, their significance to the national economies of Europe is likely be much higher. It is their responsibility to carry out and manage critical phases of R&D, where success can lead to the development of very important new products. They will also play a crucial role in setting up commercial ventures exploiting the new technologies.

While the above discussion lists some features shared by the general-purpose technologies, it is obvious that there are also significant differences between them. ICTs are the most mature of the three fields, and for the period reaching till 2020 it can be expected that they will offer the best commercial opportunities for SMEs. The distinct feature of biotechnology is that it touches the core values of ourselves as human beings as it opens up the possibility of manipulating not only our genes but also the capabilities and urges of our brains. The potential of nanotechnology is still uncertain, as it is still only slowly emerging in research. By 2020 we shall probably not see many widely diffused applications of pure nanotechnology. What may happen instead is that there will be ICT and medical products incorporating efficient nanotechnology components.

The rapid evolution of *information and communication technologies* can be expected to continue at least for the next ten years. Microelectronics (processors and memories) and optoelectronics (optical networks) are the two most rapidly developing fields of technology. Starting from about 2010 the continuation of Moore's Law in microelectronics would require the gradual incorporation of components with features of the nanometre scale. This is one of the reasons why microelectronics is expected to be among the first fields to introduce nanotechnological components. Nevertheless, the period of transition from microelectronics to nanoelectronics can by no means be expected to be smooth. Software plays a crucial role in all applications of information technology, and the shortage of highly-skilled software engineers will remain acute for the foreseeable future. To put it in other words, there are no easy solutions by which the productivity of software development can be raised significantly in the near and medium term.

In *biotechnology* (including medicine) many of the strong technological trends are directly related to gene technology. Growing understanding of the genetic and molecular foundations of medical conditions can be expected to increase the productivity of pharmaceuticals research. Nevertheless, on the basis of recent trends, it will still take about ten years to develop and test a new drug molecule. At most a few dozen new original drug molecules can be expected to be introduced annually to the world market during the next ten years or so. Methods based on DNA microarrays and other diagnostic techniques could bring about the development of a new branch in health care – that of preventive medicine. The new technologies could also make it possible to determine the efficacy and side-effects of some drugs beforehand for each individual to be treated. The demand for health-care services could also be increased by expected advances in the emerging field of tissue engineering, in which replacement cells and tissues are grown implanted in patients. The provision of health-care services should be facilitated by lab-on-a-chip technologies as well as communication and database technologies that allow daily gathering and analysis of information on individuals' health. In agriculture and animal husbandry the potential of biotechnology depends on consumer acceptance, a factor that is difficult to predict.

Scientists engaged in microelectronics and molecular biotechnology are approaching *nanotechnology* from their own fields. In microelectronics the movement towards nanotechnology is driven by the need to achieve further advances in miniaturisation, while in biotechnology the need for new diagnostic tools is a major driving force. The miniaturisation of diagnostic devices has already made it possible to design DNA chips that contain tens of thousands of strains of DNA molecules or thousands of proteins. In traditional fields of materials technology there is a growing need for properties that can only be achieved using production methods that are based on building layers of molecules. Nevertheless, the gestation period of all technological revolutions is long, taking decades, so it not likely that many full-fledged nanotechnologies will be available by the end of the 2010s.

1.5.2 General-purpose technologies in a historical perspective

When a new general-purpose technology is introduced into widespread use, a technological revolution can take place. As can be seen in the case of the personal computer, the new general-purpose technology soon finds plenty of applications. A large number of economic opportunities emerge for new products, services, and companies exploiting the new technology. Whole industries not seen before may spring up; in the case of computer technology these industries included computer manufacturing and software industries. Over the next few decades the new general-purpose technologies of biotechnology and nanotechnology can have a similar pervasive impact on the European economy. While it is next to impossible to predict what will be the exact breakthrough applications and consequences of these technologies, it is useful to gain some perspective by studying what happened when two new general-purpose technologies came into widespread use. The first of these changes took place in the 1920s in the United States and involved the introduction of the electric motor in manufacturing. The second example is of more recent origin and concerns the diffusion of the personal computer.

Electric motors had been invented and commercialised in the 1880s, but it took many decades for their adoption to become widespread. Factors that contributed to the electrification of industrial plants in the United States in the 1920s included technical advances accomplished in electricity generation and power transmission after the First World War. These advances made it possible to replace dispersed plant-specific electricity generators with more cost-efficient regional power plants. Political and institutional changes reduced the powers of municipal and town governments to regulate the nascent electricity-generating industry, and consequently it became easier for industry to acquire financial capital for building power plants and transmission lines. As a result, during the 1920s the availability of electricity improved, and in manufacturing plants it became increasingly common to give up mechanical energy transmitted via shafts and belts and adopt instead electrical unit drives powering individual machines (David and Wright 1999).

The impact of the electric motor on the economy of the United States can be seen in the total factor productivity of manufacturing industry. Its annual growth rate exceeded 5 % between 1919 and 1929; more than five times as much as the average that had prevailed during the preceding three decades. Improvements in the productivities of labour and capital were recorded as well. While the capital-output ratio had been rising in the United States during most of the years between 1899-1919, sharp falls were recorded during the 1920s. Similar developments took place in the United Kingdom, where the capital-output ratio in manufacturing declined at the rate of 2.4 % per annum in 1924-37. This decline reversed an opposite trend that had prevailed from 1856 to 1913. Electrification saved investment capital by removing the need for shafts and belting and also by making it possible to develop efficient floor plans. Achieving increases in material flows became possible in factories of all types. As group drives were replaced with unit drives, maintenance work on one machine became a less disruptive operation (David and Wright 1999).

The fact that electrification enabled the adoption of rational floor plans in manufacturing contributed also to labour productivity. In the new electricity-based production lines much higher rates of material flows were achieved than in old institutions that were based on distributing mechanical power. The foundations for improved labour productivity were laid by the fact that unit drives made it possible for workers to specialise and improve their skills. The use of electricity also put higher requirements on the skills of workers, and encouraged wage increases for trained employees. The rise in real wages encouraged higher hiring standards and reduced labour turnover. In the United States increases in real wages were also linked to legislation that stopped mass immigration from Europe.

What can be learned from the introduction of electricity into industry is not only that it is important to adjust regulations and to ensure sufficient financing for investments. In the United States it was the availability of educated workers that made possible the rapid productivity advances experienced in the 1920s. High-school education had been reformed already before the electrification of the manufacturing industry. High-school graduates had acquired skills and attitudes that made them eminently suitable for receiving instruction on the factory floor. Conversely, in the United Kingdom a lack of educated workers hampered productivity advances in the late 1920s and early 1930s, when manufacturers in that country adopted the electric motor. The old apprenticeship system was no longer able to respond to the need for skilled factory workers, and reforms in secondary education were carried out too late to support the electrification process from the start (David and Wright 1999). The comparison of the developments in the United States with those the United Kingdom provides a lesson on the value of proactive reforms in education. Successful reforms can facilitate the diffusion of technical advances and support the ensuing growth in productivity. More generally, it has been shown that improvements in educational systems may not always accelerate the rate of invention but do correlate with a faster rate of assimilation of new technologies (von Tunzelmann 2000). This enables later developing countries to catch up the technological pioneers.

Computerisation presents another example of productivity changes that can be associated with the introduction of new general-purpose technologies into widespread use. In 1960 the level of services provided by computer hardware and software was still negligible in the United States. By the year 1980 computer hardware and software provided about 2 % of the total service flow from capital and consumer durable assets. In 1990 the proportion had grown to 4.9 %, and in 1998 it was already 8.2 % (Jorgenson and Stiroh 2000). While these developments were taking place, economists were engaged in a heated debate on the productivity paradox of the information technology. Computers were seen everywhere else but in productivity statistics, as Robert Solow had noted.

The productivity impact of the personal computer became evident much more slowly than had been anticipated by most economists. Between 1990 and 1998 multifactor productivity added only 0.8 percentage points to the annual average growth of the private sector GDP in the United States. However, towards the end of the decade the country experienced a period of rapid growth in the productivity of labour (OECD 2000a: 119). A comparison of labour productivity growth rates between the years 1991-1995 and 1996-1999 has shown that the growth of labour productivity was increased by 1.04 percentage points between these two periods (Oliner and Sichel 2000). Almost one half of that increase, 0.45 percentage points, has been estimated to result from the increased use of information technology (IT) capital in the economy. Moreover, increased efficiency in the production of IT goods contributed 0.37 percentage points, reflecting the fact that in the semiconductor industry multifactor productivity was growing at an astounding annual rate of 45 % between 1996 and 1999. The remainder of the productivity improvement was explained by increases in the efficiency of production in other fields of industry.

It is possible that future introductions of new general-purpose technologies will have noticeable impacts on labour productivity at the level of the national economy. However, as the structure of the economy grows increasingly varied and as the volumes of production tend to grow in most fields of the economy, achieving leaps in productivity at the level of national statistics becomes increasingly difficult. Nevertheless, the remarkable productivity improvements in the semiconductor industry show that at least within individual sectors of the economy huge advances in productivity can be achieved through advances in technology.

1.5.3 Emerging sector-specific technologies

The development of emerging sector-specific technologies is influenced both by advances in general-purpose technologies and by methods that suit the requirements of particular industries. While new general-purpose technologies are rare occurrences and may bring about comprehensive changes in the economy and patterns of employment, advances in emerging technologies usually take place in small steps and are of limited societal significance. Nevertheless, over a period of twenty years, the cumulative impact of incremental changes in technologies applied in important sectors of the economy can have a significant impact on competitiveness, employment, skill requirements and work organisation in these industries.

Annex 1 presents a detailed list of emerging technologies that are expected to have an impact on employment, through changes of labour productivity and product-service demand, in the 12 sectors of the European economy. In what follows an overview of the main impacts of emerging technologies on these sectors is presented.

1. Agriculture, forestry and fishery
Expected technological developments in these fields of primary production include genetic engineering and cloning of plant, animal and fish species. Increasingly sophisticated methods will be available for recycling waste products from farms. These technologies can be expected to be in widespread use by the year 2020, but most of them will be introduced on an industrial scale only after 2010. The prospects and employment impacts of such technologies as the use of gene technology in tree farming or deep sea fishing methods are more uncertain; in any case we expect that most of the emerging technologies will have a remarkable impact on productivity growth in the sector.

2. Energy, water, mining products, crude oil
By the year 2020 it should be commonplace to produce methane at a low cost from urban and farming waste. The competitiveness of biomass, solar cells and wind energy can be expected to improve vis-à-vis fossil fuels, while the latter can also be expected to be used in relatively clean plants based on combined gas cycles. The demand for fuels that can be used in fuel cells in buildings and cars could increase dramatically. Future water purification and waste-water treatment plants could benefit from biotechnological methods. In mining unmanned robots as well as methods allowing ultra-deep drilling and solution mining could increase productivity. The prospects for CO_2 capture and sequestration as well as economic conversion of heavy crude oil could be realised by 2010. Almost all of these technologies have a remarkable impact on productivity, much higher than that on demand.

3. Chemical, mineral, plastic and petroleum products

By the 2010s many profound changes are going to be introduced into chemical processes (especially catalysis), giving rise to materials, mostly plastics, with advanced properties and high performances (conducting, self-healing capability). Some technologies will be focused on biological aspects, both as processes (enzyme) and products (bioplastics). All of this will have a remarkable impact on demand, while productivity is rather unaffected.

4. Ferrous and non-ferrous ores and metals

By the end of the first decade of the 21st century, substantial progress will have been made towards the production of ultra-pure steel with significant impact on productivity. Impact on demand will be influenced by recycling where use will expand without commensurate increases in consumption of basic metals. Similar advantages will come within the same time-scale for long-life, high strength and temperature alloys. In the area of other high performance metals titanium will be available at prices competitive with aluminium, non-ferrous metal casting will be performed magnetically. Steel casting will be by thin strip casting. All these processes will improve productivity significantly. By the middle of the second decade, bulk availability of nano-structural and sub-micro structural metals with a wide range of desirable properties should be available, impacting demand in this sector.

5. Steel products, machinery, transport equipment

The expected time-scale for significant developments in this sector is again the end of the period after 2010. There will be a gradual introduction of improvements in the transport equipment field as fuel cell technology promotes the use of hydrogen occlusive alloys for in vehicle storage and other high temperature ceramic and metal matrix compounds are perfected. Improved performance characteristics of mechanical components will drive productivity improvements in a wide range of power generation and transportation equipment with improved wear and surface condition, reducing friction losses. New alloys will support recycling. Towards the end of the period nano-scale production of components will impact on many areas in terms of new products, stimulating new demand and improvements in productivity particularly materials.

6. Electrical and optical goods, office and data processing, toys

In the coming decade many advances are foreseen in the area of significantly increased computing power and with it the ability both to model and to simulate complex systems and problems. The precise impacts of these will depend on Europe’s ability to embrace the emerging technologies. Europe’s strengths in software development can be leveraged but lack of control over the hardware development may be a problem. The shift from silicon based to bio computing may happen in the period, while the impact of these developments may be delayed as in the past. Much faster information processing technologies and communications systems capable of much higher densities of use will continue to raise productivity of sectors employing the technologies.

7. Textiles, clothing, paper, wooden goods

Emerging technologies for textiles are blurring the traditional distinctions and providing many opportunities outside the clothing and related industries. Intelligent materials for construction and environmental control will expand the demand profile for agile textile producers with the requisite technological capabilities. The combination of textile technologies with new polymer based technologies will open up the medical field. Cross-linked technologies with sensing and communication devices are other major opportunities. Within the wood and paper sector many new technologies based on the life sciences will provide a boost to demand and still meet sustainability needs.

8. Food, beverages, tobacco

In the medium term (five years from now) there will be available many new technologies for processing food, giving rise to products with higher performances (sterilisation, life cycle) and increasing productivity of food industry. Also in the area of packaging there will be remarkable innovations such as edible films and active packaging. These are going to increase the performance (quality, life cycle) of food products and to give customers a larger variety of solutions for their differentiated needs. Fewer innovations are currently foreseen in the long term (after 2010), the impact of which on productivity and demand is rather varied.

9. Building and construction

By 2010 a few technological innovations will strongly increase the productivity of the construction industry, by making available new kinds of concrete, which also allow "products" with higher performances in terms of duration and sustainability. Advanced ICTs are going to be applied extensively in designing buildings and establishing 'smart buildings'.

10. Services for repair, wholesale and retail, transport, communication

The transition to fully automated vehicles could be already allowed by existing technologies. Five to ten years will be necessary to introduce these systems in a huge number of transport systems operating in the EU. Strong resistance could come from management and service industries related to transportation such as insurance companies. Emerging technologies for supply chains will provide in about 3 years a remarkable increase of productivity in many plants. Recent expansion and investments in high-speed fibre-optic backbones and satellites for the Internet or more generic data traffic has erased natural boundaries. Most of technologies are ready to use, while it may be expected to take 5 years to allow telecom companies to reduce debt due to the last 10 years of investments.

11. Other market services

Financial, insurance and tourism services will benefit, just in the medium range, in terms of productivity growth from the widespread application of advanced ICTs. This will allow more efficient, flexible and customised marketing relationships with customers through more friendly tools and procedures, and a more effective utilisation of the existing provision of infrastructures.

12. Non-market services: education, healthcare

The implementation of emerging technologies in the non-market services area is expected to take place in the next 10 years. Despite the likely differences in development from country to country in the EU, e-learning will offer the possibility to construct a huge variety of education paths, assembling different pieces of knowledge from schools distant in Europe. Furthermore in less than a decade, schools will provide full access to computers, reducing the digital divide, that will continue in homes. With an estimated number of 10 million potential patients needing artificial devices and one million treated with image-guided surgery techniques, the most important role for healthcare will be played by new technologies that produce non-invasive systems for diagnosis and care. In a shorter period most of these technologies could be imported from the USA and Japan.

2 Models, assumptions and scenarios

2.1 Introduction

The long-term employment impacts of technical change were estimated in this study by carrying out simulations with the GEM-E3 and ASTRA models. The simulations were based on specific assumptions about future productivity of labour and consumption demand. The assumptions were derived on the basis of analyses of long-term trends in the different sectors of the European economy. As a part of those analyses emerging technologies that are likely to affect sectoral employment levels were identified. Annex 1 presents those technologies, while Annex 2 shows the expected growth rates of labour productivity and Annex 3 presents the assumed future consumption shares of various goods and services.

In this chapter we shall describe how we arrived at our assumptions about productivity and consumption. We shall also show how we implemented the scenarios that depict different innovation policies in this study. However, we shall start by introducing the two economic models used in simulations, because they will be referred to when we shall discuss our specific assumptions about productivity, consumption and scenarios.

2.2 GEM-E3 model

The GEM-E3 model is an applied general equilibrium model in which the world is divided into 18 zones that are linked together with endogenous trade. However, international capital flows are excluded. Each of the zones has the same model structure, but parameters and variables are zone specific.

In the GEM-E3 model the economy is divided into 18 sectors. Four of the sectors are involved in the supply and distribution of energy while the remaining sectors are broad aggregates of the rest of the economy. The production in each sector is modelled by using a nested constant-elasticity-of-substitution (CES) production function. The description of the use of inputs and primary factors in each sector follows from a procedure involving several steps; at each step, inputs and primary factors are optimally combined according to a constant-returns-to-scale CES production function. The behaviour of the producers is modelled on the basis of standard assumptions about profit maximisation in a perfectly competitive environment.

The two primary factors of production are capital and labour. The labour market is assumed to be perfectly competitive and total labour supply is determined by households that maximise their utility functions. For each period, the model endogenously allocates the available labour force over sectors. As a general-equilibrium model GEM-E3 is based on the assumption that all markets are cleared; therefore unemployment as such cannot exist. The results can, however, be interpreted as showing the level of employment that would be created on the basis of the model; that level could be compared with the available supply of labour, estimated by using other means than the GEM-E3 model. Capital is a quasi-fixed variable, and is defined in a way that allows firms to change next year's capital stock by investing in the current year. It is assumed that the stock of capital is immobile not only between countries but between sectors as well.

Government activities are modelled almost in the same manner as the other sectors of the economy. Thus, the use of inputs is determined through cost minimisation. However, government expenditures, investment demand and tax levels are exogenous. The financing of government expenditures is provided from nine different sources of government revenues: indirect taxes, environmental taxes, direct taxes, value-added taxes, product and export subsidies, social security contributions, import duties, foreign transfers and profits or losses from state-owned firms.

The households are modelled as one representative household, which can supply labour, save, invest and consume thirteen consumer goods. The representative household allocates its resources in an inter-temporal environment. The household's consumption behaviour is derived from utility maximisation, and consists of two steps. First the household allocates its resources between present and future consumption, given the wage rate, the interest rate and the long-term time preference. Secondly the household takes total consumption in a period as given and makes an intra-temporal decision about how to divide the total consumption between the different consumer goods in the economy.

The demand for products by the household, the producers and the public sector constitutes the total demand. It is allocated between domestic products and imports, following the Armington specification. In this specification, cost minimising sectors and households use a composite commodity that combines domestically produced and imported goods, which are considered as imperfect substitutes. The GEM-E3 model also distinguishes between goods imported from EU countries and the rest of the world. An index for optimal allocation of imported goods according to country of origin and price is calculated, and this index price is then used to allocate consumption between the imported and the domestically produced goods. It is further assumed that countries apply a uniform rule for setting export prices, independently of the country of destination. The Armington assumption implies that the various countries within the European Union can supply exports at different prices.

2.3 ASTRA model

The ASTRA model was developed in the project Assessment of Transport Strategies (ASTRA) financed by the European Commission. The objective was to develop a tool for analysing the long-term impacts of a common transport policy in Europe. ASTRA covers the EU-15 countries and its time horizon reaches till the year 2026. ASTRA is a system dynamics model comprising four modules: macroeconomics (MAC), regional economics and land use (REM), transport (TRA) and environment (ENV).

The macroeconomic module provides an aggregated European macroeconomic environment in which the other modules are embedded. The MAC module is constructed as an extended Keynesian model. It follows a similar approach as the module developed as part of the project Environmentally Sustainable Transport (EST) of the OECD. The MAC module consists of three major elements: a supply side model based on supply of production factors, a demand side model based on the elements of final demand, and a sectoral interchange model based on an input-output table. The MAC works on a yearly time basis.

In the ASTRA model the EU has been split into four macro regions. Each of them is modelled using the same macroeconomic framework, which is adapted to regional specifics by different parameterisations. All monetary values are calculated in real values of 1995 euros. Most variables are calculated net of all taxes as taxes are treated separately.

The labour productivity model in ASTRA is based on values for the ratio of employment per gross-value-added, the inverse of productivity, from the 25-sector input-output table of Eurostat. For the purposes of this study the past productivity values were derived from historical trends and were calibrated to reflected employment statistics.

As regards model development, the main contribution of this study concerned improvements in the implementation of international trade relationships in the ASTRA model. Intra-EU trade was not a major focus of this study, and so the flows of goods and services were modelled only roughly on the basis of relative productivity developments between the four European regions, the GDP growth of each importing country, and world GDP growth. The model for exports from the four European regions to thirteen rest-of-the-world regions (RoW) is completely new. It was developed by using an approach based on system-dynamic calibration analyses. The required data were derived from the OECD online database except for labour productivity time series which were calculated on the basis of the World Development Indicators 2001 database from the World Bank and the Industrial Statistics Database 2001 (INDSTATR) from the United Nations Industrial Development Organization (UNIDO). In the trade in services it was possible to distinguish only between intra-EU and extra-EU exports. The extra-EU trade flows were modelled on the basis of relative changes of productivity, the GDP growth of the importing country, and World GDP growth.

2.4 Deriving assumptions about future productivity growth

The models described above were used to simulate trends in employment in Europe between 2000 and 2020. The simulations were based on assumptions about future productivity and consumption. We shall describe first how the projections of future productivity levels were derived. The following section will show the derivation of the consumption demand projections.

The assumed productivity growth rates for the period 2000-2020 in different sectors of the EU economy and the rest of the world are shown in Annex 2. Table A2.1 shows how the productivity growth rates vary slightly from one scenario to another in the GEM-E3 simulations. No international productivity spillovers were assumed to take place as a result of changes in EU R&D and innovation expenditures, and therefore a single set of productivity growth rates was used for the world outside of the EU in all of the scenarios. Table A2.3 of Annex 2 shows the set of productivity growth assumptions used in the ASTRA simulation of the Baseline Scenario.

The assumed growth rates of labour productivity growth rates were derived on the basis of various considerations. One of them was the analysis of past trends in productivity, and another concerned taking into account the impact of emerging technologies that are listed in Annex 1. Productivity is also going to be affected by gradual improvements of technologies that are already being used. Similarly, future developments in general-purpose technologies are going to boost productivity in several sectors of the economy simultaneously.

In simulations we have carried out in this study we have assumed that during the next two decades the elasticity of labour productivity with respect to R&D expenditures will be in the range of 0.10 to 0.15 in Europe. A number of studies have produced results that are commensurate with this assumption, and a group of such studies is listed in Table 2.1. The table also shows the results of tests we carried out using data on 10 manufacturing sectors in 8 major EU countries for the period 1994-1999. Our calculations show that the elasticity of labour productivity was 0.14 with respect to R&D expenditures. (The elasticity was the same with respect to R&D expenditures per employee.)

Table 2.1. The impact of R&D expenditures on productivity - results of recent studies.

R&D variable	Dependent variable	Elasticity coefficients	Type of analysis	Years covered	Source
Estimate of R&D stock	Log of value added	0.09 to 0.12	386-491 U.S. manufacturing firms, cross section	1967, 1972, 1977	Griliches 1995, table 3.1
Trend growth of real R&D expenditures	Growth of partial productivity	0.12	652 U.S. manufacturing firms	1966-1977	Griliches 1995, table 3.2
R&D growth	Growth of output	0.06 (not significant)	U.S. industries, 4-digit SIC classes	1973-1978	Scherer 1993
R&D per sales	Total factor productivity growth	0.36 (with computers) 0.13 (without computers)	143 U.S. industries 3-digit SIC classes	1973-1989	Griliches 1995, table 3.3
Estimate of stock of business R&D	Multifactor productivity growth	0.13 (increasing over time)	16 OECD countries, aggregate cross section	1980-1999	Guellec and van Pottelsberghe 2001
Growth of R&D expenditures Growth of R&D expenditures per employee	Growth of value added per employee	0.14 0.14	10 manufacturing sectors in 8 major EU countries, cross section	1994-1999	Tests carried out for this study

The findings presented in Table 2.1 are sometimes surprisingly consistent. A recent OECD study on the ‘New economy’ suggested that “the empirical evidence typically shows that a 1 per cent increase in the stock of R&D leads to a rise in output between 0.05 and 0.15 per cent” (OECD 2000b:14). A study of 16 OECD countries covering the years 1980-1998 found that “an increase of 1 % in business R&D generates 0.13 % in productivity growth. The effects are larger in countries which are intensive in business R&D and in countries where the share of defence-related government funding is lower.” Higher returns accrue for foreign-funded R&D and public R&D carried out in universities (Guellec and van Pottelsberghe 2001:3). More divergent relationships between R&D and productivity can be observed, depending on, for instance, time spans selected for study. The elasticity is not to be seen as representing an automatic, mechanistic relationship.

While a relatively uniform picture emerges on the basis of studies considered here, there are limitations. For instance, although R&D efforts often aim at achieving higher productivity by increasing the value of output or by reducing the costs of production, R&D expenditures are an input indicator. They do not directly measure the extent of the actual technical change that has been achieved as a result of R&D efforts. Moreover, R&D expenditures exclude such innovative activities as design, engineering, training, and marketing. The measurement of productivity changes is problematic especially in those sectors in which the growth of productivity is very fast and prices fall. The use of hedonic prices, reflecting the high user benefits of new products equipped with sophisticated features, creates a risk of exaggerating productivity growth (Colecchia and Schreyer 2001; OECD 2000b). Other complicating factors include the estimation of time lags between R&D expenditures and their impacts and correctly identifying and measuring other factors that explain the growth of productivity, such as organisational innovations, improvements in skills and competences, and the benefits of networking collaboration.

2.5 Deriving assumptions about future consumption patterns

Consumption coefficients used in simulations for the different sectors of the economy for the period 2000-2020 are shown in Annex 3. Here we shall summarise how these coefficients were derived. The effect of technical change on consumption demand is based on the diffusion of new products (increasing final demand), greater competition, reductions in prices, and changes in preferences (see Sylos-Labini 1969; Pasinetti 1981). While these mechanisms are endogenous in the models used in the simulations, there are long-term factors involved that the models do not take into account. These include Engel's law (according to which the share of expenditures on such products as food tends to decrease as household incomes grow), various saturation thresholds and the demand for goods and services based on new technologies. The latter quantity starts from a low level, but in many cases it grows faster than the consumption of products and services based on well-established technologies.

The projection of future consumption patterns is based on an informal methodology. For instance, relating to the use of ICT technologies, all of the scenarios take into account the fact that, when compared with the United States, Europe is likely to experience a catching-up phase during the next few years. During the second half of the 1990s the impact of the new economy was three times larger on the United States as on the EU (McMorrow and Roeger 2001: 80-81). The share of ICT in the capital stock was about 7.5 % in the United States, but only about 3 % in the EU (Schreyer 2000). Such indicators show that both in consumption and in investment there is room for catching-up in Europe. That is why in GEM-E3 simulations, in which expenditures on communication services are shown as a separate category, in all of the scenarios an increase in the consumption shares devoted to communication services was assumed for the period 2000-2020 in Europe. However, the intensity of the impact was varied according to the general characteristics of the scenarios.

Table 2.2. Long-term trends in the demand shares of consumption goods and services.

Categories of consumption goods and services		Year	Share %	Year	Share %
Food, beverages and tobacco					
An accelerating decline is observed in the share of consumption demand for food, beverages and tobacco in Europe, when the U.S. figures are taken as a prediction for the future.	West Germany	1970	30	1994	19.8
	Italy	1970	38.7	1996	18.9
	France	1970	25.9	1996	17.6
	U.K.	1970	33.3	1996	19.9
	U.S.A.	1970	18.6	1996	10.6
Clothing and footwear					
A decline is evident in the relative consumption shares of clothing and footwear.	West Germany	1970	10.3	1994	7.6
	Italy	1970	8.5	1996	8.7
	France	1970	9.5	1996	5.1
	U.K.	1970	8.8	1996	5.9
	U.S.A.	1970	8.3	1996	5.7
Furniture, furnishing and household operation					
A slight decline is evident in the relative consumption shares of furniture, furnishing and household operation.	West Germany	1970	10.1	1994	9.3
	Italy	1970	6.8	1996	8.9
	France	1970	10.2	1996	7.3
	U.K.	1970	7.8	1996	6.5
	U.S.A.	1970	7.3	1996	5.4
Gross rent, fuel and power					
The growth of relative consumption in this category reflects increased prices of energy. The assumption in this report is that there will be no steep increases in energy prices in the foreseeable future.	West Germany	1970	16.3	1994	22.9
	Italy	1970	12.4	1996	18.0
	France	1970	15.3	1996	22.0
	U.K.	1970	17.1	1996	19.7
	U.S.A.	1970	18.1	1996	18.6
Medical care and health expenses					
Some increase is already evident in the consumption share of health care expenditures. In the future these expenditures are expected to grow further due to ageing populations in Europe as well as new products and services.	West Germany	1970	2.7	1994	3.8
	Italy	1970	3.8	1996	6.6
	France	1970	7.1	1996	10.2
	U.K.	1970	0.9	1996	1.6
	U.S.A.	1970	9.5	1996	18.0
Transport and communication					
The slightly increasing trend in transport and communication reflects the growth of mobility among the population and lately also attractive new communication products and services.	West Germany	1970	14.0	1994	16.6
	Italy	1970	10.3	1996	12.4
	France	1970	13.4	1996	16.5
	U.K.	1970	12.6	1996	17.1
	U.S.A.	1970	15.0	1996	14.4
Recreation, entertainment, education and cultural goods					
An increasing trend in the consumption share of recreation, entertainment, education and cultural goods and services reflects, among other things, the high income elasticity of tourism.	West Germany	1970	10.2	1994	10.1
	Italy	1970	7.7	1996	8.5
	France	1970	6.9	1996	7.3
	U.K.	1970	8.6	1996	10.8
	U.S.A.	1970	8.5	1996	10.8
Miscellaneous goods and services					
There has been a marked increase in the consumption of miscellaneous goods and services, which including personal care and restaurants, cafes, hotels, etc.	West Germany	1970	6.3	1994	9.9
	Italy	1970	11.8	1996	18.1
	France	1970	11.7	1996	14.0
	U.K.	1970	10.8	1996	18.5
	U.S.A.	1970	14.6	1996	16.5

Source: OECD 1999.

It is reasonable to assume that the process of catching-up of the United States by Europe is not limited only to the ICTs but takes place also in many other sectors of the economy. The result is that in the end European consumption patterns are close to those that are currently prevailing in the United States. Another convergence process takes place between Southern Europe and the EU as a whole. Table 2.2 (OECD 1999) presents these convergence processes and other long-term trends that can be discerned in the consumption of different categories of goods and services on the basis of historical data. These findings were used in defining assumptions about future consumption patterns that are presented in Annex 3.

Table 2.2 shows how the share of basic consumption goods has tended to decline in Europe, and how the demand for health care and other service-intensive consumption categories has grown over time. In our simulations the growth of consumption expenditures related to medical care and health is expected to accelerate in the future, reflecting the ageing of the EU population, a diminishing share of these expenditures covered by society, and new attractive health-care products and services. In contrast with the past, transport expenses are expected to remain flat in the future, reflecting the trend in the United States, where the share of transport services was 15.0 % in 1970 and 14.4 % in 1996. This hypothesis is further supported by the fact that road traffic and vehicle intensities in Europe are very similar to those in the United States (OECD 1999:46). Similarly the share of the consumption category Gross rent, fuel and power is expected to remain constant or increase only slightly, as the assumption is that there will be no energy shocks in the period 2000-2020.

2.6 Defining scenarios for the study

An important element of the methodology applied in this study is scenario analysis. The Baseline Scenario is based on the assumption that the current patterns in R&D and innovation policies, consumption and labour productivity will continue. R&D as a proportion of GDP will stay at the current level in all regions of the EU. As a result, productivity growth for each sector is assumed to continue at its current rate. The Baseline Scenario defines a reference with which the impacts of increased R&D and innovation expenditures can be compared. In the Baseline Scenario public and private R&D and innovation expenditures are assumed to be increased by 1.5 % each year.

The effects of additional increases in publicly and privately funded R&D and innovation efforts in Europe are shown in the three alternative policy scenarios. In each of these scenarios an equal annual increase in the share of total innovation expenditures of the EU GDP is assumed. The increase in the innovation intensity of the EU economy would amount to about 3.5 % over and above the 1.5 % increase assumed in the Baseline Scenario.

While the alternative policy scenarios are similar in that they involve an equal overall increase in innovation and R&D expenditures, they differ from each other in the way the increase is distributed among the sectors of the economy. As the productivity response of each sector is different from the others, the overall employment impacts of the scenarios differ from each other. The following discussion describes the scenarios of the study in more detail.

2.6.1 Baseline Scenario

In the Baseline Scenario the R&D and innovation expenditures follow the current sectoral pattern and remain constant as a proportion of GDP. Productivity growth per sector and region will be in line with the current OECD projections. The EU is going to continue to lose its competitiveness in labour-intensive sectors, but will remain competitive in services, electric & electronic equipment, computers, telecommunication equipment, and chemicals.

In regard to labour productivity, the continuation of previous trends (especially those that prevailed during the years 1994-1999) is assumed, but a general slowdown is expected after 2010 due to demographic evolution. In regard to consumption, the continuation of present trends is assumed.

2.6.2 Uniform Scenario

In the Uniform Scenario R&D spending is increased uniformly, at an equal growth rate, throughout the economy, affecting all technologies and sectors. Nevertheless, the rate at which labour productivity is improved differs from one sector to another, depending on the extent that emerging technologies are utilised in the sector. Some of the increases in innovation and R&D expenditures can be expected to be targeted sectors in which the potential for productivity improvement and product development is scarce.

In labour productivity, the general pattern of the Baseline Scenario is maintained, but an overall acceleration in annual productivity growth of about 0.5 percentage points is assumed. The increase is spread evenly across all of the sectors. A general slowdown in productivity is assumed to take place after 2010 due to demographic developments in Europe. In consumption, in this scenario demand coefficients are the same as in the baseline scenario.

2.6.3 Diversified Scenario

In the Diversified Scenario the increase in R&D and innovation expenditures is allocated to sectors that already demonstrate strong performance at least on a regional basis and therefore can be said to enjoy a comparative advantage of one kind or another. Some of the sectors that will benefit from increased R&D and innovation expenditures include those that apply traditional technologies but employ large numbers of people. Examples include agriculture, construction and tourism. Sectors targeted for increases in R&D and innovation expenditures include chemicals, equipment manufacturing, transport equipment, food industry and various services.

The weakness in this scenario is that the long-term prospects it involves may not be quite optimal, as some of the technologies of well-performing sectors may be approaching the phase of relative decline. In these cases increased efforts in innovation are not likely to produce the best results.

In labour productivity, in this scenario, the different regions of the EU are expected to follow different paths of productivity improvement, with each region strengthening its high-performing sectors. An overall acceleration in annual productivity growth of about 0.5 percentage points is assumed relative to the Baseline Scenario. A general slowdown in productivity is assumed to take place after 2010 due to demographic developments in Europe. In consumption, the demand coefficients will be the same as in the baseline scenario.

2.6.4 Concentrated Scenario

In the Concentrated Scenario increases in R&D spending are concentrated in advanced technologies (electronics, telecommunications, genetic engineering, nanotechnology, aeronautics & space applications). Sectors which are affected are those that rely heavily on these technologies, and include electronic equipment, services, high-tech manufacturing, transport equipment and chemicals. In these sectors the competitiveness of the EU is expected to improve (depending on the strategies of competitors), but sectors that are not technology-intensive will probably lose some of their competitiveness. Given the pervasiveness of ICTs, biotechnology and nanotechnology, new products should appear also in the residual large category of miscellaneous goods and services. The overall impact on employment will depend largely on the size of the future market for technology-intensive products and services.

In labour productivity, the rate of growth will be increased in electronics, trade and transport, other market services and non-market services. An overall acceleration in annual productivity growth of about 0.5 percentage points is assumed relative to the Baseline Scenario. A general slowdown in productivity is assumed to take place after 2010 due to demographic developments in Europe.

In consumption, compared with the baseline scenario, the following changes have been implemented. 1) There is an increase of 1 percentage point in 2010 and 2020 in the consumption share of medical care and health, transport and communication (only communication in GEM-E3), recreational services and miscellaneous goods and services. 2) There is a parallel decrease of 1 percentage point in food, beverages and tobacco; clothing and footwear; gross rent, fuel and power; furniture, furnishing and household operation.

2.7 Conclusion

The aim of this study is to simulate the long-term employment impacts of small increases in R&D and innovation expenditures in different sectors of the economy. This chapter has shown how, in order to make the realisation of this goal possible, two economic models were selected for the purpose, crucial assumptions about consumption and productivity were made, and scenarios were defined to depict the differences in R&D and innovation expenditures. The next chapter shows what the simulation results were.

The plausibility of the results would be enhanced if the scenarios were to differ from each other only with regard to R&D and innovation expenditures. However, as we have seen, the models used in our study are not capable of taking endogenously into account the various long-term changes that are induced by increases in R&D and innovation expenditures. That is why labour productivity and consumption coefficients have been adjusted in the simulations, reflecting the improvements in productivity and changes in consumption patterns that are likely to be induced in the long run by changes in R&D and innovation expenditures. The coefficients are reproduced in the Appendices of this report, and the assumed changes can be justified on various grounds. Nevertheless, on pure modelling grounds, it would be better to develop models that are specifically designed for depicting changes that are induced by increases in R&D and innovation expenditures. Such changes are not limited only to changes in productivity and consumption but include changes in sectoral and international capital investment. Models of this type have difficulties of their own, and it is likely that much of the sectoral details represented in our study would be lost in the process.

In our approach the changes in labour productivity and consumption are especially pronounced in the Concentrated and Diversified Scenarios. In the Concentrated Scenarios increases in R&D and innovation expenditures are targeted to sectors that are expected to experience rapid improvements in technology in the future, *i.e*., electronic equipment, services, high-tech manufacturing, transport equipment and chemicals. These sectors are adept in developing new products, inducing changes in consumption patterns. These changes were taken into account by assuming that in comparison with the Baseline Scenario, there is an increase of 1 percentage point in 2010 and 2020 in the consumption shares of medical care and health, transport and communication (the latter in the GEM-E3 model only), recreational services and miscellaneous goods and services. Moreover, there will be a parallel decrease of 1 percentage point in the consumption share of food, beverages and tobacco; clothing and footwear; gross rent, fuel and power; furniture, furnishing and household operation. In the other scenarios consumption shares of different product categories are the same as in the Baseline Scenario.

In the Diversified Scenario the increase in R&D and innovation expenditures was allocated to sectors that have demonstrated their ability to perform well in the main regions of the EU. These sectors included chemicals, equipment manufacturing, transport equipment, trade, transport and communication services, as well as the food industry and related services. In R&D, advanced materials, biotechnology, energy and ICTs were emphasised. In the other scenarios there were no differences between regions in the assumptions about future labour productivity developments.

The fact that our approach cannot represent structural changes in the economy resulting from flows in capital investment from one sector and country to another makes it safe to expect that our simulation results will show the lower boundaries of changes in employment that would result from changes in R&D and innovation expenditures. As could be seen during the ICT boom of the late 1990s, changes in the intersectoral and international flows of capital are an essential feature of the economic and societal changes that are induced by new opportunities in technology. Changes related to capital investment could be expected to heighten the differences that emerge between our scenarios, strengthening the employment performance of sectors that are able to develop new products rapidly and weakening the performance of sectors that have no such promise.

3 Modelling the impacts of technology on international trade

3.1 Technological Development and Trade

Public R&D expenditures are often justified by the need of 'International competitiveness'. However, a clear definition of 'International competitiveness' is often missing. Considering the R&D expenses the political goal could rather be described as achieving 'Structural competitiveness'. Though out of a wide range of industries, only selected sectors will benefit directly from public R&D development, other branches may, via (often-overestimated) multiplier effects, increase productivity and therefore (sectoral) competitiveness too. Consequently exports will rise, which will generate new jobs eventually. However, since these jobs obviously depend heavily on the export-performance, they are also sensitive to any disturbances on the world market. Furthermore sectors that are affected under average by this policy can, due to factor movements, be expected to decrease their outputs significantly. It makes sense to assume that the decreasing output is substituted to a large extend by increasing imports, which in turn will put the associated jobs at risk. Since it is likely that the induced structural change will eliminate 'low productivity sectors' first, political decision-makers should be well equipped to face these negative employment effects, induced by their indeed necessary impulse of structural change.

Since politicians and economists tend to take an idea seriously, only if it is modeled in a proper way (KRUGMAN, 1995), the general issues raised above will be discussed more formally in the following. However, it should be pointed at the beginning to the fact that there are only few models that deal with the main characteristics of innovation friendly policy - at least temporary imperfect competition and thus increasing instead of constant returns to scale which eventually induce structural changes, - in a really satisfying way [1]. Exceptions of the rule are e.g. the SOLOW-SWAN model with exogenous technological development (SOLOW, 1956; SWAN, 1956), a model taking into account 'learning by doing' effects developed by BARRO / SALA-i-MARTIN (1995), the HELPMAN-KRUGMAN approach developed in 1985 or the GROSSMAN-HELPMAN model (1991) with endogenous technological development. Though we are aware of these complex models, more research would be necessary to implement a similar model into the ASTRA-E approach. However, the applied simple model should, despite the assumption of perfect competition, provide some valuable results. Though innovation friendly policies will affect industrial, social and natural environment in many different ways the analysis will focus on two main impacts. First it is assumed that innovation policies via improvements of the educational system will increase human capital in the medium and long term. To model this effect the production factor labour is subdivided into skilled and unskilled labour [2]. The measure is not sector specific but aims to generally improve qualification of current and future workforce. The second variant focuses on process innovation of specific sectors. As mentioned already this measure is assumed to

[1] See e.g.HELPMAN / KRUGMAN, 1985, p. 31; KRUGMAN, 1995, p.14

[2] This classification traces back to the GROSSMAN-HELPMAN model, published in 1991, see also GRUPP (1998)

increase sectoral productivity and thus to achieve by purpose comparative advantages for selected sectors versus foreign competitors. Indeed both measures are established (and likely) to strengthen a lasting structural competitiveness[3]. GRUPP argues that "the resulting imbalance is not, however, equalized by international, but instead, leads to a stable technological specialization of the country based on the cumulative learning within its national economy, thus distinguishing the country from others. The accumulation of specific knowledge places the national economy in a position of being able to continually allocate R&D resources and to thus maintain the national specialization advantages" (GRUPP, 1998, p. 277).

Figure 1 gives a first insight of determinants of foreign trade that are, according to the model, directly or indirectly affected by technological changes.

Simultaneously the figure provides an overview of the not-considered determinants. Most important the model neglects spatial aspects and transportation costs as well as monetary effect caused by a rising or falling EURO. Both issues have been elaborated in a very sophisticated way e.g. by BRÖCKER (1998), MUNDELL (2000).

Following the factor-proportion theorem developed by HECKSCHER and OHLIN[4], each country will focus its production and consequently its export on those goods, which depend heavily on the production factor the country is best equipped with. 'Capital rich' countries will export 'capital intensive' goods and 'labour rich' economies in turn focus on 'labour intensive' goods. Since the 'Human capital' (or skilled labour) is now introduced as separate production factor, it could be argued that economies with rich human capital endowment will eventually focus export on technological superior goods.

However, the HECKSCHER-OHLIN theorem is also based on the assumption of equivalent technology (and therefore productivity) for the trading countries. But since the technological advantage is one of the main goals of innovation friendly policy this assumption of the HECKSCHER-OHLIN theorem will be abandoned in this study. Instead the presented model, which follows an idea carefully described by KOWALSKI, includes the idea of comparative advantages, which, despite specified a long time ago by RICARDO[5], still can be identified as one driving force for international trade, if in contrast to RICARDO comparative advantages are not considered to be given exogenously but generated by well directed technological development.

Besides the already mentioned assumption of perfect competition, the model is dealing with two groups of goods and two economies, with relative prices and known aggregated preferences.

[3] As mentioned already the structural competitiveness will not yield automatically positive employment effects.

[4] The HECKSCHER-OHLIN model is described in detail e.g. by APPLEYARD, FIELD, 1997 or BREUSS, 1997 or SIEBERT, 1994

[5] The RICARDO model of comparative costs is described in detail e.g. by ROSE, 1981 or BREUSS, 1997

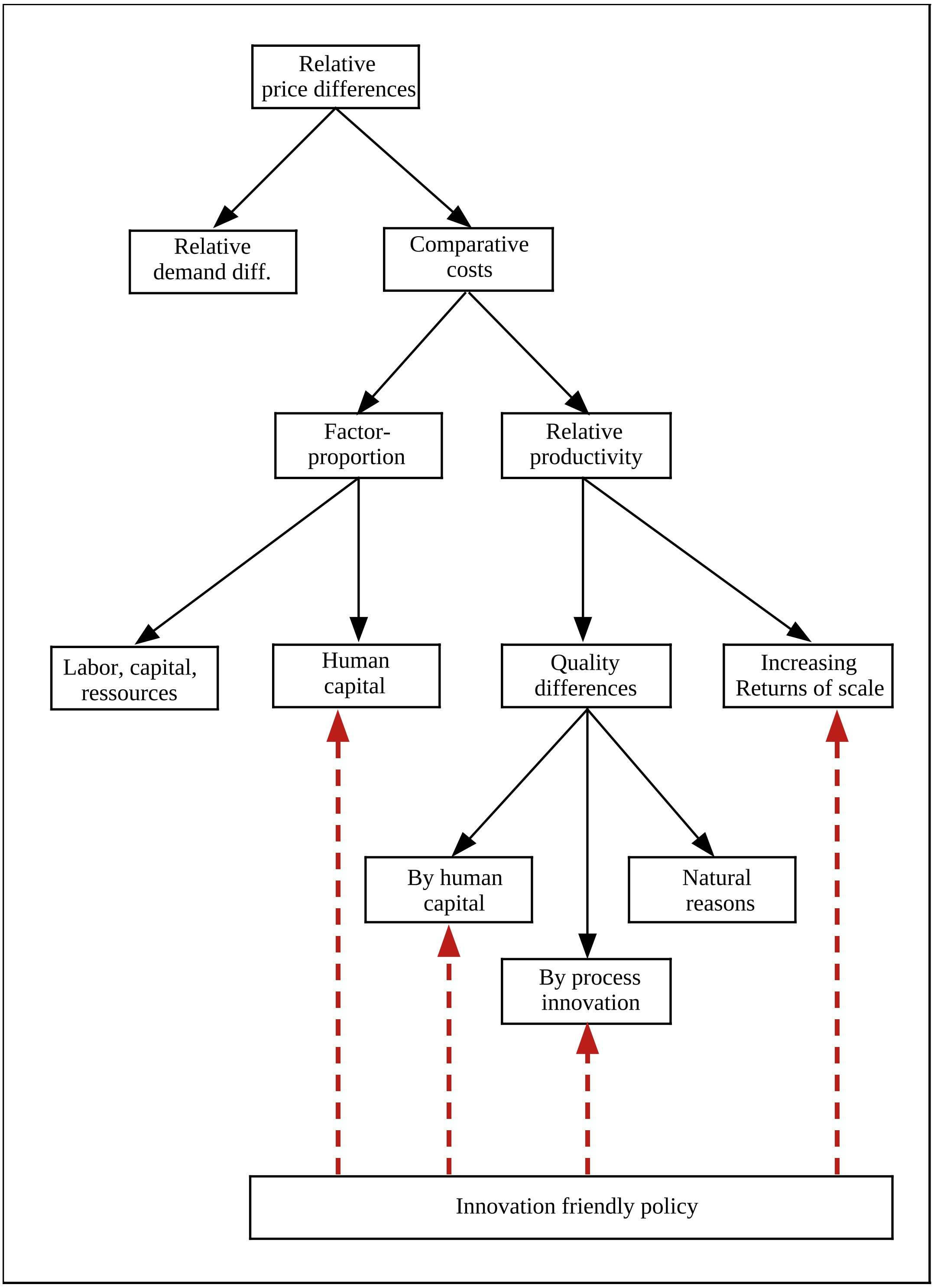


Figure 1: Determinants influencing foreign trade

Source: Based on a figure presented by GRUPP (1998, p. 275)

3.2 Alternative A: Increasing Human capital via improved educational system

The sectoral data for the European macro regions (see ASTRA-model) are subdivided by 12 sectors. The cumulative output of technological superior goods forms goods of group 1 while the output of the other sectors belongs to goods of group 2. The factors 'Resources', 'Labour (unskilled)', 'Capital' and 'Human capital' (Skilled labour') are fully employed to produce either goods of group 1 or of group 2. Any possible combination of output is given by the following transformation curve:

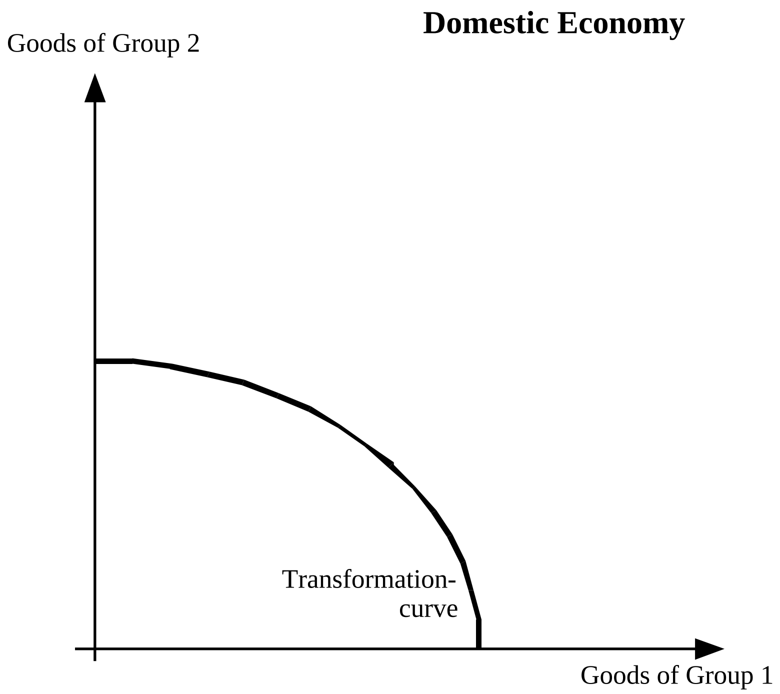


Figure 2: Transformation curve

Production is realized if the domestic budget (determined by all kinds of incomes) tangents to the transformation curve. Without international trade the production would automatically determine the consumption, i.e. the highest available preference curve also tangents this point.

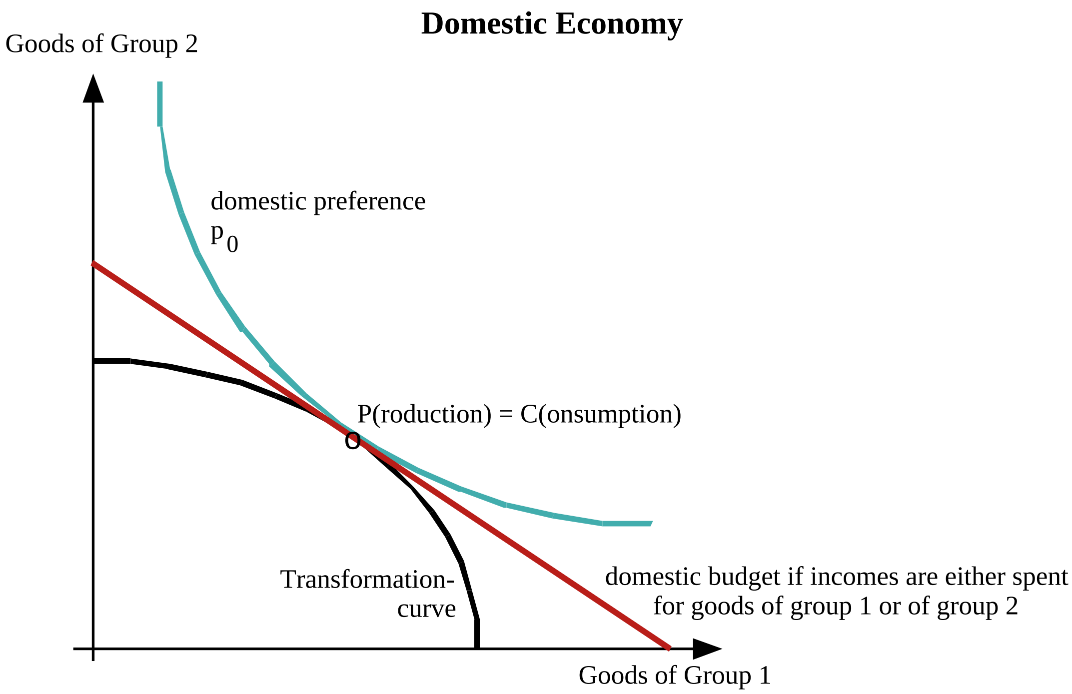


Figure 3: Production and consumption without trade

Of course external and intra-EU trade is one of the main ideas of modern economics, such that instead of domestic budgets (here relative) world prices determine the domestic consumption. It is now assumed that goods of group 1 are relatively more expensive at the world market, i.e. the 'world-price-line' is steeper than the 'domestic price line'. Since consumers are eager to maximize their benefits this yields to a separation of production P and consumption C, which implies exports and imports and which eventually leads to an increased welfare signed by a jump to a higher preference p_1.

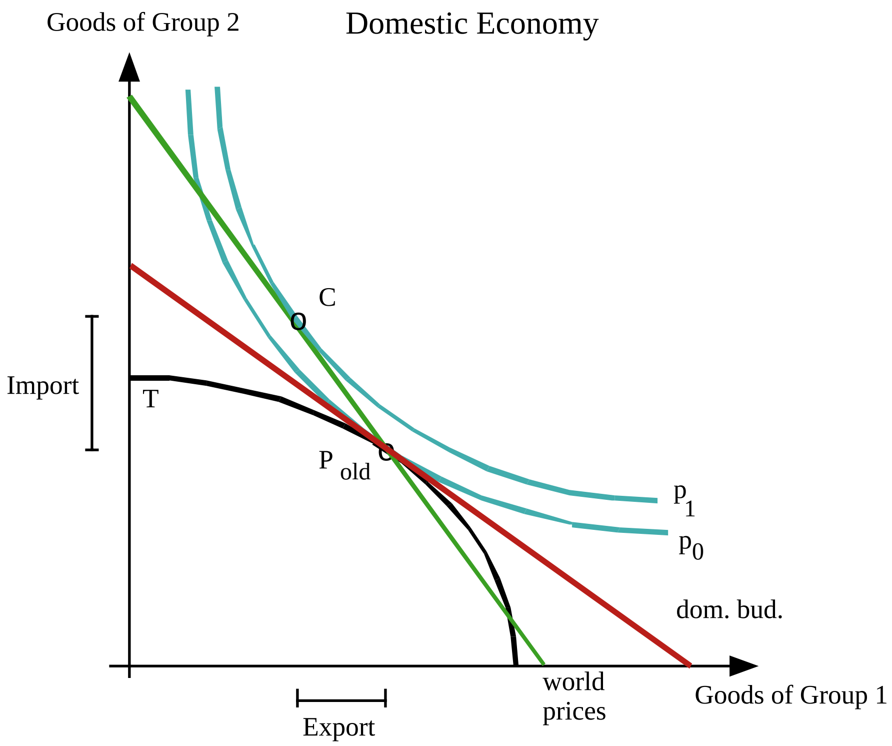


Figure 4: Production and consumption with trade and fixed production

Figure 4 shows the advantages of free trade, even if the production is considered to be fixed. However, since production factors in Figure 4 are not fully employed anymore the economy will tend to shift production P. The optimal production can be derived by a parallel shift of the 'world prices' until transformation curve and world-price line just tangent. Notice that the shifting does not imply a change of the relative prices. In fact due to the assumption of perfect competition overall supply and relative prices are considered to remain constant, despite additional production. For the sake of clarity the domestic budget and the preference p_0 are not given.

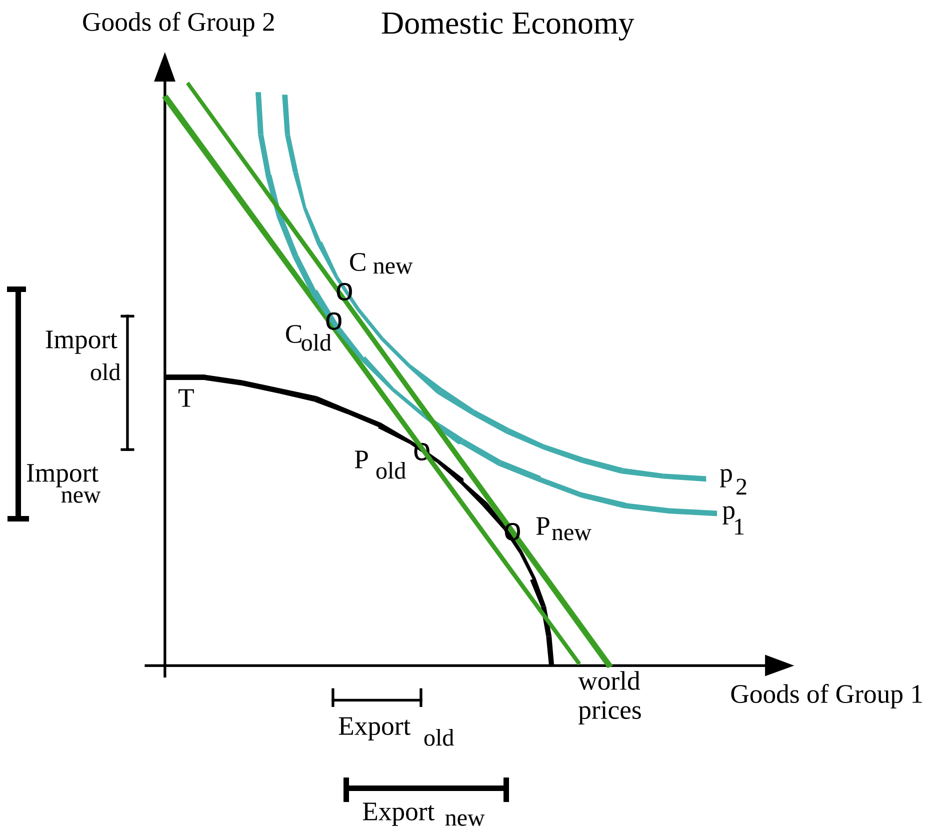


Figure 5: Production and consumption with variable production

Clearly the shifting or specializing of production leads to increasing welfare, exports and imports. Since the additional production of goods of group 1 is facing decreasing production of goods of group 2 the sign of the net employment effect can not be projected easily. It is now assumed that Figure 5 is closest to the current situation for the four macro regions of Europe. What happens if intensive investments on human capital finally pay off? The effect would be equivalent with additional capital. Since all sectors could potentially benefit by the improvements of the educational systems, the transformation curve would be shifted parallel outwards[6]. Now the world prices are shifted again, such that eventually the next preference p_3 is reached. In Figure 6 old production, consumption, export and imports are omitted. The revised parameters are marked by 'hci' (human capital improvements)

[6] Though from the microeconomical point of view the shifting would imply a quantitative rather than a qualitative improvement it is assumed, that qualitative improvements will finally result in increasing sectoral monetary output. Thus the effect would be similar to rising quantitatives. Certainly an exact parallel shift will not occur, since human capital is more important for goods of group 1. However, still all sectors will benefit by improvements and the effects with a not exactly similar shift would be similar.

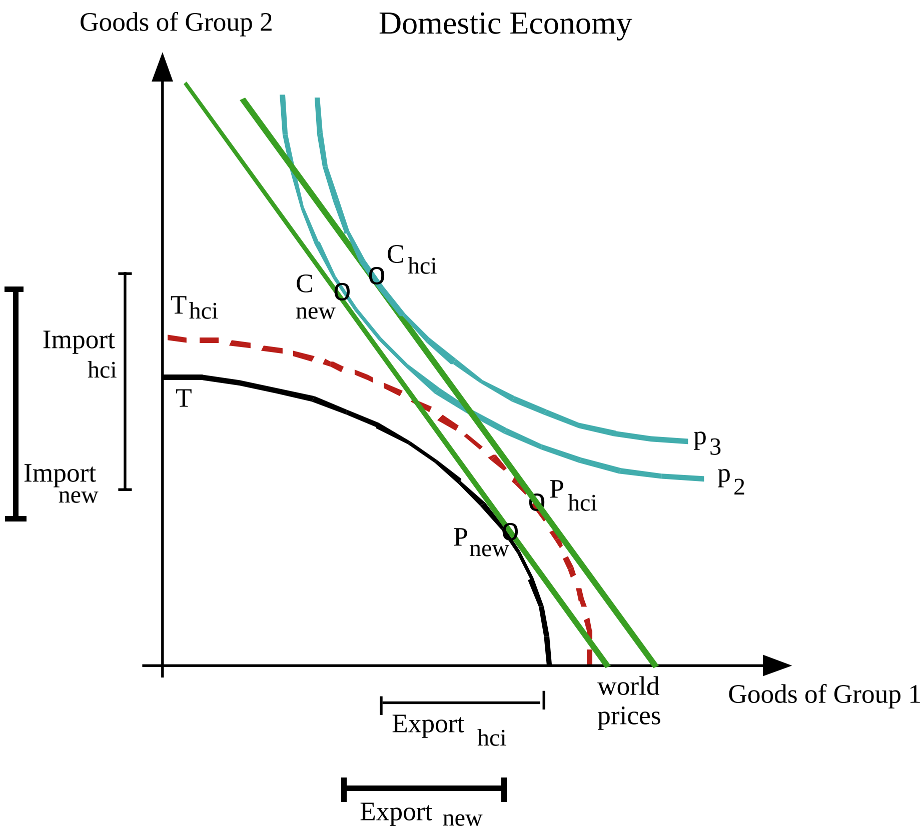


Figure 6: Production and consumption after human capital improvements

Though the newly established export and import levels hardly differ from former ones, (imports seem to decrease slightly) the policy leads to positive production effects for both groups, i.e. the above described extended potential for all sectors is implemented. Thus the policy may not favor necessarily the international accounting balance, but should nevertheless contribute to the strengthening of structural or international competitiveness. However, due to continous structural changes there is of course no guarantee that all sectors will benefit by such a policy. Furthermore the rather simple model abstracts from a variety of important aspects. But still the overall results including the net employment effects look rather favorable and despite the simplicity of the model the consequent implementation of such a policy can be recommended strongly. Considering the already defined scenarios (see also annex) this alternative could be interpreted within the following scenarios

*Uniform technology scenario

*Baseline Scenario and partly

*Diversified scenario.

3.3 Alternative B: Comparative advantages via process innovation of specific sectors

While the investment in human capital is supposed to affect production of all sectors in the long run, effects of specific R&D expenditure will differ significantly for the considered sectors. According to a study elaborated by the 'Institut für Systemtechnik und Innovationsforschung' and the 'Niedersächsisches Institut für Wirtschaftsforschung' about sectoral R&D expenditures sector 5 (Steel products, Machinery, Transport Equipment, Office and Data Processing) and 6 (Electrical, Optical Goods) can be considered to be highly innovative[7]. In the following table each sector is classified into one out of three groups – highly innovative sectors (direct effects e.g. via direct investments), medium innovative sectors (sectors, which absorb significantly intermediate inputs of highly innovative sectors[8]) and low innovative sectors (without strong links to highly innovative sectors).

Table 1: Innovation intensity of sectors (data refers to German situation)

sector	Group 1 (highly innovative)	Group 2 (medium innovative)	Group 3 (low innovative)	% of export outside EU	% of absorbed group 1 inputs[9]
Agriculture, forestry and fishery			X	1	6
Energy, Water, Mining Products, Crude Oil		X		1	10
Chemical, Mineral, Plastic, Petroleum Products		X		15	11
Ferrous and non-ferrous ores and metals		X		5	12
Steel products, Machinery, Transport Equipment, Office and Data Processing	X			32	45
Electrical, Optical Goods	X			10	39
Textiles, Clothing, Paper, Wooden Goods			X	9	8
Food, Beverages, Tobacco			X	5	6
Building and Construction		X		0	23
Services for Repair, Wholesale and Retail, Transport, Communication		X		17	11

[7] Based on results elaborated by GRUPP et al., 1995, p. 29f.
[8] Based on the input coefficients of input-output tables
[9] Percentage of all intermediate inputs

Other Market Services like Lodging, Catering, Credits, Insurances			X	2	3
Non-market Services			X	3	4

Obviously the knowledge intensive sectors already form the major part of exports, in particular with regard to the here relevant trade flows among EU and non-EU regions. However, it makes probably sense to subdivide the regions outside the EU (13 have been defined for this project) into less industrialized regions like Africa, Latin America, China and though catching up rapidly major parts of Eastern Europe and more or less equally equipped economies like Japan and the USA. Considering trade with less industrialized regions the following effects may be caused by specific R&D expenses. While Figure 2 to Figure 5 are still valid for the overall background the transformation curve in Figure 7 is shifted towards the highly and medium innovative goods of group 1 and 2 (in the model aggregated to one group) at the cost of less innovative but often labour intensive group 3.

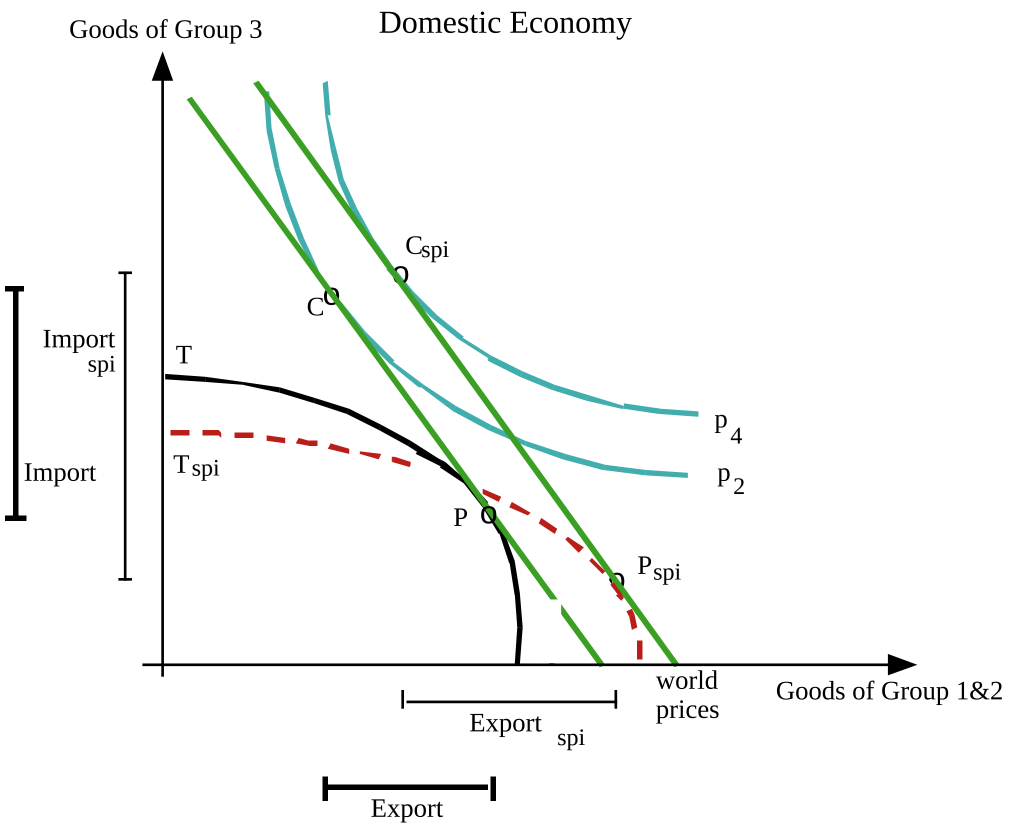


Figure 7: Concentration on comparative advantages

The parameters marked by the index 'spi' show the effects of the specific process innovation versus the situation provided in Figure 5. Though specialization and consequently international trade grow faster than in Figure 6 (human capital improvement) the implications for the overall welfare and employment are not clear. Though p_3 (Figure 6) and p_4 (Figure 7) will cause higher benefits compared to p_2 neither one can be considered to be superior to the other.

Trade with the advanced industries of the USA and Japan follows similar patterns. However, trade focuses on goods of group 1 and 2. Often goods of the same group are traded (intra sectoral trade), which makes it hard to project future flows without more intensive research. Nevertheless the Concentrated technology scenario is still waiting and some interesting impulses could be given even with a simple model like this. If increases in R&D spending are concentrated on advanced technologies (electronics, telecommunications, genetic engineering, nano-technologies, aeronautics & space applications the currently leading position is not necessarily with EU (if it is the causalities look similar to Figure 7). Lets assume the comparative advantage is with the United States or Japan. Hence it is likely that these products are – up to now – imported by the EU rather than exported. Figure 8, which basically follows Figure 5 with some simplifications, shows the starting position.

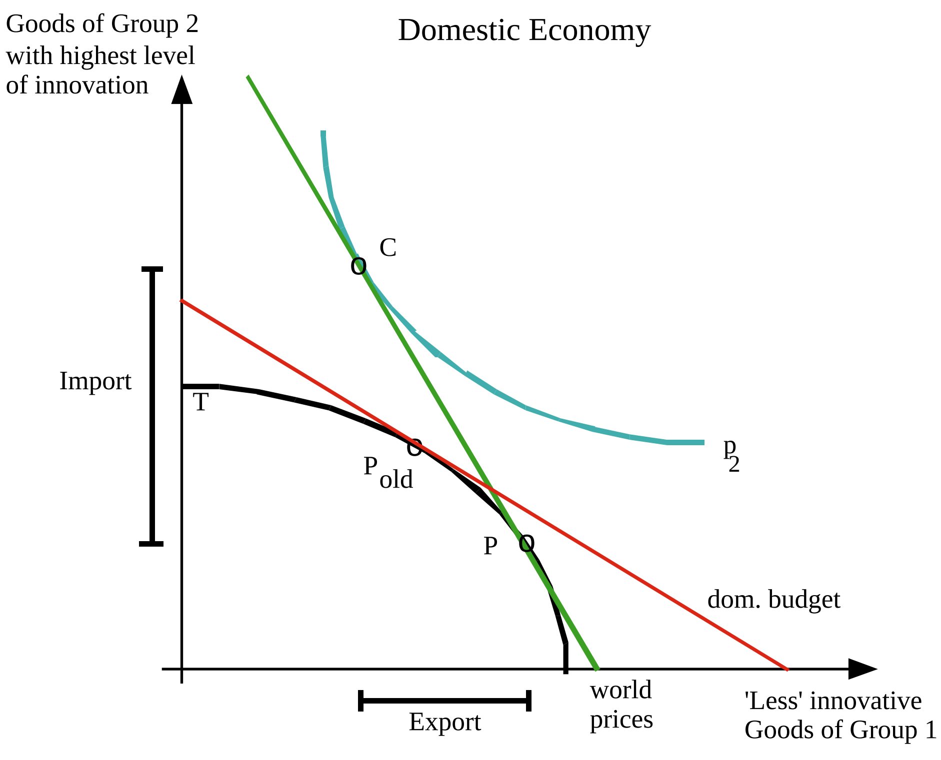


Figure 8: Trade of Group 1 goods

The concentrated efforts on the most innovative sectors lead to a shift of the transformation curve. Though all sectors will finally benefit by the R&D expenditures, the transformation curve will be extended strongest towards the most innovative sectors. Besides the domestic budget will also be turned in favor of these superior goods.

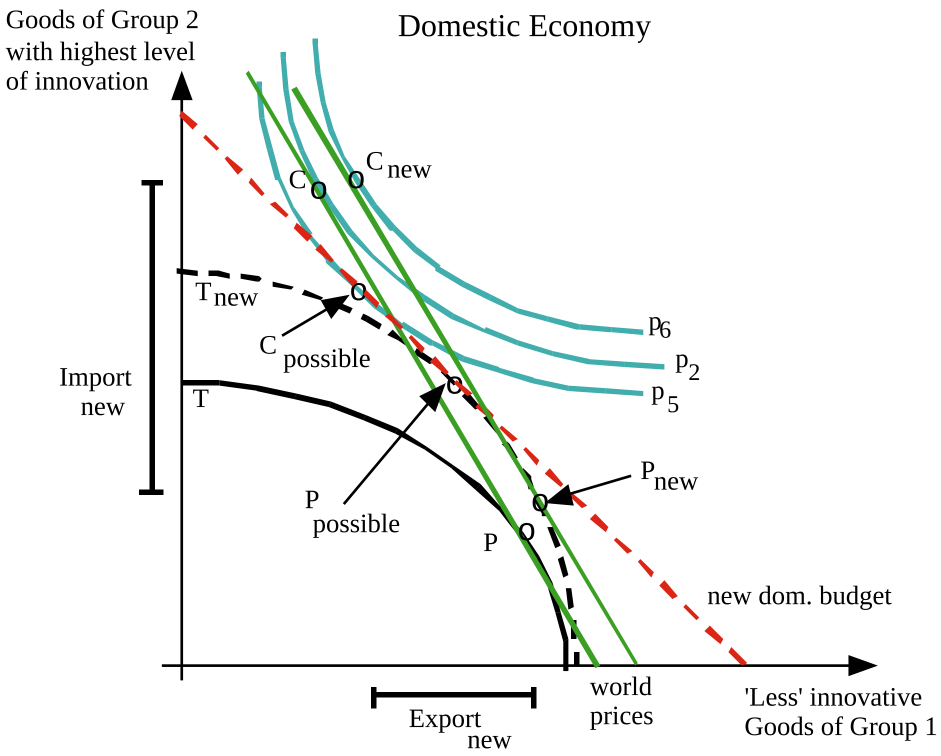


Figure 9: Concentration on most innovative products

Though the possible production $P_{possible}$ of most innovative products has clearly been extended, realized new production P_{new} benefits most by the (relatively small) positive indirect effects for 'less' innovative products, which eventually allows the realization of C_{new}[10]. Though again the simplicity of this (in fact more or less of any) model should be mentioned, the results show that the concentrated scenario may after all not cause the most favorable results. It is interesting that even if the EU would produce most innovative goods cheaper in the end the situation would not change significantly.

However, this conclusion is still based on the assumption of perfect or at least sufficient competition. While the assumption may come close to reality for some sectors, e.g. microelectronics, communication or biotechnology, it clearly fails for the production of aircraft. Intensive and specific R&D expenditures may in this case indeed strengthen the position of the domestic (here European) sector. Eventually the policy will induce positive employment effects, which makes such a policy very attractive. On the other hand it must be questioned if the approach is not at odds with the rules of fair competition and free trade. It is not our task to answer the question (which should be adressed by political decision makers) but we will explain the causalities of this rather strategic trade policy.

[10] C_{new} in particular implies higher welfare compared to $C_{possible}$, which could be achieved within EU if hypothetically trade of these goods would be substituted by intensive public R&D expenditures.

3.4 Strategic trade policy

In 'Is Free Trade Passé' KRUGMAN (1987) picks up an idea of outlined by BRANDER and SPENCER in 1983 and 1985 respectively. It is assumed that two regions are generally capable of producing a specific highly innovative good. The perfect competition is replaced by a duopolistic market structure. To illustrate this assumption the market of wide-bodied passenger aircraft is considered. The only companies capable of developing and producing the aircraft are Boeing, located in the United States, and Airbus in Europe. Without public interventions both companies are equipped with qualitative and quantitative similar production factors. Once the company decides to build the aircraft, production factors are strictly bound to the challenging project and there is no way back without serious financial crises. Thus both companies only have binary choice: Produce (P) or Not-Produce (N). The production is expected to be profitable if either Boeing or Airbus enter the market alone – it is not profitable if both companies decide to produce. Due to the duopolistic market structure only four different strategies can occur. Both companies produce, despite being aware that the return on investment is (probably slightly) negative, both companies decide not to produce, or either one produces alone. The following payoff matrix is taken from KRUGMAN (1987, p. 136). Payoffs for Airbus are given by the upper right numbers of the cells and Boeing's by the lower left numbers respectively.

Table 2: Hypothetical payoff matrix with fair competition

		Airbus	
		Producing	Not Producing
Boeing	Producing	-5 -5	0 100
	Not Producing	100 0	0 0

The game would end in a draw, if neither one would have a kind of a headstart. But since we assumed above (fig. 8), that the United States are in general slightly better in producing the most innovative products and if we add that only Boeing has the experience of introducing the last remarkably huge passenger aircraft (Boeing 747) the game would probably go to Boeing in the end – leaving Airbus with a payoff of '0'. If now the EU would intervene let's say by very specific R&D expenditures to bring Airbus ahead the game could indeed turn. Additional investments of **10**, which the EU would certainly label as R&D expenditures for the aerospace sector and which would be blamed to be illegal subsidies by the American competitors, the payoff matrix would look as follows (see again KRUGMAN, 1987, p. 136)

Table 3: Hypothetical payoff matrix after European R&D expenditures / subsidy

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Airbus</td></tr>
<tr><td>Producing</td><td>Not Producing</td></tr>
<tr><td rowspan="2">Boeing</td><td>Producing</td><td>5
-5</td><td>0
100</td></tr>
<tr><td>Not Producing</td><td>110
0</td><td>0
0</td></tr>
</table>

Since Airbus would not risk a negative payoff the decision would certainly be to produce - either way whether Boeing produces or not. Boeing, however, knows that it will not enter the market alone and will therefore prefer not to produce. Thus the European public expenditure ensure Airbus an income of 110 instead of certainly possible '5'. In turn Airbus guarantees highly qualified new workplaces within Europe. Note that both additional income and ensured jobs are now provided at the cost of Boeing's or America's income.

It is worth mentioning that, even if the strategy is considered to be fair or at least legal, the development of new wide-bodied passenger aircrafts needs immense investments and is accompanied by various uncertainties leading to high financial risks. The assumption that the production is profitable, if only one firm is entering the market could - considering the development of the Boeing 747 that almost lead to a financial disaster for Boeing – indeed be questioned. In this case the not-investing competitor could easily gain market shares and domestic workplaces would be at stake.

4 Simulation results

4.1 Introduction

The simulations of the impact of technological change were carried out with two models, GEM-E3 and ASTRA. Given that the two models differ considerably, the differences in the extent of the impacts that the two models estimate is not surprising. The general trends however that were identified by the two models are comparable and consistent. The projections of both models imply a moderate GDP growth and a slow growth in employment. In both models technological progress has positive results in terms of both GDP and employment. Given the strengths and limitations of each models, the forecasts of GEM-E3 for GDP and employment should be considered more reliable; ASTRA is more suitable for the regional and detailed sectoral analysis, especially as regards services.

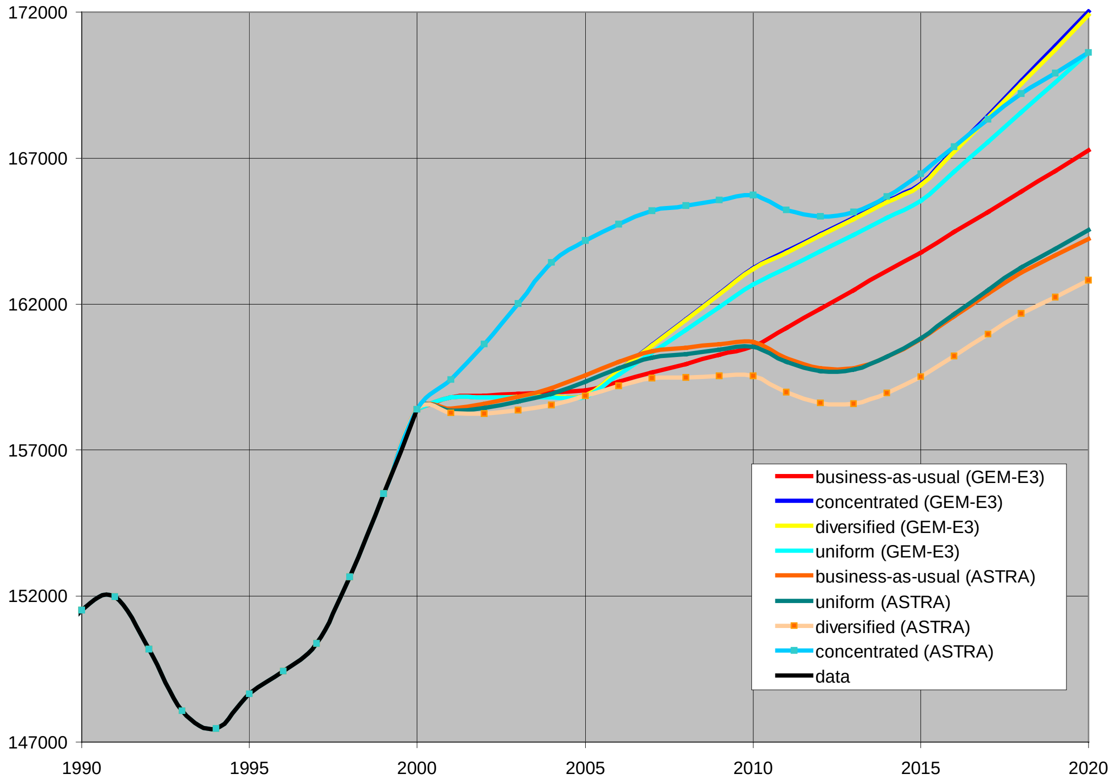
Table 4.1. The results of scenario simulations, changes between 2000 and 2020, per cent.

	Baseline Scenario		Uniform Scenario		Diversified Scenario		Concentrated Scenario	
	GEM E3	ASTRA	GEM E3	ASTRA	GEM E3	ASTRA	GEM E3	ASTRA
Employment growth (labour demand)	5.6	3.7	7.7	3.7	8.5	2.5	8.6	10.3
GDP	52.1	57.9	59.9	60.4	64.3	60.8	65.7	64.3
Average annual growth of GDP	2.12	2.2	2.37	2.28	2.51	2.29	2.56	2.39
Investment	49.8	71.4	72.2	74.1	83.5	75.0	89.9	77.1
Consumption	55.0	59.9	62.8	62.6	66.9	63.0	68.9	67.0
Exports	49.8	119.9	53.7	122.3	57.3	124.8	56.0	123.0
Imports	33.0	125.4	41.4	127.8	46.1	130.6	48.2	128.5

The clear conclusion is that the long-term employment outlook is slightly positive according to both models. However it should be noted that there are good reasons for believing that our simulation estimates represent the lower boundaries of the employment effects that can be expected to result from increases in R&D and innovation expenditures.

The second observation that can be immediately made is that there were comprehensive differences in the employment outcomes of the alternative policy scenarios. The wide divergence of the possible employment paths is presented in Figure 4.1. However, a closer look reveals that in fact the simulation results produced by the GEM-E3 model tended to converge to a high level (see also Figure 4.2), while the results of the ASTRA simulations were more dispersed.

Figure 4.1. The level of EU labour demand between 2000 and 2020 in the different scenarios (thousands of full-time job equivalents, GEM-E3 and ASTRA simulations).



N.B. Business as usual = Baseline Scenario.

ASTRA produced both the highest and lowest labour demand figures, suggesting that in this regard the model is more sensitive to changes in labour productivity and consumption than the GEM-E3 model, which therefore behaved more consistently in our simulations. The differences in the aggregate imports and exports of the EU countries are even more marked than those in employment.

On the whole GEM-E3 can be regarded as a more mature model than ASTRA. One of the strengths of the GEM-E3 is the representation of the European labour market and various sectors of the global economy, while ASTRA gives a more interesting description of the regional differences in the European economy. In what follows the results of the simulations are described in more detail and the relative strengths of the two models are exploited in creating a relatively consistent overall picture of the employment outcomes.

4.2 The results of the GEM-E3 simulations at the EU level

In the Baseline Scenario it was assumed that R&D and innovation expenditures are maintained at a level that stays constant as a proportion of GDP. In the GEM-E3 simulations the result was that the future average annual growth of GDP in the EU-15 countries would decline. The annual GDP growth averaged 2.24 % between 1983 and 2000. In the Baseline Scenario the growth rate would be reduced to 2.12 % per year between 2000 and 2020.

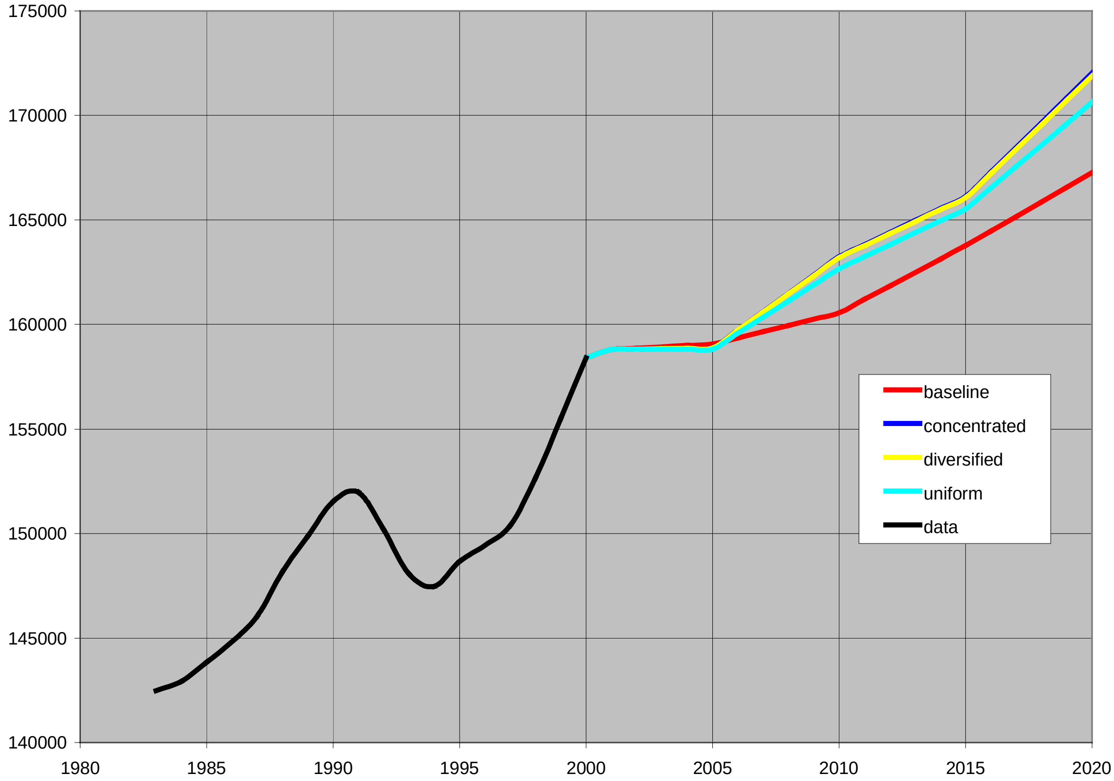
Compared with the Baseline Scenario the alternative policy scenarios assumed an increase in R&D and innovation expenditures equalling about 0.10–0.15 % of the GDP of the EU-15 countries. The result was that in GEM-E3 simulations there was to be an increase in both in the level of GDP growth and employment in all of the alternative policy scenarios. As can be seen in Table 4.1, in the GEM-E3 simulations the best employment results were obtained in the Concentrated and Diversified Scenarios. In the Concentrated Scenario the stimulation was applied to those sectors of the economy that rely heavily on the application of advanced technologies. In the Diversified Scenario the increase in innovation expenditure weighted towards sectors that are already highly competitive in the main regions of Europe.

In the GEM-E3 simulations the differences in GDP levels between the scenarios were quite small even in the long run. In the Uniform Scenario the increase in R&D and innovation expenditures was shared between different sectors of the economy. As the resulting increase in productivity was low in those sectors of the economy that do not apply the most advanced technologies, the aggregate improvement in GDP growth, international competitiveness and employment was slightly smaller than in the Concentrated and Diversified Scenarios.

Figure 4.2 shows the employment outcomes of the different scenarios according to the GEM-E3 model. By the year 2020 the Baseline Scenario would produce the smallest increase in the level of employment, amounting to 5.6 % or 9.2 million jobs. The increase would set the elasticity of employment with respect to GDP growth at about 0.1, which would be comparable to what was observed in the period 1980–1995. The low responsiveness of employment to GDP growth has been a key characteristic of the EU compared to the United States.

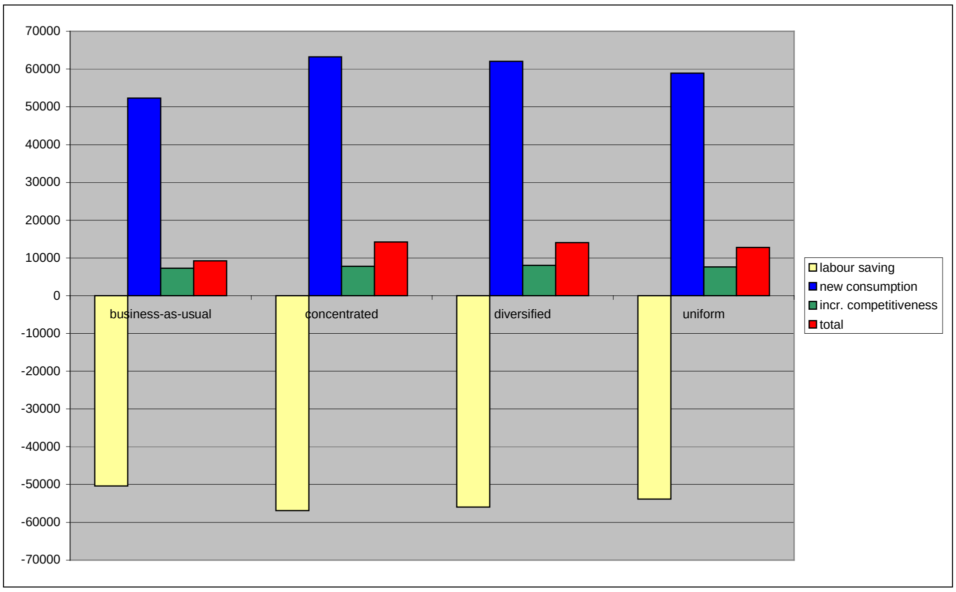
The Uniform Scenario results in lower employment levels than the two other scenarios that involve increases in R&D and innovation expenditures. The *aggregate* employment outcomes of the Concentrated and Diversified Scenarios are almost equal. This would suggest that at the European level the employment outcomes of R&D and innovation policies emphasising high technology would be almost similar to those focusing on industries that already have demonstrated their competitive strengths. While technology policy can have an impact on labour productivity and the growth of the economy, issues affecting labour supply and the functioning of the labour market (*e.g.* participation rates, working time, flexible contracts) can play a crucial role in mediating the employment outcomes. If the elasticity of labour supply is increased with respect to wages, a higher level of employment ensues in our simulations. An important advantage of a more responsive labour supply would be a higher level of employment and thus a wider distribution of the benefits of economic growth amongst the population.

Figure 4.2. Labour demand in the in the EU-15 countries in 2000–2020 (thousands of full-time job equivalents; GEM-E3 simulations).



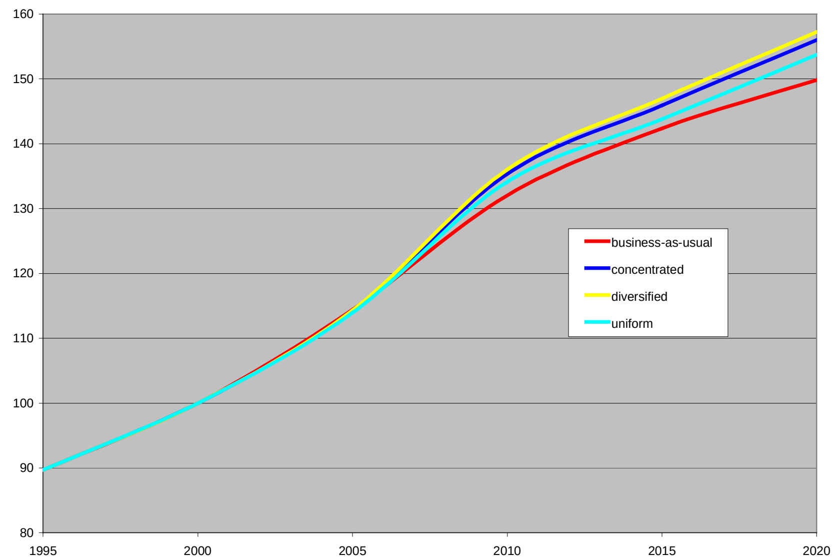
The mechanism that makes possible the growth in employment in conditions of labour-saving technical change is illustrated in Figure 4.3. The total impact of technical change on employment consists of three parts. There is an immediate technology-related employment impact due to labour-saving productivity increases. This is partially compensated by increased consumption of existing and new products and services, both of which create new jobs. Employment is enhanced also by increased exports made possible by improved international competitiveness. In the GEM-E3 simulations the magnitudes of changes in labour productivity and consumption were based on our assumptions; those related to international trade arose on the basis of the characteristics of the model.

Figure 4.3. Decomposition of changes in employment in the EU-15 countries resulting from technical change (thousands of job full-time-equivalents; GEM-E3 simulations).



The employment impact of increased exports is smaller than that resulting from domestic consumption. This is natural since the EU is largely self-sufficient and exports correspond only to a small part of its GDP. Figure 4.4 shows how exports from the EU to the rest of the world are expected to grow in the different scenarios. In the GEM-E3 simulations exports vary only slightly between the scenarios, but this is natural given the small differences in R&D and innovation expenditures on which the scenarios are based. Small increases in exports are shown in all of the scenarios in which innovation expenditures have been increased. Somewhat surprisingly, the Diversified Scenario produces higher exports than the Concentrated Scenario.

Figure 4.4. Exports from the EU-15 countries to rest of the world (constant prices, year 2000=100; GEM-E3 simulations).



Needless to say, our simulations do not take into account the possibility that productivity-enhancing policy changes can be introduced in countries outside of the EU. Such policy changes are almost inevitable since economic competition between nations is nowadays very much focused on technological competitiveness and productivity. Another factor that is likely to reduce the export benefits of increased R&D and innovation expenditures is that international technology spillovers are a fact of life. Scientific discoveries and innovations made in one country are sooner or later adopted in other countries; that is why the productivity benefits of increased R&D expenditures are not limited only to the country that pays the added costs. The same concerns sectoral spillovers. R&D and innovation expenditures carried out in one industry tend to benefit other sectors as well in the long run, thus somewhat reducing the sectoral differences that will be described next.

4.3 The results of the GEM-E3 simulations at the sectoral level

According to the GEM-E3 simulations, growth of production in different sectors of the EU economy would range between 20 % and 80 % over twenty years. The highest growth rates would be achieved in the sector of Other manufacturing goods, a composite sector that is expected to include many of the new products that will be developed as a result of technical progress. Large production increases would be achieved in Electronic equipment and Transport equipment as well. Comparable increases would also be seen in Other services and construction, a sector that combines important service activities as well as construction in the GEM-E3 model and is the largest job provider among all of the sectors. The lowest production growth would be take place in Agriculture, Textile industry and Non-market services.

Table 4.2. Sector-specific production growth in the EU-15 countries in 2000-2020 (index, year 2000=100, constant prices; GEM-E3 simulations).

Sector	Baseline Scenario	Uniform Scenario	Diversified Scenario	Concentrated Scenario
Agriculture	122.2	126.6	127.8	128.9
Energy and metals	125.9	131.3	134.0	134.6
Chemical products	129.7	135.1	139.8	138.5
Other energy intensive	125.6	132.7	135.6	137.5
Electronic equipment	145.6	161.3	160.5	174.1
Transport equipment	144.0	152.8	163.6	159.2
Other equipment goods	148.4	157.5	163.9	164.0
Other manufacturing products	161.9	173.6	178.0	180.4
Food industry	130.7	135.3	137.1	138.4
Trade and transport	135.5	141.7	144.8	146.0
Textile Industry	123.6	126.9	129.4	128.3
Other services and construction	141.7	150.8	155.5	157.9
Non-market services	125.9	127.8	128.9	129.2
Total	136.6	143.6	147.4	148.7

As can be expected developments in sectoral employment would follow a similar pattern as the growth of production, but employment is moderated by the assumed changes in the levels of productivity in the different sectors of the economy. As can be seen in Table 4.3 the largest employment gains can be expected in Other manufacturing products, where employment growth of almost 38 % would be achieved. Large increases in employment would also take place in Other equipment goods and Transport equipment. Job losses would concentrate on Energy and metals, Agriculture and Textile industry.

Table 4.3. Changes in sectoral employment levels in the EU-15 countries between 2000 and 2020 (per cent; GEM-E3 simulations).

Sector	Baseline Scenario	Uniform Scenario	Diversified Scenario	Concentrated Scenario
Agriculture	-6.5	-5.1	-3.4	-2.9
Energy and metals	-8.0	-6.0	-5.7	-3.7
Chemical products	-0.6	2.0	-0.9	2.5
Other energy intensive	-4.1	-1.7	0.1	-0.7
Electronic equipment	12.0	12.9	17.6	10.7
Transport equipment	8.4	11.6	2.5	12.5
Other equipment goods	14.8	18.0	17.3	19.1
Other manufacturing products	25.3	31.8	33.2	37.7
Food industry	-1.0	0.3	0.3	2.8
Trade and transport	4.2	6.4	8.1	7.1
Textile Industry	-4.3	-3.8	-8.6	-2.3
Other services and construction	9.8	13.5	14.7	15.4
Non market services	1.8	1.0	2.9	-0.4
Total	5.6	7.7	8.5	8.6

Table 4.4 shows the level of employment in the various sectors of the EU economy in the year 2000 and in 2020. The sector Other services and construction can be expected to remain as the largest single provider of jobs. This sector even increases its share of the total employment in the economy. The importance of other service-related sectors is also to be noted. Non-market services and Trade and transport will remain important providers of employment opportunities in the future. While significant relative gains can be expected in the numbers of jobs in Other equipment goods, Other manufacturing products and in some other manufacturing activities, the numbers of jobs in each of these sectors will remain at a lower than in the service-related sectors. Needless to say, many of the service-sector jobs will be dependent on manufacturing industries – and *vice versa*.

Table 4.4. Employment in different sectors of the in the EU-15 countries in 2000 and 2020 (thousands of job full-time-equivalents; GEM-E3 simulations).

		Baseline Scenario	Uniform Scenario	Diversified Scenario	Concen-trated Scenario
	2000	2020			
Agriculture	4352	4071	4131	4206	4224
Energy and metals	3771	3470	3545	3557	3630
Chemical products	6037	5998	6155	5985	6187
Other energy intensive	5179	4968	5093	5186	5142
Electronic equipment	2751	3082	3105	3236	3047
Transport equipment	4776	5179	5329	4895	5374
Other equipment goods	11880	13632	14018	13931	14154
Other manufacturing products	4125	5171	5437	5495	5679
Food industry	4654	4607	4668	4668	4787
Trade and transport	29587	30825	31468	31986	31692
Textile industry	2962	2834	2850	2708	2895
Other services and construction	49192	54001	55821	56409	56768
Non-market services	35650	36297	36018	36699	35515

Total	164915	174135	177639	178962	179094

Figure 4.5 illustrates more clearly the future importance of services in employment creation. In all scenarios the sectors that dominate new job creation include Other services and construction and Trade and Transport. Non-market services do not perform quite as well, and in the Concentrated Scenario a decline is projected for employment in this sector. Significant increases in employment are to be expected in Other manufacturing products and Other Equipment goods, as was already shown in Table 4.4.

Figure 4.5. Changes in sectoral employment in the different scenarios in 2020 (thousands of full-time job equivalents; GEM-E3 simulations).

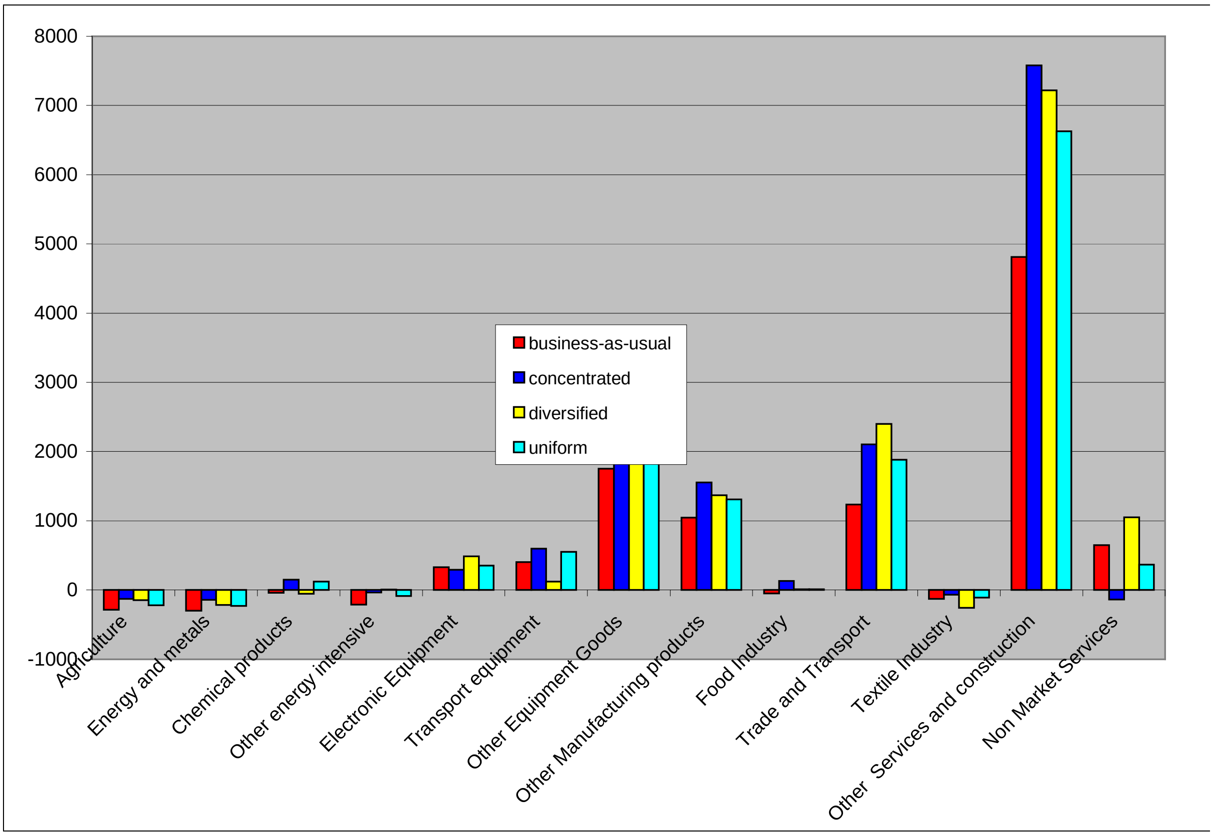


Figure 4.5 also shows some clear differences between the scenarios. For almost all sectors of the economy the Concentrated Scenario produces the best employment outcomes. The exceptions are – in addition to Non-market services – Trade and transport, and Electronic equipment. For these sectors the highest employment levels would be achieved in the Diversified Scenario. In many but not all sectors the 'business-as-usual' or the Baseline Scenario would result in the lowest levels of employment. Surprisingly, the Concentrated Scenario would produce the lowest employment result for Electronic equipment.

It is evident that in all scenarios employment growth is expected to concentrate in services. Therefore it can be suggested that the most effective employment policies would probably be those that are successful in the service sector. Agriculture is expected to continue to lose its share of total employment, while there are signs that manufacturing may be stabilising, with some sub-sectors even increasing their employment shares. Electronic equipment, although often considered a promising sector, is not expected to gain an important role in the provision of new jobs, because labour productivity is assumed to grow at a high rate in this sector.

The most striking sectoral difference between GEM-E3 and ASTRA simulations concerned employment in the Non-market services. In ASTRA simulations a clear decline was foreseen in the employment level of this sector. Moreover, ASTRA was a bit more optimistic about the transport equipment sector, but more pessimistic for the other machinery and the electronics sector.

4.4 Technology flows between sectors

One of the most important findings in the economics of technical change is that the results of R&D efforts do not benefit only the company that carries out research or technology development. The benefits spill over to other companies in the sector, other sectors and even to other countries. The main vehicles of the spillovers are research publications, patents, people changing jobs, as well as products and capital equipment embedded with knowledge.

The GEM-E3 model does not allow a direct estimation of the spillover effects, but a picture of the complex technological interlinkages that exist between various sectors of the economy can be formed on the basis of input-output coefficients that are produced endogenously in simulation runs of the model. The following study of these input-output coefficients makes it possible for us to see how the effects of improvements in labour productivity in one sector will propagate to the rest of the economy. The study also reveals which sectors of the economy will derive the highest secondary benefits from productivity improvements that are assumed to take place in the different scenarios. Moreover, simulations with the GEM-E3 model show how some of these relationships can be expected to evolve by the year 2020 in different scenarios.

In input-output analysis *forward linkages* of a sector show by how much the output of the sector rises, if the demand for goods produced in every sector of the economy is increased by one unit. The forward linkages indicate the extent to which the output of one sector is used as an intermediate input in the rest of the economy (and within the sector itself). That is why the forward linkages represent the significance of the sector’s output as an input in the economy as a whole. Moreover, an industry that has higher forward linkages than other industries is relatively more sensitive to changes in other industries’ output. The analysis of forward linkages in an economy typically indicates that interdependencies between domestic industries tend to decrease over time as foreign inputs become increasingly important and that the role of non-manufacturing industries becomes stronger reflecting the growing importance of the service sector (cf. Guo and Planting 2000).

Table 4.5. The importance of various sectors of the economy as producers of inputs to the rest of the economy in 1995 and 2020 (linkage indicators and rankings).

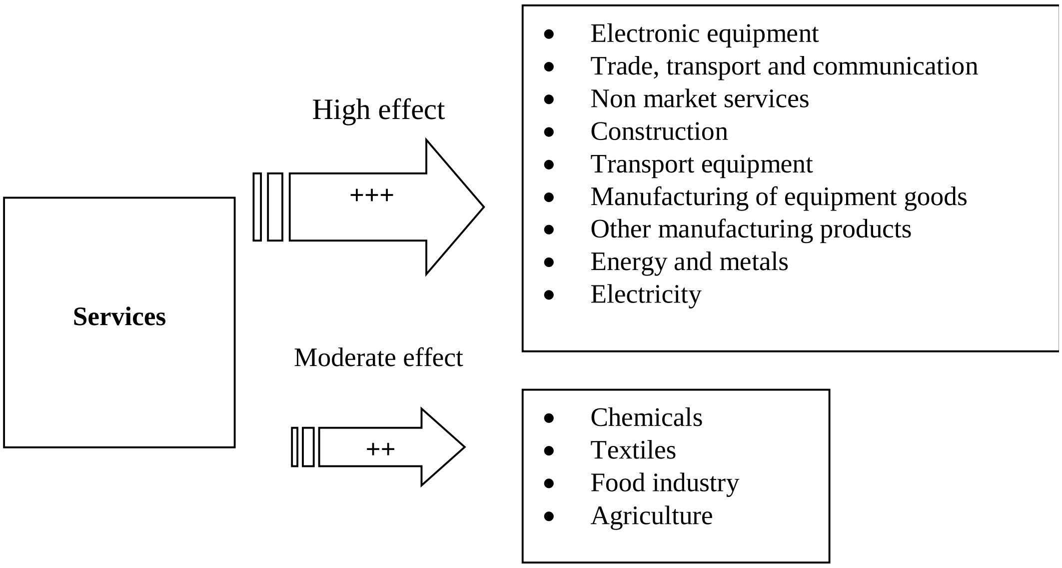
Sectors of the EU economy	1995*		2020 Scenarios**							
			Baseline		Uniform		Diversified		Concentrated	
	Linkage	Ranking	Linkage	Ranking	Linkage	Ranking	Linkage	Ranking	Linkage	Ranking
Other Market Services	6.63	1	5.37	1	5.22	1	5.36	1	5.36	1
Trade and transport	4.24	2	3.39	2	3.39	2	3.39	2	3.38	2
Chemical Products	3.15	3	2.46	4	2.44	4	2.45	4	2.45	3
Other Equipment Goods	2.88	4	2.47	3	2.45	3	2.45	3	2.45	4
Ferrous and non ferrous	2.66	5	2.13	6	2.14	5	2.12	6	2.12	6
Other energy intensive	2.62	6	2.11	7	2.11	6	2.11	7	2.10	7
Oil	2.49	7	2.14	5	2.08	7	2.14	5	2.13	5
Agriculture	1.88	8	1.71	8	1.71	8	1.70	8	1.70	8
Food Industry	1.77	9	1.57	9	1.55	9	1.57	9	1.56	9
Non Market Services	1.70	10	1.56	10	1.55	10	1.56	10	1.55	10
Textile Industry	1.63	11	1.50	12	1.51	12	1.50	12	1.50	12
Construction	1.62	12	1.46	15	1.44	15	1.47	13	1.46	14
Gas	1.62	13	1.51	11	1.53	11	1.51	11	1.50	11
Electricity	1.60	14	1.46	14	1.47	13	1.46	14	1.46	15
Other Manufacturing prods	1.59	15	1.46	13	1.46	14	1.46	15	1.46	13
Transport equipment	1.55	16	1.43	16	1.42	16	1.42	16	1.43	16
Electronic Equipment	1.51	17	1.41	17	1.40	17	1.41	17	1.40	17
Coal	1.45	18	1.34	18	1.32	18	1.35	18	1.34	18

*Source: Eurostat. **Source: simulations with the GEM-E3 model.

Table 4.5 shows the forward linkages and rankings of the 18 sectors covered in the GEM-E3 model. The indicators for the year 1995 are from the Eurostat 1995 input-output table of the EU economy, and those for the year 2020 are taken from the GEM-E3 scenario simulations. The table shows that the initially small changes in innovation expenditures have only small impacts on the relative importance of the various sectors of the economy even during such a long period of time as 20 years. Among the few notable changes is the rise of the relative ranking of Gas in all of the scenarios and of Oil in almost all of the scenarios. The ranking of Construction declines in all of the scenarios.

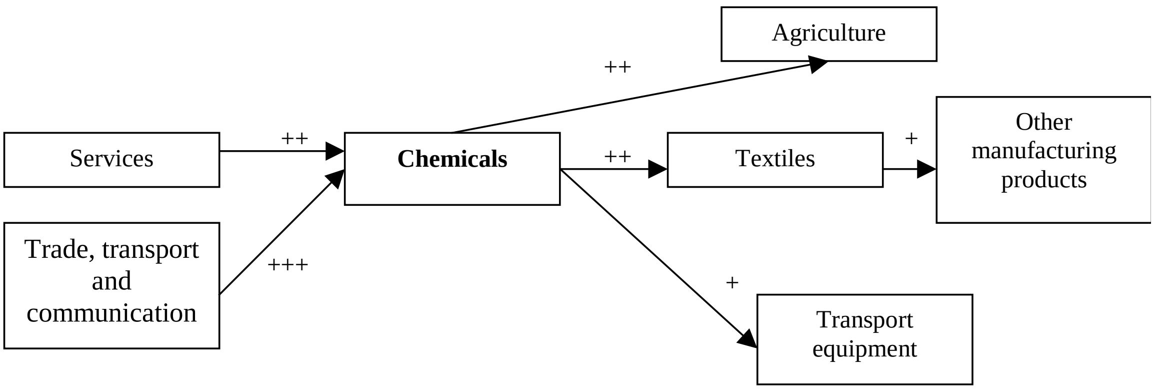
Table 4.5 shows that two service-sector activities, *Trade and transport* and *Other market services*, have the highest forward linkages in the EU economy. A more detailed analysis would show that for these two sectors the self-consumption of the sector's output is low. The output of Other market services is diffused rather homogeneously across all of the sectors in the EU economy. The most important user of Trade and transport is the Ferrous and non-ferrous metals sector, while agriculture, coal, gas and electricity are less dependent on these services. Figure 4.6 shows in more detail which sectors of the economy would benefit most from technical advances in the service sector.

Figure 4.6. Sectors benefiting from technological progress in services.



In Table 4.5 the third highest-ranking sector is the Chemical sector. Its forward linkages are more concentrated towards the Textile industry and Transport equipment sectors. Other manufacturing sectors and agriculture are also good customers of the Chemical sector. In addition the Chemical sector consumes a large share of its own output. Figure 4.7 represents these relationships schematically.

Figure 4.7. Sectors benefiting from technological progress in the Chemical sector.



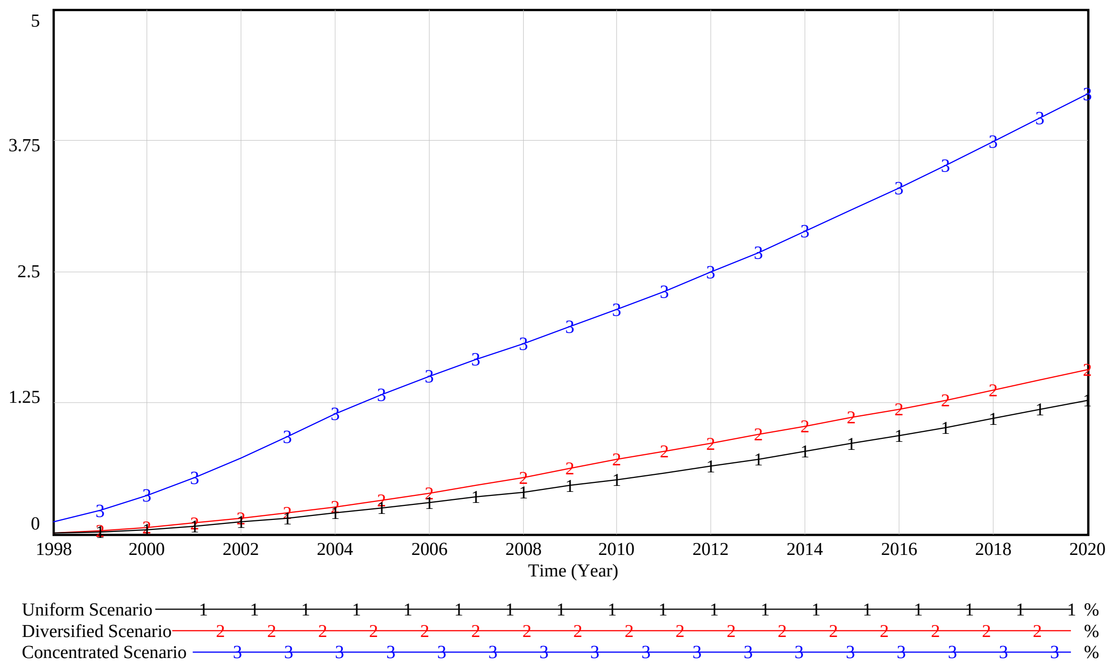
As shown in Table 4.5 the small stimuli given in the four alternative policy scenarios would according to the GEM-E3 model results not have a significant impact on the structure of the EU economy even during a period as long as 20 years. In reality, of course, the structure of the EU economy would be affected not only by changes in innovation expenditures but also by a great variety of other influences. The GEM-E3 model takes into account only those propagation effects of technical change that are caused by the sales of goods and services from one sector to another. As we have already noted, there are many other transmission mechanisms involved as well. In addition, inter-sectoral and international capital flows, not accounted for in the model, could also have a significant impact by accelerating the growth of the most competitive sectors of the economy. For these reasons it is safe to say that Table 4.5 presents the lower boundary of the effects of technical change on the structure of the European economy.

4.5 The results of the ASTRA simulations at the EU level

The ASTRA model produced a much higher GDP level in the Baseline Scenario than the GEM-E3 model. In the Baseline Scenario the growth of the EU GDP would have been 64.1 % according to the ASTRA model, while in the GEM-E3 simulations the growth was 52.1 %. Nevertheless, in the ASTRA model the employment growth in the Baseline Scenario would have been only 3.1 % between the years 2000 and 2020. In the Uniform and Diversified Scenarios the employment outlook would be even worse than in the Baseline Scenario. In comparison with the GEM-E3 model the ASTRA model seems to emphasise the difficulties that the EU economy has in job creation even if substantial growth is achieved in the EU GDP, investment, consumption and exports.

While in general the ASTRA model seems to draw a more sluggish picture of the EU economy than the GEM-E3 model, the ASTRA model is more optimistic about the responsiveness of the EU economy to technology policies focusing on high technology. This is seen in Figure 4.8, which depicts the growth patterns of the EU GDP in the three alternative policy scenarios in relation to the Baseline Scenario. In all of the following figures the ASTRA results are presented as deviations from the Baseline Scenario.

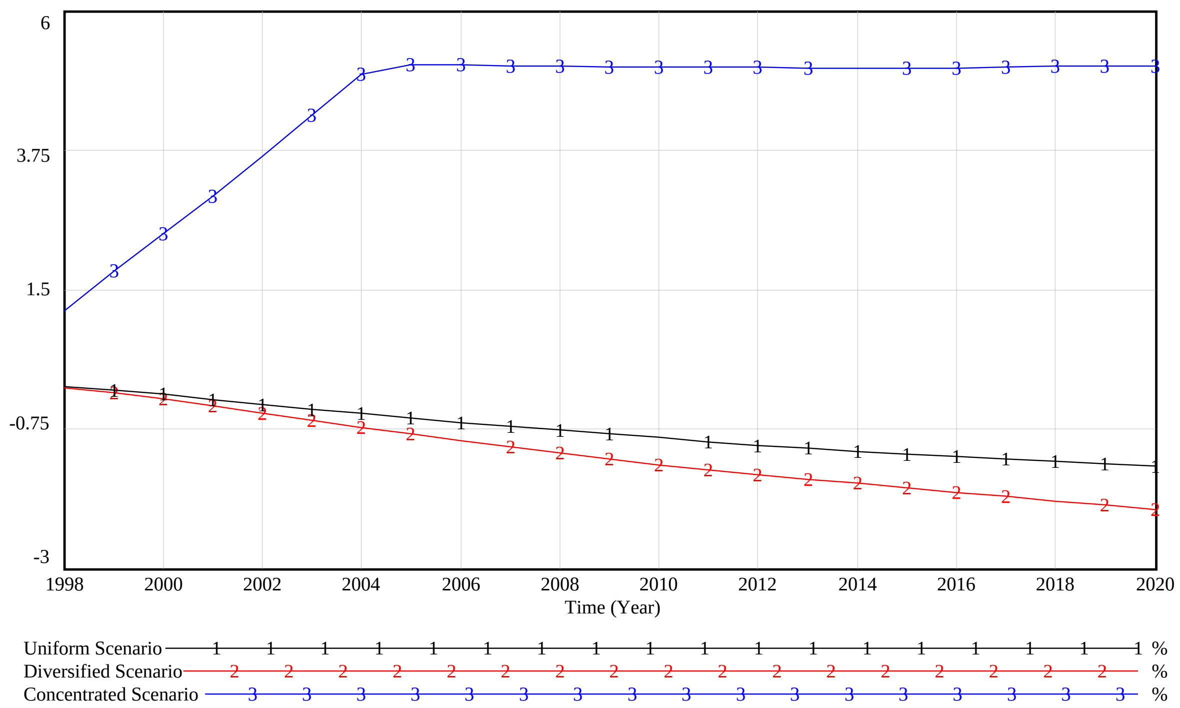
Figure 4.8. GDP growth in the EU-15 countries (percentage difference from the Baseline Scenario; ASTRA simulations).



In the ASTRA simulations the responsiveness of the EU economy to the policies of the Concentrated Scenario is seen not only in the GDP growth but in employment as well. In Table 4.1 the aggregate increase in employment is 9 % by the year 2020 in the Concentrated Scenario, while in the Uniform and Diversified Scenario the employment growth would be 1 % or 1.8 % less than what would take place in the Baseline Scenario. The employment outcomes of the ASTRA and GEM-E3 simulations are at a comparable level in the Concentrated Scenario, while in other scenarios wide differences can be found. Figure 4.9 shows how, when compared with the Baseline Scenario, the response of employment to the policies of the Concentrated Scenario was in the ASTRA simulations particularly strong during the first few years.

While in the ASTRA simulation the results of the Concentrated Scenario were remarkable in that they produced employment results that were significantly different from the other scenarios, within the Concentrated Scenario the crucial period concerns a few years during which a relative difference with the other scenarios becomes established. The crucial difference seems to be a direct result of the assumptions about consumption in the Concentrated Scenario. As new products can be assumed to emerge as a result of increased R&D and innovation expenditures in high-technology sectors of the economy, consumption was assumed to increase and those changes were phased in over a period of 8 years starting with 1996 and lasting until 2003, directly affecting the structure of consumption expenditures of private households. The interrelationships and feedback mechanisms in the ASTRA model then transfer the first-round direct impacts of productivity changes and new consumption demand to further elements of the model and into secondary impacts in future years.

Figure 4.9. Employment in the EU-15 countries in 1998-2020 (percentage difference from the Baseline Scenario; ASTRA simulations).



After the crucial period of the first few years the ASTRA model seems to return to its inherent concept of Europe as not a particularly dynamic economy even when an added emphasis is put on high technology. In what follows we shall try to see if regional differences can be expected in the response of the EU economy to the differences in R&D and innovation policies in our scenarios.

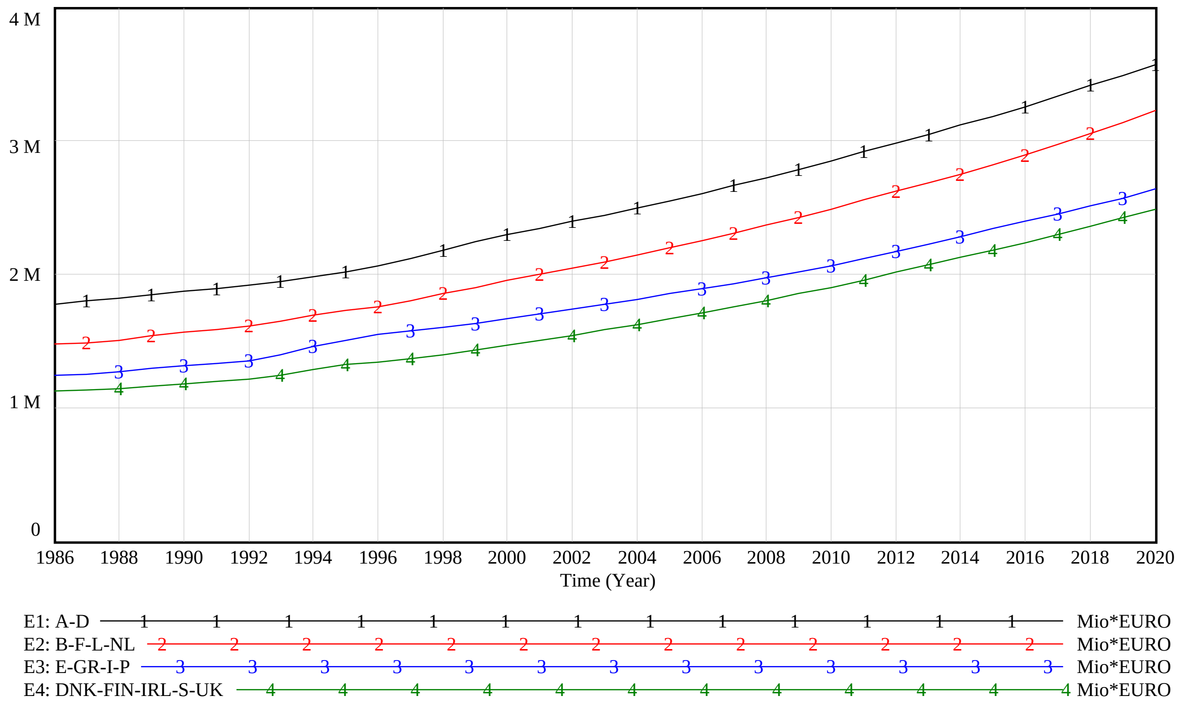
4.6 Regional results of the ASTRA simulations

Both the GEM-E3 and ASTRA models allow the study of the regional implications of our scenarios, but as the regional subdivision is more interesting in the ASTRA model, we shall show results only from that model. Altogether four subregions of the EU are implemented in the ASTRA model:

- E1: Austria, Germany (A-D);
- E2: Belgium, France, Luxembourg, Netherlands (B-F-L-NL);
- E3: Spain, Greece, Italy, Portugal (E-GR-I-P);
- E4: Denmark, Finland, Ireland, Sweden, United Kingdom (DNK-FIN-IRL-S-UK).

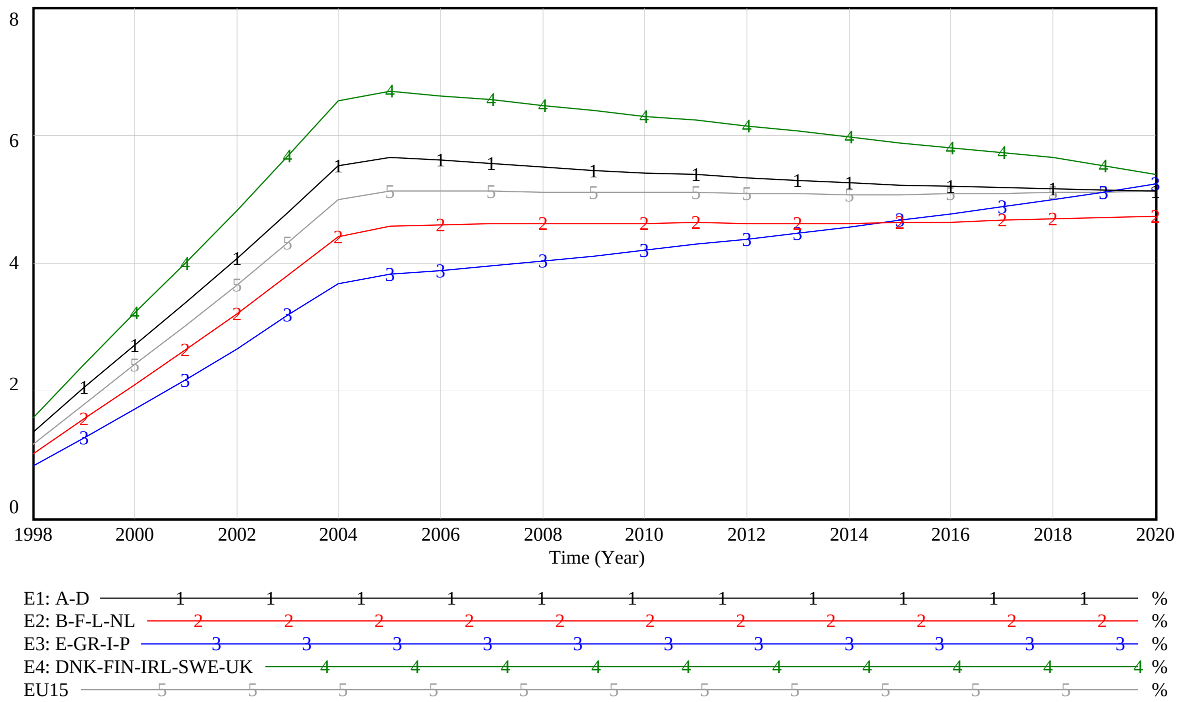
The impacts of the scenarios differ slightly from region to region due to differences in regional composition of industries, which influence the extent to which labour productivity responds to changes in innovation policy. Figure 4.10 shows that differences can be seen already in the regional GDP outcomes of the Baseline Scenario.

Figure 4.10. GDP in the main EU regions in the Baseline Scenario in 1986-2020 (millions of Euro; ASTRA simulations).



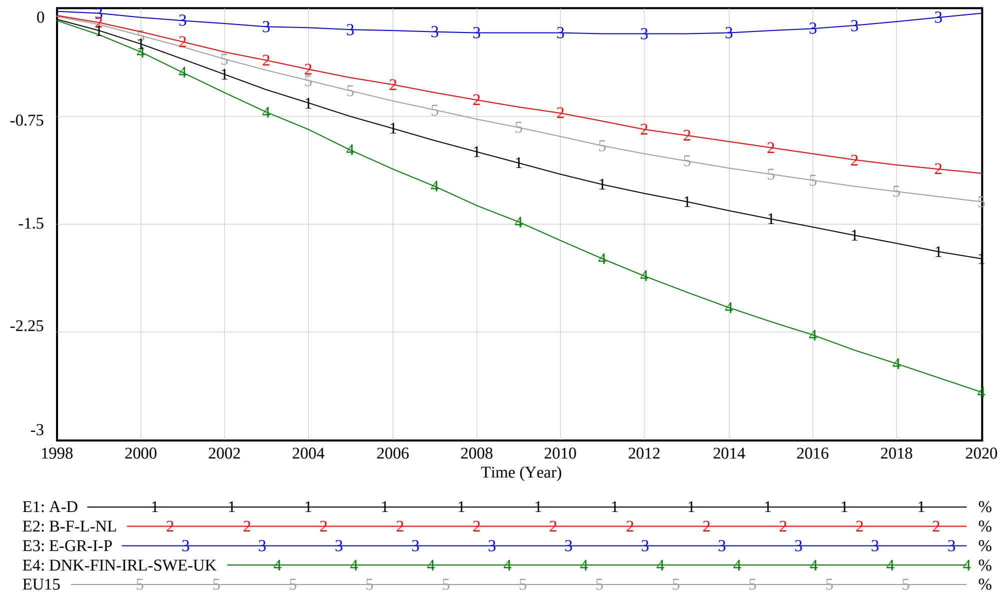
In what follows we shall show the employment results of different scenarios in the EU regions. First of all, Figure 4.11 shows how in the Concentrated Scenario a similar regional pattern of employment growth takes place as at the aggregate EU level. The consumption-related increase is particularly strong in the Germany-Austria region and the weakest in the Mediterranean region of Spain, Greece, Italy and Portugal.

Figure 4.11. Employment in the main regions of the EU in the Concentrated Scenario in 1998-2020 (percentage difference from the Baseline Scenario; ASTRA simulations).



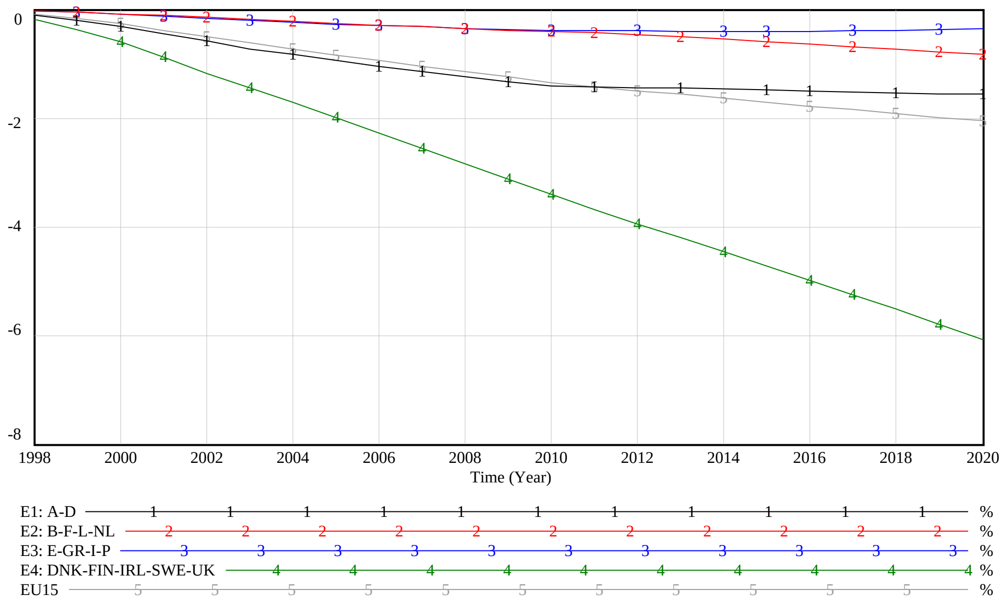
As we already know, in ASTRA simulations the aggregate employment outcomes of the Uniform and Diversified Scenario are worse than those of the Baseline Scenario. As Figures 4.12 and 4.13 show, the outcomes are particularly bad for the Northern European region of Denmark, Finland, Ireland, Sweden and the UK.

Figure 4.12. Employment in the main regions of the EU in the Uniform Scenario in 1998-2020 (percentage difference from the Baseline Scenario; ASTRA simulations).



Both the Uniform and the Diversified Scenario (Figure 4.13) produced the best employment results for the Mediterranean region in the ASTRA simulations.

Figure 4.13. Employment in the main regions of the EU in the Diversified Scenario in 1998-2020 (percentage difference from the Baseline Scenario; ASTRA simulations).



The regional results of the ASTRA model strengthen the impression that the employment creating effects of the Concentrated Scenario are highly dependent on the ability of the economy to introduce new products that increase consumption demand. The new products have to be not only acceptable but also attractive to consumers in order to ensure the realisation of the employment benefits of technology policies favouring R&D and innovation expenditures in high-technology sectors of the economy. Similar, but more muted processes underlie the more optimistic results of the GEM-E3 model as well. The overall impression of the ASTRA results is that technology policies concentrating single-mindedly on enhancing labour productivity while ignoring the demand side would not lead to the best possible employment results.

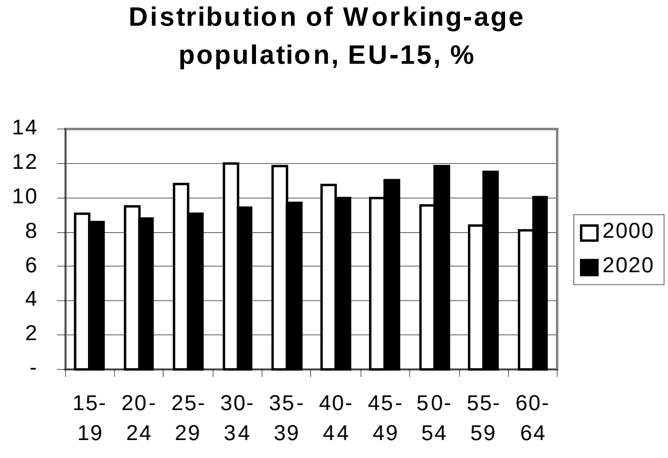
4.7 Comparing employment estimates with projected labour supplies

The employment estimates arising from our computer simulations can be regarded as estimates of the demand for labour in the EU. That is why it is of some interest to compare these estimates with independent projections of the EU labour supply to see if shortages of labour or high rates of unemployment can be expected to dominate in the future. We start our exploration by studying demographic factors influencing the future labour supply in the EU.

Population projections depend on assumptions about fertility, mortality and migration. The Eurostat projections of the EU-15 population range from just over 360 million to nearly 420 million by 2020. The wide variation suggests that there is considerable uncertainty. The UN *World Population Prospects* (2000 revision), based on world forecasts to 2050, estimates that the population of the EU-15 countries will decline between 2000 and 2020 by around 0.7% (interpolating between the 2015 and 2025 figures). This is because fertility levels are expected to be below the replacement rate (2.1 children per woman).

The age distribution of the population is another important determinant of the size of the working population. In Europe the population structure is ageing. A great majority of the workforce of the year 2020 has already been born. Although life expectancy at birth is expected to rise for the EU-15 (from 78.5 years in the early 2000s to 80.9 years in the early 2020s), and the infant mortality rate is expected to fall (from 5.4 per thousand to about 3.6 over the same period), even so there will be a substantial shift towards an older age distribution of the population. This, of course, by itself will further reduce the available pool of potential employees. The changing age distribution of the population in the EU-15 countries can be seen in Figure 4.14.

Figure 4.14. Distribution of population in working-age groups, EU-15, 2000 and 2020



Source: Eurostat.

Given the low levels of fertility, international migration is expected to be the main determinant of differences in population growth, and the advanced countries will continue to be the main receivers of this migration. Partly because of migration effects, individual countries in the EU-15 will range from an increase of over 25 % in Luxembourg to a decline of 6.5 % in Italy, to 2020. However, this conclusion is based on the assumption that migration levels stay constant at the existing rate. Without immigration from non-EU countries the population in Germany, Italy and Sweden would already be in decline; however the labour market participation rates of immigrants are lower than of the domestic population. The shares of foreign workers in different countries in 1990 and 1997 are presented in Table 4.6.

Table 4.6. Shares of foreign workers in the national labour force, 1990 and 1997.

Country	Share of foreigners in the labour force	
	1990	1997
Austria	7.4	9.9
Belgium	n.a.	7.9
Denmark	n.a.	3.0
France	6.2	6.1
Germany	7.1	6.6
Ireland	2.6	3.4
Italy	n.a.	1.5
Luxembourg	45.2	55.1
Netherlands	3.1	2.9
Portugal	1.0	1.8
Spain	0.6	1.1
Sweden	5.4	5.2
UK	3.3	3.6

Source: OECD 1999c (n.a. = not available).

A simulation exercise to forecast the likely impact of EU enlargement on migration from 10 Central and East Europe (CEE) countries to Germany and the EU-15 was recently undertaken by Brücker *et al*. (2001), based on assumptions about differences in GDP levels and their possible rate of convergence. For Germany, which received 66 % of the immigrants in 1999, the total number of immigrants would rise by 2 to 2.25 million by 2010 and then level out. For the EU-15 the total increase was 3-4 million, i.e. around 1 % of the expected population levels – not enough to cover the shortfall detected above if we use the 'medium' projection for population supply. Moreover, Coppel *et al*. (2001) argue that, though it should work in the 'right' direction, migration will not by itself overcome the ageing issue. Furthermore, migration and its promotion raises political problems for many governments, so one cannot readily assume that it will expand to fill any arising gaps between the supply of and the demand for labour.

An convenient way of assessing the future balance between supply of and demand for labour in the EU countries is to compare our simulation estimates for the demand for labour with population projections estimated by Eurostat. Eurostant has estimated the EU population until the year 2025, with intermediate projections for 2005, 2010, 2015, 2020. The projections are given for three different scenarios of low, medium and high population growth and range from just over 360 million (low) to nearly 420 million (high) by 2020. The considerable differences between these figures illustrate the uncertainties that are involved. Table 4.7 shows the projected growth rates of the EU population.

Table 4.7. Eurostat projections of EU-15 population growth rates, 2000-2020.

	Low	Medium	High
2000-2005	-0.00%	+0.26%	+0.56%
2000-2010	-0.05%	+0.22%	+0.53%
2000-2015	-0.09%	+0.18%	+0.48%
2000-2020	-0.14%	+0.15%	+0.43%
Overall increase	-2.68%	+2.99%	+9.42%

Source: Eurostat

If the share of the working population could be expected to stay constant in Europe over the next two decades, population growth rates given in Table 4.7 could be directly compared with the growth rates of labour demand given in Table 4.1. We may recall that according to our simulations the demand for labour can be expected to increase between 2.5 and 10.3 per cent in the EU over the next two decades. Even in the Baseline Scenario, where no additional increases in the GDP share of R&D and innovation expenditures are assumed, the demand for labour will grow between 3.7 % (in ASTRA simulations) and 5.6 % (GEM-E3 simulations). In the Eurostat population projections the medium scenario is the most plausible one, allowing only a growth rate of 2.99 % in the labour supply, if the share of the working population would stay at the current level. The immediate conclusion is that at the EU level labour shortages may be a reality by the year 2020, if the share of the working population cannot be increased by reducing the number of the unemployed or other means. The probability of labour shortages would be heightened, if R&D and innovation expenditures would be raised.

In conclusion it is more probable that by the year 2020 European labour markets will be characterised by labour shortages rather than by widespread high levels of unemployment. Nevertheless, given the differing positions of expanding and contracting industries and regions as well the differences between the employability of highly-skilled and unskilled workers, the discrepancies across individual industries, regions and occupations may become more marked than they are today. If migration turns out to be insufficient in providing labour in the required numbers, other sources may have to be found. These may have to come mainly from the ranks of part-time workers, the unemployed, older workers, or females. However these groups not at present in full-time jobs will not become more employable without substantial training efforts. There is in theory some scope for increasing hours of work per week or per year, but the trend of part-time working has been upward rather than downward in many EU-15 countries, while the trend in working hours per employee has been downward rather than upward.

4.8 Assessing some of the complexities of the EU labour market

So far we have barely touched on the complexities of the European labour market. Technical change is but one of the factors that will have a strong impact on the future level of employment in Europe. Moreover, the overall level of employment is only one of the significant characteristics of the labour market. In order to have a deeper understanding of the future of employment in Europe it is necessary to have at least some idea of the expected differences in employment between males and females and the prospects of youth employment.

In order to further our understanding of the European labour market we produced a set of projections of some important characteristics of the market. Like the majority of projections currently available from other sources, we used data from the 1990s as a basis for the projections. However we noticed that there were significant changes in some of the key parameters even within the decade of the 1990s, so the forecasts must be treated with care. As with the scenarios in preceding sections of the study, on which our forecasts are partly based, the results are not so much predictions as a range of possibilities depending on the supposition that certain key relationships continue to hold. The results highlight areas where policy may have to intervene to set things back on course. Such policy areas are studied further in the scenario context in Chapter 4 below.

The data we used were the latest available from the EC or the OECD. The analyses in this section all use panel-data methods, identifying two attributes of each observation: the country it relates to, and the precise year that it relates to. Using the country attributes allows us to take into full consideration the national differences in levels of most of the variables. Using the time attributes frees us from having to make simplifications such as a crude time trend – we allow for the individual specificities of each year as they affected the 15 countries, e.g. whether it was a year of recession or robust expansion. The data can be shown to exhibit 'cyclical' patterns, even when some structural variables are allowed for.

The first task is to relate the varied data on changing employment patterns to macroeconomic data on growth etc. The following variables were selected:
- real GDP;
- average labour productivity (per year);
- average hourly productivity;
- real compensation per employee (GDP deflator, as an index of real wage rates);
- real unit labour costs; and
- average hours worked.

The employment data were provided for quite a number of indicators, from which we selected the following:
- employment rate, total/male/female (% of each population aged 15-64 in employment)
- self-employed rate, total/male/female (% of each employment level)
- part-time employment, total/male/female (ditto)
- fixed-term contracts, total/male/female (ditto)
- full-time equivalent (FTE) employment rate, total/male/female (% of each population aged 15-64 - FTE employment is defined as total hours worked divided by the average annual number of hours worked)
- youth unemployment rate (% of the labour force aged 15-24)
- unemployment rate (% of the labour force aged 15+)

The first step is to correlate *changes* in the employment indicators with *changes* in the economic indicators specified above. All the results reported allow for the fixed effects of differing country and differing year as already explained, though these fixed effects are not reported in Annex Table A4.1 for reasons of space.

The employment rate change indicators are very significantly and positively correlated with growth rates of GDP – this holds good for total employment and for males and females separately. They are also strongly correlated (a little weaker for females) with labour productivity growth, but here the correlations are all negative. Thus in the short term, a rise in labour productivity is negatively associated with changes in employment rates, as our earlier arguments presumed – in the long term, things may be different, as was seen in the previous chapter, where more full-fledged models of the EU economy were applied. Furthermore, hourly as opposed to annual productivity shows no significant correlations in either direction. The coefficient on labour productivity changes suggests an elasticity of around -0.2, which is what was coming to be recognised as valid for Europe in the later 1990s though not before, when the figure for the elasticity used in GEM-E3 of -0.1 seemed to apply.

There is a negative correlation between males in self-employment and changes in the rate of GDP growth. Self-employment appears to be rising in some segments, including ICT-related, but falling in others. Changes in the overall rate of part-time employment are significantly, even if not strongly, related to a majority of the economic variables, but the factors differ between males and females. The female rate of part-time employment rises as hourly productivity rises and falls as average hours of work increase.

Total rates of unemployment, first for youths (relative to their age group) and then overall (relative to the working population), are strongly negatively correlated with GDP growth, as would be expected, but surprisingly not with any of the other economic variables. Youth unemployment appears to 'over-respond' to changes in total unemployment.

The results of further statistical evaluations of the 'fixed effects' of country and period specificities yielded some additional findings of interest. For a given overall relationship between employment changes and GDP changes, countries with a higher share of employment in services have higher employment changes. There is also a negative relationship between this relationship and the variability in GDP growth as measured by its standard deviation, i.e. employment changes will be smaller if GDP growth is more unstable. There is little difference between male and female employment behaviour in these respects. The full-time equivalent employment rates show less consistent behaviour than uncorrected employment rates. This suggests that countries partly absorb the differential impacts on employment through varying employment relationships that influence the real levels of employment worked.

Finally, the relationships between youth unemployment rates and total unemployment rates and growth of GDP are positively related to the standard deviation of GDP; that is, for a given rate of growth of GDP, the two unemployment rates are higher in countries that had a more unstable growth record. This is as might be anticipated.

The relationships established in this analysis can be used to provide employment estimates under the various scenarios outlined in Chapter 2 above. What these projections can do is to provide another look at the plausibility of our scenario simulations. Moreover, they provide interesting indications about future directions in male and female employment, general unemployment and youth unemployment. In this section, because of availability of results from the scenarios, we have limited ourselves to forecasts based on the relationships with real GDP growth. The results are given in Tables 4.8 and 4.9.

Table 4.8. Differences from Baseline predicted to 2010, percentage points.

VARIABLES	Concentrated	Diversified	Uniform
Employment rate, Total	1.9	1.8	1.1
Employment rate, Male	2.1	2.0	1.3
Employment rate, Female	1.7	1.6	1.0
Self-employment rate, Male	-0.4	-0.4	-0.2
FTE Employment rate, Total	1.2	1.1	0.7
FTE Employment rate, Male	1.6	1.6	1.9
Youth Unemployment rate	-4.0	-3.9	-2.4
Unemployment rate	-2.0	-1.9	-1.2

Table 4.9. Differences from Baseline predicted to 2020, percentage points.

Variables	Concentrated	Diversified	Uniform
Employment rate, Total	3.4	3.0	2.0
Employment rate, Male	3.8	3.3	2.2
Employment rate, Female	3.1	2.7	1.8
Self-employment rate, Male	-0.7	-0.6	-0.4
FTE Employment rate, Total	2.1	1.8	1.2
FTE Employment rate, Male	2.9	2.6	4.9
Youth Unemployment rate	-7.3	-6.4	-4.3
Unemployment rate	-3.5	-3.1	-2.1

It is of considerable interest to compare the results of these projections with the employment targets set at the Lisbon Summit. The 2010 target for total employment was set at 70 % and at more than 60 % for females. In the Baseline Scenario the predicted EU-15 rate for total employment shows a linear increase, from 63 % to nearly 71 % over the two decades. However the level as of 2010 falls short of the Lisbon Summit objective, reaching just 67 % in 2010, even though the Lisbon level is expected to be surpassed ten years later. Since in the Baseline Scenario the Lisbon targets would not be achieved, we can conclude that for these goals to be attained or closely approached by 2010, it may be necessary to introduce policies such as those involving increased R&D and innovation expenditures. The results we obtained for total employment rates in 2010 are 67 % - Baseline Scenario; 69 % - Concentrated; 69 % - Diversified; 68 % - Uniform.

By the year 2020 the male employment rates will increase in the Baseline Scenario from under 73 % in 2000 to over 76 % in 2020. Female employment rates are expected to rise in most regions, so female employment in the EU-15 is predicted to rise throughout, from 54 % in 2000 to 65 % in 2020. In 2010 we predict a rate of nearly 60 %, as compared with the Lisbon target of over 60 %, indicating that under baseline assumptions the much-doubted Lisbon target might be almost reached. In other scenarios female employment rates are about 61 % in 2010.

Male self-employment rates can be expected to decline overall, especially after 2010, though they are predicted to rise in Germany and stabilise in the Nordic countries. Youth unemployment rates for the EU-15 trend downward very acceptably, though perhaps over-optimistically, but with significant regional variations. Youth unemployment may also be seen as an indicator of the general employment situation of unskilled workers. Therefore some decline is to be expected in the unemployment level of the young and the unskilled, but still these two groups can be expected to constitute a large share of the numbers of the unemployed.

For both 2010 and 2020, the Concentrated scenario does ‘best’ in terms of achieving the highest desirable outcome, for all variables except male full-time equivalent employment rates, where the Uniform scenario appears to do best. However the differences between the Concentrated and the Diversified scenarios are mostly very small until 2010, and not very large even by 2020.

5 Technology-sector links in the EU economy 2000-2020

5.1 Introduction

Among the objectives of the study of technology policy and employment for the European Parliament, there are two whose link is the goal of this contribution. First, the identification of the key technologies in the 2020 horizon and, second, the identification of the key sectors because of their employment potential. The goal of this document is to explore the technology-sector linkages. This is indeed a fundamental issue that also determines the relative importance of the technologies and sectors. The value-added and the employment prospects of the sectors have been assessed with the GEM-E3 and ASTRA models. The propagation of an improvement in a particular technology (e.g. a productivity improvement in ICTs), developed within a particular economic sector, to the rest of the sectors is the main subject of interest of this brief document. The kind of questions to be addressed are the following: Which sectors benefit most from a particular technological development? How will that pattern evolve up to the year 2020 and across technological scenarios?

The input-output methodology (see e.g. DoC (1997) and Guo and Hewings (2001)) allows to derive some interesting insights related to these issues, by taking into account the intersectoral linkages of the economy within a mathematical framework.

The main advantage of the input-output method is that it benefits from using large sectoral databases. Information coming from many sources is systematically compiled so that the quantitative intersectoral linkages are assessed. Furthermore, the economic literature, starting with Leontief in the 1950s, has developed many useful analytical developments that can be applied to the row input-output tables. This document will just explore the implications of some simple theoretical tools.

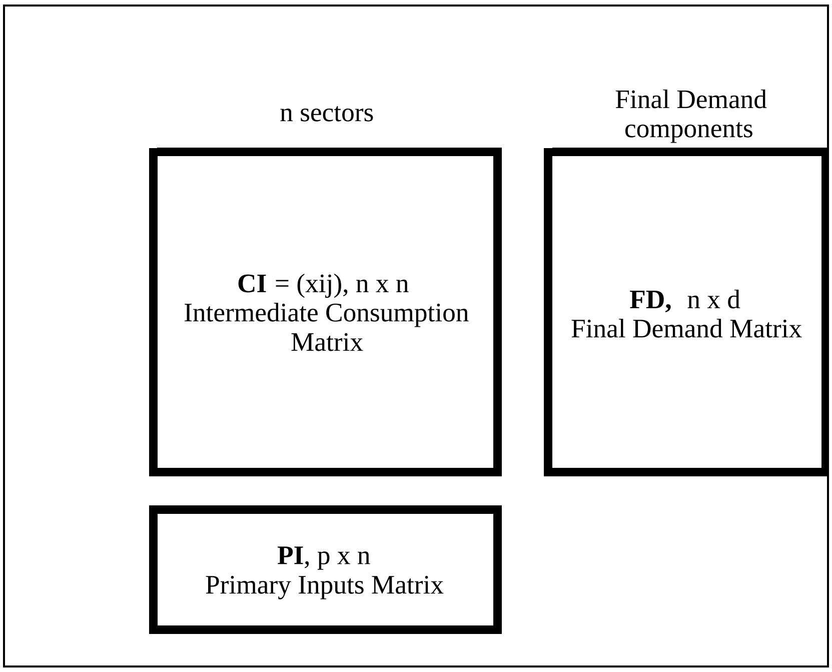
5.2 Brief exposition on the input-output method

An input-output table can be represented with three major blocs (see

Figure 10). It is assumed that there are *n* sectors in the economy. Firstly, the Intermediate Consumption matrix (CI) depicts the interrelations between all the sectors of the economy. Each element of that matrix, x_{ij} , represents the sales of sector *i* to sector *j*. Secondly, there appears the Final Demand matrix (FD), where the final demand of each sector is represented, *i. e.* consumption, investment and exports. Finally, the Primary Inputs matrix (PI) express the required primary inputs of each sector of the economy: labour, capital and imports. For any sector *i* the row of the matrixes CI and FD captures its intermediate and final demand, respectively. For any sector *j* the column of the matrixes CI and PI represents the intermediate and primary inputs, respectively.

Figure 10

Blocs of the Input-output Table



The Leontief inverse matrix plays a key role in the computation of all the linkages indicators. This matrix is formally derived in the following paragraphs.

Every sector *i* verifies the following identity that sets that the total demand (intermediate plus final) of each sector is equal to its production:

$$x_{i1} + x_{i2} + ... + x_{in} + D_i = X_i \qquad (1)$$

where: x_{ij} = sale of sector *i* to sector *j*, and then $x_{i1} + x_{i2} + ... + x_{in}$ is the *intermediate* demand of sector *i*; D_i = *final* demand of sector *i*; and X_i = overall production of sector *i*.

Furthermore, the coefficient a_{ij} can be defined as:

$$a_{ij} = x_{ij}/ X_j \qquad (2)$$

The coefficient a_{ij} means the amount of production of sector *i* that sector *j* requires to produce one unit of output. Equation (1) can be expressed in terms of the a_{ij} coefficients so that:

$$a_{i1} X_1 + a_{i2} X_2 + ... + a_{in} X_n + D_i = X_i \qquad (3)$$

Expressing (3) in matricial format and rearranging the terms yields the basic expression of the input-output analysis:

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1} \mathbf{D} \qquad (4)$$

where: **X** = the production vector of the economy, **I =** the identity matrix, **A** = the matrix of a_{ij} coefficients and **D** = the final demand vector of the economy. Notice that only matrices **CI** and **FD** are involved in (4).

The expression (**I** - **A**)$^{-1}$ is known as the *Leontief inverse matrix*. Each element of this matrix stands for the required increase in the production of sector *i* to meet an increase of one unit in the final demand of sector *j*. In fact, the required increase in the output of sector *i* has two components. First, in order to satisfy the one unit demand increase of sector *j*, sector *i* must increase its production by a certain amount but, moreover, given the fact that to do so sector *i* requires inputs of the other sectors of the economy[11], those sectors will demand an additional increase in the production of sector *i*. The sum of these successive induced increases in the production of sector *i* raises further the production of sector *i*. In this way the Leontief inverse matrix takes into account the nature of the interrelations between all the sectors of the economy.

There are two kind of linkage indicators that can be computed from the previous conceptual framework:

(1) Backward linkages. The vertical sum of the elements of the Leotief inverse matrix for one sector (summing over any column) informs about how much the output of the economy (the sum across all the sectors) increases if the demand of the sector rises by one unit.

(2) Forward linkages[12]. The horizontal sum of the elements of the Leotief inverse matrix (summing over any row) informs about how much the output of the sector rises if the demand of all the sectors of the economy rises at the same time by one. This gives an indicator of the degree to which the production of a sector is used by the economy as a whole. The higher this linkage, the more other sectors are using its production as intermediate consumption. Therefore, this can be a proxy for what we are looking for here, the diffusion of a technological improvement in one sector to the rest of the economy. The advantage of this approach is that it can give quantitative estimates of the sectors that use as an input the production of the sector of interest. A map of the forward linkages can be made for any sector, and study its evolution through time and across scenarios.

On the other hand, it is important to remark that applying the input-output methodology implies assuming certain hypothesis. First, it is supposed that the intersectoral relationships of the economy remain constant over time. This to some extent is overcome in this study because GEM-E3 does compute endogenously the input-output coefficients for each scenario in the year 20202. Second, it is assumed that each sector only produces one homogenous kind of good or service. Third, the model also assumes constant returns to scale. Finally, there are not externalities between the sectors of the economy. In addition to these caveats, in order to interpret the forward linkages as indicators of sectoral diffusion of certain technologies, the following additional assumptions are made:

- Even if a technological improvement takes place in a subsector, it is assumed that

[11] This is captured by the off-diagonal terms due to the presence of the full matrix **A** in the expression of the Leontief inverse matrix. If the matrix **A** were diagonal, there would not be the noted intersectoral effects.

[12] Verspagen (2001) proposes an alternative kind of forward multiplicator derived directly from the x_{ij} elements. This indicator informs about how much the cost of the whole economy (sum of all sectors) rises if the cost of the sector considered increases.

all the sector incorporates it, and therefore diffuses it to the rest of the economy.

- The pattern of diffusion of all technological developments taking place in a sector is proportional to the sales to other sectors of the economy, which is captured by the input-output tables. Of course, it is rather restrictive to assume that the diffusion of an innovation is only channeled through the intersectoral sales of the sector and proportionally to them.

5.3 Results

The noted linkage indicators have been computed for the EU economy in 1995 and 2020, in all the scenarios of the study: baseline or business-as-usual (BAU), concentrated, diversified and uniform. The data come from EUROSTAT (1995 input-output table of the EU economy), and from the GEM-E3 model, which computes endogenously the x_{ij} elements for all scenarios in the year 2020.

5.3.1 Baseline Scenario: Backward and Forward linkages, aggregated indicators

Tables 1 and 2 present the aggregated results for 1995 and the year 2020 in the baseline scenario. With regard to the backward indicators, all of them decrease by around 14%, showing a drop in the degree of interlinkages between the sectors. This trend is also found by Guo and Planting (2000) for the case of the US economy over a 24 years period.

Table 1

Backward Linkages	1995	2020	change %
01 Agriculture	2.18	1.87	-14
02 Coal	2.08	1.78	-14
03 Oil	2.99	2.58	-14
04 Gas	2.39	2.06	-14
05 Electricity	2.13	1.84	-13
06 Ferrous and non ferrous metals	3.01	2.58	-14
07 Chemical Products	2.53	2.16	-15
08 Other energy intensive	2.37	2.04	-14
09 Electronic Equipment	2.42	2.07	-14
10 Transport equipment	2.64	2.25	-15
11 Other Equipment Goods	2.36	1.98	-16
12 Other Manufacturing products	2.41	2.04	-15
13 Construction	2.28	1.90	-17
14 Food Industry	2.66	2.29	-14
15 Trade and Transport	1.88	1.63	-13
16 Textile Industry	2.56	2.17	-15
17 Other Market Services	1.96	1.69	-13
18 Non Market Services	1.78	1.54	-13

The forward linkages, while all of them fall, have however more dispersion. Some sectors such as Chemicals, Ferrous and non-ferrous metals and Trade and Transport, see their indicator falling by around 20%, while the rest of the sectors experience smaller drops.

Table 2

Forward Linkages	1995	2020	change %
01 Agriculture	1.88	1.71	-9
02 Coal	1.45	1.34	-8
03 Oil	2.49	2.14	-14
04 Gas	1.62	1.51	-7
05 Electricity	1.60	1.46	-9
06 Ferrous and non ferrous metals	2.66	2.13	-20
07 Chemical Products	3.15	2.46	-22
08 Other energy intensive	2.62	2.11	-19
09 Electronic Equipment	1.51	1.41	-7
10 Transport equipment	1.55	1.43	-8
11 Other Equipment Goods	2.88	2.47	-14
12 Other Manufacturing products	1.59	1.46	-8
13 Construction	1.62	1.46	-10
14 Food Industry	1.77	1.57	-12
15 Trade and Transport	4.24	3.39	-20
16 Textile Industry	1.63	1.50	-8
17 Other Market Services	6.63	5.37	-19
18 Non Market Services	1.70	1.56	-9

5.3.2 Technology Scenarios: Backward and Forward linkages, aggregated indicators

Table 3 shows the forward and backward indicators for all the technology scenarios. The sectors are ordered by the size of the linkages.

*Backward Linkages **			2020							
	1995		Baseline		Concentrated		Diversified		Uniform	
	Linkage	ranking	Linkage	ranking	Linkage	ranking	Linkage	ranking	Linkage	ranking
06 Ferrous and non ferrous metals	3.01	1	2.58	2	2.56	2	2.58	1	2.58	1
03 Oil	2.99	2	2.58	1	2.58	1	2.57	2	2.46	2
14 Food Industry	2.66	3	2.29	3	2.28	3	2.28	4	2.27	3
10 Transport equipment	2.64	4	2.25	4	2.25	4	2.29	3	2.25	4
16 Textile Industry	2.56	5	2.17	5	2.15	6	2.17	5	2.17	5
07 Chemical Products	2.53	6	2.16	6	2.15	5	2.17	6	2.16	6
09 Electronic Equipment	2.42	7	2.07	7	2.09	7	2.06	7	2.08	7
12 Other Manufacturing products	2.41	8	2.04	10	2.02	10	2.03	10	2.03	10
04 Gas	2.39	9	2.06	8	2.06	8	2.05	8	2.04	8
08 Other energy intensive	2.37	10	2.04	9	2.04	9	2.03	9	2.03	9
11 Other Equipment Goods	2.36	11	1.98	11	1.98	11	1.99	11	1.99	11
13 Construction	2.28	12	1.90	12	1.89	12	1.89	12	1.90	12
01 Agriculture	2.18	13	1.87	13	1.86	13	1.86	13	1.82	13
05 Electricity	2.13	14	1.84	14	1.83	14	1.83	14	1.81	14
02 Coal	2.08	15	1.78	15	1.78	15	1.77	15	1.75	15
17 Other Market Services	1.96	16	1.69	16	1.69	16	1.69	16	1.69	16
15 Trade and Transport	1.88	17	1.63	17	1.63	17	1.63	17	1.62	17
18 Non Market Services	1.78	18	1.54	18	1.54	18	1.53	18	1.54	18

* Interpretation: How much the production of the economy (sum over sectors) rises if the demand of the sector rises

*Forward Linkages ***			2020							
	1995		Baseline		Concentrated		Diversified		Uniform	
	Linkage	ranking	Linkage	ranking	Linkage	ranking	Linkage	ranking	Linkage	ranking
17 Other Market Services	6.63	1	5.37	1	5.36	1	5.36	1	5.22	1
15 Trade and Transport	4.24	2	3.39	2	3.38	2	3.39	2	3.39	2
07 Chemical Products	3.15	3	2.46	4	2.45	3	2.45	4	2.44	4
11 Other Equipment Goods	2.88	4	2.47	3	2.45	4	2.45	3	2.45	3
06 Ferrous and non ferrous metals	2.66	5	2.13	6	2.12	6	2.12	6	2.14	5
08 Other energy intensive	2.62	6	2.11	7	2.10	7	2.11	7	2.11	6
03 Oil	2.49	7	2.14	5	2.13	5	2.14	5	2.08	7
01 Agriculture	1.88	8	1.71	8	1.70	8	1.70	8	1.71	8
14 Food Industry	1.77	9	1.57	9	1.56	9	1.57	9	1.55	9
18 Non Market Services	1.70	10	1.56	10	1.55	10	1.56	10	1.55	10
16 Textile Industry	1.63	11	1.50	12	1.50	12	1.50	12	1.51	12
13 Construction	1.62	12	1.46	15	1.46	14	1.47	13	1.44	15
04 Gas	1.62	13	1.51	11	1.50	11	1.51	11	1.53	11
05 Electricity	1.60	14	1.46	14	1.46	15	1.46	14	1.47	13
12 Other Manufacturing products	1.59	15	1.46	13	1.46	13	1.46	15	1.46	14
10 Transport equipment	1.55	16	1.43	16	1.43	16	1.42	16	1.42	16
09 Electronic Equipment	1.51	17	1.41	17	1.40	17	1.41	17	1.40	17
02 Coal	1.45	18	1.34	18	1.34	18	1.35	18	1.32	18

** Interpretation: Shows by how much the production of a sector is used by all sectors of the economy. More precisely, it measures how much the production of the sector rises if the demand of all the sectors rises at the same time by one

With respect to the ranking of sectors by their backward linkage indicator, the situation is rather stable when comparing the 1995 results with the baseline in 2020. The same happens when comparing the baseline in 2020 with the various scenarios. The size of the linkages in 2020 for all technology scenarios are very similar to that of the 2020 baseline. This to some extent shows that the order of magnitude of the technological shocks is rather small, therefore not affecting the very nature of the intersectoral linkages.

The conclusions for the ranking of forward linkages are rather similar. Those sectors with higher forward linkages are Other market services, Trade and Transport and Chemical Products, and Other equipment goods. Such sectors will be further studied in the following, given their stronger linkages.

3.1. Sectoral Indicators of Forward linkages

Tables 4 to 8 present the sectoral decompostion of the forward linkages, that is, which sectors use the production of any sector and by how much. All the tables represent percentages of the forward linkage indictor. For instance, the first row of Table 4 shows that 63% of the production of the Agricultural sectors is self-consumption, and that the sector to which it sells more is the Food industry, 20% of its overall production. Two sectors have very low self-consumption values, Trade and Transport and Other market services, because of their pervasive nature that makes them indispensable for most economic sectors. It is interesting to note that their production is diffused rather homogeneously across all the sectors.

Table 4
1995: Sectoral Decomposition of Forward Linkages (%)

	01 Agriculture	02 Coal	03 Oil	04 Gas	05 Electricity	06 Ferrous and non ferrous metals	07 Chemical Products	08 Other energy intensive	09 Electronic Equipment	10 Transport equipment	11 Other Equipment Goods	12 Other Manufacturing products	13 Construction	14 Food Industry	15 Trade and Transport	16 Textile Industry	17 Other Market Services	18 Non Market Services
01 Agriculture	**63**	0	1	0	1	1	1	2	1	1	1	3	1	20	1	4	1	1
02 Coal	0	**82**	2	2	8	2	1	1	0	0	0	0	0	0	0	0	0	0
03 Oil	2	1	**71**	8	3	2	2	1	1	1	1	1	1	1	2	1	1	1
04 Gas	1	0	9	**78**	3	2	2	1	0	1	1	1	1	1	1	1	0	0
05 Electricity	1	2	2	1	**72**	4	2	2	1	2	1	2	1	1	1	2	1	1
06 Ferrous and non ferrous metals	1	3	1	2	2	**62**	1	1	4	6	7	5	3	1	1	1	0	1
07 Chemical Products	4	2	3	2	2	3	**48**	4	3	5	3	4	3	4	1	6	1	2
08 Other energy intensive	2	1	4	2	2	7	3	**51**	2	3	3	3	7	3	2	2	2	2
09 Electronic Equipment	1	1	1	2	1	1	1	1	**82**	2	3	1	2	1	1	0	1	0
10 Transport equipment	2	2	2	1	1	1	1	1	1	**81**	1	1	1	1	2	1	1	1
11 Other Equipment Goods	3	5	3	4	3	3	2	2	6	8	**44**	4	4	2	1	2	1	2
12 Other Manufacturing products	1	1	1	1	1	1	1	2	2	3	2	**75**	4	1	1	1	1	1
13 Construction	1	4	2	3	3	2	1	2	1	1	1	1	**69**	1	1	1	3	2
14 Food Industry	8	1	1	1	0	1	2	1	1	1	1	1	1	**73**	3	3	1	1
15 Trade and Transport	3	3	5	3	3	7	5	5	5	5	4	5	4	5	**29**	5	2	2
16 Textile Industry	1	0	0	0	0	0	1	1	1	1	1	2	1	1	1	**88**	0	1
17 Other Market Services	3	4	5	4	4	5	5	5	5	5	5	5	5	5	4	5	**23**	3
18 Non Market Services	1	1	2	2	2	2	2	2	2	2	2	2	1	2	1	2	3	**68**

Table 5

2020-Baseline: Sectoral Decomposition of Forward Linkages (%)

	01 Agriculture	02 Coal	03 Oil	04 Gas	05 Electricity	06 Ferrous and non ferrous metals	07 Chemical Products	08 Other energy intensive	09 Electronic Equipment	10 Transport equipment	11 Other Equipment Goods	12 Other Manufacturing products	13 Construction	14 Food Industry	15 Trade and Transport	16 Textile Industry	17 Other Market Services	18 Non Market Services
01 Agriculture	**67**	0	0	0	0	1	1	2	0	0	0	3	0	19	1	3	1	0
02 Coal	0	**85**	2	2	7	1	0	1	0	0	0	0	0	0	0	0	0	0
03 Oil	1	0	**76**	7	2	2	2	1	1	1	1	1	1	1	1	1	0	0
04 Gas	1	0	8	**81**	2	1	1	1	0	1	0	0	0	1	0	0	0	0
05 Electricity	1	2	2	1	**77**	3	2	2	1	1	1	1	1	1	1	1	1	1
06 Ferrous and non ferrous metals	1	2	1	1	1	**71**	1	1	3	5	6	4	2	1	0	0	0	0
07 Chemical Products	4	1	3	2	1	3	**56**	3	3	4	3	3	2	3	1	5	1	1
08 Other energy intensive	2	1	4	2	1	7	3	**59**	2	2	2	2	6	3	1	1	1	1
09 Electronic Equipment	1	1	1	1	1	1	0	0	**85**	2	2	1	1	0	0	0	0	0
10 Transport equipment	2	2	1	1	0	1	1	1	1	**85**	1	1	0	1	1	1	0	1
11 Other Equipment Goods	2	4	3	3	3	3	2	2	5	8	**49**	4	3	2	1	2	1	1
12 Other Manufacturing products	1	1	1	1	1	1	1	1	1	2	2	**79**	4	1	0	1	1	1
13 Construction	1	3	2	2	3	1	1	1	1	1	1	1	**74**	1	1	1	2	1
14 Food Industry	7	0	1	0	0	1	2	1	1	1	1	1	0	**79**	2	2	1	1
15 Trade and Transport	3	2	4	3	2	8	4	5	4	4	4	4	4	4	**35**	4	2	2
16 Textile Industry	1	0	0	0	0	0	1	1	0	1	0	2	0	0	0	**91**	0	0
17 Other Market Services	3	3	5	4	4	5	5	5	5	5	4	5	4	5	4	5	**26**	3
18 Non Market Services	1	1	2	2	1	2	2	2	2	2	2	1	1	2	1	1	2	**73**

Table 6

2020-Concentrated Scenario: Sectoral Decomposition of Forward Linkages (%)

	01 Agriculture	02 Coal	03 Oil	04 Gas	05 Electricity	06 Ferrous and non ferrous metals	07 Chemical Products	08 Other energy intensive	09 Electronic Equipment	10 Transport equipment	11 Other Equipment Goods	12 Other Manufacturing products	13 Construction	14 Food Industry	15 Trade and Transport	16 Textile Industry	17 Other Market Services	18 Non Market Services
01 Agriculture	**67**	0	0	0	0	1	1	2	0	0	0	3	0	19	1	3	1	0
02 Coal	0	**86**	2	2	6	1	0	1	0	0	0	0	0	0	0	0	0	0
03 Oil	1	0	**77**	7	2	2	2	1	1	1	1	1	1	1	1	1	0	0
04 Gas	1	0	8	**81**	2	1	1	1	0	1	0	0	0	1	0	0	0	0
05 Electricity	1	2	2	1	**77**	3	2	2	1	1	1	1	1	1	1	1	1	1
06 Ferrous and non ferrous metals	1	2	1	1	1	**71**	1	1	3	5	6	4	2	1	0	0	0	0
07 Chemical Products	4	1	3	2	1	3	**56**	3	3	4	3	3	2	3	1	5	1	1
08 Other energy intensive	2	1	4	2	1	7	3	**60**	2	2	2	2	6	3	1	1	1	1
09 Electronic Equipment	1	1	1	1	1	1	0	0	**86**	2	2	1	1	0	0	0	0	0
10 Transport equipment	2	2	1	1	0	1	1	1	1	**85**	1	1	0	1	1	1	0	1
11 Other Equipment Goods	2	4	3	3	3	3	2	2	6	8	**50**	4	3	2	1	2	1	1
12 Other Manufacturing products	1	1	1	1	1	1	1	1	1	2	2	**79**	4	1	0	1	1	1
13 Construction	1	3	2	2	3	1	1	1	1	1	1	1	**74**	1	1	1	2	1
14 Food Industry	7	0	1	0	0	1	2	1	1	1	0	1	0	**79**	2	2	1	1
15 Trade and Transport	3	2	4	3	2	8	4	5	5	4	4	4	3	4	**35**	4	2	2
16 Textile Industry	1	0	0	0	0	0	1	1	0	1	0	2	0	0	0	**91**	0	0
17 Other Market Services	3	3	5	4	4	5	5	5	5	5	4	5	4	5	4	5	**26**	3
18 Non Market Services	1	1	2	2	1	2	2	2	2	2	2	1	1	2	1	1	2	**73**

Table 7

2020-Uniform Scenario: Sectoral Decomposition of Forward Linkages (%)

	01 Agriculture	02 Coal	03 Oil	04 Gas	05 Electricity	06 Ferrous and non ferrous metals	07 Chemical Products	08 Other energy intensive	09 Electronic Equipment	10 Transport equipment	11 Other Equipment Goods	12 Other Manufacturing products	13 Construction	14 Food Industry	15 Trade and Transport	16 Textile Industry	17 Other Market Services	18 Non Market Services
01 Agriculture	**67**	0	0	0	0	1	1	2	0	0	0	3	1	19	1	3	1	0
02 Coal	0	**86**	2	1	6	1	0	1	0	0	0	0	0	0	0	0	0	0
03 Oil	1	1	**76**	7	2	2	2	1	1	1	1	1	1	1	1	1	0	0
04 Gas	1	0	8	**81**	2	1	1	1	0	1	0	0	0	1	0	0	0	0
05 Electricity	1	2	2	1	**76**	4	2	2	1	1	1	1	1	1	1	1	1	1
06 Ferrous and non ferrous metals	1	2	1	1	1	**71**	1	1	3	5	6	4	2	1	0	0	0	0
07 Chemical Products	4	1	3	2	1	3	**57**	3	3	4	3	3	2	3	1	5	1	1
08 Other energy intensive	1	1	3	2	1	7	3	**60**	2	2	2	2	6	3	1	1	1	1
09 Electronic Equipment	0	1	1	1	1	1	0	0	**86**	2	2	1	1	0	0	0	0	0
10 Transport equipment	1	2	1	1	0	1	1	1	1	**86**	1	1	0	1	1	1	0	1
11 Other Equipment Goods	2	4	3	3	3	3	2	2	6	8	**50**	4	3	2	1	1	1	1
12 Other Manufacturing products	1	1	1	1	1	1	1	1	1	2	2	**79**	4	1	0	1	1	1
13 Construction	1	3	2	2	3	1	1	1	1	1	1	1	**75**	1	1	1	2	1
14 Food Industry	7	0	0	0	0	1	2	1	1	1	1	1	0	**79**	2	2	1	1
15 Trade and Transport	3	2	4	3	2	8	5	5	5	4	4	4	4	4	**35**	4	2	2
16 Textile Industry	1	0	0	0	0	0	1	1	0	1	0	2	0	0	0	**91**	0	0
17 Other Market Services	3	3	5	4	4	5	5	5	5	5	4	5	4	5	4	5	**27**	3
18 Non Market Services	1	1	2	2	1	2	2	2	2	2	2	1	1	2	1	1	2	**73**

Table 8

2020-Diversified Scenario: Sectoral Decomposition of Forward Linkages (%)

	01 Agriculture	02 Coal	03 Oil	04 Gas	05 Electricity	06 Ferrous and non ferrous metals	07 Chemical Products	08 Other energy intensive	09 Electronic Equipment	10 Transport equipment	11 Other Equipment Goods	12 Other Manufacturing products	13 Construction	14 Food Industry	15 Trade and Transport	16 Textile Industry	17 Other Market Services	18 Non Market Services
01 Agriculture	**67**	0	0	0	0	1	1	2	0	0	0	3	0	19	1	3	1	0
02 Coal	0	**85**	2	2	7	1	0	1	0	0	0	0	0	0	0	0	0	0
03 Oil	1	0	**76**	7	2	2	2	1	1	1	1	1	1	1	1	1	0	0
04 Gas	1	0	8	**81**	2	1	1	1	0	1	0	0	0	1	0	0	0	0
05 Electricity	1	2	2	1	**77**	3	2	2	1	1	1	1	1	1	1	1	1	1
06 Ferrous and non ferrous metals	1	2	1	1	1	**71**	1	1	3	5	6	4	2	1	0	0	0	0
07 Chemical Products	4	1	3	2	1	3	**56**	3	3	4	3	3	2	3	1	5	1	1
08 Other energy intensive	2	1	4	2	1	7	3	**59**	2	2	2	2	6	3	1	1	1	1
09 Electronic Equipment	1	1	1	1	1	1	0	0	**85**	2	2	1	1	0	0	0	0	0
10 Transport equipment	1	2	1	1	0	1	1	1	1	**86**	1	1	0	1	1	1	0	1
11 Other Equipment Goods	2	4	3	3	3	3	2	2	5	8	**50**	4	3	2	1	2	1	1
12 Other Manufacturing products	1	1	1	1	1	1	1	1	1	2	2	**79**	4	1	0	1	1	1
13 Construction	1	3	2	2	3	1	1	1	1	1	1	1	**75**	1	1	1	2	1
14 Food Industry	7	0	1	0	0	1	2	1	1	1	1	1	0	**79**	2	2	1	1
15 Trade and Transport	3	2	4	3	2	8	4	5	4	4	4	4	3	4	**35**	4	2	2
16 Textile Industry	1	0	0	0	0	0	1	1	0	1	0	2	0	0	0	**91**	0	0
17 Other Market Services	3	3	5	4	4	5	5	5	5	5	4	5	4	5	4	5	**26**	3
18 Non Market Services	1	1	2	2	1	2	2	2	2	2	2	1	1	2	1	1	2	**72**

The differences between the 2020-Baseline case with respect to all the technological scenarios are very small, and the only clear trend is that the percentage of self-consumption diminishes for most of the sectors for the 1995-2020 period in the baseline. The values across the 2020 technology scenarios are very similar.

3.2. Sectoral Indicators of Forward linkages: detailed view of some sectors

Figure 2 to 4 represent the sectoral decomposition of the forward linkages for the four sectors with highest forward linkages. Figure 2 shows that the Other market services sector production spread very uniformly across the rest of the economic sectors. On the contrary, the production of the other three sectors is more concentrated in some key sectors. The Trade and transport sector main customer is the Ferrous and non-ferrous metals sector. The sectors that make less relative use of its production are the service sectors, agriculture, coal , gas and electricity. For the remaining sectors, the linkage is rather similar, approximately half that of the Ferrous and non-ferrous metals sector.

Figure 2

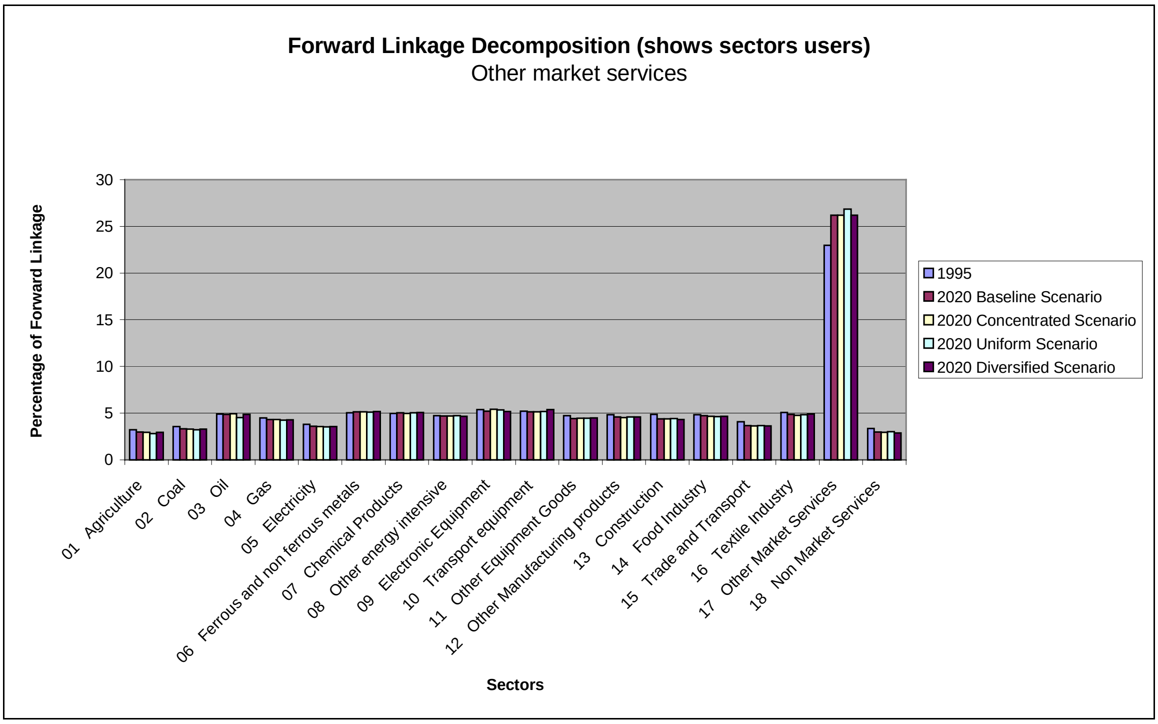
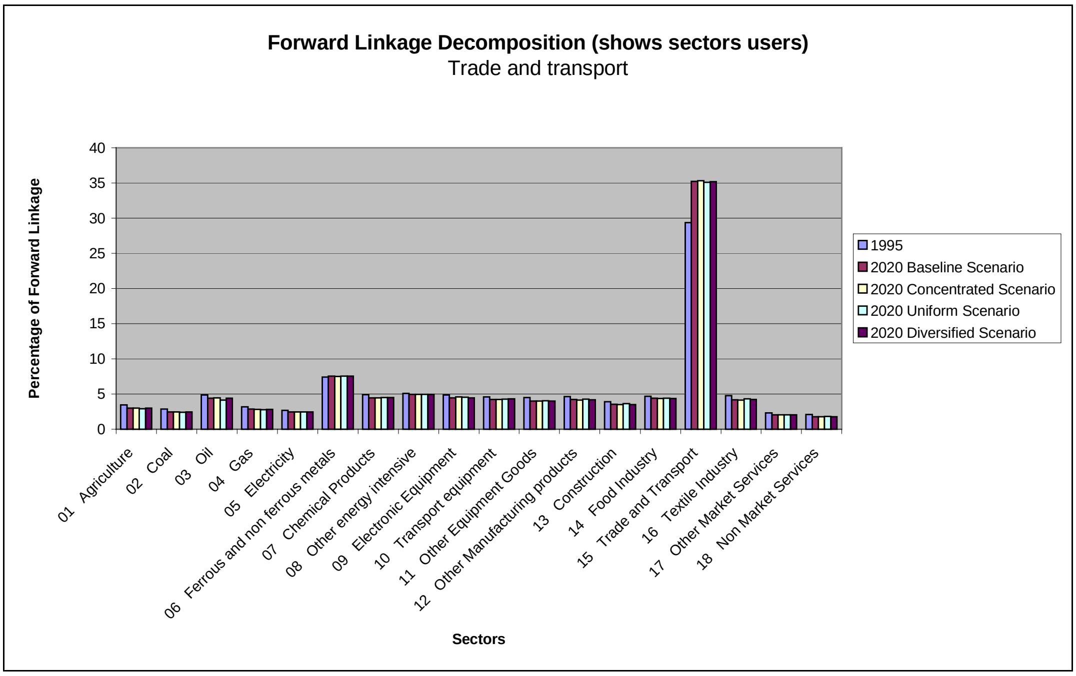
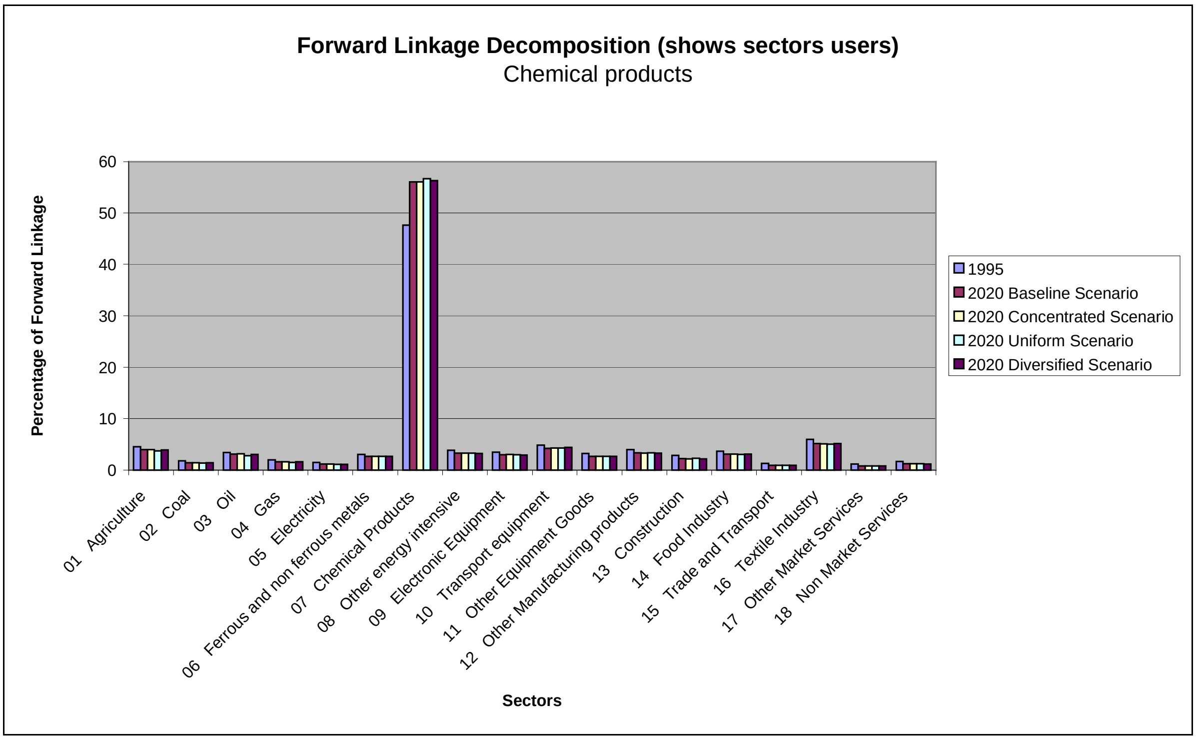


Figure 3



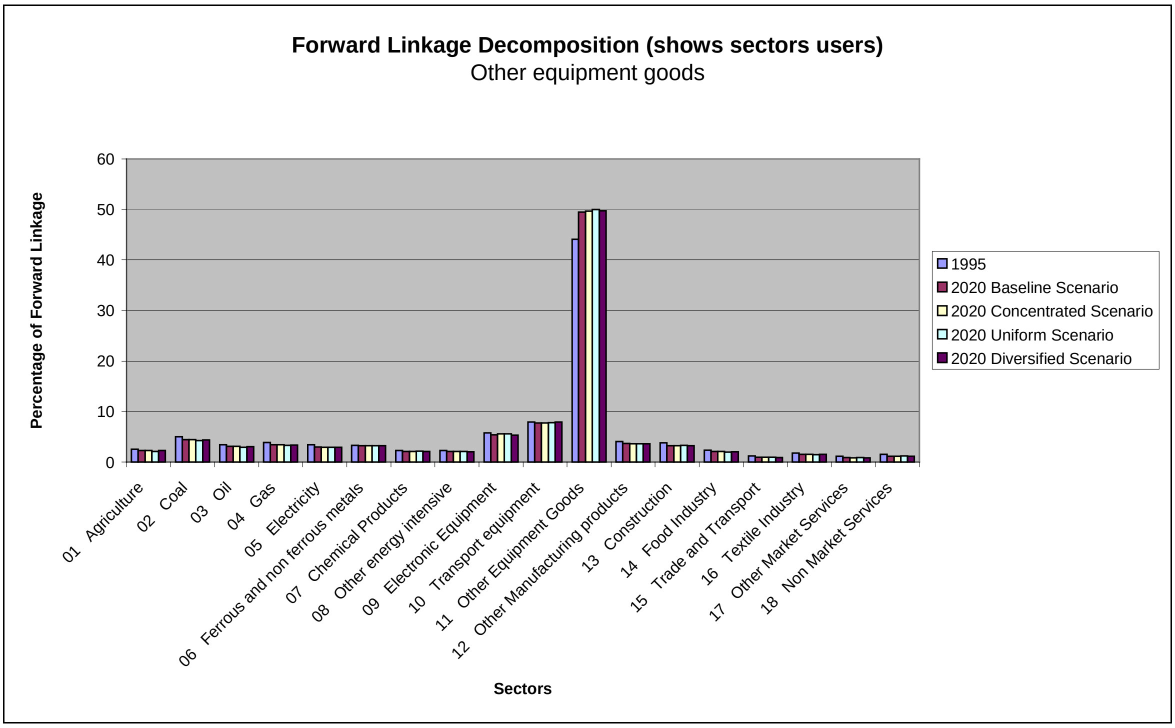
The Chemical sector forward linkages (Figure 4) are even more concentrated towards some sectors: the Textile industry and Transport equipment. In addition the Chemical sector has higher self-consumption than the previously analysed sectors. Other manufacturing sectors and agriculture are also good customers of the Chemical sector.

Figure 4



The Other equipment goods industry is rather concentrated on the Transport and Electronic equipment sectors.

Figure 5



5.4 Conclusions

This simple application of the Leontief methodology confirms that the kind of technological shocks implemented in the GEM-E3 model is rather small, without significant effects in the intersectoral linkages of the economy (always with respect to the baseline scenario). Those sectors whose production is more used by other sectors of the economy in the year 2020 are the same as those in the year 1995. In the following they are summarised, appearing between brackets the values of the forward linkage indicator (a measure of the degree to which the economy making use of the production of the sector) in 2020 baseline scenario:

- Other market services (5.37): most of the sectors of the economy benefit in a similar way.
- Trade and Transport (3.39): Ferrous and non-ferrous metals is the sector benefiting the most from it.
- Chemical Products (2.46): the Textile industry, Agriculture and Transport Equipment are the sectors that benefit more from it.
- Other Equipment Goods (2.47): Transport equipment sector and, to a lesser extent, Electronic equipment and Other Manufacturing Products are the sectors more favoured.

Therefore, even if this brief document is just a first approximation, it could be argued that technological improvements in these sectors will largely diffuse to the rest of the economic sectors of the economy.

The identification of the sectors most benefiting from the implementation of a certain technological innovation can be made in simple terms with the empirical approached here proposed. But this requires accepting rather restrictive assumptions, being probably the most important one the proportionality of the diffusion of the technological shock.

6 Labour supply issues

6.1 Skills

As a point of departure, and in order to avoid drawing a complex demarcation line between skills/competencies/aptitudes, a definition of skills could distinguish between:

- generic (or transferable) skills
- core skills (in disciplines and occupations)
- work-related skills

However, the three sub-groups of skills are not mutually exclusive. They rather reflect parts of the current policy debate on Lifelong learning, which is often based on assumptions on an easy transfer of skills from academia to industry. The possibility of developing generic or transferable skills (opposed to core skills) varies between scientific disciplines. As pointed out in a collective work on “Skills development in higher education and employment”[13], what are transferable skills in one discipline can form part of the core skills in another discipline. Communication is a core skill in law, as is problem solving in engineering and IT skills in computer science. In addition, there is no recipe for transforming core skills in an academic discipline to work-related skills[14].

Any overview of present skill needs and any forecast of future needs has to take into account how these needs are measured. Obviously, the supply of skills in a 2020 perspective depends on the ability of the education & training systems, and of the actors involved, to anticipate occupational and qualification trends. CEDEFOP has analysed the manner in which research on the anticipation of qualification trends is organised in EU member states [15]. A synthesis of the country reports supporting the CEDEFOP study reveals the following main characteristics in research and anticipation:

- shift from large-scale, independent, nation-wide qualification analyses towards <u>regional, local or even enterprise-level analyses of qualification needs</u>

- in some countries (especially DK, F and FIN) a move from quantitative forecasting of labour force demand to a <u>more qualitative research</u> for instance <u>scenario-type studies</u> designed to allow more rapid response to labour market changes

- although forecasting methods become more sophisticated, they still are better at describing developments than anticipating trends

Once the prospective skill reports are delivered to public and private decision-makers the question arises on the ability (and willingness) of the actors involved to use this information and to adjust systems and training arrangements to what is considered to be future

[13] Neville Bennett, Elisabeth Dunne and Clive Carré, Open University Press, UK 2000.
[14] ibid.
[15] Burkart Sellin (ed.): "Anticipation of occupation and qualification trends in the EU", CEDEFOP 2000.

requirements. A summary of an Italian skill needs analysis reports on little impact on training policies due to:

> "lack of initial co-ordination between those conducting the surveys and those who might have used their findings" and also due to the "multiple objectives of those surveys, which were both used for statistical purposes and for the guidance and the reform of the training system"[16].

The French report reveals similar problems:

> "It is difficult to solve the problem of adapting qualifications and skills to enterprises' needs despite increasingly sophisticated methods".

Certainly, any implementation also depends on the quality of the predictions made and on past experiences with skill forecasts. In a research paper to the UK National Skills Task Force[17] the authors suggest some trajectories for improved forecasting methods:

- a considerable improvement of the scope and quality of data
- more dynamic models (or scenarios) and less linear models
- a better understanding of the mechanisms of substitution and of lifelong learning
- a shift of emphasis from forecasting needs for specific skills to proactively adapting to identified (broader) skills, provided that the learners have a solid general education.

These recommendations open up a new research agenda. However, the purpose of this chapter is to refer to some experiences pertinent to the approach to be chosen when the EP study is drafted.

6.2 Labour demand/ supply and substitution

A quite rich statistical source is presented annually by DG Employment, the latest publication is "Employment in Europe 2001". The analysis of trends in labour demand for the period 1995-2000 concludes as follows:

> "High- and medium-skilled workers in high-tech sectors contributed to a net job creation of almost 1.8 million jobs. By contrast, employment of the low-skilled in both high-education sectors and in other sectors declined by more than 1 million jobs". [18]

However, this conception of labour demand is not unanimously shared. In a joint work between an economist and a sociologist [19] the authors conclude that:

> …"even in the advanced industrialised world, it is too simple to assume that all countries are converging to a common modern technology in which ever-increasing broader skills are needed from modern national workforces. We have brought together the evidence on a range of macroeconomic phenomena, including growth rates, unemployment, the wage level and income distribution, all of which tell a story of heterogeneity. We have suggested that this is likely to be indirectly reflected in

[16] Sellin, op.cit.
[17] J. Haskel and J. Holt: "Anticipating future skill need: Can it be done? Does it need to be done?", DfEE 1999.
[18] Employment in Europe 2001, p. 36.
[19] David Ashton and Francis Green: "Education, Training and the Global Economy", Edward Elgar 1996, p.94.

heterogeneity in the skills demands of employers, in the skills supplied by national institutions, and hence in the skills actually used in modern economies".

OECD studies are more in line with the European Commission employment report. Among a selection of OECD countries (USA, Japan, France, Germany, Italy, Canada, Australia and New Zealand) there is, however, no unilateral tendency in the employment growth by skill group measured as the average annual growth between roughly speaking 1980-90 [20]. The results are interpreted as follows [21]:

> " … it is the white collar high-skilled grouping that has tended to show the fastest growth, followed by the white collar low-skilled group. Blue collar high-skilled jobs have declined in most countries (the exception is the US), while blue collar low skilled ones show a more varied picture…"

In the same report OECD analyses data from Germany, Italy, France, US, Japan and Canada with regard to a two-fold split of occupations: skilled = white collar high skilled workers and unskilled = the three other skill groups. It turns out that employment of high skilled workers has increased faster than that of low skilled, at an average of 2-3% during the 1980s. Low-skilled jobs have increased in Canada, Japan and the US, only a little in Italy, while declining in France.

One complicating factor in the OECD comparison is that data is not available for the same time period. Also, we have to notice that the EC employment report covers a distinct time span (1995-2000) than the OECD study (~1980-90). The point is that OECD draws the same conclusions as the EC services on the basis of similar material, opposed to the much more cautious and critical approach in the work of David Ashton and Francis Green.

These labour demand trends might be useful background music in part 3.2. of the EP study, i.e. in the work of interpreting the outcome from the five scenarios outlined in part 2 and when making projections for the demand of skills in a 2020 perspective.

After having analysed trends in labour demand, "Employment in Europe 2001" embarks on an analysis of the main conditions for labour supply, which are:

- present labour force participation
- unemployment rate
- demographic projection (migration, mobility and population ageing)

Certainly, the demographic projections are more reliable than any estimation of future unemployment and labour force participation. The labour supply trends are in most cases based on data for the period 1995-2000 supplemented by qualitative assessments sometimes reflecting a wider time span.

Ashton and Green[22] try to gauge the supply of skills by the output of education systems. They depict an increase in most countries due to the widespread expansion of higher education and more recently of company training.

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[20] A. Collecchia and G. Papaconstantinou: "The evolution of skills in OECD countries and the role of technology", OECD/STI working paper 1996/8.
[21] ibid, p. 9.
[22] op.cit.

A comparison of these labour supply observations and a similar analysis made by CEDEFOP [23] on trends in the development of occupations and qualifications reveals numerous thematic similarities. (The wording of the CEDEFOP reports is given in parenthesis):

- women account for most of the rise in participation rates (CEDEFOP: women and vocational training)
- participation of older workers (C: employment rates among older people)
- younger worker are more likely to combine work end education (C: trends in the participation of young people in education and training)
- new entrants are better qualified than ever (C: employment and vocational training of low-qualified people in the EU)
- demographic patterns: migration, mobility, ageing (C: training and qualification requirements in the light of foreseeable demographic trends)

The quantitative estimations of labour supply to be developed in the EP study could have (some of) these factors as a point of departure.

CEDEFOP has also attempted to summarise supply and demand factors in the field of vocational education and training [24]. Whereas they apply a broader perspective than the issue of labour demand/supply, we have to cite them in order to grasp their intentions:
"A whole range of factors influence the highly complex link between the preparation and delivery of education or training qualifications and socio-economic demands".
Then some of these factors are enumerated:

- demographic developments;
- social, cultural or contextual factors influencing the individuals‘ choice patterns, attitudes and motivation;
- female participation in education/training and employment (gender question);
- degree of migration and mobility of skilled or unskilled labour;
- regional factors: e.g. bigger agglomerations/cities or countryside, old industrial structures or structures marked by the new (service) economy;
- labour and qualification demand of businesses linked to existing company structures and work organisations on regional, sectorial or national level;
- technological innovations, and more especially the introduction of new information and communication techniques and their application;
- new (macro-economic) developments, e.g. huge government (including EU-funds) investments in certain areas, governmental R&D programmes, regional development activities etc.;
- ecological investments and respective regulations, changing work safety and health provisions, consumer protection regulations concerning goods and services, etc.;
- internationalisation of the economy, international trade relations and competitiveness;
- development of education/training systems (initial and continuing) and public/private partnerships (alternance training schemes);

[23] "European trends in the development of occupations and qualifications", Thessaloniki 1999, ISBN 92-828-7192-4.
[24] "Anticipating occupational and qualificational developments", CEDEFOP 2001.

• balance between and/or mutual attractivity of general/academic versus vocational/technical education/ training provision;
• transparency of (national) occupational classification and qualification systems, efficiency of guidance and counselling services etc.;
• speed and efficiency in transferring know-how from research and professional evidence into adapting VET provision.

The authors of the CEDEFOP report emphasise that it is too simplistic to assume that the link between education and employment is one-dimensional, namely leading
from labour demand to a more or less direct response in the supply of skills and qualifications.

In a sectorial analysis as the one undertaken in the context of this study, we need to estimate the labour supply stemming from the reskilling of workers from other industries (e.g. defence[25] and "sun set" manufacturing sectors). For the ICT sector a new supply of 12% has been projected in a 1998-2003 horizon[26]. Certainly, the substitution effect applies for all economic sectors, but it may be particularly strong in the ICT labour market due to the present lack of ICT staff and- until recently- a booming dot.com-market allowing very young webmasters etc. only having experience from their computer rooms at home to enter the market. It is an open question whether this was an isolated phenomenon in the www-history or if it points towards a continued uptake of Internet-entrepreneurs with short formal education and work experience. Certainly, this depends on what segment of the ICT labour market we are talking about [27].

A quite strong message from the synthesis report of an ESTO study labelled "Skills in high tech sectors"[28], is that the substitution effect complicates every effort to forecast labour supply from the education system and into specific economic sectors. Consideration should also be given to how substitution effects are defined. In the UK country report forming part of the ESTO study cited above, substitution is defined as the % of workers in ICT industries who have not gone through formal ICT training.

6.3 Skills at a sectoral level

Although it is generally accepted that contemporary societies are becoming more knowledge-intensive, only few observers claim that this process entails a widespread upskilling of the workforce, nor does it make sense to speak about a general deskilling. The manner in which technology is embedded in the production process and the work organisation, partly determines the skill effects of technology. Most observers agree that we are faced with a polarisation of skills linked with processes of segmentation of the labour market[29]. Thus there

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[25] This part of the report was written before the 11th of September 2001.
[26] IDC report compiled for Microsoft, "Europe's growing IT skills crisis", London 2001, http://www.idc.com.
[27] K. Ducatel, J. Webster, W. Herrmann: "The information society in Europe - Work and life in age of globalization", Rowman&Littlefield 2000, p. 152, argue e.g. that ex-users of ICT who combine technical competence with an understanding of the business, may be more valuable in any user support role than technical specialists.
[28] ESTO study co-ordinated by Anders Ekeland, STEP, Oslo and Mark Tomlinson, CRIC, University of Manchester: "The supply and demand of high technology skills in UK, Norway and Netherlands", forthcoming publication from IPTS.
[29] cf. David Ashton/Francis Green, op. cit. p.82.

are different wage levels and structures in the segmented labour markets. A higher demand for skilled workers can either imply lower wages for the unskilled or higher unemployment rates among unskilled workers (cf. the skill bias phenomenon extensively covered in economic literature).

A sectorial analysis is one angle for analysing skill levels. With a view to nurture the sectorial perspective in the study to be presented to the EP, I will summarise a few relevant works, in particular those done for the UK skill task force.

6.3.1 Sectorial skills

Chris Hendry at the City University Business School in London has studied the materials technology, biotechnology, and opto-electronics industries in UK [30]. For all three,

> "problems arise in the lack of management and commercial skills to complement technological training. The requirement for this differs according to the stage of development the industry is at, but all three industries experience this problem in some respect - whether it is for project management, cost control, negotiation skill for alliance-building, marketing, or the ability to recognise the commercial applications of research".

Mark Tomlinson [31] has systematised these sectorial findings in an informative table:

Table 1: Skill problems by sector

	Advanced materials	Biotechnology	Opto-electronics (photonics)
Growth prospects	The UK is well placed to grow in this area	UK has the 2nd largest biotech industry. Strong growth	Rapid and continuous growth.
Key skills	Fundamental knowledge of materials; Support skills such as testing techniques, modelling and simulation; Project management skills.	Multidisciplinary skills; Strong science base; Entrepreneurial and management skills; Marketing skills; Alliance formation is crucial.	Diverse skills; Specialists within sub-sectors; Craft skills often important; Strong emphasis on learning from customers; Combination of science and business skills.
Skill gaps	Shortage of traditional materials graduates (esp. polymers, basic metals and ceramics);	Shortage of biochemical engineers; Separation of physical science and biology in the national	Lack of technical skills; Lack of commercially aware science graduates;

[30] "NEW TECHNOLOGY INDUSTRIES", p.32, Skill task force research paper, UK, September 1999.
[31] Ekeland/Tomlinson, op.cit, in the UK literature survey.

	A mismatch between graduate and PhD competencies and those demanded; Difficulty in predicting skill requirements.	curriculum a problem; Lack of suitable courses; Lack of commercial acumen and management skills (esp. by scientists); Brain drain (esp. to US) a serious problem.	Lack of an organisation representing the industry and a lack of focus; Suggestions of brain drain.
Skill utilisation	A lack of supervisory skills, team work and management skills.	Problems translating university research out of the lab.	Lack of business acumen; In house development sophisticated.
Skill supply	PhD programmes; Industrial collaborations; Supply chain partnerships	Lots of professional bodies; Clustering used concentrate key players;	Lack of professional bodies; Clustering useful.

6.3.2 ICT skills

Attention has to be paid to ICT skills, both as generic and applied skills. This illustrates the complexity of analysing ICT skills, whereas they are applied in the ICT sector at the same time as they are generic skills for all economic sectors. This point refers back to the distinction made above between core skills (in disciplines) and generic (transferable) skills.

One tentative breakdown can be ICT skills for:

- internetworking
- software application environment
- distributed (client/server) environment
- technology-neutral environment (skills to align organisations' IT investments with the business process)

Presently, new ICTs reinforce a demand for the ability to engage in formal reasoning and symbol manipulation, with less emphasis on physical skills. Moreover, the trend towards ICT integration means not only new forms of cross-skilling but also different patterns of work bringing together different specialists[32].

CEDEFOP has studied the "Impact of ICT on vocational competencies and training" [33]. The report sums up what kind of key skills enterprises deem important for the future and how these skills are coupled to new content of training:

- adoption of new computerised and networks instruments

[32] Ducatel et al, op.cit, p. 150ff.
[33] CEDEFOP, December 1999.

- development of oral and written communication techniques
- an enterprise culture: production, communication, quality, focus on the client
- development of managerial abilities with all the various specialist skills
- knowledge of new products and services
- marketing, commerce and selling techniques
- integration of business and commercial management in technical curricula
- provision of training in technology to commercial students
- foreign languages (which are generally left to self-training)
- updating and further training on practical issues in various technical, commercial and administrative specialities

Attention also has to be paid to the up- or deskilling effects of ICT, which were discussed at the beginning of this chapter. Current developments in ICT increase drastically our ability to handle data and information. ICT expand our information sources, without necessarily creating or extending knowledge. Some authors pinpoint that computerisation can take the form of informating which create information about work processes (=upskilling) or can lead to automating which can have an effect of deskilling [34].

This phenomenon can be further explored by studying the effects of computerisation at the level of the firm, and later generating conclusions that are valid at sectorial level. To achieve at a balanced view of the present and future development of skill, it is useful to compare such studies, often of a sociological/anthropological nature, with macroeconomic overviews reporting e.g. that 75% of the net job creation in EU took place in high education sectors[35]. To put it briefly, more jobs are done by high-educated workers, but this does not necessarily imply that the work tasks performed can be classified as high-skill.

[34] See e.g. Shosbana Zuboff: "In the age of the smart machine - The future of work and power", 1984, NY, Basic Books and the general discussion on up-/deskilling above.
[35] Figures for the European Union covering 1994-99, cf. "Employment in Europe 2000", European Commission, DG Employment.

6.4 *Future key competencies*

The German Ministry of Education and Research (BMBF) commissioned a Delphi Survey labelled "Wissensdelphi" and "Bildungsdelphi"[36]. The survey is of high relevance for the present EP study because it is an extensive Delphi exercise counting on 500 experts. Moreover, it is interesting to note that no distinction is made between the supply and demand side of skills. In one part of the survey the experts were asked to give a rating to the importance of various competencies in year 2020 within three educational fields, i.e. general education, vocational education/training and higher education [37]. The experts were asked to assign 12 points according to the importance that they attached to the various competencies. The rating for each educational field was:

1. General education

Technical and methodological competence for learning	2.38
Psycho-social (human) competence	2.36
Competence in foreign languages	2.30
Competence in media	1.61
Intercultural competence	1.48
Competence in specific areas	1.47
Other competencies	0.39

2. Vocational education/training

Competence in specific areas	2.58
Technical and methodological competence for learning	2.26
Psycho-social (human) competence	2.16
Competence in foreign languages	1.84
Competence in media	1.57
Intercultural competence	1.23
Other competencies	0.38

3. Higher education

Competence in specific areas	2.80
Technical and methodological competence for learning	2.17
Competence in foreign languages	1.91
Psycho-social (human) competence	1.89
Intercultural competence	1.46
Competence in media	1.38
Other competencies	0.39

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[36] Delphi-Befragung 1996-98: "Potentiale und Dimensionen der Wissengesellschaft - Auswirkungen auf Bildungsprozesse und Bildungsstrukturen", München/Basel 1998.
[37] "Schulische/AllgemeineBildung, Berufliche Bildung, Hochschulbildung".

As part of the Delphi survey a number of workshops were held. The conclusions from these are helpful in order to interpret the quantitative results [38]:

> A comparison between the assignments given in each educational field shows that there is only one substantial difference in rating with regard to competence in specific areas, which scores significantly lower in general education.
>
> The fact that "technical and methodological competence for learning" achieves a high score reflects that knowledge must constantly be renewed and that Lifelong learning requires new learning methods.
>
> Psycho-social (human) competence (rated as number 2,3 and 4) is considered to be a key competence for adaptation, orientation and social networking in changing social structures characterised by increasing individualisation.
>
> Not surprisingly competence in foreign languages is assigned a middle value by being ranked number 3 and 4 among six key competencies. The lower ranking for competence in media and intercultural competence is explained by the mere fact that these two had to compete with four other key competencies.

6.5 Skills, employability and unemployment

In a condensed form, the contemporary and future changes in labour conditions for European employees can be summarised as follows[39]:

A shift from employment security to confidence in competence coinciding with the birth of the notion employability. Employability should be understood in a broad sense reflecting:

- the adaptability to changes in the labour market
- improvement of the qualifications of the work force with a view to alleviate exclusion mechanisms in the labour market
- upward social mobility for those already employed
- higher qualifications increasing the employment chances for people without job experiences and for the unemployed who have been forced to leave the labour market

Security of employment was close to be implemented in protected segments of the labour market, at least in some Northern European countries. For regions of Europe with a historical high unemployment rate "security of employment" has only been a remote dream. A strengthened confidence in competence is partly embedded in each employee by means of his or her formal competence, combined with what is often labelled "real competence", i.e. also taking account of non-formal and informal competencies. However, the organisational competence often reflected in efforts to develop "learning firms" or "learning organisations" constitutes an intrinsic element in strategies for employability.

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[38] op.cit. p. 65ff.

[39] See Holter, Karlsen, Salomon: "Omstillinger i arbeidslivet", The Work Research Institute's Publication Series Nº 3, Oslo 1998.

This implies that the competence development in a work organisation has to be linked to its overall strategy. Opposed to some observations indicating that the main reason for sending employees to training courses is an individual wish to acquire more knowledge[40], training should increasingly anticipate changes in markets and technologies. Much on-the-job training already serves this purpose. As we move to what is sometimes called the border less firm, firms become part of (global) networks in which collective learning in networks can take place. However, networking and net-learning only offer a potential framework for interactivity and collaboration. Very much depends on the actual layout of arrangements for networking and net learning.

The sectorial composition of unemployed people's previous jobs reveals that there is a relatively high share of people who were previously employed in industry, while the opposite tendency can be observed in services [41]. Analyses of the skill level of the unemployed confirm that high-skilled individuals are the least likely to be excluded from the labour market, while more than 40% of the unemployed are individuals with a low level of educational attainment [42].

However, there are huge national differences. One burning issue is whether these will continue, e.g. in Austria only 5% of the unemployed have higher education, whereas this group represents 20% in Spain. Another factor subject to substantial national variations is the rate of unemployment originating from the services, which is higher in countries were temporary contracts flourish for such jobs (France, Holland, Sweden, Finland).

6.6 Education and training systems

The notion "education and training systems" encompasses public and private suppliers of learning. Hence, we do not apply an institutional perspective on education and training. The way in which education & training systems function and the changes they undergo have strong repercussions on their role in the future supply of skills. We will concentrate on university education because at this level it is easier to study the interaction between "school" and "labour market". A second reason for this focus relates to the main entrance point that we choose for the analysis, which is globalisation characterised by world-wide competition in higher education. However, the private offer at lower levels of education mostly serves as supportive or complementary tools to arrangements set up by the public system[43]. Although it might happen that such trends as the growth in net based learning and a dissatisfaction with the public system will alter this picture in some regions/countries, it is unlikely that international competition will become a dominant trend in EU primary and secondary education in a 2020 horizon [44].

[40] cf. ibid. on research results from Nordic countries pointing in this direction, p. 185ff.
[41] cf. p. 45ff in Employment 2001
[42] ibid.
[43] cf. special edition of Le Monde Interactif,: "Internet va-t-il démanteler l'école?", 26 September 2001.
[44] However, the "Extending market model" scenario for non-tertiary education developed by OECD (discussed later in this document) outlines flourishing of "individualisation and home schooling" and a substantially reduced role for public education authorities, op.cit. p. 124ff.

6.6.1 *Globalisation and the transformation of universities*

The phenomenon of globalised education and training systems should be seen in conjuntion with the general globalisation of our contemporary economy and society. Without trying to come up with the ultimate definition of the specific features of globalisation of education and training, we will try to distil some major trends and issues[45]:

Trends:

- involvement of a wide range of stakeholders

  This should not necessarily be understood as "privatisation" of higher education or as an opening-up of a hitherto "closed system". Public/private partnerships for education&training are no novelty but they are on the increase[46].

- more international movements of students

  Structured exchanges between institutions spurred by European programmes (Erasmus, Leonardo da Vinci); whereas earlier the academic mobility mainly depended on individual initiatives

- multicultural learning environments (both for virtual and on-site classes)

- global circulation of (western?) ideas and pedagogical tools

- introduction of systems for quality control and benchmarking

  More comparisons of the performance of educational institutions are carried out at national level and on a European/ world scale. This has often to do with a drive towards quality control and with benchmarking exercises sparked off by stronger international competition. Moreover, benchmarking seems to be an upcoming control tool used by national ministries towards educational institutions.

- education as an international commodity ?

  A whole new sector of higher education is emerging alongside traditional, national, state-regulated systems. On a world scale, 400 corporate universities existed at the beginning of the 1990s, whereas they count up to 2000 today[47]. There is a huge private offer and competition between nations to attract students. In some countries, student fees become an additional revenue for the public purse.

Issues

- access

  New groups at national level (e.g. adult earners), new flows spurred by European/international exchange programmes

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[45] One source of inspiration is works of Robin Mason , Institute of Educational Technology at the Open University (UK), e.g. her book "Globalising Education. Trends and Applications". Routledge, 1998 as well as her intervention at the International Conference on ICT for Education in Vienna, 7-9 December 2000.

[46] For instance, such partnerships are probably the only solution for gathering premises when dispersed knowledge has to be put together in the production of quality learning software.

[47] "A virtual revolution: Trends in the expansion of distance education", American Federation of Teachers, May 2001, p. 17.

- accreditation

The increase in the development of cross-country modules and the de-monopolisation of training provision will at least have long term effects on accreditation of learning contents.

- student readiness

Adult learners are generally highly motivated, but there is a further challenge to motivate increasing number of people hit by structural change in industries and services

- implications on existing institutions

Most likely, we will see an institutional specialisation to survive in international competition:
research universities
campus universities
virtual universities
corporate universities

The present transformation of higher education affects the role of universities as research institutions. In future, we will probably see fewer high ranking research universities mainly funded with public money. The diversification of higher education institutions might entail a clearer split between universities involved in education of researchers vs. education for the general labour market.

The alliances between corporate universities and traditional (mainly public) universities often imply joint ventures where corporate universities package and distribute courses or content from existing institutions. At least in the USA, this can be a method of gaining access to the educational 'seal of approval' offered by regional or national accreditation agencies[48].

The present transformation of education & training systems also features discussions and even strife on standardisation of education models as well as standards for metadata facilitating retrieval of educational material from the web. The arena for this debate is i.a. the International Standard Organisation, which hosts an activity labelled International Standards for Information Technology for Learning, Education, and Training[49]. Several initiatives are presented but no agreed standards have emerged so far[50]. ISO is presently discussing a draft of educational standards from the Global Alliance for Transnational Education[51]. These standards are apparently backed by the US education online company Jones International as well as IBM, Sun-Microsystems and Coca-Cola[52]. There is a European, especially a French concern, about the strong position of USA in the global learning market. Up to 80% of the online learning content is made in US. [53]

[48] cf. "A virtual revolution', p. 17.
[49] http://www.jtc1sc36.org
[50] For an overview of initatives in the field of metadata on education and training, see The IPTS report 53 (April 2001), p. 11ff, article by Rocio Garcia Robles.
[51] http://www.edugate.org
[52] cf. Le Monde Interactif, "Internet va-t-il démanteler l'école", 26 September 2001.
[53] cf. Observatoire des ressources pour la formation, http://www.preau.ccip.fr/

There is little doubt that future university candidates will be endowed with more international and multicultural experiences. Their ability to capitalise on these experiences depends very much on upcoming standards for accreditation. Such standards will be vital for the future labour market of high skilled persons . We can imagine various scenarios for how and what kind of regime of accreditation (and quality control) that will emerge, ranging from anarchy to highly respected international agreements . The future supply of degree-holders is also contingent on to what degree a likely specialisation of higher education institutions will have positive effects on students' skill level. Finally, there is a question about the skills supply in the soaring e-learning market [54]. A weak European position in setting e- learning standards and providing e-learning will not underpin the supply of skills that are apt for the European citizens.

6.6.2 Contradictory features of globalisation

Globalisation entails both diversification and convergence. Also, globalisation is characterised by a dual process of competition and co-operation. These contradictory features do not necessarily co-exist in a kind of dialectic state of peace. The point is that globalisation of education and training generates contradictory processes.

Globalisation of education and training leads to a diversification of the supply of learning. Today, learners are offered a panoply of learning tools and products but as pointed out earlier, these do not represent a cultural variety whereas very much is made in the U.S. Whether this process has as a consequence that the curricula become less dependent on standards set by national ministries of education, is an open question. In the longer run, the diversification could entail that future generations get a less common educational background. Ideally, this trend will contribute to the making of a "mosaic society"[55].

On the other hand, European education and training undergoes a process of convergence, i.a. as a consequence of joint partnerships to develop courses and curricula in the frame of transnational projects. One outcome is the production of joint curricula, where a number of institutions from different countries are involved in the production of learning modules constituting new curricula. The process slowly transforms the national systems as first modules and later curricula become integrated in national education systems which, in former days, the education ministries neatly controlled.

Reflected in and speeded up by the socalled Bologna process, European higher education undergoes a convergence towards a structure based on Bachelor and Master degrees. However, there is no unilateral trend towards a standardised study period. In other words; 3 years for Bachelor, 5 years for Master and 8 years before getting a PhD title is not on the verge of becoming a general rule.

The Bologna process started when a limited number of European education ministers signed the "Sorbonne declaration" in May 1999, aiming at a more convergent architecture of higher education qualification systems in Europe. At a follow-up conference in Bologna one year later, more ministers agreeed on the objective of a "European Higher Education Area

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[54] Estimations of the size of the European year 2000 market vary between € 0.33 bn and € 3 bn, cf. the Observatory for Technology of Education in Europe, http://www.txtnet.com/ote/

[55] Cf. the IPTS Futures Project: Synthesis report, EUR 19038 EN.

by 2010" to be constituted by common cornerstones of qualifications. The cornerstones should be supported by a credit system such as the ECTS (or one that is compatible with the European Credit Transfer System), providing both transferability and accumulation functions. At the Prague conference in 2001 all together 32 countries were represented and they took stock of the results so far [56].

In spite of the achievements with regard to the degree structure (Bachelor/Master), there is no unilateral trend towards simplification and transparency that could enhance the position of European higher education. Many European countries have complex degree structures sometimes shaped in a "trinary" structure (universities, colleges/polytechnics, short post-secondary education). We may see that fast changes in skill structures coupled to new alliances between learning providers reduce the power of national ministries of education. Their efforts to spur convergence at a European level might therefore be somewhat counteracted by trends on which national authorities have limited influence.

In a labour market context it is worth noting that there seems to be a new impetus for professional higher education [57]. This can be explained by new skill needs, particularly in the flourishing service sectors, but also by various measures to increase the employment chances of graduates. Recently, more "professional Bachelors" are set up to meet the demand for professionals with 2-4 years tertiary education. Also, there is a more limited move towards new "professional Masters". Among the examples are the introduction of advanced professional education and training in Italy (FSI), Foundation Degrees at the British universities and the "licence professionnelle" in France.

In relation to the Sorbonne/Bologna process it is reported that:

> *"The debate has to take into account that there are various ways in which first degrees can be relevant to the European labour market…"[58]*

One should bear in mind that an evolution towards shorter university degrees is not necessarily a "quick fix" answer to skill needs in a knowledge-intensive society. Ideally, this evolution should be inscribed in a move towards Lifelong learning, provided that the degree-holders learn to become lifelong learners during their intital education.

Today we witness more competition and co-operation in education and training between increasingly autonomous public institutions and private learning institutions. In higher education we are moving towards an international market with a fierce competition in attracting foreign students. This is particularly true for English-speaking countries (UK, Australia and USA…). The growing market for technology assisted learning further underscores the internationalisation of education and training. As part of this picture we see increased competition between public and private providers of university training. According to professor Jacques Vaulthier (EduFrance and consultant for UNESCO) the certificates

[56] http://www.salamanca2001.org/

[57] "Trends in Learning Structures in Higher Education ". Follow-up report for the Salamanca and Prague Conferences of March/May 2001 by Guy Haug and Christian Tauch, to be downloaded at: http://www.unige.ch/cre/activities/Bologna%20Forum/Bologna_welcome.htm

[58] Haug/Tauch, op.cit.

offered by companies like Microsoft and Cisco are about to become comparable with diplomas issued by major universities[59].

At the same time, there is increasing co-operation. Large enterprises set up their own corporate universities, but 62% of them have alliances with traditional universities.
Developments in ICT contribute to the transformation of the traditional university into a mixture of campus and virtual university. Particularly in the USA, pure virtual universities emerge as part of the move towards specialisation of higher education institutions discussed above.

At a European level there are efforts to build upon various national initatives in this field. The European Commission is co-ordinating various measures (such as Community education and RTD instruments) in the frame of the initiative labelled e-*learning*[60].
Leading European e-learning companies issued a declaration at the European e-learning summit in May 2001, organised jointly with the European Commission, centred on three messages [61]*:*

- *extending educational opportunity*
- *accelerating educational innovation*
- *exploring public/private partnerships*

Private providers of e-learning are making extensive market surveys in which they also take account of the demand for the skills needed to explore this market. One example is "Corporate e-learning: exploring the frontier" made by a consultancy firm [62]*. Another firm predicts a high demand for people who can develop courseware that is multilingual, addresses various topics and takes advantage of Web functionality. It is forecasted that by 2005 one of the ten most in-demand jobs in Global 1000 Companies will be online learning design*[63]*. A more European perspective can be found in the project MESO (the observatory of Multimedia Educational SOftware), supported by the European Commission* [64]*.*

For Europe as a whole, there is a need to take stock of the human capital situation in the enlargement countries with a view to counteract a brain drain from east to west, although the situation for the moment is not critical [65]. Furthermore, the proximity to the Mediterranean countries might put the issue of human capital on the agenda for the Euro-Mediterranean co-operation.

The future supply of high-skilled workers will depend on the quality of Europe's education&training institutions and their ability to retain and attract students. This "quality label" can i.a. be broken down to the success in converging university trajectories and in

[59] "Les offres Cisco ou Microsoft avec des certificats de compétences mettent en balance les diplômes des universités mêmes des grands pays', Le Monde Interactif, special edition, "Internet va-t-il démanteler l'école", 26 September 2001.
[60] "*e*-learning – Designing tomorrow's education". Communication from the Commission, COM (2000) 318 final.
[61] Summit declaration May 2001, see: http://www.ibmweblectureservices.com/eu/elearningsummit/
[62] W.R. Hambrech&Co, March 2000.
[63] http://www4.gartner.com
[64] http://www.meso.odl.org/index.html
[65] An overview of human resources (incl. internal and external brain drain) is given in the EC document: "Impact of the enlargement of the EU towards the associated CEEC on RTD-innovation and structural policies", Brussels 1999, ISBN 92-8284675-X.

implementing a transparent credit transfer system. Alternatively, or perhaps in parallel, public institutions may become less powerful in the accreditation of learning trajectories and of institutions , thus placing a larger burden on enterprises when screening the qualifications of job applicants. In addition, we will see more competition between university diploma with an official seal and competence certificates issued by well-known companies.

The present drive towards shorter university cycles ensures a faster supply of university candidates to the labour market. The long term effects of this reform should be assessed in conjunction with the ability of universities and enterprises to compensate for shorter initial education by offering the newly recruited personnel continuous training so that they are put on a Lifelong learning track.

6.6.3 Future trends in education and training

The process of globalisation occupies a central position in national technology foresight studies and in prospective reports covering the field of education and training. These works are often based on Delphi surveys. A report from the Swedish Technology Foresight project[66] points out that globalisation will vary from country to country, depending on, i.a., the number of players involved, development of regional models and the pervasiveness of international standards in the field of education and training. The UK technology foresight panel on Leisure and Learning [67] is more concerned about the (competitive) advantage of British players in the field, especially the force of the English language in a converging move between leisure and learning towards what they label "infotainment". The German Delphi survey referred to above features "an increasing internationalisation" as one major framework condition[68]. A fourth analysis deals with the geo-political dimension as one 'critical dimension' while developing six scenarios for the future of schools (mainly up to tertiary level) in the OECD area. Finally, a Norwegian prospective analysis identifies globalisation of knowledge, studies and diplomas as one driving force in the transformation of Norwegian higher education[69].

Any thought about the design of future education and training has to (implicitly) choose between extrapolating present observations or outlining qualitatively new trajectories.
There is no clear-cut distinction between present and future trends in the Swedish and British foresight studies referred to above. One underlying assumption seems to be that what we see today will continue or be strengthened in the years to come.

By contrast, the OECD's Centre for Educational Research and Innovation has developed six scenarios for tomorrow's schools[70].
The basic question for the scenarios was what directions will schooling take over the medium to long term up to 2015-2020, and how might policies shape these futures?
Under the heading *What Future For Our Schools* OECD synthesises the six scenarios as follows:

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[66] "The Foresighted Society", ISBN 91 7082 668 4, Stockholm 2000.
[67] Office of Science and Technology, ISBN 0-11-430128-X, UK 1996.
[68] ibid., p. 55.
[69] The OECD and the Norwegian scenario analyses are further described below.
[70] They were presented at the April 2001 meeting of the OECD educational committee at ministerial level. Cf: http://www1.oecd.org/els/pdfs/EDSMINDOCA008.pdf

"The first two scenarios project from existing features or trends. Scenario 1 posits the continuation of bureaucratic institutionalised systems, resisting radical change. However the contribution to important social functions made by a stable system should not be undervalued. Scenario 2 delineates futures where existing market approaches to education are extended much further than today, with both positive and negative results.
Two “re-schooling” scenarios describe a strengthening of schools’ public recognition, support and autonomy. In Scenario 3, this comes from schools developing much more powerful social links and community leadership functions. In Scenario 4, most schools have become flexible “learning organisations” with a strong knowledge focus and highly motivated teachers. These scenarios have desirable outcomes, but would require some radical changes from the status quo.
Two “de-schooling” futures involve the dismantling of much of school institutions and systems. In Scenario 5, this comes about through the widespread establishment of non-formal learning networks, facilitated both by ICT and a “network society” environment. In Scenario 6, it comes about through an exodus of teachers that is unresponsive to concerted policy measures and leads to the more or less extensive “meltdown” of school systems".[71]

A similar scenario methodology but limited to the use of ICT at university level, is applied in a Norwegian background study made as a preparation for the last Green Paper on Higher Education[72]. Here, three scenarios are outlined ("Scenarios for ICT in higher education")[73]. The driving forces identified are identical with similar studies in whatever country:

- the appearance of the knowledge economy
- globalisation of knowledge, studies and diplomas
- individualisation (less loyalty to one institution) and new values among students
- digitalisation of information and processes

The authors claim that the direction of the driving forces is rather predictable. They go on by identifying factors of uncertainty that are more apt for public influence and political interventions:

- the ability of higher education institutions to undergo an organisational and pedagogical renewal
- "industrialisation" of the learning scene: speed and resistance
- the extent to which ICT will/can be integrated in learning
- who defines the learning scene: the State or the Market ?
- standardised vs. tailor-made student courses
- the importance of formal education (diplomas) vs. experience from projects ("quick fix")
- how higher education will be financed (design of incentives for institutions and for students)

[71] A more complete description can be found at: http://www1.oecd.org/publications/e-book/9601031e.pdf
[72] http://www.odin.dep.no/kuf/engelsk/publ/veiledninger/014071-120002/index-dok000-b-n-a.html
[73] The web page of the commission in charge of drafting the Green paper, is now closed and the electronic version of the scenario report is not accessible any more.

- student needs of socialising vs. time efficient training (campus life vs. on-line courses from your home computer)

On this basis three scenarios are developed:

1. "Socrates.campus.edu"
   A successful integration of traditional academic values with a business perspective on learning costs and efficiency.
   A combination of virtual and campus training.
   Education is not an international commodity, but regulated by institutional agreements within networks characterised by co-operation and competition.

2. "Kontrapunkt"
   In this scenario "traditional academic values" prevail, i.a. the independence from external, commercial influence.
   ICT serves as a supporting and exchange tool for education and training, without being totally integrated in current learning practices.
   Higher education institutions hardly develop new training courses for part-time learners. The student population cultivates traditional academic values at campus universities and they love to live "unplugged".
   Brain drain from Norwegian higher education to foreign universities and to the private industry.

3. "The market of the learning nomad"
   The supply of learning is huge, fragmented and personalised (tailor-made). "Academic agents" operating from a kind of learning bureaux serve well-known professors. "Learning agents" serve students and offer them continuous updating of their knowledge and competencies. Design of virtual courses and the explorative dimension of learning are of great importance for learners who carry their "university" under their arm.

The time perspective of the scenarios is year 2010. The report ends up with a set of recommendations basically centred on the factors of uncertainty enumerated above.

The litmus test for a successful development of higher education seems, according to this report, to be a successful integration of traditional academic values in kind of a business model. The second scenario describes the dire state of higher education if Alexander Humboldt's legacy prevails and the third scenario pays attention to some inconveniences attached to a purified business approach to universities. The Norwegian background study does not discuss the possibility of and conditions for a fruitful integration of a business model in academia.

Without claiming that USA necessarily is a forerunner of the future European scene in higher education, it is worthwhile to have a look at the overseas debate. A report from the American Federation of Teachers (AFT) [74] does certainly not represent an impartial view, but it clearly formulates two approaches to the "virtual future" of universities[75]:

[74] "A virtual revolution: Trends in the expansion of distance education", American Federation of Teachers, May 2001
[75] p. 18.

- maximise course taking while minimising the "inputs" of faculty and development time
- faculty independence in teaching and research, academic control of the curriculum, academic freedom in the classroom and collegial decision-making

AFT argues that if the model of "student as customer" becomes the pre-eminent value, there is the real danger that the curriculum will not be coherent or rigorous enough to meet the student's long term interests. For obvious reasons, the notion of long term interest is very problematic if we presuppose that somebody knows the long term interests better than the students themselves. In the context of the present EP study it is important to take into account that "student as customer" is one upcoming concept in European education, but it has been refuted by student representatives in the Bologna process who rather consider themselves as stakeholders.

In higher education a number of concepts and values are emerging. There is little doubt that the propensity of young Europeans' to embark on higher education is not only related to job prospectives but also based on certain values. University studies and campus life are often considered as a "rite de passage" [76]*. This leads us to identify an explanatory factor into which 'social and cultural values' can be classified (cf. the table at the very end of the document).*

Thus, we also get an entrance point to understanding the illiteracy level among young people. In some circles higher education is a "rite de passage", whereas other circles disregard the school and education in general. The latter attitude can generate illiteracy and exclusion from the labour market.

A further exploration of the German foresight study referred to above reveals that it is based on an explicit methodology. The study builds on an extensive Delphi survey that <u>measures</u> agreement between experts on future trends. The British and Swedish surveys basically <u>refer</u> to opinions expressed by experts in order to illustrate qualitative statements. It can be said that the projections in these three studies are not breathtaking. What they come up with is of little difference from projections with a more limited time span. In other words, and logically enough according to the methodology applied, there are no radically new trajectories or no scenario describing any dramatic change.

The German Delphi survey [77] outlines learning arrangements and methods as well as learning processes that the experts deem important for the future. Concerning the first aspect, the experts highlight five learning arrangements and methods:

- inter- and multidisciplinary learning arrangements
- project based learning
- self-managed learning based on own initiative
- group- and team learning
- media supported learning

[76] The OECD indicators "Education at glance" for 2001, show that the 1999 entry rates to tertiary education for selected EU countries varied between 68% in Finland and 52% in Italy.
[77] p. 72 and 76

As for the learning process, the German experts pinpoint that the role as teacher is being transformed into an advisory role for learners who increasingly "discover" new knowledge in learning teams and project work. This vision is more likely to be implemented in vocational training than in general and higher education, according to the Delphi expert panel[78].

The German Delphi survey points towards future knowledge systems heavily centred on Lifelong learning. The UK technology foresight study[79] argues along the same lines and predicts that:

> "Within the next decade education will be very different, more sharply related to the individual needs and more closely subject to consumer control, more global, with public and private suppliers establishing education markets around the world".

The UK study therefore develops the notion "infotainment" at the cross-section between leisure and learning. Along the same line of thought, the Swedish foresight study[80] questions today's strict division of life into childhood, school, (professional) career and retirement:

> "Perhaps work should be alternated with education by means of apprenticeships systems and institutionalised forms of further education".

It follows from this that a future education and training system centred on Lifelong learning has to reshape the period of initial training, which today can last until the candidates receive their final university degree. Statistics on what occupational groups that receive training at work and that are active in self-learning today, show a very strong bias towards well educated white-collar occupations. To embark on Lifelong Learning, which not solely means self-learning at home, requires high motivation and the availability of personal tools ('learn-to-learn").
Besides a reshape of initial education there is a huge demand for information on Lifelong Learning opportunities. The quality of existing information has to improve and there is a special need for targeted information addressing user groups with low access to continuous and further education. [81]

Along the same line of thought, it is likely that initial education (from primary to post-secondary) provided by the public education system might become an experimental site/melting pot for “equal access to ICT learning”. If public schools (in the non-British sense of the word) fail, they might be reduced to institutions for the lower echelons of the digital divide while private institutions take care of the rest. The OECD scenarios referred to above, discuss such challenges for the public system.

Provided that the Member states choose to have an active education policy, it is likely that initial education, at least below university level, might be subject to public interventions promoting equality between pupils. We will probably have more political strife around the traditional value of “education as a public good”. In view of the soaring private market for education services, a growing proportion of household expenditure will most likely be spent

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[78] ibid, p. 75.
[79] ibid, p. 36.
[80] op.cit, p. 29.
[81] cf. "Citizens Digital Learning - A study on Lifelong learning, ICT and Employability" made by ECOTEC Research&Consulting for IPTS. To be downloaded at: http://www.jrc.es/pages/projects/gateway.htm

on education and on self-learning [82]. Therefore, we can expect that more public debate will be triggered on issues like the correlation between income and education level.

Leaving the systems perspective and returning to the discussion on skills, one should notice that besides a stronger advisory role of teachers, the profession will be increasingly transformed by the rise in distance education. New skill structures appear in virtual universities where often senior staff (lecturers) conceive and develop the content of the curriculum, technical advisory staff do the web design and "adjunct" faculty members are working with the students by grading assessments, answering e-mails and directing online discussions[83]. This trend leads to new occupational structures (curriculum developers, content deliverers, assessment specialists…)
Another trend is the strengthening of vocational guidance to assist the learners in the transition from school to labour market [84]. Consequently, we witness a growth in advisory staff at post-secondary and university level. Vocational guidance is often carried out in partnerships between stakeholders in education and in the labour market, also encompassing some private actors.

The drive towards more (and better?) vocational guidance is one sign of closer ties between education&training and the labour market. This has implications on the future supply of labour in the sense that there might be smoother and probably shorter transition periods. It is likely that today's increase in professional Bachelors and Masters will be more dominant in the future, given the mushrooming of private education&training arrangements and the rapidity of technological change.

Developments in ICT (like mobile communication based on UMTS) make education and training more ubiquitous to the extent that some believe that a university can be "carried under your arm" (cf. the third ICT/university scenario described above). The evolution in learning technologies and public measures to increase the employment chances of learners (e.g. vocational guidance) are quite different factors that both entail new skill structures in educational institutions and in their partner organisations.

If the private and public education&training systems are to confirm their role in the supply of a labour force with adequate skills, they need to invest a lot because technology supported learning of high quality is far from low cost. This points back to the scenarios for macroeconomic development in part 2 of the EP study. Over the next twenty years there can only be a substantial supply push if the systems and the individuals can afford to pay the bill.

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[82] Attendance at private schools is well-known in UK. In Japan and Korea there are substantial household contributions for supplementary private tuition.
[83] cf. "A virtual revolution….", American Federation of Teachers.
[84] See Duatel et al. for an examination of vocational guidance and other active labour market policy (ALMP) measures.

The following table is an attempt to summarise observations from the literature review with regard to the skill supply factors of direct relevance:

SKILL SUPPLY FACTORS	
Classification of factors	*Short description of factors*
labour force participation	
education level of new entrants	better qualified than ever because of widespread expansion of higher education
participation rate of women	higher salary and more public subsidies to child care stimulate female labour; women slightly outnumber male students at university level
participation of older workers	signs of postponed age of retirement; part-time work for older employees
participation of younger workers	more likely to combine work and education; propensity to start university training is not only a social/cultural factor as described below, but also depends on factors such as financing of education, employment and salary perspectives
efficiency of vocational guidance and counselling services	shorter and smoother transition periods between education and labour market
transparency of occupational classification and qualification systems	at local, regional, national and European level
demographic patterns	
ageing	"from 2007 and onwards the age group 55-64 will surpass the 15-24 group"
migration	can be mathematically calculated from demographic projections, but basically this is a political and cultural factor
mobility (occupational and geographic)	inter- and intraregional *labour* mobility, strong among high-skilled
factors linked to education and training systems	
Transparency of accreditation schemes in education	level of control of upcoming standards: agreements between national ministries, supranational bodies, professional associations, user groups (e.g. firms) ?
harmonisation of university trajectories	implementation of European/international credit transfer systems
reform of university	shorter cycles; more "professional" degrees designed to meet

teaching	immediate labour market needs; increase in distance and technology supported learning; UMTS fostering "ubiquitous learning"
outcome of ongoing specialisation in higher education	larger variety of universities: research, campus, virtual and corporate; Competition and co-operation between these.
new skill structures in education and training systems	effects of new learning technologies: new occupational structures in the systems and in partner organisations
student mobility	affects the skill level of students who are increasingly endowed with international and multicultural experiences.
students' level of digital literacy	general high, but unequal due to variations in the PC density in private homes and other factors producing school inequality
"putting Lifelong learning into practice"	ability to adapt initial training to LLL, "learn-to-learn" and motivation to and infrastructure for self-learning
social and cultural values	values influencing the individual's choice patterns, attitudes and motivation for education, training and work, e.g. university education as "rites de passage" for young people
attractiveness of general/academic vs. vocational/technical education	this factor is similar to "social and cultural values" but depends more on the structure of education&training systems (cf. experiences from the dual system in Germany and Austria)
unemployment rate	at present highest rate among low-skilled and those previously employed in industry opposed to high-skilled service workers; strong national differences might imply that future estimations should reflect institutional conditions with regard to labour contracts, job opportunities for degree-holders etc.

7 Employment sector projections

The relationship between output and employment is usually measured by the elasticity of employment with respect to output. The elasticity of employment with respect to output will differ across sectors, regions and time and depend on contextual variables other than output. Chief amongst these is a measure of factor utilization (or 'state-of-the-cycle') at the date the output change occurs and, second, the rate of (trend) labour productivity growth. If output grows at a time when capacity is under-utilised and there has been labour hoarding then the effect on employment is likely to be small or negligible, perhaps even negative. Elasticity estimates should allow for such cyclical effects.

If trend labour productivity growth exceeds output growth then rising output and falling employment will coincide. Scarpetta, Bassanini, Pilat and Schreyer (2001) [85] conclude, "in some [OECD] countries where high or rising labour productivity was associated with sluggish or falling employment, MFP [multi-factor productivity] growth did not show any significant improvement, or fell in the 1990s as compared with the previous decade." This finding has special relevance to Continental Europe and suggests that elasticity estimates should be conditional on the rate of MFP growth or some measure of technical progress.

Having duly allowed for capacity effects the task of projecting the level of employment demand that is associated with a given rate of output growth requires an associated projection of the rate of labour productivity growth. Although the study informs us that this is to be a matter for expert input it also states "the sectors where a higher proportion of new R&D spending is allocated are expected to demonstrate faster productivity growth….Sectors where R&D spending is not increased will keep their current productivity growth rates." [86]. A conclusion of the empirical literature, however, is that there are productivity 'spillovers' from R&D spending most clearly observed at firm level but also inter-sectorally.[87] The implication, contrary to the above assumption, is that labour productivity growth in a given sector may, in part, depend on R&D spending in other sectors.

Another and distinct consideration is that labour productivity growth depends not just on R&D spending but also on sectoral investment rates (real capital deepening) and education and training (human capital deepening).[88] A partial solution to the first of these difficulties has been employed in a different context[89] by devising an index of technical progress by sector and region that is based on a composite of investment rates and R&D spending. A partial solution to the second problem is used by Scarpetta et al (op., cit.p.22). The unadjusted growth in labour input is the sum of the growth rates in numbers engaged and average hours person. Scarpetta et al,. employ a quality-adjusted measure of the labour force to allow for human

[85] Stefano Scarpetta, Andrea Bassanini, Dirk Pilat and Paul Schreyer. (2000) *Economic Growth in the OECD area: Recent Trends at the Aggregate and Sectoral Level p6.* OECD. Economics Department Working Paper No 248. June, 2000.

[86] Ibid. p.8

[87] Cite OECD studies in support of this here.

[88] Scarpetta te al (op,. Cit.) clarify the effects of human capital deepening and other factors on labour productivity.

[89] Osmo Forssell and Hans Gunther. (1999) *Incentives for Industrial Energy Efficiency*. Working Paper for Task 5. Industrial Benefits and Costs of Greenhouse Gas Abatement : Applications of E3ME. Dec 1999 (p.23?)

capital deepening. They do this by "calculating the labour input as a weighted sum of different groups of workers with different levels of education, each weighted by their relative wage." This essentially gives workers with higher education levels higher weights: if a country's labour force education levels are increasing this increases the growth rate of its 'standardised' labour input even if the total number of hours worked remains unchanged. The calculated labour productivity growth rates differ markedly depending on whether unadjusted or quality-adjusted labour inputs are used. Human capital deepening of the European labour force has been much more pronounced than in the United States over the last decade and a half. If the calculated employment-output elasticities can be modified to allow for human-capital deepening then projected employment levels can be refined and the projections made contingent education levels as well as other supply-side features of the European labour force.

The draft 'Literature Review and Methodological Outline'[90] cites a negative long-run employment-output elasticity of -1.22 at industry level for the EU15 over the period 1975-93. Even allowing for the fact that EU elasticities are generally lower than US and Japanese values both overall and in the Services sector, the cited negative value for Industry is likely prove an unreliable guide when making future employment projections. Taken at face value, it implies, *other things being equal*, that each 12% growth in EU industrial output will result in a 10% drop in the EU industrial employment, whereas, a similar output growth rate in the US and Japan will lead to a 3% and 6% growth rate in their respective industrial employment levels.
Of course, other things have not been equal in the past. Accordingly, the naïve elasticities that are obtained by dividing the percentage employment change by the percentage change in output need to be refined to account for other relevant structural factors mentioned above.

It is simply implausible that the rates of factor substitution, trend productivity growth or of European competitiveness relative to the US or Japan will evolve over the next two decades in a way that is consistent with the reported 'naïve' elasticities. A structural model is required to net out business cycle or factor utilization effects (and other causes of underlying trend labour productivity growth) on employment and to estimate the pure output or output elasticity effect. Section 3.5 p.23. of this review provides a fuller account of how this may be done.

The European Commission[91] using trend components in GDP and employment show that the overall elasticity is rising in Europe and falling in the U.S. The relevant data are given in Table 1. While the 1980-90 values are similar to those reported by Vivarella and Pianta (1999)[92] the gap closes considerably over the course of the 1990s.

Table 1. Employment Elasticities for the EU and U.S.

Total Economy Employment - Output Elasticities 1980-2000		
	European Union	***U.S.***
1980-1990	+0.19	+0.59
1991-2000	+0.27	+0.43
1995-2000	+0.33	+0.38

Source. European Commission *Employment Outlook 2000.* Chapter 3. P.54.

[90] IPTS-ESTO - *Impact of Technological and Structural Change on Employment: Prospective analysis 2020.* Part 1 report, Literature review and methodological outline, Table 2.1. p.18.Seville, March 2001.
[91] European Commission. (2000) *Employment Outlook 2000.* Chapter 3, page 54.
[92] Pianta & Vivarella (1999) report an elasticity for the whole economy of 0.10 for the EU 15 and 0.60 for the U.S. for the period 1975-1996. IPTS/ESTO op. cit., Table 2.1. p.18.

It is clear that the measured elasticities are unstable over time. This suggests that there is also a need to employ a properly specified structural ***dynamic*** model in making long-run elasticity estimates, such as the ECM (Error Correction Model) recently used by Guellac and van Pottelsburghe de la Potterie[93] in a related context.

To the extent that unstable elasticity estimates are due 'industry structure' or 'industry composition' effects they can be relieved by making disaggregated estimates. These, however, often pose their own problems. In particular, disaggregated elasticity estimates are often implausible and unreliable. This can arise due to data or other deficiencies in making the estimates. An attractive methodological device to relieve the problem is to use Shrinkage Estimators.[94] Essentially, 'first-pass' elasticity estimates are made at sectoral and regional level by conventional methods. Mean Sectoral and regional elasticity estimates are calculated from these values. The 'second-pass' elasticity estimate is constructed as a weighted average of the 'first-pass' elasticity and mean elasticity. The weights are the relative uncertainties with which the elasticities are estimated (in approximate terms, their relative standard errors). The Cambridge Econometrics group report considerable success with this method in eliminating 'outliers'. It also has the added attraction of using the relative certainties of the estimates rather than arbitrarily restricting estimates to be non-negative or to exceed some arbitrarily specified lower bound.

The following supply-side or production relationship is central to the ensuing analysis;

$$\dot{y} = (1-\omega)\dot{l} + \omega\dot{k} + m\dot{f}p \qquad [1]$$

where,

$\dot{y}$, is the projected growth rate of output to the year 2020.
$\dot{k}$ is the growth rate of capital (measured in efficiency units) to year 2020.
$\dot{l}$ is the growth rate of labour (measured in efficiency units) to 2020.
$m\dot{f}p$ is multifactor productivity growth to the year 2020.
ω is the cost share of capital in output; $(1-\omega)$ is the cost share of labour.

The implication of the point made above is that the projected output growth rate, $\dot{y}$, already incorporates both projected market size and competitiveness effects (or should do). This allows us to focus on the supply side implication of that projection. In order to produce the projected level of output capital and labour inputs are required. How much of each input is required will depend on the rate of multifactor productivity growth and on how capital intensive is the production process. It is instructive to re-arrange equation [1]:

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[93] Dominique Guellec and Bruno van Pottelsberghe de al Potterie. (2001). *R&D and Productivity Growth: Panel Data Analysis for 16 OECD Countries.* STI Working Papers 2001/3. OECD. June. 2001. These authors use an ECM model, correct for 'cyclical' effects and distinguish between the effects of public, business and foreign R&D on productivity growth.

[94] Neil Jennings and Ben Gardiner (1999). Working Paper for Task 2*: Robustness of Industrial Projections and SimulationProperties*. Industrial Benefits and Costs of Greenhouse Gas Abatement Strategies: Applications of E3ME. Cambridge Econometrics. Dec 1999.

$$\dot{l} = \dot{y} - mf\dot{p} - \omega(\dot{k} - \dot{l}) \quad [2]$$

Equation [2] states that over any given time interval the growth in employment, measured in efficiency units, is equal to the projected output rate minus the multifactor productivity growth minus the growth in the capital-labour ratio weighted by labour's share of output. Since the first right hand side variable is given then completing the forecast for labour demand involves projecting multifactor productivity growth, $mf\dot{p}$, growth in the capital-labour ratio, $(\dot{k} - \dot{l})$, and the share of wages in output, ω. Multifactor productivity growth, $mf\dot{p}$, depends technological change. The change in the capital- labour ratio, $(\dot{k} - \dot{l})$, depends on both technological change and changes in the relative price of capital and labour. Re-arranging equation [2] gives a slightly different focus on projecting labour demand,

$$(1-\omega)\dot{l} = \dot{y} - mf\dot{p} - \omega\dot{k} \qquad [3]$$

Here the cost share weighted growth in labour input is equal to the projected growth in output less MFP growth less the cost share weighted growth rate of capital deepening. The basic difference between equations [2] and [3] is that the former requires a projection of the capital-labour ratio whereas the latter requires a projection of the growth rate of capital stocks (measured in efficiency units i.e. capital deepening). Re-arranging equation [3] gives,

$$\varepsilon = \dot{l} / \dot{y} = 1/(1-\omega)[1-(mf\dot{p} + \omega\dot{k}) / \dot{y}] \qquad [4]$$

Equation [4] is an expression for the elasticity of employment with respect to output, ε, (abstracting from demand-side effects). It serves to clarify that the employment elasticity is not a fixed coefficient that can be estimated naively and used for projection purposes. The true ***ceteris paribus*** elasticity of employment with respect to output is $1/(1-\omega)$ - the inverse of the elasticity of output with respect to labour input or (given constant returns) labour's cost share in output. The naïve elasticity, discussed above, is measured as $\dot{l} / \dot{y}$ and, as such, incorporates the effects of each of the right-hand side variables in equation [4]. This naïve elasticity is, in fact, a reduced form variable. Its sign and magnitude depend on the extent to which the sum of total factor productivity growth and capital led growth exceeds or falls short of output growth. These latter variables change over time both secularly and cyclically and give the naively measured employment elasticity the appearance of undue instability. Re-writing equation [4] as,

$$\dot{l} = \alpha_0 + \alpha_1\dot{y} + \alpha_2\dot{k} + \alpha_3 mf\dot{p} \qquad [5]$$

and augmenting with suitable dynamics, specification modifications and a stochastic term permits the employment elasticity to be estimated econometrically as $\hat{\alpha}_1$ by conventional methods.

Equation [5] clarifies that in order to project employment growth to 2020 not only must the α coefficients be estimated and output forecasts, $\dot{y}$, available for the period but capital deepening, $\dot{k}$, and multifactor productivity growth, $mf\dot{p}$, must also be forecast over the same forecast horizon.

Of course, equation [5] abstracts from the effects of EU R&D spending on EU productivity growth. It also abstracts from demand side effects that the latter has on EU output levels. In short, the demand-side effects are already incorporated in the output forecasts or should be. Although the demand and supply side effects are in reality integrated it is probably necessary and fruitful to separate them analytically as has been done. Technically this can be accommodated on the supply side by estimating a suitably modified version of equation [5] using instrumental variable techniques. I focus on a couple of the more important modifications that are required below.

Equation [5] is an equilibrium expression that needs to be modified to incorporate capacity utilization effects. An implicit assumption of equation [4] is that capital and labour are always fully utilized. If this is not the case and there has been 'labour hoarding' (for example during a recession) then future output growth can be accommodated (at least in part) by increasing the utilization rate of existing employees rather than by expanding employment levels. The IPTS/ESTO study recognises the importance of the distinction, "Another important aspect to consider in this analysis is the influence of employment driving factor over time and the distinction of the of the business cycle and the long term effects. This study focuses on the factors driving employment in the long term."[95] There are many ways of incorporating factor-utilization or state-of-the-cycle effects. For example, when estimating MFP growth rates Guellec and van Pottlesburg de la Potterie (2000) incorporate unemployment as a cyclical indicator variable in an Error Correction Model (ECM) and report results that are very striking when judged by conventional statistical criteria. Another possibility is to replace the ECM with an asymmetric adjustment mechanism. This would be appropriate if the speed and strength of employment responses differs as between booms and slumps.

Equation [5] is a generic expression for the elasticity of employment with respect to output. Employment elasticities, however, will vary over sectors and across regions. Equation [5] can be re-written to accommodate these differences,

$$\varepsilon_{ij} = \dot{l}_{ij} / \dot{y}_{ij} = 1/(1-\omega_{ij})[1-(\dot{mfp}_{ij} + \omega_{ij}\dot{k}_{ij}) / \dot{y}_{ij}] \qquad [6]$$

Here, ε_{ij}, is the employment elasticity in sector 'i' of region (or country) 'j'. The subscripts have an identical interpretation for each of the remaining variables.

Total employment growth in country/region 'j' is given by,

$$\dot{l}_j = \sum_{i=1}^{n} \theta_{ij}\dot{l}_{ij} \qquad [7]$$

In words, the rate of employment growth in country 'j' is a weighted sum of the employment growth rates in each of the sectors comprising country 'j'. The weights, θ_{ij}, are the total employment shares of each sector in country j's economy. As such θ_{ij} represent 'structural' or 'compositional' effects. For example, if the growth rate of the ICT sectors of two economies is identical the country with the bigger exposure to the ICT sector (i.e. with the bigger θ coefficient) will grow faster.

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[95] IPTS/ESTO op.cit., p.6.

In interests of clarity and in order to avoid complicating detail the regional and sectoral details are suppressed in the remainder of this exposition: they can, of course, be picked up in the operational phase of the work.

When the output growth projections that have been made in Parts 1 and 2 of the IPTS/ESTOstudy are multiplied by the corresponding employment elasticities they yield the projected growth rates of employment over the period to 2020,

$$\dot{l} = \varepsilon \dot{y}$$

Regional and sector details can be added with some appearance of complication in the formulae,

$$\dot{l}_j = \sum_{i=1}^{n} \theta_{ij} \varepsilon_{ij} \dot{y}_{ij} \qquad [8]$$

Equation [8] encapsulates the core of the forecasting exercise. The output growth rates, $\dot{y}_{ij}$, are available from Parts 1 and 2 of the study. The elasticity values are obtained from estimating a version of equation [6] and using appropriate structural estimates and projections for MFP and capital deepening. The θ_{ij} coefficients are readily obtained from the opening employment structures of each of the countries/regions. The Guellec and van Pottlesburgh de la Poterie estimates may be used together with the projected R&D values to project MFP over the forecast horizon. It appears likely that specific rates of capital deepening have been assumed in making the output projections in Parts 1 & 2 of the study and these same values should, for consistency, be used in completing the elasticity estimates. Attaching numbers to equation [8] completes the basic employment forecast.

Equation [8] gives the growth of employment ***measured in efficiency units***.
The labour efficiency unit has 2 dimensions. First, it refers to the *number* of hours worked. Second, it adjusts for the '*quality*' of labour by giving, for example third level graduates a higher weighting than non-graduates. [The weighting measure used by Scarpetta et al., to 'quality-adjust' the labour force is the relative wages of graduates and non-graduates]. Once the growth in hours worked is forecast it can be decomposed into the different types of labour required as follows;

$$l = l_2 + \lambda l_3 \qquad [9]$$

The required labour force, l, is measured in ***standardised hours*** worked and is estimated using a version of equation [8]. Each hour worked by a worker with second level education is given a count of 1 and they work a total number of hours, l_2. The total number of hours worked by those holding third level qualifications is l_3 and each such hour is given a weighting of λ (where $\lambda > 1$) giving a total of λl_3 'standardised' labour hours.
Let the share of third level workers in the employed workforce be,

$$\pi = l_3 / (l_2 + l_3) \quad [10]$$

It follows that the number of 2nd level hours required is,

$$l_2 = \left[1 + \lambda\{\pi / (1 - \pi)\}\right]^{-1} l \qquad [11]$$

The number of 3rd level hours required is,

$$l_3 = (l - l_2) / \lambda \quad [12]$$

In short, the total number of ***standardised hours*** can be readily decomposed into the number of ***actual hours*** required of workers with second level education and, separately, for workers with third level education. In order to operationalize equations [11] and [12] a structural estimate or times series projection of the share of third level educated workers in the workforce π must be made - This is a variable that is trending upwards over time and not a fixed coefficient. Second, the weighting given to third level hours λ also be projected to 2020 either on a structural or time series basis.

Finally, the number of education categories considered may be increased but with the expense of some added complication.

The numbers of persons with 2nd and 3rd level education that are required can be obtained by dividing the actual (and not the standardised hours) by the average number of hours worked per year for each category. The average number of hours per week is affected by conventions such as the number of holidays in the year and changes in the 'standard' number of hours worked per week. The dominating influence, however, is the number of part-time workers. The share of part-time workers in employment has a number of influences most notably the female participation rate in the labour force. The Eurostat EU labour force projections to 2025 must already incorporate an assumption of female participation rates and probably also on full and part-time working.

The average number of hours worked is also influenced by labour market flexibility, custom and practice and the level of support facilities e.g. Scandanavian women who enjoy favourable child support facilities also tend to have high fulltime participation rates. It is a common theme of published work that countries with good recent employment performance tend to be those with good labour market policies (i.e. good performance in implementing the OECD Jobs Strategy).

8 Workplace organisation, skills and technology

In terms of proportion of GDP invested in information and communications technologies (ICT), the EU invested at about three-quarters of the rate of the USA in 1993. By 1997, the EU rate of investment had dropped to only slightly half the USA rate, but although the gap between the USA and the EU narrowed in 1998, it widened again in 1999. Since 1993, the USA expenditure in terms of investment in ICT per capita has been more than double that of Europe for every year since 1993. There are very wide variations between individual EU countries in terms of these parameters, but no EU country attains US levels in terms of ICT investment.[96] Reflecting the slower rate of investment in ICT, the need for organisational and skill change in the EU is likely to be substantial, but somewhat less than in the USA.

The European Commission is striving to develop programmes to meet the rapidly growing needs for educated people experienced by the ICT producing sector; and to alleviate the severe skills shortages which seem likely to continue to afflict this important and rapidly growing sector. It has called for a new strategy for jobs in the Information Society. "The rise of information and communication technologies is the defining socio-economic development of the late 20th. century, influencing not only jobs, industrial output and the relative economic performance of nations, but also the way people live." The ICT sector created 400,000 new jobs between 1995 and 1997 - about one in four of the total of new jobs created in the EU[97] . Trends such as the rapid expansion of mobile telephone usage and growth in the audio-visual sector indicate that there are continuing major opportunities for employment expansion.

The development of bioinformatics is critical to realising the benefits which are emerging from genomics and combinatorial chemistry. Nanotechnologies involve working at molecular and atomic levels to create structures with precisely designed and fundamentally new properties. In both these areas, the availability of appropriate numbers of those with essential skills - in the next several years, mainly high level scientific skills - is vital to the long-term prosperity of the European economy.

However, lack of adequate skills is a very important factor in other more traditional sectors of the European economy, and this aspect is also addressed in this paper.

Traditionally, workplaces are organised around a tight division of labour and narrowly designed specialized jobs. But some firms have decided that this approach is unsuitable to cope with the introduction of ICT and have undertaken fundamental changes in their internal organization. Changes include changes in factory layout such as the introduction of product-based cells. New ways of controlling the flow of production total quality management and just-in-time production. Organizational hierarchies are being flattened, eliminating some middle management positions, with responsibilities being pushed down to production workers with the aim of empowering them. This can be facilitated by the introduction of work teams whose leaders adopt the roles of coach or facilitator rather than supervisor or manager, and in

[96] European IT Observatory Reports, 1994-2001; www.eto.org.uk/eito
[97] ESF Info Review, (February, 1999), Newsletter of Employment and the European Social Fund, No 7, European Commission DGV, Brussels, p2.

which workers exercise broader skills : firms which introduce new work practices also report higher skill levels. [98].In 1996-7, about one third of establishments in a survey of ten European Union countries were reported as having adopted such new work practices.[99]

Among companies that have adopted ICTs, the best results have been obtained by those that also carried out organisational changes. Only small productivity increases have been achieved when new technologies have been introduced into old organisational structures. The organisational changes that are needed include the introduction of self-managing teams, decentralisation of decision making, reduction of layers of management, and empowerment of employees to make critical decisions together with customers. These requirements for organisational change can be expected to remain in place at least for the next two decades. There is also need for a "move away from traditional technocratic orientations within which 'systems' are selected and implemented , with ergonomic and job design issues entering at a late stage, to one in which managers are trained to be more effective in developing the synergies between human and technical resources" [100]

Another urgent task is the definition of proper balance between the increased comfort of communication made possible by ICTs and associated work stress and strain on families of white-collar and maintenance workers.

8.1 Visions of the future of technology and work

New ICT-related developments are encapsulated by various buzzwords such as teleworking, telecottages, telecommuting, call centres, virtual workplaces, virtual organizations convergence, the unified field theory of networking, and pervasive computing. "The network nature of work spins out of central offices into homes, back offices, cars, third world countries and outsourcers (It also spins work from employees onto customers - as ATM machines made bank tellers out of bank customers) ".[101]

Such developments are driven and promoted principally by major vendors of computers, telecommunications equipment and services, computers and systems, who are developing technologies and aim to introduce products and services over the next decade with the aim of causing major transformations in the use of networks and telecommunications. It has been suggested that virtual organizations will engage suppliers, producers and customers in work processes on an as-needed basis to mass produce customized products and services. The results anticipated include significant reductions in cost and cycle time, and unparalleled levels of quality and customer satisfaction.[102]

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[98] International Labour Office, World Employment Report 1998-99: Employability in the global economy: how training matters, International Labour Office, Geneva, 1998, pages 41-44 ;P. Osterman, How common is workplace transformation and how can we explain who does it?, in Industrial and Labor Relations Review, Vol 47, No.2., 1994; P. Cappelli et al., Change at Work, Oxford University Press, New York, 1997.
[99] New forms of work organization, European Foundation for the Improvement of Living and Working Conditions, Dublin, 1997.
[100] C. Freeman and L. Soete, Afterword and Policy Conclusions, in K. Ducatel (Editor) Employment and Technical Change in Europe: Work Organization, Skills and Training, Edward Elgar, 1994, p221
[101] K.Kelly, What does the network economy mean for work, in Telework'99.
[102] N. Fredric Crandall and Marc J Wallace Jr, The Virtual Workplace: Work and Rewards in the 21st Century, ACA Journal, Spring 1995.

Teleworking involves working from home with the aid of new technology: it can be defined as the use of telecommunications to enable work-based activities outside the traditional workplace. Electronic homework is carried out at home using telecommunications to receive and forward work to clients. Home based teleworkers can work for a single company, or work freelance for a number of clients. Work can be performed at any location so reducing the need for commuting, and can also be seen as a potential means of job creation in remote areas. Telecentres or telecottages involve the use of shared computer and telecommunications resources, and were established in Denmark and Sweden in the mid 1980s: Britain's first telecottage was set up in 1989. Some companies have set up telecentres in remote areas to undertake routine correspondence and administration.

Virtual workplaces are envisaged which will make use of technology to enable employees to work together across space and time. Perhaps not surprisingly, ICT consultants in the US are leading the trend. A third of respondents to a survey were already working on contract assignments which include at least some time telecommuting and nearly all would like their future assignments to involve telecommuting. As ever, the issue of control is of importance, both from the point of view of the worker and of his or her employer or client. Many of the ICT professionals' clients resist telecommuting, usually because of concern about their ability to control and measure the performance of remote workers. But, in addition to electronic communication technologies such as teleconferencing and videoconferencing, technologies that enable managers to track performance are being developed. From the point of view of the client, teleworking offers them advantages of cost savings by reducing their need for office based physical facilities. [103]

Revolutions in working practices will be largely driven by technological advances in areas such as computing, fibre optics, wireless communications and software development. Gsenger quotes Alastair Glass, head of photonics research at Lucent's Bell Labs, stating that that a single optical fibre today can carry enormous quantities of information - 400G bit/sec at present - and that capacity is doubling every year. The computing power of a microchip doubles every eighteen months or so and the cost of computing power has been halving every two years. Similarly, telephone costs have been falling very rapidly.[104]

IBM is reported as claiming that technological developments could result in the wide availability of handheld devices that combine telephony, data and multimedia functions. It foresees the availability of permutations of notebook computers, personal digital assistants (PDA), cellular phones and pagers - a vision of employees scattered everywhere connecting to the network over new and exotic devices so that users can run business processes from wherever they happen to be.[105]

Some aspects of this concept are illustrated by the following vision: while travelling on business, people can get off the plane at the airport or go into their hotel and have access to a device which will communicate to services which update their schedules and automatically make airline or hotel arrangements for the new meeting they have to attend tomorrow. End users would simply hear network tones equivalent to phone tones on the multi function device they carry, and advanced features such as security, directory services and intelligent quality of

[103] D. Black, The emerging virtual workplace, IT careers, Oct 5, 1998.
[104] D.Coyle, The weightless world, in Telework '99, p10
[105] M. Csenger, Vendor Vision, Network World, 05/03/99

service would be built in but not necessarily all such features would be visible to the users. While achieving such a utopia would involve the use of a wide variety of devices, the general aim is to develop software so that all the different networks and network services appear as one integrated system to the user.

The major parts of the biotechnology industry both in Europe and the US are biopharmaceuticals and agricultural. Traditionally, pharmaceutical products were based on small molecule chemistry.[106] New developments in biotechnology have made it possible to create new drugs using biology. Dedicated biotechnology companies, seed companies and agrochemical /life science companies now comprise a new bioagrifood industry. Bioinformatics is the storage, retrieval and analysis of data for scientific research which aim to provide answers to biological questions. The development of bioinformatics is critical to realising the benefits which are emerging from genomics and combinatorial chemistry. This cluster of new technologies offers the potential of improving the efficiency and speed of the process of screening compounds for their effectiveness. A commonly used bioinformatic technique in pharmaceutical research consists of software tools which create and compare 3-D structural models of proteins and other molecules to aid prediction of their interactions. It is hoped that the ability to read DNA sequences will lead to deeper understanding of the susceptibility of individuals to disease and give greater insight into the structure and assembly of proteins. As a consequence of bioinformatics, computers have become vital in the research process from the outset, providing details of external research via the Internet and allowing targets to be found from data mining in sequence databases.[107]

Nanotechnology is a hybrid science combining engineering and chemistry. The emerging and rapidly growing fields of nanoscale engineering science and technology involve working at molecular and atomic levels to create structures with precisely designed and fundamentally new properties. Much of the nanotechnology research taking place now will take more than 20 years to complete, but nanotechnology could start to have major impacts on the economy from five to 15 years in the future.

In January 2000, President Clinton requested a $227-million increase in the U.S. government's investment in nanotechnology research and development. This initiative nearly doubles America's 2000-budget investment in nanotechnology, bringing the total invested in nanotechnology to over $500 million for the 2001 national budget. In a written statement, White House officials said that "nanotechnology is the new frontier and its potential impact is compelling." About 70 percent of the new nanotechnology funding will go to university research efforts, which will help meet the demand for workers with nanoscale science and engineering skills. The initiative will also fund the projects of several governmental agencies, including the National Science Foundation, the Department of Defense, the Department of Energy, the National Institutes of Health (NIH), National Aeronautics and Space Administration (NASA) and the National Institute of Standards and Technology (NIST) . NASA's plan includes the development of robotics using nanoelectronics, biological sensors and artificial intelligence.NIH plans to develop novel imstruments that can be used to collect DNA sequence variation and gene expression data from individual patients , initially to identify genes involved in causing diseases and later to diagnose the exact form of the disease the patient is suffering from so as to design the therapy to treat the patient's disease. NIST envisages that new information technologies an technologies such as nanomagnetics will

[106] L. Galambos, and J Sturchio, Science in the Twentieth Century, Chapter 13, 1997
[107] S. Crowther, M. Hopkins, P, Martin,E. Millstone, M. Sharp and P. Van Zwanenberg, Benchmarking Innovation in Modern Biotechnology, SPRU, University of Sussex, December, 1999,especially Annex A.

eventually replace today's semiconductor electronics and is developing the critical measurement infrastructure which will be required by these radically new technologies. Nanotechnology could initiate a new industrial revolution: it could change the way almost everything, including medical systems, computers and cars, are designed and constructed. It may have its biggest impact on medicine. Patients could drink fluids containing nanorobots programmed to attack and reconstruct the molecular structure of cells and viruses to make them harmless.. Nanorobots might even be programmed to perform delicate surgical operations -- such nanosurgeons could work more precisely than the sharpest scalpel. By working on such a small scale, a nanorobot might operate without leaving the scars left by conventional surgery. [108]

There are those who forecast "the possibility of a golden age in which economies are based on limitless ideas not limited materials… abundance, not scarcity drives the future…The digital society is a place of abundance , not limitations of choice, not diktat"[109]

8.2 How realistic are such visions?

ICTs

Over 500,000 ICT job vacancies are currently unfilled in the EU because employers cannot find staff with the appropriate skills. This figure could rise to 1.2 million by 2002 unless the problem is addressed as a matter of urgency. As a consequence of these skills shortages, firms do not derive the full benefits available from their ICT systems and have to postpone new technology projects. [110]

Network technologies.

By 1999, there were over 9 million workers in the European Union engaged in new working practices directly involving the use of networked technologies, unevenly distributed across Member States[111]. This represents very rapid growth: for example, there were only 1.25 million people involved in home-based telework in 1994.

Surveys in Europe have indicated very positive attitudes towards carrying out work from home using Information Technology, and it is possible that telework will continue to expand very rapidly in the future because of this and the rapid development of ICT. In Denmark, it has been forecast that home-based telework will develop primarily in the public sector, in finance

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[108] M.C. Roco, National Technology Investment in the FY 2002 Request by the President, in AAAS Report xxvi, Washington D.C., July 2001, pp225-233; K. Bonsor, How Nanotechnology Will Work, HowStuff Works website, 2000;
[109] Extract from article in Wired magazine, cited by Coyle (op. cit).
[110] ESF Info Review, op. cit,.1999.
[111] J.Millard, Foreword, in Proceedings of the Sixth European Assembly on Telework and New Ways of Working, 2000, (Telework '99) p3

and insurance in education and in certain specific industrial sectors. [112] In the UK, it has been predicted that one in five office workers will be teleworking within the next five years.[113]

The range of technologies coming into use has changed and increased remarkably in the last decade. There are clearly huge problems of interfacing vast varieties of devices to form an integrated network, although suppliers are working hard and expending vast resources to solve the immense technical and software problems involved. However, the processes through which these changes affect employment, skill needs and working lives are relatively stable in comparison with the frenetic rate of development of technology, so it is worth considering earlier European research on the implications of Information Technology for working lives even though it was based on consideration of earlier specific technologies.

Technological change introduces uncertainty to working conditions and the threat of loss of control over important features of working life. Adaptation to new technology is often protracted. As we have seen, technological change is being promoted by those organisations that develop the technology and sold to corporations on the grounds that it will increase their profitability. Accordingly the practice of the last several decades of introducing much ICT-related change in the absence of significant preparation of and consultation with the workforce is liable to continue for the next few decades. This, together with the following factors are liable to give rise to problems. As discussed above, much ICT-related change is brought about through the extensive and persuasive efforts of product and system vendors selling to major corporate buyers, and sound advice on how to introduce new technologies is often readily available. For example, in relation to teleworking, four key challenges have been identified: resistance to change; technology development so rapid that it exceeds expertise to use it within the organisation to use it; concern over data security; and meeting worker expectations. To be successful in this environment requires clear definition of goals, careful planning, regular communication and adequate management support, the establishment of agreement between management and workers on crucial issues and the establishment of adequate channels of two way communication.[114]

Nevertheless, in relation to ICT introduction in general, needs to consult with users are often neglected, resulting in inefficient use of systems installed (sometimes complete failure) and user resistance. Training users in the use of new systems is often neglected. Many potential users are daunted by the need to acquire new skills, unsure of whether they are capable of acquiring the necessary skills, and often do not even understand what new skills they need to acquire. Especially as a consequence of the frantic rate of development of computer and telecommunications systems, user-device interfaces may be badly designed, and, in sharp contrast to the visions of those who promote such technologies, cannot always be relied on to work perfectly. There are frequent mismatches between technical performance and user requirements. Communication between engineers, software writers and end-users is often poor and manuals are often inadequate. Companies are often frustrated because they have acquired systems that do not meet specifications and workers are frustrated because the new systems may not work effectively and enable them to enhance their efficiency. Further, training is often totally inadequate. There has been widespread failure to recognise the need for training associated with ICT systems. The idea that workers can simply pick up skills on the job or by

[112] T.Kauppinen, Self-employment and telework in the EU, in Telework'99, p125.
[113] S.McCaffrey, Work is Changing- The Future is now, in Telework 2000, London.
[114] I. Norman, A Vision for Management inTelework, 2000, London

reading manuals is prevalent, and there is rarely sufficient recognition of the need for ongoing training as hardware and software is updated and new applications are introduced[115]. Many such problems have been exacerbated by the very rapid pace of introduction of new technologies.

The service sector

Technological change, and in particular ICTs, are becoming increasingly important in some service sectors. Employment of skilled workers has been rising and the most rapid rate of increase in employment has taken place amongst professionals and technicians. There has been a structural shift towards services and a tendency towards polarization in skill requirements in service sector jobs. This has been largely the result of "a grouping of service industries at each end of the technology spectrum. While the information and knowledge intensive service industries in the finance, insurance, real estate and business sectors… have generated a significant share of the jobs created over the last 15 years, most other jobs created in the service sector are at the other extreme-labour intensive."[116] (for example see discussion of call centres below). In relation to clerical jobs, the evidence indicates that the skills consequences of developments in the applications of ICTs may be mixed, or even result in deskilling.

It would appear that there has been substantial technology related downsizing in some of the service industries which had been growing quite rapidly during the 1990s, especially financial services. Especially at risk are employees involved in bureaucratic tasks in large organisations that involve processing large volumes of transactions such as banks and insurance companies, shops and mail order houses. But there is likely to be employment growth in a range of activities from high technology consultancy and systems provision to cleaning, catering and security, cooking, gardening or driving jobs and in jobs which are not conducive to automation because work involves interpersonal exchanges - such as home care workers or advisory/counselling work. Many of these activities are likely increasingly to be outsourced by large firms.

Some sectors such as construction, transport, hotels, travel and security and cleaning include a modern professional sector and a relatively traditional sector. For example, ICT systems are becoming increasingly part of the fabric of large new buildings including data cabling, opto-electronics, switchgear, computerised control, building management, security systems, housing services. Many other construction sites also increasingly involve the installation of ICTs systems - road traffic systems, residential cable networks, etc.. There is also a part of the industry dominated by traditional installers and repairers of equipment in buildings, many of whom lack appropriate skills. This leads to both resistance to the installation of new technologies (at the time of construction or as a retrofitted system) and often to damage of systems through inexpert repairs. As new technologies projects become more widespread in smaller buildings and in the home, upgrading the technological know-how of traditional and small firms will be a major challenge. Technological change, and in particular ICTs, are becoming increasingly important in some service sectors. The use of the Internet appears to be

[115] K. Ducatel and I. Miles, Information Technology and the Quality of Working Life, in K. Ducatel (Editor) Employment and Technical Change in Europe: Work Organization, Skills and Training, Edward Elgar, 1994, pp194 and 195.
[116] International Labour Office, op.cit., 1998, page 33

expanding in some areas of retailing (for example in bookselling). But the long term future remains controversial, in the light of the substantial costs of warehousing and delivery systems and less positive response from customers than has sometimes been assumed.[117]

Call centres

Call centres (or telecentres) represent a very rapidly growing form of employment in Europe. They are workplaces in which customer service telephone agents are physically located in one large room or building. The agents are supported by sophisticated information and communications technologies that enable them to answer telephone enquiries from customers or undertake telesales and telemarketing. Large organisations often own their own call centres and there are specialist call centre providers that service more than one organisation. Dataquest forecast that the number of call centres in Europe would roughly double between 1998 and 2002 and that by 2002 they would employ about 1.3% of the working population of Europe. Financial service industries have been most strongly associated with their development. At present, they are heavily concentrated in the UK, but they are expected to spread more widely, especially in Northern Europe: they are being adopted rather more slowly in southern European countries such as Spain, France and Italy.

The technology provides the basis for the creation of 'factory-like' working conditions in which the worker is subjected to a management and control regime analogous to that which previously only prevailed in manufacturing industry. In striving for higher productivity, managers use indicators and develop and apply measurement formulae based on parameters such as number of calls handled, lengths and difficulty of calls and number of callers in queue. They use training in, for example, cutting the average length of call by providing trainees with the skills needed to signal the end of a call, and this is claimed to enhance productivity significantly. Call centre operators are encouraged to use their own initiative or positive discretion within a framework of a highly controlled and monitored work environments in which management consultants and trainers use training sessions to discipline their thought processes. It could be argued that performance measurements enter into the social interaction between operator and customer; and that this constitutes a form of exploitation of emotional labour which is far more insidious or invasive for the employee than the shopfloor practice associated with Taylorism and scientific management.

New technologies under development facilitate the creation of 'virtual telecentres' . These will perform the same function as call centres, but will allow individual agents to work from home with their work controlled by managers and supervisors as they are currently controlled in today's call centres. This would permit agents to be located anywhere in the world and would facilitate savings in the costs of space and other overheads.[118]

While agreeing that stressful 'pressure-cooker' working conditions associated with staff retention and recruitment problems apply in some of the larger and more regimented call centres, Huws and Denbigh suggest that such problems are associated with the larger and more regimented call centres. They suggest that recent technological developments mean that such concentrations are no longer necessary for many functions. "The combination of high -

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[117] C. Freeman and F. Louca, As time goes by: From the Industrial Revolutions to the Information Revolution, Oxford University Press, 2001, page 324.

[118] G. Poynter and A. de Miranda, Inequality in the service sector in S.Wyatt et al Editors, Technology and In/equality, Routledge, 2000, pages 172-196.

speed digital telephone networks and sophisticated software and switching technology which underlie modern computer telephony integration means that calls can now be re-routed seamlessly to any point. Using this technology, remotely based agents can in effect be managed exactly as if they were physically together in a call centre. The virtual call centre, as this development is known, opens up, many opportunities for flexible management of variable workloads including facilitating the transfer of work to other time-zones, outsourcing or the use of teleworkers." [119]

Poynter and de Miranda disagree with Huws and Denbigh about the current state of development of virtual telecentre technology, suggesting that "A number of experiments along these lines are currently being undertaken, but the technology is still a long way from being mature enough to allow the practical realisation of telecentres capable of developing the economies and the flexibility which the vision foresees."[120]

SMEs: ICTs in traditional sectors

The use and implications of new Information Technologies and their implications for work organisation and skill requirements in SMEs are under-researched topics on which relatively little data is available. SMEs account for about half of employment in Europe and, accordingly, meeting their needs for networking, appropriate work organisation, Information and Communications Technology systems and skills is of vital importance to the economic future of the European Union. But telework is being introduced mainly by large companies, and many SMEs are not yet aware of the benefits or necessity for introducing new ways of working.[121] For example, teleworking is not in place yet in eight out of ten UK companies due to the nature of the work, lack of ICT support, lack of space in people's homes and inertia.[122] Doubtless, the great majority of these eight in ten companies are SMEs.

Most firms in the less advanced regions of the EU are SMEs, and most operate in traditional sectors. Indeed, in the EU as a whole, small firms employing less than 50 people account for about half of total employment - some 50 million jobs, and SMEs employing up to 250 people account for about 65% of employment.[123] Increasingly, such firms can only remain competitive if they learn to innovate. Often this involves learning to use ICT equipment and systems in their production processes, and in the products or services. There are huge opportunities for SMEs to use new technology to increase productivity and to increase quality - just a few examples are the application of Computer-Aided Design in foundries, the use of computer-controlled cutting in garment production, the use of production control in food and drink production and in crockery manufacture, and the use of computers to control stocks in retailing.

Where firms in traditional sectors do use new technology, they often use technology that is produced by their materials and equipment suppliers, and sub-contractors rely on their customers for precise specifications. But there is extensive evidence that firms which do not employ qualified scientists or engineers have great difficulty in absorbing knowledge from

[119] U. Huws and A.Denbigh. Virtual call centres -a new work solution for carers and people with disabilities, in Telework, '99, pages 126-128.
[120] Poynter and de Miranda, 2000, op.cit
[121] P.Johnston , Working towards the future, in Telework, '99 p18
[122] P.Hewitt, Work is Changing- The Future is Now, Telework 2000.
[123] Eurostat Yearbook

such external sources. Most firms in traditional sectors such as construction, food, plastics, clothing and mechanical engineering were founded by practical people, few of whom yet recognise or understand the need for graduates or technicians in scientific, technological or management disciplines. If there is nobody in a firm who can understand the knowledge generated in universities and Research Institutes, then the firm cannot use such knowledge. Firms cannot innovate effectively unless they employ staff who understand science, technology and modern management methods, and are able to apply them. But it is not sufficient for a firm to gain access to useful knowledge. It has also to organise methods for the internal diffusion of new knowledge and skills, to ensure that knowledge which is received from external sources is communicated and utilised effectively throughout the organisation.

The principal factor constraining firms' demand for scientific and technological knowledge is their own lack of scientific and technological capability. Universities play important roles in producing new knowledge and in educating students. But firms can only gain access to such knowledge if they employ people capable of reading the textbooks, journals and manuals in which it is published, and communicating directly with the people who produce it. There is a considerable amount of empirical research data which demonstrates that this capability is related to the educational level of a firm's staff - in particular to the employment of qualified scientists and engineers able to understand the output in terms of books and papers produced by universities and Research Institutes which generate new technology. Qualified staff can also participate in personal discussions with people who generate new knowledge. In principle, the higher the level of knowledge and understanding within the company (the more elevated its skills profile) the better its staff are able to be aware that new knowledge could help their business; and the better they are able to use new knowledge to improve the company's competitiveness.

EU and individual Government policies focus on encouraging individuals to learn throughout their working lives. This is very necessary to encourage economic development, but it is not sufficient by itself. Increasing the capacity of SMEs to locate appropriate new knowledge and technology and to apply it appropriately to their businesses has been relatively neglected. Particularly in less prosperous regions, one of the principal problems detracting from the European Union's competitiveness is failure of SMEs in traditional industries to modernise their products and processes by using new technology, in particular ICTs. The European Commission has programmes and proposals which help such regions. The vast majority of these programmes operate by increasing the supply of suitably educated and trained people, but the failure of SMEs to demand highly qualified workers is of at least equal significance to their capacity to innovate and become more competitive.[124]

Biotechnology

The major parts of the biotechnology industry both in Europe and the US are biopharmaceuticals and agricultural. Europe is catching up the US in terms of the number of biotechnology firms, but it lags behind in terms of sales and employment. In 1999 the US biotechnology industry employed 153,000 and the European industry employed 46,000. But in the five years up to 2000, the European industry grew faster than the industry in the US.

[124] P.Senker, op.cit 1999.

Nevertheless, barriers to the expansion of the European biotechnology industry include shortages of experienced managers and skilled researchers in some areas.[125]

High technology research

Europe is lagging behind the US in terms of bioinformatics activity, and most probably in relation to nanotechnology. Bioinformatics and nanotechnology are currently at the research stage, and the principal skill requirements are for highly educated scientific researchers: at the time of writing, no drugs have yet been developed as a consequence of advances in bioinformatics. While bioinformatics is far more advanced in Europe than nanotechnology, European firms perceive that recruitment of appropriately skilled and knowledgeable staff is one of the major barriers to entry into bioinformatics. The growth of medium-sized pharmaceutical firms is constrained by their ability to recruit staff with appropriate bioinformatic skills although there is currently an encouraging growth in the availability of appropriate courses[126].

High technology SMEs

While the vast majority of SMEs operate in traditional sectors, small high tech companies have great significance in contributing to innovation , productivity and growth of the economy as a whole.

The main barriers to technology transfer for small companies in high tech sectors are that it is difficult for the small number of people they employ to have sufficient time and a sufficiently wide range of knowledge and experience to cope with the numerous problems these firms face; and these firms are also often very short of financial resources. Some recent EU programmes appear to help these SMEs to overcome such obstacles, but the design of other programme do not seem to have taken the specific needs of SMEs or specific technologies into account. This has been overcome to some extent by SMEs relying on transfer of technical knowledge from supplier and buyer firms [127]. During the last 10 years, a substantial number of biotechnology companies have been created in Europe. During this period, EU member countries have stimulated the start-up and development of such companies, and co-operation between research centres universities and the companies. Many European biotechnology SMEs are intimately connected with larger firms as research collaborators suppliers of intermediate products, research materials and equipment, and they report that they have benefited from such links in a number of ways. The main method by which high tech SMEs overcome barriers to technology transfer is by building good informal relationships with academics and this includes bartering goods and services in exchange for access to university expertise. Companies offer lectures to students, or give valuable materials in return for university information, advice and help. The expertise needed by SMEs takes many forms, including market information (in parallel computing), use of university instrumentation (in advanced engineering ceramics and biotechnology) and scientific knowledge.

[125] Crowther et al., 1999, op.cit., page 161
[126] Crowther et al, 1999, op.cit., Annex A.
[127] Senker, J., 1997, Overcoming Barriers to Technology Transfer in Small and Medium Sized Firms in Campodall'Orto,S., (Ed.), *Managing Technological Knowledge Transfer - Proceedings COST A3*. Office for Official Publications of the European Communities, Luxembourg.

How firms' learning capacity can be stimulated

In order to improve productivity and enhance product and service quality, the most important direction in which it is necessary to enhance firms' learning capacity is to enable them to innovate effectively. This involves learning to use new science and technology in their products, processes and services, and learning to use new management methods. To do this, it is necessary to encourage firms to recruit new categories of staff, in particular technicians, graduates and postgraduates in scientific and technological disciplines such as ICT which are relevant to development of new activities. Such recruits have greater capability than existing less qualified staff for acquiring the knowledge needed to implement new technology. It is true that, in addition to universities, several Research Institutes in European countries offer scientific and technological knowledge to firms. But such Institutes' efforts to promote innovation are relatively ineffective because far too few SMEs employ sufficient people with the capability or knowledge to permit them to take full advantage of their services. [128]

Such problems are addressed directly by the British Teaching Company Scheme (TCS). TCS sets up partnerships between academic institutions and companies to bring benefits to industry, academic institutions and to develop a group of high quality, young, technical managers. The Scheme operates through programmes in which academics in universities join with companies to contribute to the implementation of strategies for technical or managerial change. Each partnership, called a TCS programme, involves academic participation with company managers in the joint supervision and direction of the work of at least one young graduate in a relevant discipline.

In firms that have not previously recruited graduate scientists or engineers, a TCS programme can put in place an organisational mechanism which initiates knowledge transfer from academia. It can also play a significant role in creating more favourable attitudes to the recruitment of such graduates[129]. Firms can enhance their capability to learn and innovate by recruiting the graduate Associates who work for them on Teaching Company Schemes. Their education and training also provides these graduates with the competence and contacts necessary to continue to 'network' outside the firm - with university staffs and with personnel from other firms. In this way, they can acquire knowledge which can help their firm to continue to innovate.

Similar schemes operate in other European countries - in EUNET club member countries - Denmark, France, and Ireland. Agencies in these countries joined with agencies in Austria, Germany, Norway and Sweden (with observers from the Czech Republic) to co-operate in 'T3net' a two year project funded by the European Commission. Their principal activities included international technology transfer fellowships, further promotion of the technology transfer and training concept; and provision of familiarisation courses for officials of agencies wishing to establish similar programmes. It has been suggested that "Given their almost

[128] See for example Entorf, H. and Kramarz, F., (1997), "Does Unmeasured Ability Explain Higher Wages of New Technology Workers?", *European Economic Review,* 41(8) pp1489-1509, and IRDAC (1991), *Skills Shortages in Europe*, Industrial Research and Development Advisory Committee of the Commission of the European Communities, Brussels.
[129] Senker, P., and Senker, J., (1994)"Transferring technology and expertise from universities to industry: Britain's Teaching Company Scheme", *New Technology, Work and Employment,* 9(2), pp. 81-92.

universal success, it is not unreasonable to foresee the spread of programmes combining technology transfer and training throughout Europe and beyond" [130]

SMEs' capacity to absorb new science, technology and management methods needs to be stimulated. This can be achieved by increasing their willingness to recruit people with the necessary education and training in relation to science, technology and new management methods. At the same time, they need help in learning how to organise to diffuse new knowledge internally so as to ensure that knowledge received from external sources is communicated and utilised effectively throughout the company.

Some organisations such as the British Teaching Company Scheme fulfil this function, and similar organisations operate in several other European countries, mainly the more prosperous ones. But the success of specific organisational mechanisms depends on the culture and institutions of the particular countries in which they are located. For example the capabilities and motivations of those who work in higher education and in Research Institutes vary between countries. There are variations between countries in the ways in which universities are run and financed. For this reason, and because of differences in culture between countries, it is much easier to persuade academics in universities in some countries to devote their time and attention to the needs of manufacturing industry than it is in others. Moreover, in some countries, it is very difficult - perhaps impossible - for Governments to establish, foster and sustain organisations with the high degree of autonomy enjoyed by the Teaching Company Directorate which runs Teaching Company Schemes in Britain.

For such reasons, it is not always possible simply to transfer organisational mechanisms which work well in one country to every other European country. For organisations to be effective, they need to be tailored to the culture and political institutions of the countries in which they are located. This highlights the need for organisational innovation on a European scale. Organisational innovation is as necessary to economic development as are scientific progress and technological innovation.

To meet the needs identified would involve resource-intensive programmes and actions to develop, design and pilot new types of organisation. One possible approach could be to seek to apply the concept of "extension" to manufacturing, and perhaps to service sectors in Europe. Agricultural extension workers have been highly successful in modernising agriculture in several countries including the United States by going out to farmers to promote the use of new technology actively. There are schemes to apply the concept of 'extension' to manufacturing in the United States - appropriately educated and trained workers go out to manufacturing firms and help them to reshape their organisations to facilitate learning. The Manufacturing Extension programme was developed to support the innovative capacities of SME manufacturers within a region. Support included individual project engineering, training courses and assistance in selecting software and equipment.[131] Such approaches could be adapted to be suitable for some countries in Europe, and could provide the basis for the design of effective organisations on the scale necessary to meet the needs outlined. [132]In view of the

[130] Monniot, J., (1998) Adding international dimensions to people and technology, *Industry and Higher Education*, Vol. 12., No 1.

[131]Crow, M., and Bozeman, B., (1998) *Limited by Design: R&D Laboratories in the U.S. National Innovation System*, Columbia University Press, pp67-69.

[132]Senker, P., Education and training for innovation: individual and organizational learning, in The IPTS Report, No 39, IPTS/JRC, Seville, November 1999, pages 20-25

enormous size of the SME sector in terms of employment; and in view of the very large employment in SMEs in traditional sectors, sustaining and increasing this employment by enabling SMEs to use new science, technology and management methods effectively must surely be a high priority. There is, therefore, an urgent need for research and development followed by pilot schemes to establish organisations able to fulfil such functions in member countries, especially in those where conditions are unfavourable for application of Teaching Company type approaches.

Networking is essential to the success of many SMEs, especially of science and technology driven enterprises. International business is becoming increasingly networked and is facilitated through partnerships with overseas distributors, trading companies, complementary manufacturers and other specialist suppliers in addition to traditional buyers and sellers. Advances in information, communications and transport systems have resulted in significant reductions in business transaction costs. Despite their resources constraints, SMEs can now take advantage of telecommunications, the Internet and e-mail to make operating in international markets a viable, cost-effective possibility for SMEs unable to contemplate such a move previously. But often they lack knowledge of developments they need to know about so as to compete in an increasingly global environment. Even within small firms, information channels may be very complex, giving further scope for the constructive application of IT.[133] Recent advances in technologies - ICTs in particular - have accelerated already rapidly changing skill requirements in SMEs. The enormous number of SMEs need to be able to modernise their products, production processes and/or services to take full advantage of the productivity and quality improvements made possible by ICTs. But there is extensive evidence that firms which do not employ qualified scientists or engineers have great difficulty in absorbing knowledge from external sources. Firms cannot innovate effectively unless they employ staff who understand science, technology and modern management methods, and are able to apply them. But it is not sufficient for a firm to gain access to useful knowledge. It has also to organise methods for the internal diffusion of new knowledge and skills, to ensure that knowledge which is received from external sources is communicated and utilised effectively throughout the organisation.[134]

Numerous ICT companies, some of them very large, are devoting immense resources to the development of a vast variety of products and services in competition with each other; but also to some extent in collaboration with each other so as, for example to facilitate the construction of unified user-interfaces so that users perceive that they have access to unified systems. The principal customers are large corporations whose aim is to increase their profitability. The consequences for work organisation and skill needs are extraordinarily difficult to predict.

In seeking to exploit the potential benefits from such developments, corporate systems purchasers may often neglect to take full account of the needs, skills, expectations and desires of their own employees, and their needs for training. This is not only undesirable in 'human' terms, but is also liable to lead to inefficiency in the use of systems, and in many cases, as is by no means unknown in the past, to catastrophic failure of systems to perform in accordance with the specifications which they were designed to meet.

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[133] S. Macdonald et al., Information for Innovation in SMEs, The impact of the education and training provided by the Yorkshire and Humberside Universities Association, Sheffield University Management School, 2001.

[134] P. Senker 'Education and Training for Innovation: individual and organizational learning', *The IPTS Report*, November, pp 20-25, 1999.

The net result of all this effort is extremely difficult to predict. However, certain immediate trends are clear, for example that teleworking, telecommuting, working from home using IT facilities, are likely to continue to expand rapidly, if only because they meet corporate needs in terms of reduced overheads and, also, generally, are concordant with individual needs and desires. The expansion of call centres, and their development into an even larger proportion of employment, seems set to continue for some time, although their increasing displacement by virtual telecentres is likely to take effect at some time in future. However, here, not only the broad direction of future development controversial, as it is in so many aspects of the IT revolution, but even the capability of the technology at present arouses controversy.

In terms of employment, the European biotechnology industry is still quite small, but growing fast. While production is growing rapidly, R&D is still highly significant in terms of its employment. Overall, principal skill requirements are for highly educated scientists. Both bioinformatics and nanotechnology could begin to have significant effects on the European economy and employment within the next ten years, and very major impacts within 20 years. However, it is practically certain that some of the applications envisaged at present will be extremely important, and that some will fail completely. At this stage, it is quite impossible to predict which will succeed and which will fail. Both these technologies are currently at the research stage in which their principal requirements for skilled scientists, a high proportion of them with doctorates. Within, say, the next ten years, some applications of these technologies may well move out of the laboratory and into design and production. This could well have significant effects on requirements for production workers. But it will only begin to be feasible to predict the size and nature of such requirements at a time when it becomes clearer which applications will actually prove successful. Bioinformatics results from the application of ICT to biotechnology, and could have important implications for employment within the next ten years or so. No doubt there will be other future significant interactions between new technologies such as between nanotechnologies and other rapidly changing technologies which will be significant for employment over a longer period.

Twenty five years ago, the few people who predicted that computers would eventually be so cheap and powerful that they would be widely used in small businesses and even households were thought to be harmlessly insane: it was more generally thought at that time that domestic robots would be in widespread use in households. Ten years ago, mobile phones were hardly noticed, and yet now the implications of third generation mobile phones for work organisation and skills is now a relevant topic for consideration. Similarly, within ten years from now, there will undoubtedly be widely diffused technologies and interactions between technologies that hardly anyone has heard of yet. Accordingly, the problems of realistic prediction of implications for work organisation and skills over more than five or ten years are immense.

Because of their immense contribution to employment, the skill needs of SMEs arising from their use of networking and other technology, and implications for the ways in which they organise work are of great significance to the future of the European economy. But this is an area that is grievously under-researched - and, partly because of the huge number and variety of SMEs - it is difficult to give this subject the close attention it merits. In view of the very large employment in SMEs in traditional sectors, sustaining and increasing this employment by enabling SMEs to use new science, technology and management methods effectively must be a high priority for the European Union. There is, therefore, an urgent need for research and development followed by pilot schemes to establish intermediate organisations able to stimulate SMEs to demand higher level skills in member countries, especially in those countries where conditions are unfavourable for application of the Teaching Company type approaches outlined above.

8.3 Sectoral outlook

Of key concern are the relationships between R&D expenditure, technological change, output growth and employment growth. Since the past cannot provide an exact guide to the future some qualitative judgments are required and have been made in the report. The past does, however, provide some guide to the future and it seems sensible to draw on the accumulating empirical work of the OECD and others on the structural and quantitative nature of these key relationships. These empirical studies have focussed on the Information & Communications Technology (hereafter ICT) sector but have application to technological change generally and will be referred to repeatedly in this review.

A distinction between the ICT sector and non-ICT sectors of the economy is usually made in published academic studies of ***recent*** technological and structural change. Within the ICT sector a further distinction is also frequently drawn between ICT-producing and ICT-using sectors. The OECD has recently formulated a definition of the ICT sector[135]. Country-level studies of Canada and Finland use variants of that definition. So also does the Groningen ICT data-base, which covers many countries over the last decade.

The OECD ICT-producing and ICT-using sectors distinction is a satisfactory nomenclature that encompasses the relevant technologies and permits one to draw on published work on the ICT sector. That work identifies the quantitative relationship between R&D expenditure and technological change, as measured by Multifactor Productivity (hereafter MFP) and between MFP, capital deepening and employment. While it is true that these historic relationships are largely associated with ICT and that they may differ for new technologies they, nonetheless, have facilitated the best available quantitative mapping between R&D spending, productivity growth, output and employment.

[135] OECD (2000) Working Party on Indicators for the Information Society, *Measuring the ICT Sector*. Paris. Measuring the size of the ICT sector and its contribution to growth differentials is covered in;
Paul Schreyer (2000) *The Contribution of Information and Communications Technology to Output Growth: A Study of the G7 Countries.* STI Working Paper 2000/2. OECD Directorate for Science, Technology and Industry. March, 2000.
Dirk Pilat and Frank C. Lee. (2001) *Productivity Growth in ICT-Producing and ICT-Using Industries: A Source of Growth Differentials in the OECD?* OECD Directorate for Science, Technology and Industry. OECD. STI Working Papers 2001/4. June 2001.

8.3.1 Measuring the Technology sector(S)

Available datasets suffer from a number of measurement deficiencies[136]. For example, the price deflators that are used in converting nominal to real values in the ICT (Information & Communications Technology) sectors differ substantially from country to country. Some are constructed using *hedonic* pricing methods to account for quality changes (which are especially important for ICT goods, for example, personal computers) while others do not. In other countries quantity indexes that do not allow for quality changes are used. The evidence suggests that some of the observed inter-country differences in ICT output performance is a chimera of these differences in measurement methods. For example, Pilat and Lee (2001)[137] suggest that the measured rapid decline in the ICT production price indices for France and the U.S., the gradually declining Danish index and the relatively stable indices for other countries that have been observed since 1984 "is likely to reflect to a considerable extent the use of a hedonic deflator in both France and the United States, the use of an adjusted hedonic deflator in Denmark and the use of conventional deflators in other countries."
These price deflators are used in calculating real ICT output. It follows that real output is incorrectly measured and is not strictly comparable across countries. This, in turn, means that measured values for the elasticity of employment with respect to output will differ from their true values. For example, other things constant, the measured elasticity for France is biased downwards relative to Denmark and, more so, relative to other non-US countries.

Relevant OECD datasets[138] that document R&D spending in Europe distinguish between spending in High, Medium and Low-Technology sectors. There is an overlap between the industries included in the High-Technology and the ICT sectors they are not identical. The OECD R&D database has the advantage of being more broadly-based and, hence, more relevant to wider set of technologies considered in Section 3.3. of the IPTS/ESTO study.

The level and distribution of R&D spending in Europe is the key policy variable that is used to distinguish the five policy platforms or scenarios set out in the IPTS/ESTO report. It is unfortunate that some data-set incompatibilities hinder the statistical estimation of key structural parameter estimates for a key relationship in that study. However, valuable insights on methodology and quantified outcomes are available from this work.

[136] For a full review of these see
[137] Pilat and Lee, 2001. *Productivity Growth in ICT-Producing and ICT-using Industries: A Source of Growth Differentials in the OECD.*
[138] Insert citation of OECD datasets here.

8.3.2 R&D Spending & MFP Growth

R&D (Research & Development) spending quickens MFP (Multifactor Productivity) growth. Correspondingly, it reduces the amount of labour required to produce any given level of output. It follows from these considerations that the five R&D-driven policy platforms outlined in Part 1 of the study would benefit from a more exact and documented specification. The effects of R&D spending on MFP growth need to be incorporated explicitly when making employment forecasts from the output projections.

Perhaps the most relevant study here is the recent study by Guellec and van Pottelsburghe de la Potterie[139]. Their principle findings are;

(i) Multi-Factor Productivity (MFP) growth in a country responds to indigenous R&D spending in that country.
(ii) Multi-Factor Productivity (MFP) growth in a country responds to 'spill-over' effects from R&D spending in other countries.
(iii) The size of 'external' R&D spillover effects are generally larger than domestic R&D spending effects and depend on the R&D intensity and technological proximity of the home country.
(iv) The long-run MFP effects of R&D spending differ significantly from the short-run effects.
(v) The measured MFP effects of R&D spending clearly depend on the level of factor utilization (or state-of-the-cycle).

[139] Dominique Guellec and Bruno van Pottelsburghe de la Potterie (June 2001) *R&D and Productivity Growth; Panel Data Analysis of 16 OECD Countries.* STI Working Papers 2001/3. OECD.

8.3.3 The R&D Policy-Output Growth Relationship

A key purpose of the study is to model the effects of a set of technology policy interventions on output levels and growth rates at sectoral and regional level and to derive the implications for employment, education and training. While it is acknowledged that technology policy takes a variety of forms (such as taxes, subsidies, patents, education) these are afforded a background role in the study: the key and dominant policy emphasis is placed on the level and distribution of R&D spending. The general technology ***policy stance*** is measured by how R&D spending compares with that prevailing in the US or Japan. The five particular ***policy scenarios*** considered in the study refer to specific regional and sectoral distributions of a given R&D budget.

Endogenous growth models, dating from the work of Romer (1986)[140] allow output (and output growth rates) to depend not only on conventional capital and labour factor inputs but also on R&D inputs. Moreover, they allow for sectoral 'spillovers' i.e. R&D spending in a particular ICT sector may affect output levels not only in that sector but also in other sectors. (The World Wide Web is an oft-cited example of such a 'network' spillover.) A key implication of endogenous growth models is that output growth and labour productivity growth rate projections are conditional on the projected level and distribution of R&D spending. We have earlier alluded to the effects of R&D spending on Multi-Factor Productivity (MFP). That relationship is essentially a production technology relationship affecting the costs and level of supply of output. What is at issue here are the resulting effects on the relative price and demand for output.
It would appear that no allowance is made for R&D productivity 'spillovers' in the current work. I infer this from the following quotation 'Sectors where R&D spending is not increased will keep their current productivity growth rates'[141]. Two additional considerations are important in gauging the likely effects of R&D spending on productivity growth rates. First, does the production technology exhibit constant or increasing returns to scale?[142] If the latter is the case then productivity growth rates increase with size or scale. The Ruhr valley or, more recently, 'Silicon' valley are cited as examples. (In a different economic geography context, urbanization is also cited as an example of increasing returns.) The basis of increasing returns production is market size and the economic specialization it permits. For our purposes the importance of increasing returns lies in its implications for the efficiency and distributional effects of R&D spending. Regional and sectoral industrial concentrations are to be encouraged if there are positive industrial agglomeration effects from R&D spending - an opposite policy may be regarded as more 'equitable' to smaller regions/sectors but will carry the expense of output and efficiency losses. These potential trade-offs between efficiency and equity are not explicitly articulated or identified. Of course, the 5 nominated policy platforms that are identified will have different identified output and employment consequences but the regional distribution of those outcomes and, the regional distribution of R&D support that will be required to achieve them is not explicitly considered. It is possible to deal with these issues more satisfactorily in an optimizing framework. I will return to this later.

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[140] Romer (1986)
Romer (1990) *Endogenous Technical Change*. Journal of Political Economy 98, pp. 71-102.
[141] Ibid. p,8
[142] Insert reference to discussion in dynamic I-O model here.

Second, a Concentrated Technology policy requires an application of the equimarginal principle to R&D allocations i.e. R&D spending is allocated to those sectors and regions where it has greatest effect until those effects are equalised across all regions and sectors. In order to operationalise this policy one also needs to know if there are diminishing (output growth) returns to R&D spending in the constituent sectors/ regions and at what levels of R&D spending these set in. The output growth equation needs to be specified as a non-linear function of R&D spending in order to identify these effects.

While an advantage of the GEM-E3 and ASTRA models is that they can incorporate the effects of ***competition*** with and ***trade*** between the EU and other world regions (notably US and Japan) they suffer the disadvantage of an inadequately specified R&D policy - output growth relationship.

Foreign Direct Investment (FDI) is an important vehicle by which technology is transferred from one country to another, especially the smaller countries. Finland and Ireland have both had exceptional FDI and MFP in recent years. Many factors attract high FDI including a low corporate tax environment and an educated labour force. Many of the Candidate Countries share these characteristics. Hence, it is likely that FDI will be re-allocated in favour of the Candidate Countries after accession: the overall scale of FDI in the EU region may decline. These factors are, of course, difficult to project. It would appear that no attempt has been made to incorporate them into the output projections. The implicit assumption of 'no change' in relation to FDI is unlikely to be met in the circumstances.

9 *Impact of technology policies*

This study has investigated the effect of various policies relating to technology and employment. In this sub-section, we discuss a number of strands in the field of technology that are affected by policy measures. We look at four of these –R&D-push and demand-pull, public and private R&D, diffusion of R&D, and business sectors. We also consider the role of other policies with respect to technology policy.

9.1 R&D-push and demand-pull

An R&D "push" strategy promotes new technology directly to the next level in the chain, be they technology transfer organisations or industry sectors companies, suggesting that the producer drives market demand. An open-ended technology push strategy - aimed at forcing the introduction of new technologies - is thus no longer acceptable as an effective instrument for sustaining economic growth. However, it should be noted that the basic research funded by governments at universities, and in their own research establishments, results in some new technology and in many incremental contributions to emerging technologies.

One effective method of creating more "pull" on a new technology is to introduce a market orientation. A key step in this strategy is to reduce the cultural gap that exists between government aspirations, industry capability and consumer response. Thus a pull strategy may begin with an assessment of demand pressure from the consumer. This application of market principles to encourage the commercial uptake of publicly funded technology is particularly valuable in the international marketplace.

The recognition that new technologies are a driving force for economic growth compels governments to attempt to tune R&D-push and industry/consumer demand pull. The rationale for intervention is based on the need to maintain economic growth and full employment and, in the current climate, usually needs to demonstrate compatibility. The result is often a cycle in which governments seek to track and respond to deficiencies in the market. Sometimes the push and pull interventions are effective, but on other occasions they occur too late or have little impact due to other factors. A further complication is that it is usually difficult to detect the impact of policy measures, even in the medium or long term.

We now turn to the impact of the different policies suggested earlier in this report on this component of technology policy i.e. what implications arise for R&D push and demand pull strategies if the proposed technology policy scenarios are adopted? The points and arguments set out above lead us to conclude that demand-pull R&D strategies are likely to result in less risky, incremental new technology products. R&D-push strategies involve higher risk, but the chances of technological breakthroughs with higher rewards are increased. Which of the technology policy scenarios will encourage more R&D-push and which imply more demand-pull R&D? The quantitative analysis of the study suggests that the *concentrated technology policy* will result in more R&D-pull and basic research effort with respect to the *background scenario*. As the title implies, the *uniform scenario* will not influence the relative amount of

R&D-push and demand –pull. The *diversified scenario* is likely to result in a reduction in R&D-push and more demand-pull.

9.2 Public and Private R&D

Public funding of R&D is an established instrument of technology policy. It affects private R&D expenditure, and according to the assumptions of the scenarios, it should do so in a positive way through complementary or stimulated activity. A number of studies point to significant spillover effects from public R&D. Thus, the main strengths of public relative to private sector funding tend to be associated with broader strategies and social benefits. Public R&D pulls together a wider concerted effort on priority fields. Public funding encourages increased cooperation between academia and industry. Public good objectives such as the generation of accessible codified knowledge, and the development of skills, are more effectively met. Public subsidies overcome the narrow view taken by individual companies and, to an extent, the secrecy driven by a need for competitive edge and profit. In addition, public funding is considered to stimulate private investment in R&D.

However, the positive effects of public R&D have been contested in the literature. Some studies have concluded that increased public R&D expenditure may have an adverse effect if companies see it as a way of reducing their internal R&D expenditure, by the substitution of or "crowding out" of their own research efforts. Massive increases would distort innovation activity by encouraging those seeking subsidies. It is necessary to put the relative impact of public and private R&D into perspective. Private R&D is likely to have a greater impact on employment than public R&D, if only by virtue of its relatively greater magnitude in most countries. For example, EU funding is only 1-2 percent of total R&D funding in Europe. It has been claimed that R&D funded programmes by themselves do not make a substantial difference to the rate and direction of technical change in Europe. Experience has also shown that governments' ability to predict applications of new technologies is limited.

In broad terms, current public R&D is more socially oriented towards the environment, biotechnology, and health and the life sciences, while funding for defence and energy is being reduced. Larger, strategic industries are likely to benefit more from public R&D unless sectors are specifically targeted, whereas SMEs are more likely to gain equal benefit from tax incentives. Direct subsidies are usually made available to support four main activities - academic/industry networks, new high tech (start-up) companies, international collaboration, and tax incentives. The first three allow governments to target areas with higher social rates of return. Tax incentives give companies more freedom of choice in the R&D they do, and they may choose short-term projects with little social rates of return, resulting in weaker spillover.

The above conflicts direct R&D policy towards an appropriate set of actions aimed at influencing or controlling the factors which will constrain the technological performance of companies. Policy instruments are based on the rationale that support should be additional, it should result in greater social benefit, and it should provide higher extra benefits. Thus technology policy is not implemented to achieve intrinsically technological goals, but as a means of action aimed at improving social and economic welfare. The relevant questions for an effective technology policy are therefore about the ultimate goal, the objectives, targets and instruments, and the level of efficiency achieved.

We now look at the implications of the alternative technology policies for public and private R&D. The *background and uniform scenarios* provide the basis for the current position and a continuation of the status quo. A more *concentrated technology policy*, promoting new technologies, is likely to have a more stimulating effect on business, but with greater risk of failure if the chosen technologies fail to result in more effective processes or attractive products. However, the additional resources suggested are modest in relative terms. The *diversified scenario* will provide more investment in areas of lower technology where stimulation of the industries is expected to be more difficult and have less dramatic effects.

9.3 Business sectors

Industry comprises a complex and overlapping set of sectors with embedded emerging and mature companies - large, medium and small - and with a range of short and long lifecycles of processes and products. The company profiles of business sectors can differ markedly from sector to sector. In biotechnology there are a large number of independent, high-tech SMEs driving technology forward. In the aerospace sector, a few large companies, with an extensive supplier base of SMEs dependent upon them, dominate the market. The disparate times taken to develop technology may vary from rapid products in the electronics sector (which may mature in one or two years) to those using new materials in the aero-engine sector, which may take an order of magnitude longer to reach production. A further layer of complexity arises from the fact that some sectors are essentially process based, where innovations may take place incrementally and where employment may be reduced as a consequence, at least initially. Other sectors are primarily product based, and it is here that new technology usually has the greatest impact, with more positive effects on employment.

Given the above complexity of business, it is not a straightforward task to formulate and implement a technology policy that will achieve maximum value in terms of impact on employment across all business sectors. However, some studies have attempted to show how different policy instruments may be used effectively in different sectors. In one case, R&D co-operation and subsidies were suggested as the most appropriate policy instruments for the aerospace sector (a complex system of innovation), whereas bridging institutions to facilitate diffusion were thought to be more relevant to the high-tech biotechnology sector.

Foresight studies have sought to identify strategic areas of technology, and sometimes time-scales to maturity. A recent IPTS document has identified a number of demand driven S&T themes (including those based on knowledge, health and sustainability) and a set of enabling themes (including gene, information, communication, and nano-technologies, advanced materials and complex systems). An important issue is to reconcile the growth of industry-based new technologies with the widening use in service-based activities, such as the fast-growing services. For instance, the impact of the high technology industries and knowledge intensive services became more apparent in the last decade.

What impact will the different technology policy scenarios have on business sectors? The *background and uniform technology policy scenarios* already provide more emphasis on advanced technologies. The *concentrated technology policy scenario* will provide some further help to the high-tech sectors to maintain their position in international markets. Business decides to base its R&D locations on a number of factors and it is unlikely that a shift towards a *more diversified technology policy* with a regional focus will have much effect.

9.4 Diffusion of R&D

Diffusion is essential if research is to be taken forward to exploitation. As noted above, it is at the diffusion and application stages that the benefits of increased productivity, and perhaps employment, accrue. The efficiency of diffusion processes is a key determinant in the utilisation of technology. There are two issues here, one relating to the attitude of researchers (whether in public or private organisations) and the other to the methods employed by them to make their research known to others. In the first case, many researchers in public institutions prefer to communicate their results primarily to other researchers in their field. Similarly, researchers in private organisations may be prevented from publishing all of their work outside for reasons of commercial confidentiality. Where widespread impact is intended, it is more likely to be achieved by improving the direct and indirect channels to users and other beneficiaries (networks, publications, mobility, consultancy) rather than by trying to measure and interpret what use has been made of research. However, this would create a problem for policymakers who are required to provide some justification for research expenditure through evaluation of major programmes. In general, qualitative methods of evaluation produce useful guidance for the organisation and implementation of R&D.

We reiterate, technology transfer is inherently a marketing problem. Action to identify target markets, select markets with a high probability of adopting technology, and work with companies to develop marketable products will provide greater yields from research activity in the marketplace. Thus, EU R&D programmes usually include a dissemination strategy for the research results. CORDIS acts as a support instrument for the more effective diffusion of EU research and technology. The instrument includes a database of EU funded projects, measures to facilitate participation in projects, and access to funding at the upstream side, to the Innovation Relay Centres, technology marketplace and technology implementation plan downstream.

What are the key issues relating diffusion and the technology policy scenarios? The *background and uniform technology policy scenarios* reflect the current position in the Framework Programme that requires researchers to disseminate their research results. Arrangements are also made to evaluate the impact of major EU R&D programmes. A greater amount of quality research is expected to flow from the *concentrated technology policy*. There is likely to be more involvement of research institutions in the more advanced technological fields, and more patents should emerge, suggesting that this policy will provide the most effective diffusion of research results. By contrast, we assess that the diffusion from the *diversified technology policys* will be less effective. In the former case, the regional effect may encourage introspective behaviour with local diffusion in national languages. In the latter case, the technology may be less advanced and therefore less likely to spillover into other areas.

9.5 Comment on the impact of technology policies

In attempting to map the impact of the different technology policies over the next two decades, we need to consider the path down which current and developing policies are taking Europe. These are embedded in the major policy instruments, the Framework Programmes.

The Fifth Programme sets out the priorities for the EU's research, technological development and demonstration activities up to 2002. Four thematic programmes prioritise quality of life and management of living resources, user-friendly information society, competitive and sustainable growth, and energy, environment and sustainable development. There are three horizontal programmes that focus on confirming the international role of community research, promoting innovation and SMEs, and improving human research potential and the socio-economic knowledge base.

The next Framework Programme for research and innovation in Europe will cover the period from 2002 to 2006. This new programme is expected to concentrate funds on key priorities, helping research teams work in networks, and improving the mobility of researchers. The key emerging technologies and research priorities are likely to be genomics and biotechnology for health, information society technologies, nanotechnologies and intelligent materials, aeronautics and space, food safety and health risks, sustainable development and global change, and citizens and governance in European society. More funds will be provided for SME participation, help with IPR, access to capital and partners, and researcher mobility activities.

We have reviewed the elements of the current and next Framework Programme to demonstrate that any shift in European technology policy based on the outcome of the scenarios in this report will occur in the medium and long term. Impacts from the current Framework Programme may be seen about 2005. Similarly, the next Framework Programme is likely to influence the period up to 2010. We should therefore expect any major decisions taken as a result of the conclusions of this report and other advice to influence European employment and competitiveness from 2005. We have seen that public R&D is considered to have only a marginal effect on employment. Therefore we are drawn to conclude that any modest increase in funding will not have any significant effect, even if the funds are distributed through the most optimistic scenario (*concentrated technology policy*) produced by the models earlier in the report.

Our conclusions on the impact of the technology policy scenarios flow from the above discussion around R&D-push and demand-pull, public and private R&D, diffusion, and business sectors. If the next (2002-2006) Framework Programme, or the one following it, is provided with additional support for the development of new technologies, the actual impact may prove to be less than the predictions. However, if we consider technology policy alone, our view is that the *concentrated technology policy scenario* is most likely to deliver some additional benefit over the period between 2005 and 2020, from the relatively modest investment being considered. There may be other ways of allocating the additional resources more effectively. We will revisit this provisional finding after we have considered the role of other policies in terms of technology.

9.6 Role of other policies

Other policies, often not specifically addressed as technology-type issues, may nevertheless have powerful if indirect effects on relating technology growth to employment growth. Indirect policy-making procedures are rarely linear or rational models of decision-making, and are more likely to occur through adjustment, improvisation, and bargaining. Impact may appear straightforward, but it is more often controversial, incremental, difficult to detect, and take a long time to appear ("creep"). The impact of policy measures on employment should consider a wide range of factors including income, tax, productivity, competitiveness, skills, industry sectors, and investments.

Other EU policies that bear directly or indirectly on technology policy are those focused on "households", education, employment, industry, and macroeconomics. Each is linked to technology in different ways, as we will illustrate briefly in the following sub-sections.

"Household" policies

A main factor considered is the change in composition of households, particularly the employment of adult women. More women are entering technology-related work. This trend is likely to continue given the active encouragement in EU policies. In addition, the rates of women's pay are rising towards the level of men's as more women move into higher skilled jobs. The age structure of the European workforce is also under scrutiny and proposals have been put forward to attempt to raise the participation of older workers. The level of "motor skills" are declining, whilst "cognitive and interactive skills" are increasing in Europe. As far as technology is concerned, the effect on skills may be to introduce new ones or replace old ones with machines.

Education policies

Education provides skilled people to generate and apply technology, fitting them for training in particular tasks. Education also acts as a source of creativity and provides the means to absorb and apply new knowledge. In most areas, new technology requires a broader and greater depth of skills, making education and training a rate-determining factor in the successful application of new products and processes. Hence, a major challenge for education policy over the next two decades will be to ensure that there is an adequate supply of skilled people to work in emerging technological fields and to have the vision to apply them more broadly.

EU policy on education to 2006 is wide-ranging, covering aspects relevant across the spectrum from schools to lifelong adult learning. Many areas are aimed at developing skills that will later be used by those who pursue careers in technological fields; in other areas adults will be helped to improve their skills through vocational training. More directly linked to technology is the Marie Curie Fellowship scheme. This action provides grants to support researchers training in countries other than their own, but within the European area. Whilst the impact of this scheme on the development of European researchers and institutions is undoubtedly significant, these impacts are less easy to detect than those from technical innovations. Nevertheless, the Commission has developed a methodology for assessing the scheme's impact and plans to implement it over the coming years.

A strong and relevant education policy is therefore a vital precursor to the attainment of the goals of technology policy. The two policies are also mutually interactive in that new technologies provide material for many courses in higher education institutions.

Employment and unemployment policies

Cyclical movement of employment and unemployment rates can have a braking effect on technology. The current labour pool comprises a mix of full-time, part-time and temporary workers, and the short and long-term unemployed. Since the majority of the 2020 workforce has already been born, forecasting the labour supply at that time should be possible with reasonable certainty. Many part-time and temporary workers are young people. These have the potential for some beneficial effects, for example allowing more time for learning, but there is also instability as a significant number of worker move regularly from contract to contract, or in and out of employment. EU legislation has been introduced to contain the growth of temporary contracts.

Levels of employment will affect the growth of new technology. Unemployment in Europe is relatively high, but many of those without work are low or unskilled people who would not be suited for new technology work. Training and re-training programmes are therefore needed to ensure that there is an adequate pool of skilled labour for the technological areas being promoted by the EU.

Industry policies

Current EU policy on SMEs is embodied in the Multi-annual Programme on Enterprise and Entrepreneurship for the period 2000 to 2005, and focuses on the new economy challenges for the SME. The main areas of action are aimed at enhancing growth and the competitiveness of business, promoting entrepreneurship, simplifying and improving the administrative and regulatory environment for business, promoting research, innovation and business creation, improving the financial environment for business, and giving business easier access to Community support services, programmes and networks. The policy seeks to create a climate of confidence among enterprises by making business start-up easier and more attractive, and lowering the cost of doing business. Innovation is recognised as a critical process, driven by competition, technology and research, but dependent on the ability of enterprises to use their human and intellectual capital to exploit market opportunities.]

The preceding discussion implies that much of the growth of employment, in high-tech and indeed other areas, is expected to come from SMEs. However, market requirements drive industry to focus on the short term. This is especially so in the case of SMEs whose horizons are usually based on months rather than years. With new technological areas orientated towards the longer term, or where there is little prospect of short-term applications, it is no surprise that the overwhelming majority of SMEs have no practical interest or enthusiasm for this area, and will rely on picking up old technology from larger enterprises. But the small proportion of enlightened SMEs, often started up by an entrepreneur with an innovative concept, or spun off from a university or larger company, act as seedcorn for future technological growth. A fundamental issue is therefore how to identify and then encourage the SMEs who will make a real contribution to the advancement of technology and hence employment.

An area of concern to industry is the protection of patents resulting from innovations. Patents fall within the intellectual property rights measures overseen by EU trade policy. Europe is good at scientific performance (relative to publications) but less effective at technological and commercial performance (as measured by patents etc.) and declining in these respects relative to the USA and Japan. In 1999, the number of patent applications to the European Patent Office was almost 45,000, an increase of 40 percent on the 1990 figure. About 20 percent of patent applications were categorised as high-tech.

A global, uniform system of intellectual property rights will be difficult given the differences in national systems. Historically, the development of ipr has been influenced by national needs to encourage inward technology transfer and national innovation, to support and regulate individuals and industry. In Europe, the EU is seeking to find a balance between harmonisation of ipr across the Community or letting the nation states set their own system of inventor protection and dissemination. EU policy on ipr must reconcile individual rights with the provisions of Community law on the free movement of goods and services, and on competition and antitrust. New technology has made protection more difficult in some areas where the ability to copy protected works has been made easier. A need has been identified for more efficient IP management in the technology transfer process.

The actions adopted in the above policy areas – and particularly those in education and employment – will have a major impact on technology policy. An adequate labour pool must be available to carry forward innovations and new technological developments. Within this pool there must be additional people with the required skills to maintain progress commensurate with the level of additional funding proposed under the alternative technology policies. There would be little point in increasing funding under technology policy if few skilled workers were available to undertake R&D.

We should also note that EU policies for competition and other forms of regulation, trade and investment can also have a major influence on technology and employment. We have concluded that EU R&D funding is in itself too small to have a major influence on the rate and direction of technical change in Europe; but these other policies can influence corporate decisions on technical change. More impact may therefore be achieved through the raft of direct and indirect policy instruments.

It is to be expected that the range and complexity of EU policies will result in some conflicting objectives. However, it is vital that where areas of policies overlap, or have similar objectives, actions are co-ordinated to ensure the most effective use of public funds. Less impact will occur from additional investment in R&D if technology and other policies are not synchronised, or worse, are found to be acting in opposite directions.

9.7 Policy mesures to stimulate R&D development

Increased productivity, employment and innovation is a priority of all Member States and of the European Commission. One fundamental challenge facing the high-skill sector is whether the existing training and skills formation system is capable of equipping future R&D workers with the requisite high-level skills and breadth of competences needed to take full advantage of new technologies and organisational innovations. It will be suggested that, at the top end, knowledge is moving too rapidly to be encoded and institutionalised into a stable set of occupations, and hence new mechanisms are necessary to facilitate the effective generation and transmission of knowledge between higher education institutions and business.

The emergence of the knowledge-based economy has profound effects on the organisation of R&D activities, and the types of skills and knowledge required for production and innovation activities. Throughout Europe, hundreds of policy measures and support schemes aiming at taking full advantage of new technologies and organisational innovations have been implemented or are under preparation. The diversity of these measures and schemes reflects the diversity of the framework conditions, cultural preferences and political priorities in the Member States. The growing importance of knowledge, as implied in the scenarios, calls for a reassessment of the institutional arrangements for knowledge formation. Emerging evidence might suggest that business is responding by developing closer links with governments and key universities through 'strategic partnerships'.

Successful innovation depends upon the generation of new ideas, knowledge, and employment. These depend greatly upon the existence of a strong and diversified science base, supported by a modern research infrastructure, which, in turn, is dependent on government support. Against this background, this chapter examines developments in policy measures concerning improvement of the link between research, productivity and employment.

There are a number of ways in which policy makers may influence the uptake of research results by industry. Some are indirect, for example the modification of framework conditions such as legislation which allows greater interaction between public sector research institutes and businesses, or regulations for IPR handling. Others are more direct such as schemes which encourage joint R&D projects between staff in higher education institutes and those in companies, or the joint supervision of research students.

The most popular governmental R&D support policy measures are funds directly provided by government or government-controlled agencies to companies in order to finance R&D and innovation projects which are considered too risky to be financed on a purely commercial basis. At one extreme lie grants, which are normally provided to companies in order to finance a proportion of the innovation and R&D process. This proportion can vary depending on a number of factors (level of risk in the project, nature of the expenses, geographical location, etc.). Grants can be reimbursable in case of success or not. These subsidies normally cover pre-competitive R&D but increasingly also cover activities closer to the market. Although a large number of these measures are provided under the Innovation Finance label, this report will consider in detail this type of action which does not involve the other actors of Innovation Financing. From the policy making point of view, however, an interesting point is to see how this type of direct subsidy measure, which is slightly out of favour, coexists with other, more indirect measures. Grants are reported by the national correspondents as the most numerous measures to support R&D and innovation activities. The main beneficiaries are generally SMEs or public institutions (universities, research centres, etc.). This vehicle is applied at national and regional level with an important macroeconomic impact on economic development and employment levels. Grants can sometimes be considered to be hidden subsidies favouring less developed regions (Eastern Germany, Mezzogiorno, etc.).

Tax relief is another frequently used mechanism by which companies can offset against their revenues the expenditures sunk into R&D activities. Tax relief has a long history for companies undertaking R&D in some countrie. Tax relief for private or corporate investors who invest in Innovation-linked projects is a relatively new feature in a number of countries (notably UK and Netherlands). Tax relief for R&D has played and will continue to play in the future a major role in the stimulation of R&D and innovation. In a number of member states as well as in Central European Countries (Bulgaria, Hungary, Romania) new measures for tax relief are under discussion at Government level. The situation appears now to be in a state of change and taxation is and will be used to an ever greater extent to promote R&D and Innovation. For example, in Portugal the system of tax credits for R&D investments by firms was extended for the fiscal year 2001, providing better conditions for R&D performers There are also new ideas such as that in Spain: in the framework of a new law, aiming at fostering competition in the Spanish Economy, an additional 10% in tax deduction is allowable for SMEs related to investment in technological facilities and training in new technologies.

Soft loans are loans provided through public organisations under more favourable conditions than a commercial loan. These conditions can be linked to specially low interest rates, to the absence of collateral required, to the fact the loan is forgivable (does not need to be repaid in case of failure, which makes it in effect similar to a grant), or other condition. Another version is the subsidy to commercial interest rates which directly reduces the cost to the company of borrowing money. Faced with the difficulties experienced by start-up firms in obtaining loans from the private sector, a number of Member States have set up public institutions which provide loans, very often together with equity, at preferential conditions for the very early stages of high tech firms. These preferential conditions can include interest rates below the market rates, a financial assessment which takes into account the innovative value of the project, a lower collateral requirement from the borrower, repayment dependent on the success of the project and other factors.

Other types of measures can in one way be compared to direct subsidies because they very often have a financial cost to the public body. They are not targeted directly at firms but can concern financial institutions, innovation support organisations or can be of a purely regulatory nature. They are generally designed, however, to have a leverage effect on private financing that make them more economically efficient than pure subsidies to firms. They are also seen as less likely to compete unfairly with private initiative or to produce economic distortions, hence better for the development of a sustainable R&D and innovation system which can survive with no or minimal state intervention. One can include amongst such measures:
Guarantees could be considered as just another form of subsidy, very similar in their principle to direct subsidies, the difference being that state intervention takes place only if the R&D project fails commercially or if the investment does not fulfil its objectives. The most common form of guarantees apply to bank loans and there is a wide array of different loan guarantee mechanisms in most EU Member States. They are also used, although on a more limited scale, to guarantee investments by risk investors. In Germany, within the programme FUTOUR [143] public venture capital is made available to focus in Eastern Germany.

One of the major concerns of policy makers in the recent past has been to improve the financial environment of firms, reducing the need for direct intervention on a project to project basis, leaving it to the market to sort out the question of evaluating, financing and following projects.
Several countries have prioritised policy measures concerning the transfer and valorisation of research results between the public and private sectors. Bearing in mind the obvious methodological limitations of applying quantitative analysis to these measures, they have seen a relative decline in priority in Denmark,France and Greece, in all other countries it has remained stable. Whilst there is widespread recognition that the relationship between the

[143] Title of the measure FUTOUR 2000 - Promotion for technology-oriented start-ups in East Germany, Federal Ministry of Economy and Technology – BMWI, Scharnhorststr. 34-37, Germany, Phone: +49 30/2014-7648, 7649, Fax: +49 30/2014-7033, Web Site: www.bmwi.de, www.vdivde-it.dewww.fz-juelich.dewww.futour.de
FUTOUR offers state-subsidies, venture capital, and consulting services for (a) persons who plan to create a new, technology-oriented firm and (b) for already existing young technology-oriented firms in Eastern Germany in order to strengthen their innovation efforts. Support is only given to firms which are especially innovative and carrying out R&D. Promotion is providedfor a conceptual stage and an R&D stage.

various actors of the innovation system and the transfer of knowledge between them is extremely important to maintaining or improving national competitiveness, the specific measures introduced to achieve this goal vary according to existing national capabilities. These range from the valorisation of existing high quality research capacities through an increase in the number and effectiveness of the paths by which research knowledge may be utilised in the innovation process. (e.g. Belgium, France, Ireland, the Netherlands, Sweden and the UK), efforts to increase the speed and efficiency of existing knowledge transfer pathways and mechanisms (e.g. Germany), strengthening both the basic research infrastructure and reinforcing cooperation mechanisms (e.g. Spain, Greece and Portugal), or via the removal of institutional or legislative obstacles to the diffusion of research results (e.g. Italy and France).

Mobility schemes, which aim at the transfer of knowledge through the movement of personnel, through recruitment and secondment, enable host or recruiting organisations to benefit from the expertise of qualified, and in some cases, experienced, researchers. These are evident across a number of member states, with the principal emphasis on the mobility of university based researchers, mainly postgraduates, towards industry. Evidently Denmark and Germany have been decreasing the relative importance of the topic (with the latter placing more attention on how to overcome an increasing shortage in high qualified labour by educational measures), and France and Ireland increasing its importance. In Germany, a number of changes have been made to immigration laws in order to address skills shortages in critical industrial sectors. An "Emergency Programme" on opening the German labour market to IT specialists came into operation in July 2000 (so-called "green card"[144]). Furthermore, a, new sub-programme "KfW-Mittelstandsförderung - Beschäftigung und Qualifizierung" (SME promotion in the field of employment and qualification by the Kreditanstalt für Wiederaufbau[145]) has been introduced. This is of indirect relevance but provides financing for qualification of newly employed personnel in SMEs via loans.
In France several measures related to this subject are still in use [146], [147], [148], [149]. However, the Ministry of Research now aims to simplify access to these measures at the regional level. In

[144] Green Card: Emergency programme to satisfy personnel demand in the IT sector, Federal Ministry for Labour and Social Order - BMA Jägerstr. 9, Germany Phone: +49-1888-527-0 Fax: +49-1888-527-2965 Web Site: www.bma.de www.bundesregierung.de/dokumente/Artikel/ix_9199.htm The Emergency programme to satisfy personnel demand in the IT Sector was established to meet a shortage of qualified personnel in the information technology sector. The programme introduces the following measures:- Easier access to jobs for top-level IT specialists from abroad,- Training offensive by the information technology industry (vocational training),- Supplementary training measures for unemployed and permanent monitoring.

[145] KfW-SME-Programme Employment and Qualification, Kreditanstalt für Wiederaufbau - KfW Palmengartenstraße 5-9, Germany Phone: 49 69 7431-0 Fax: 49 69 7431-2944 Web Site: http://www.kfw.de, www.kfw.de/DE/Unsere%20Kreditprogramme/KreditprogrammederKfW/Gewerblich4/KfW-Mittel23/Inhalt.jsp Promotion of human capital related activities by SMEs, especially concerning the creation of new jobs and the qualification of new employees. The programme shall contribute to the expansion ofemployment and new and secure jobs at SMEs. The Kreditanstalt für Wiederaufbau (KfW) provides loans at favourable interest.

[146] Support for the recruitment of researchers and R&D engineers (Aide à la Recherche pour l'Innovation - ARI), Activity report of ANVAR for 1998.www.anvar.fr/ser/html/f_ser05.htm, National Agency of Research Development - ANVAR 43, Rue de Caumartin, France Phone: +33 1 40 17 83 00 Fax: +33 1 42 66 02 20 Web Site: http://www.anvar.fr The measure responds to one of the key priorities of the Government (mobility of researchers towards SME's).The scheme is administrated by ANVAR. It aims to support SMEs that wish to reinforce their R&D personnel and resources. Its main goals are to help industrial SMEs to structure their R&D and to enhance their technological level, in order to conduct significant projects, and to gain market shares.

[147] Support for the recruitment of technicians on innovative projects (CORTECHS), ational Agency of Research Development - ANVAR 43, Rue de Caumartin, France . Phone: +33 1 40 17 83 00, Fax: +33 1 42 66 02 20, Web Site: http://www.anvar.fr www.education.gouv.fr/technologie/brochure/default.htm This measure contributes, along with other measures, to the mobility of researchers within SMEs.This scheme aims to support the recruitment of a technician, for one

Ireland, as a result of a study on good practice, a number of new graduate placements have been proposed. These are in the technology/'teaching company' and trade/marketing areas. In Portugal, it is recognised that such mobility is a key element for the education system to better respond business needs as well as for building up linkages between University and Industry. Therefore, several operational interventions have addressed this issue, although they are yet to pass into legislation and become operational. In general they concern: the promotion of student internships from technological courses and Universities in companies; joint training programmes in schools and companies; the support of "development units" in firms as an instrument for encouraging mobility; and support to the integration of doctors and masters in companies and R&D organisations. In recognition of the fact that immigration and work permit rules have acted as a barrier to entry by skilled foreign expertise, the UK is also implementing changes to these aspects.

Knowledge Transfer concerns the modalities, the ways in which policy promotes the transfer of knowledge between organisations and individuals. From the measures examined, five main modalities can be identified:

The Mobility of personnel, namely programmes that encourage individuals to work, frequently on a temporary basis, within other organisations, bringing knowledge to their hosts and learning from them. Transfer & exploitation of results, involves more direct policy intervention to facilitate the wider diffusion and subsequent development of research results, supporting both those producing results and those seeking to take them further forward towards the market, such as through intermediary organisations. Examples of these are far more numerous and can further divided in terms of the various targets.

Information diffusion modalities similarly make information more widely available, but on a more general level, such as making organisations aware not only of scientific and technological opportunities, but also of markets, support schemes and the like. This modality is frequently coupled with schemes for the transfer and exploitation of results.

Demonstrator Projects are a powerful way in which research results, as embodied in particular technological applications (such as prototypes) are disseminated to potential adopters. This are often related to large R&D projects.

Networks & Clusters reflect the inter-organisational pathways used in the transfer of knowledge. These may involve well-established groupings of various types of organisations, with a set of common interests, with channels of communications between them.

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year, within the SME willing to develop an innovative project. The aim is also to support co-operation between research bodies - in charge of the monitoring of the research project and the training of the engineer - and the SME.

[148] Support to the recruitment of PhD candidates on an applied research project within an enterprise - CIFRE convention, Ministry of Research 1, Rue Descartes, France Phone: +33 1 55 55 90 90 Web Site: http://www.recherche.gouv.fr/ National Association for Technical Research - ANRT(http://www.anrt.asso.fr/cifre.htm) The measure is a part of several measures to support mobility of students and researchers. This scheme supports the recruitment of a student by a private enterprise. The recruited student does his PhD research on an applied topic in the enterprise, under the supervision of a university or public laboratory.The scheme aims to increase the number of executives in key positions within companies, who understand research issues and who have the capacity to liaise with specialised research bodies (academics, institutes, universities or other public research performers).

[149] Support for the recruitment of post-doctorate in SME's National Agency of Research Development - ANVAR 43, Rue de Caumartin, France. Phone: +33 1 40 17 83 00, Fax: +33 1 42 66 02 20 Web Site: http://www.anvar.fr**,** Ministry of Research brochure 'jeunes chercheurs en entreprises" The measure responds to one of the key priorities of the Government (mobility of researchers towards SME's).The scheme is administrated by Regional Delegates of the ministry. It aims to support SMEs that wish to reinforce their R&D personnel and resources. Its main goals are to help industrial SMEs to structure their R&D and to enhance their technological level, in order to conduct significant projects, and to gain market shares.

Structural Support modalities refer to the ways in which policy can influence the institutional structure for innovative activities in general, and in particular, promote the transfer and diffusion of knowledge. The significance of this dimension is reflected in the fact that the action plan categorisation does enable cross-classification of such measures under other action lines.

There also appears to be a move towards measures which have an indirect effect on the intensification of industry-science co-operation. In some cases, these measures are in addition to those which, for example, provide direct funding for collaborative R&D projects. Interestingly there have been fewer national schemes that have specifically focused on stimulating science-industry networks and clusters. A major cause for this relative neglect is likely to have been the major dominance and success of EU-funded programmes which have sought to establish such wider public-private research collaborative networks[150] . This situation will certainly change over the next few years as member states are becoming increasingly interested in developing knowledge and innovation clusters to aid economic growth. The largest of these networking schemes remains the UK's LINK programme[151] which was established in 1995, although more recently the UK Biotechnology Exploitation Platform Programme[152] aims to establish syndicates of universities, firms and research intermediaries to help build and exploit intellectual property together in the field of biotechnology. The newly introduced Regional Innovation Funds[153] will also facilitate the formation of such regional networks. The Flemish government established in 1997 Cluster programme to develop networks of cooperation between enterprises and research organisations in R&D and product development (this has been changed to the new VIS scheme, with the aim of providing greater strategic orientation). In 1999, the German government started the InnoRegio programme aiming at establishing regional innovation networks in Eastern Germany[154]. In autumn 2000, out of 400 regional initiatives, 25 winning regions were selected to receive funding for establishing close links between science, education, innovative enterprises and local administrations. Sweden has recently set up new liaison functions for universities, which aims to create local regional circuits of cooperation between universities and SMEs.

There are several examples of measures which impact on, for instance, the mobility of researchers and workers, perhaps through the removal of legal barriers. For example, in Germany, such an initiative was announced by the Federal Government in autumn 2000. This included changes in the Employment Law for professors at HEIs aiming at increasing mobility, innovation orientation and a more effective use of IPR in order to commercialise new research findings. Other measures may address the issue of IPR in industry/academic collaboration. A number of countries are currently reviewing how they should support greater industry-science interactions. Thus in Ireland, Forfás together with Enterprise Ireland is considering a number of mechanisms to encourage ways of improving linkages between industry and public sector research. Thirdly, there appears to be a shift from national schemes

[150] In Germany, there is also the feeling that such networking, involving several enterprises, may weaken competition, as such networks may not be exclusively restricted to R&D activities.
[151] Foresight – LINK (second round), Office of Science and Technology, United Kingdom, http://www.foresight.gov.uk.
[152] Biotechnology Exploitation Platform Challenge (BEP Challenge) DTI - Department of Trade and Industry, UK, http://www.dti.gov.uk/beps/index.htm
[153] Regional Innovation Fund, DTI - Department of Trade and Industry, http://www.dti.gov.uk/
[154] InnoRegio - innovative networks in Eastern Germany, www.innoregio.de

which fund university-industry collaboration usually via a single mechanism applied nationally and within fairly rigid constraints, to those which provide funding for the promotion of a more flexible range of collaborative mechanisms at the local level.

Thus, as part of national (and regional) innovation policies across (and outside) the EU, numerous measures, schemes, mechanisms and programmes have been put in place, all aiming, albeit with some subtle differences and distinctions, to improve the interaction, and hence the flow and uptake of research results, across the interface between what may be termed the science base on one hand and industry on the other. There are a number of ways in which policy makers may influence the uptake of research results by industry. Indirect methods include the modification of framework conditions (such as the removal of legal barriers) while more direct schemes encourage collaboration between higher education institutes, public research organisations and companies.

Several countries have prioritised policy measures concerning the transfer and valorisation of research results between the public and private sectors, although the specific measures introduced vary according to existing national capabilities and research infrastructure. In countries such as Belgium, France, Germany, the Netherlands, Sweden and the UK, which possess a concentration of high quality research capacities, efforts generally aim at increasing the number and effectiveness of the paths by which research knowledge may be utilised in the innovation process.

In Germany there are already a variety of such channels, while in Finland, there is close cooperation between companies, research organisations and universities. In other countries, it is recognised that both the basic research infrastructure requires strengthening and that interactions between research providers and industry need improving. Examples include Spain and Portugal, where recent measures aim at reinforcing cooperation between the various actors
The policy mechanisms employed to promote and facilitate technology transfer can be further analysed in terms of three principle sets of characteristics: modalities of knowledge transfer, structural support mechanisms and targets. While these extend more generally to the full range of innovation measures, the intention here is to emphasise their dimensions with regard to Industry-Science interactions.

The production of knowledge depends greatly upon the existence of a strong and diversified science base, comprising sufficiently skilled and trained human resources, supported by a modern research infrastructure (equipment, facilities, etc.).

In turn, this is dependent on government support, both through the direct provision of finance, and through framework conditions conducive to free-thinking research. The science base may be located within universities and similar institutions, in public-sector (i.e. government) research laboratories or in independent research and technology organisations, or a combination of all three. Firms, too, may contribute to the production of knowledge through their own R&D facilities, although generally an extensive coverage of all potential basic research options exceeds the resources available, particularly as the scientific content of innovation is increasing.

9.8 Evaluating Socio-Economic Implications

Societal changes that take place during the next 20 years can be expected to blur the employment impacts of the EU technology policies. The common trends and socioeconomic issues related to the various scenarios and the implications of the changes for R&D governance during the next generation will be discussed in this chapter, while the distributional effects as well as the efficiency effects of the scenarios need much attention. For example, should R&D policy be more concentrated or more dispersed across Europe?

The simplistic view of innovation linking the primary producers of knowledge and technology and the “downstream” users who transform this knowledge into innovative products, processes and services is being replaced by a recognition of the knowledge intensification and dependence of economic activities. This demands increased interaction and knowledge exchange among the actors in the innovation system, not only between industry and science, but also industry-industry and science-science. Thus, knowledge exchange is not unidirectional, but rather a recursive process of mutual learning.

Within the complex of feedback loops, fiscal incentives, financing requirements, intellectual property concerns and other features of the “innovation environment”, the attractively simplistic view of innovation linking the primary producers of knowledge and technology and the “downstream” users who transform this knowledge into innovative products, processes and services is being replaced by a recognition of the knowledge intensification and dependence of economic activities. This demands increased interaction and knowledge exchange among various actors in an innovation system, not only between industry and science, but also industry-industry and science-science. In this view, knowledge exchange is seen not to be unidirectional, but a recursive process of mutual learning. Thus, within national (and regional) R&D policies across (and outside) the EU, numerous measures, schemes, mechanisms and programmes have been put in place, all aiming, albeit with some subtle differences and distinctions, to improve the interaction, and hence the flow and uptake of research results, across the interface between what may be termed the science base on one hand and industry on the other.

The ways in which this interaction may be promoted vary between countries. In countries where the outputs of the science base have proved inappropriate to the needs of industry, efforts have been made to improve the industrial applicability of the results of research, often through strengthening the science base infrastructure or through re-directing the research effort. In other countries a longstanding “tradition” of non-interaction between the science base (especially universities) and firms has had to be overcome. Legal barriers preventing the uptake of research results from the public sector by industry have also had to be dismantled - Greece provides a good example of this and Slovenia is also similarly hampered.

In still other cases, measures have been introduced which attempt to improve the transfer of research results from a relatively strong science base. A number of countries have increased the number of schemes in existence, extending the range of modalities through which these operate (personnel mobility, transfer of results, information diffusion, demonstrator projects, clusters and networks), or the structural means they employ (R&D funds, legal framework, tax/financial incentives, etc.) or the targets they impact (students, universities/institutes, SMEs, large companies, sectors, regions). Further distinctions have also been introduced, such as the introduction of measures in specific technological fields, particularly ICTs and biotechnology. Other countries have attempted to induce greater dialogue through various incentive schemes (often largely financial based). Many schemes concentrate on promoting the movement of personnel between the public and private sectors – some are bilateral and enhance the transfer of tacit knowledge or research skills, others are more unilateral and focus on training and the improvement of research capabilities within the industrial sector. In each case, however, the types of scheme introduced have been generally formulated according to the perceived national policy context. This diversity of approaches does not readily facilitate the identification of specific trends other than those broadly outlined above. Nevertheless, some possible broad tendencies are proposed below. Thus, issues such as education and training, IPR, legislative frameworks, clustering and cooperation, start-ups – to name several, may all feature as subsidiary effects

To encapsulate some results from the analysis of measures defined in Chapter E it is clear that the basic policy question that has been posed in all these instances is "what would be the socio-economic consequences of such policy measures? In answering this question, two major scenarios shall be highlighted:

1) A scenario under which the results of research (produced by the science base) appear to be unattractive to industry. In response, policy makers have adopted two main courses of action as
appropriate:
1. Attempts to improve the overall research capacity of the science base, and
2. Attempts to re-direct the research efforts of the science base to the needs of industry
(including measures to increase absorptive capacities at enterprises, esp. SMEs). This also implies an greater understanding of the needs and expectations of industry;

2) A scenario where despite the presence of a capable science base, the results of its research are failing to be taken up by industry. Here, two broad types of policy response may be seen:
1. Efforts to improve awareness within industry of research results from the science base (and also to develop industry's understanding of the capabilities and expectations of the science base);
2. Provision of incentives for interaction between the two sets of actors. These may be further subdivided into:
a. efforts aimed at effecting transfer through cooperative research projects;
b. efforts aimed at effecting transfer through personnel mobility, and
c. efforts aimed at effecting transfer through the provision of information services and intermediaries.

The Targets of policy mechanisms are the socio-economic and organisational types and levels at which policy mechanisms are aimed. These range from individual researchers, through research groups and institutions, to large groupings of organisations (such as sectors and regions). More specifically, the main categories of targets are:

Researchers/Young Scientists, such as through many of the specific mobility and training schemes listed above.
Universities and Research Institutes, seen as playing key roles on the generation of new knowledge and training of researchers, as well as seen as the source of spin-off companies.
SMEs, prioritised in many countries, typically characterised as in need of support for their innovative activities, both in diffusing and absorbing new knowledge.
Large Companies, seen to reflect industry in general, with R&D capabilities and often playing key roles in particular sectors.

Sectors, particularly those closely identifiable with specific technological priorities, as well as embracing a range of organisation types, working on different aspects of common technological themes.
Regions, which are targeted as in need of more general support, or reflect administrative and policy-making structures. For example, most of the Belgian examples already cited are actually regional in administrative character. A further elaboration might be made here between "targets" (i.e. the first four categories of 'actors' – researchers, universities, etc., SMEs and large companies) and "scope" (which
would encompass country, region, sector and technology). For the present, we will limit the analysis to the six target categories as defined in the above bulleted list.

Schemes aimed at expanding and improving industry-science links can be grouped under a number of different categories, which have expanded and evolved over time. Such policy mechanisms can be grouped under four broad categories centred on those aimed: at the transfer and mobility of personnel; at facilitating interaction between industry and the science base, in particular in terms of research links; at those focused on exploiting research emanating from the publics science base; and at those schemes aimed at developing public-private research and technology links.

There are a number of different ways in which (largely, but not solely) the socio-economic implications of public research can be exploited. The most immediate are schemes which are designed to initiate and exploit intellectual property (IP). The most specific programmes are exemplified by two schemes. The first was initiated in 1999 by the Finnish government to enhance technology transfer from Finnish universities and concentrating on identifying, evaluation, commercialisation and licensing of novel innovations. The second, again established in 1999, is the Norwegian's FORNY II programme which seeks to commercialise research from Norwegian universities colleges and research institutes. A number of other programmes in EU member states also have specific IP protection and exploitation initiatives elements within larger technology transfer programmes.

A growing number of member states are seeking to expand and support university-based high technology spin-outs. A specific promotion mechanism for this policy action concerns the creation of support infrastructure in the form of incubation units. Thus in 1999 the French government established an incubator structure programme design to help foster the creation of innovative firms originating from universities and other public research bodies.
Ireland in 1996 also created the Campus Companies Programme to help the establishment of universities spin-offs. The most recent scheme is the new Austrian "A plus B" measure designed to specifically stimulate the formation of university spin-off companies. Sometimes, such programmes are targeted on spin-offs in particular technologies such as biotechnology.

As research and technology required by industry has become more complex, fast moving, expensive and interdisciplinarity in nature, universities and public research organisations have had to establish larger and more flexible research centres (often with joint industry funding and personnel) to meet such demands. Governments have recognised this as part of their wider challenge of helping to stimulate the interrelationship between science and industry.
Austria created in 1997 the Kplus programme which established joint research centres ('centres of competence') with joint research public-private (60:40) funding for research. The Flemish government also established an Incubators and Innovation Centres programme to establish innovation centres and incubators located in research and scientific parks or

university campuses. In 1999 the UK created the network of Faraday Centres through support form the Engineering and Physical Sciences Research Council, which initially set up four centres across Britain.

There are surprisingly few national schemes that have sought to promote research, science and technology parks, which have either been locally organised or funded (such as the science parks centred around Cambridge or the dense network of technology parks in Germany which are often funded by regional or local governments) or latterly because they have been strongly taken up by EU funded programmes. The most specific national programme is TechGate located in Vienna which is developing a major science and technology park in Vienna.

Overall, it can be seen that an emphasis on the transfer of knowledge and technology from the science base (comprising universities, research institutes, public laboratories, etc.) to industry is firmly accepted and established in the R&D policies of western European countries.

Although initially the application of process innovation will probably result in a reduced need for labour, the final outcome depends on a set of variables and/or mechanisms which may compensate for this initial reduction in labour through an increase in demand. Together with this, it is usually accepted that product innovations, in general, are beneficial for employment, although this depends on the character of products, in particular whether the goods and services are totally new or are merely substitutes for existing ones.

In order to carry out a coherent analysis of the impact of technological changes on employment volume it is necessary to consider the economic system as a whole, as jobs which may be lost in one firm or region may be compensated for in other sectors or geographic regions. Thus, at the macroeconomic level or considering the economy as a whole, economic theory indicates a series of effects which may compensate for the process of reduced demand for labour caused by the application of new technologies: a) an increase in real income; b) improved competitiveness; c) creation of new industries ; d) higher levels of investment; and, e) mechanisms whereby some factors of production are replaced by labour.

The various focuses and ways of approaching the analysis of the interrelation between technological change and employment have generated a variety of studies of differing scope seeking to determine the role of technology in the creation or destruction of jobs. The results of the theoretical and empirical contributions differ greatly. It may, however, be said that there are at present no conclusions regarding the final effect of technological change on employment which would be universally accepted or which could be considered quantitatively adequate. However, the empirical evidence suggests that employment in the more technologically advanced sectors of the economy responds better to technological change, as does employment in those countries and regions with a stronger tradition of adopting new technologies.

Thus to conclude, the introduction of new technologies into production systems causes the simultaneous destruction and creation of jobs. The quantitative relationship, however, varies between enterprises, sectors, regions and countries, depending on competitiveness, relative position in the world economy, the institutional framework, government policies and business strategies, all of which have to work together to create a framework within which compensatory effects might be produced in the strongest and quickest way possible in order to avoid tension in the labour market.

It is widely accepted that in order to adapt to an environment of stronger competition, and to a world emphasizing the role of information, knowledge and skills, advanced economies need to continuously upgrade the overall quality of their labour force. In this respect, there is a clear role for public policy to improve the average level of skills of the labour force. It has come to be a widely held view that as well as being a fundamental characteristic of humankind, technological knowledge makes a constant contribution to welfare, increased output and, correspondingly, job creation. Only, in periods of crisis, when radical innovations are being introduced rapidly, may the situation appear otherwise. This may well appear to be the case in some regions when assessing the potential influence, unpredictable to some extent, of the information and communication technologies on the future model of our society.[155]

[155] Crespo, L. and Mogollón, R., Empresa e Innovación en Extremadura. COTEC. Madrid, 1996.

10 Policy implications

10.1 Introduction

While it has been acknowledged that innovation policy takes a variety of forms (such as taxes, subsidies, intellectual property rights, education) these were afforded only a back seat in the study. The emphasis was on the level and sectoral distribution of R&D and innovation expenditures. The Baseline Scenario and the three policy scenarios referred to specific sectoral distributions of a given increase in R&D and innovation expenditures.

In what follows we shall study what implications, if any, our study could have on policy-making. We shall review the existing innovation policy measures in Europe and present some observations on how our policy scenarios relate to these measures. We shall continue by discussing a few developments that can be expected to influence the future of the European labour markets. In conclusion it seems that a coherent policy mix that encourages not only the development and diffusion of new technologies but also supports the general level of demand is likely to produce the best employment outcomes in Europe.

10.2 Implications for innovation policy

Our scenario simulations were based on simple premises, and their import for actual policy-making should not be exaggerated. In general, policy instruments are based on the rationale that support should be additional and should result in greater social benefit. Thus innovation and technology policies are not implemented for the sake of technology, but are a means aimed at improving social and economic welfare. The criteria for an effective technology policy therefore should be about the ultimate goals, objectives, targets and instruments, and the level of efficiency achieved. According to the conclusions of the Lisbon Summit the strategic goal of the EU is "to become the most competitive and dynamic knowledge based economy in the world capable of sustainable economic growth and with more and better jobs and greater social cohesion".

Current innovation policy measures of the EU can be reviewed conveniently with the help of the Trend Chart on Innovation database, which is available on the Internet. The database presents a listing of innovation policy measures currently applied in the Member States, Candidate Countries and in Norway, Iceland and Israel. Table 4.1 presents a classification of the policy measures according to their objectives. There are more than a thousand measures in force in the Member States and Candidate countries. The most popular measures include those that are related to R&D co-operation, financing of innovation activities, commercial R&D and the diffusion of technologies among SMEs.

Table 4.1. Innovation policy measures in force in European* countries in 2001

Targets of policy measures	Instances of innovation policy measures	Per cent
Co-operation of Research establishments, Universities and Companies	151	14.1
Financing	147	13.7
Strengthening Company Research	116	10.8
Absorption of Technologies by SMEs	115	10.7
Start-up of technology companies	86	8.0
Strategic Vision of R&D	62	5.8
Innovation & Management	60	5.6
Education & Training	53	4.9
Promotion of clustering and co-op. for innovation	52	4.9
Mobility of Students, Researcher and Teachers	49	4.6
Protection of IPR	48	4.5
Raising Public Awareness	47	4.4
Administrative Simplification	26	2.4
Public Authorities	22	2.1
Legal and Regulatory Environment	16	1.5
Taxation	11	1.0
Competition	7	0.7
Other Objectives	3	0.3
Total number of policy measures	1071	100

* Member States and Candidate Countries

Source EC 2001b: Trend Chart Data Base (URL: http://trendchart.cordis.lu/Datasheets/index.cfm?).

In the quantitative simulations carried out in the previous chapters we have assumed that innovation policy measures affect only productivity of labour and consumer demand. In reality innovation policies have much wider effects on society. That is one reason why it is not possible to compare directly our innovation policy scenarios and the policy measures presented in Table 4.1. The differences between our scenarios relate to weights given to the different sectors of the economy in distributing additional innovation funding, while the measures listed in Table 4.1 cut across the sectors of the economy. Nevertheless, in the future it might become possible to develop more sophisticated methods for the study of the long-term effects of different innovation policy measures, such as strengthening company research or efforts in education and training.

The Framework Programmes for research and innovation in Europe are more easily comparable with our scenarios, since some of their measures are directly related to R&D in particular sectors of the economy. The Fifth Programme set out the priorities for the EU's research, technological development and demonstration activities up to 2002. Its four thematic programmes prioritise quality of life and management of living resources, user-friendly information society, competitive and sustainable growth, as well as energy, environment and sustainable development. The next Framework Programme will cover the period from 2002 to 2006 and will provide increased funding for research. The key emerging technologies and research priorities are genomics and biotechnology for health, information society technologies, nanotechnologies and intelligent materials, aeronautics and space, food safety and health risks, sustainable development and global change, and citizens and governance in European society.

We could relate our scenarios to the Fifth Framework Programme and assume that it represents our Baseline Scenario, while keeping in mind the fact that EU funding is only 1 or

2 per cent of the total R&D funding in Europe. However, as our simulations have shown, even small additions to R&D and innovation efforts can have perceptible implications for growth and employment in the long term. For instance, the Concentrated Scenario, which would involve the promotion of new technologies to an even greater extent than at present, would give more support to European organisations that are working at the frontiers of these technologies. The reluctance of enterprises to invest in high-risk areas could therefore be reduced further and increases in private R&D funding would accelerate the development of new products. Thus, it is possible to argue that the small additional resources could create a measurable gearing effect, as shown in our simulations.

Nevertheless, there are complicating factors. The European economy is a complex set of sectors embedded in emerging and mature companies – large, medium and small – and with a range of short and long lifecycles of processes and products. The company profiles of business sectors can differ markedly from sector to sector. In biotechnology there is a large number of independent, high-tech SMEs driving technology forward. In the aerospace sector, a few large companies, with an extensive supplier base of SMEs dependent upon them, dominate the market. The times taken to develop technology may vary from only one or two years in the electronics sector to ten years in the aero-engine sector. A further layer of complexity arises from the fact that some sectors are essentially process-based, where innovations may take place incrementally and where employment may be reduced as a consequence, at least initially. Other sectors are primarily product-based, and it is here that new technology usually has the greatest impact, with more positive effects on employment.

Given the above complexities, it is not a straightforward task to formulate and implement a technology policy that would achieve maximum value in terms of impact on employment across all business sectors. For instance, it could be argued that in the Concentrated Scenario the emphasis on high technology would require the use of measures fostering R&D co-operation in the aerospace sector, whereas bridging institutions to facilitate diffusion of new innovations could be more relevant in the biotechnology sector. The employment impacts of the Concentrated Scenario would be enhanced by spillovers from high-tech ICTs into the rapidly growing service sector.

Innovation policies focusing entirely on R&D, aiming at forcing the introduction of new technologies, would not be effective in sustaining economic growth. However, it makes sense to invest more resources ‘upstream’ into developing basic research through universities and other public or private research institutes. This is a reflection of the general trend toward greater science-intensity of technology that is evident not only in biotechnology and nanotechnology, but also during the early phases of development of other frontier technologies. In our simulations it is assumed that innovation policies affect consumption patterns as well. These effects could result from measures boosting the diffusion of innovations, attractive new products and redistribution to consumers of the economic benefits of increases in labour productivity.

Effective diffusion is essential if research is to be taken forward to exploitation. As noted previously, it is at the diffusion and application stages that the benefits of increased productivity, and perhaps employment, accrue. There are barriers to overcome at all stages of innovation and commercialisation. Many researchers in public institutions prefer to communicate their results primarily to other researchers in their field, while their colleagues in private organisations may be prevented from publishing all of their work for reasons of commercial confidentiality. Where widespread impact is intended, it is more likely to be achieved by improving the direct and indirect channels to users and other beneficiaries (networks, publications, mobility, consultancy). Action to identify target markets, select markets with a high probability of adopting technology, and work with companies to develop marketable products will provide greater yields from research activity in the marketplace. That is why EU R&D programmes usually include a dissemination strategy for the research results. CORDIS acts as a support instrument for the more effective diffusion of EU research and technology; it provides a database of EU funded projects, measures to facilitate participation in projects, and access to the Innovation Relay Centres. Despite such measures, the diffusion of innovations is usually a slow process. It was noted above how long it took for the diffusion of electric power to take place, even in the progressive US economy of the early twentieth century. There is every likelihood that the diffusion of the radical technologies stressed in this report will take as long again.

10.3 Implications for employment policy

The employment strategy of the EU rests on four pillars: employability, entrepreneurship, adaptability and gender equality. The measures of the employability pillar are designed to tackle youth and long-term unemployment, promote skills development and fight discrimination and exclusion. The entrepreneurship pillar aims at improving the business environment, emphasises job creation in the service sector, and includes regional and local actions. The adaptability pillar concerns the modernisation of the work organisation and life-long learning. The equal opportunities pillar focuses on gender issues, and the reconciliation of work and family life (EC 2001c).

An important question is whether R&D and innovation measures should be included as a separate, fifth pillar in the employment strategy of the EU. Even though the results of the simulations carried out in this study set only a lower boundary on the long-term employment impacts of R&D and innovation policies, they are not strong enough to support the idea that these measures should be regarded as a separate pillar of the employment strategy. However, it might be prudent to consider whether R&D and innovation policy measures should receive more attention from the point of view of their employment effects. This consideration might help to put more emphasis on projects and sectors that are likely to develop new products and involve job creation. New products can be expected to emerge in fields in which technical change takes place at a rapid pace – i.e., general-purpose technologies. The best job creation prospects are in services, and for that reason service industries might merit more attention in future R&D policy of the EU.

Currently many Member States of the EU promote job creation in services by opening up regulated markets for competition and promoting the development of new service-sector innovations based on information and communication technologies (EC 2001c). In Sweden and the United Kingdom the exploitation of the job-creation potential of the environmental services sector is regarded as a government priority. In the future it might be considered what is the potential of services related to biotechnology and nanotechnology. These services might relate to R&D, product development, design and testing and various services on the interface of sectors applying these technologies and the rest of the economy, i.e., marketing, legal services and financial services.

Much attention is devoted in the Member States to the weekly working time. France has reported that about 350,000 jobs have been either safeguarded or created as a result of the law on the 35-hour working week. In 2000 the average weekly number of hours worked declined to 36.2 in the EU, representing perhaps a continuation of the long-term trend of shorter working weeks in the industrialised countries. Another important indicator of changes in the organisation of work is the proportion of non-standard employment contracts. They are now estimated to represent 28.5 % of all employment contracts in the EU (EC 2001c: 84).

In regard to skills, the advent of new technologies brings with it the need for changing skills for creating the new technologies, producing the new technologies, and using the new technologies. Continued ‘upskilling’ seems to be in prospect for creating the new technologies over the next 20 years, partly in ICTs (e.g. for chip design, software and networking), but even more in biotechnology and nanotechnology. By contrast, there may well be some ‘downskilling’ of work involved in the production of ICTs as processes become increasingly standardised and as the training for such work itself becomes more standardised – the rapid expansion of ‘call centres’ is especially striking. This is less likely in biotechnology and rather unlikely in nanotechnology up to 2020. In terms of using the new technologies, the continued development of accessible ICT systems and networking probably means overall ‘deskilling’ in this area; in regard to biotechnology and nanotechnology this will depend on the rate at which products embodying these radical technologies come on to the market. Overall we therefore may expect some polarisation in labour markets in the short run and possible convergence thereafter. These patterns may well raise social problems of inequality and exclusion which could preoccupy policy-makers.

The general implication of rising demand for employment relative to supply, coupled with the skill-intensive nature of the new technologies, means that skill shortages are likely to become increasingly serious. These might be overcome by appropriate policies in three main ways: a) using immigration of skilled workers as a stopgap – but this raises political problems; b) reducing the skill intensity of work through downskilling – increasing the accessibility of the new technologies; c) raising the skill levels of the employees. Some combination of all of these will probably be called for.

Even a narrowing in skill differentials will involve major training and retraining efforts in a context in which participation of workers previously untouched by these activities is required. Moreover the persistence of innovation in these fields will intensify the need for ‘lifelong learning’ – much emphasised in current policy rhetoric but relatively little implemented to date. School-based education will need to be revamped to meet the extensive demands for the basic skills needed to use the new technologies, while university-based education will have to adjust to the more rarefied demands for creative skills in a context of rising global competition and collaboration in higher education. For enhancing skills in producing and using the new technologies, training on the job is even more indispensable.

Workplace conditions are likely to respond to two driving forces: first, the changes in skill structures implied above; and second, the impacts of the new technologies themselves. There are present indications of a polarisation in workplace conditions as well as skills. Areas associated with ‘upskilling’ seem to be linked to the flattening of corporate hierarchies and encouragement of upward flows of decision-making and learning, while areas of ‘downskilling’ seem often linked to the reinforcement of hierarchical Tayloristic practices. Currently one out of every two employees uses a computer at work in the EU. Teleworking relies on computers, and it can now be regarded as a mode of work that acts as a bridge between work practices that prevail in present industrialised society and those that will be more prominent in the knowledge-based society of the future. Teleworking helps to alleviate some problems related to productivity in services, travel to work, congestion and family life, but may create others related to increased stress and alienation. Such ‘self-exploitation’ may prove exceptionally difficult to regulate. Looking at it from the side of the firm rather than of the individual, it appears that SMEs have been relatively slow to reap the benefits of new technologies in the form of improved organisation and knowledge accumulation.

While many of these questions are well beyond the scope of phenomena depicted in our simulated scenarios, it can be noted that at least our simulations show that the level of employment is not directly threatened by expected advances in labour productivity resulting from added R&D and innovation expenditures on ICTs. On the contrary, the likelihood is that there will be shortages of skilled workers in particular.

10.4 Implications for other fields of policy

Policies that do not have a direct impact on technology or the labour markets can nevertheless influence the relationship between technical change and employment. Fostering *economic growth*, applying active and selective demand policies, appears to be essential for assuring that the positive employment prospects outlined in the study will be achieved. The level and composition of final demand has been shown to play a key role in shaping the employment outcomes. In the study’s simulations the most important compensation mechanism of jobs lost in the process of labour-saving innovation is the new consumption generated by higher incomes resulting from the distribution of productivity gains. In other words, an equitable access to productivity benefits of technical change can be a way to sustain demand and employment.

Our simulations show that policies *targeting sectors* of high technical and economic potential can produce more favourable employment outcomes than policies affecting the whole economy. The fact that the Concentrated and Diversified Scenarios show better results than the Uniform Scenario suggests that it pays to select carefully the target sectors for innovation, technology and industrial policies. Favouring sectors in which rapid technical progress opens up large numbers of business opportunities is likely to improve conditions for long-term employment growth. Particular attention has to be paid to measures favouring product development, as by necessity Europe is already strong in developing cost-saving process innovations.

Rapid technical change creates a great need for increasingly effective *education, learning and training policies*. New technologies, organisational changes and the globalisation of the economy favour highly skilled people, while workers with low skills face higher risks of unemployment. Our analysis of expected changes in technology suggests that skills related to general-purpose technologies are likely to be in short supply in the future. Successful education and training initiatives in information and communication technologies, biotechnology and nanotechnology could help to eliminate bottlenecks in employment creation. The creation of new jobs requires entrepreneurship skills as well.

Small, even if sustained, changes in R&D and other innovation expenditures should not be expected to lead to significant changes in society. However, it is tempting to consider what kinds of social phenomena would be commensurate with our simplified scenarios. The results of such an exercise are shown in Table 4.3.

Table 4.3. Social trends that would be commensurate with the scenarios.

	Baseline Scenario	Uniform Scenario	Diversified Scenario	Concentrated Scenario
Criteria of public R&D support	No increase in public spending	Uniform increase in public support across industries.	Support for industries that have proven strong and competitive	Support for industries that take advantage of the most modern technologies
Employment	Continuation of recent trends at first; then a loss of competitiveness	Slight improvement	More jobs in established sectors	More jobs in high-tech sectors
Industry	Relative decline vis-à-vis the USA	Relative decline vis-à-vis the USA slightly ameliorated	Established strengths maintained in the short term	Catching up with the USA in high technology
R&D	Continuation of recent trends and research foci	Additional resources spread evenly, low sector-specific impacts	Focus on successful industries and regions	Focus on high technology and general-purpose technologies
Diffusion	No change	Practically no change	Support for regional and sectoral diffusion of results	Diffusion via international high-tech R&D networks
Education	No change	A small general increase in the level of education	Emphasis on well established professions and skills, structural change limited	High international mobility, focus on highest achievers
Macroeconomy	No change	A slight acceleration of growth	Established industries and jobs favoured or even protected	Accelerated globalisation, inter-dependency and growth
Participation in the labour market	Increased risk of job losses in traditional industries; little new job creation	A slight growth in female employment and immigration	Less need for additional female workers	Increased higher education for women; skilled immigrants invited; more retraining as structural change is accelerated

The table shows that while there are few differences between the Baseline and the Uniform Scenario, the differences are more pronounced in the remaining two scenarios. In the Diversified Scenario the focus is on using technology policy as a means of supporting those sectors and industries that already are competitive in Europe. Consequently there would be relatively little changes in the structures of the economy, goals of education and skills requirements. In the Concentrated Scenario all of the additional innovation resources are directed into high technologies – especially information and communication technologies, biotechnology and nanotechnology. The emphasis is on accelerating the movement towards the exploitation of the most potent technologies requiring the highest qualifications and skills available on the global labour market.

10.5 Conclusion

The simulations in this study were carried out on the basis of relatively small policy differences between the scenarios. In reality policy-makers face a much wider choice of measures and instruments, and the long-term results of any action will be blurred by changes that take place as a result of the natural progression of technological and economic cycles, policy measures adopted for other goals and various random events. That is why our simulations cannot be used directly as a basis for policy recommendations.

The potency of technology and innovation policies is revealed only after long time lags. The lags make it difficult to achieve perfect timing in education and training efforts as well as in adjusting the levels of innovation expenditures earmarked for different sectors of the economy. The best results may not be achieved as a result of massive research programmes aimed at furthering particular fields of technology. The most efficient strategies may require early detection of technological opportunities created in basic research and their thorough scientific and economic evaluation.

Whatever goals and means will be selected, achieving *coherence* between economic, education, industrial and innovation policies is essential. Employment growth cannot be achieved in the conditions of technical and structural change solely on the basis of measures that improve efficiency and cost competitiveness. Without a policy based on an equitable distribution of productivity gains, the impact of supply side measures would be restricted to losses of jobs in established industries and professions, heightening strains on European society. The challenge is to combine targeted ‘Keynesian’ measures fostering demand growth with similarly selected ‘Schumpeterian’ measures fostering technical change and productivity.

The challenges are great, but the task is not hopeless. Austria, Denmark, Ireland and the Netherlands have reduced unemployment rates or maintained them at low levels, lowered the incidence of youth and long-term unemployment, increased employment rates, and reduced gender gaps. “Social dialogue in these countries created a climate of confidence among the principal social actors which encouraged wage moderation and reforms in social protection systems. Wage moderation was linked to a stabilization-oriented macroeconomic policy which led to low inflation and interest rates. Finally, labour market policy measures including training, retraining and income security schemes, which provide both security for workers and adjustment flexibility for employers, created the necessary conditions for smooth labour market adjustment” (ILO 2001:24).

11 Conclusions of the study

The analyses and simulations carried out in this study suggest a number of conclusions, but it has to be kept in mind that many of factors limit the relevance of our results to policy-making. First of all the study can be interpreted as an experiment that was carried out using two large economic models in order to see how employment would respond in these models to small increases in innovation expenditures. The relevance of the results depends crucially on the validity of the models and the assumptions used in the scenarios. Neither the models nor the assumptions can capture the complexities of the social environment in which innovation policy measures are planned and carried out. That is why our results could be rejected as simplifications.

On the other hand the results show that there are some consistencies between the scenarios. The results demonstrate that technology and innovation can play a positive role in economic growth and employment. Emerging technologies accelerate economic growth and can lead to the creation of new jobs. The models suggest that this can be achieved with the highest likelihood when the productivity benefits of technical change are distributed widely in the economy and when labour supply is responsive to higher wages and increased demand for higher skills. Our initial assumptions are simple, but the results suggest also what kinds of additional measures should accompany increased R&D expenditures to ensure optimal employment outcomes. In conjunction with our analyses of trends in technology the models show that what is needed in Europe is investment in education and training in those fields of technology that are expected to advance at the most rapid pace – information and communication technologies, biotechnology and nanotechnology.

Even a small increase in innovation expenditures tends to increase economic growth and employment in the long term. The mechanism assumed to work here is that a small initial increase in public funding leads to increases in private R&D outlays and improvements in labour productivity. Labour productivity leads to increased wages and, together with increasingly attractive new products, boosts the consumption of goods in the targeted sectors as well as the overall consumer demand in the economy. Equitable distribution of the economic gains resulting from improvements in productivity therefore seems to help to sustain demand and employment. In our simulations the employment effect of increased consumption is always larger than the labour-saving effect of productivity increases. This reflects the assumptions used in simulations and therefore cannot be seen as a solid resolution of the age-old concern about the employment impacts of technical change.

Of more interest is the finding that the impacts of increases in innovation expenditures can vary across sectors and regions of the EU. While the absolute levels of changes in employment and growth can be disputed, the outcomes of the different scenarios can be compared and the process can reveal significant mechanisms that should be taken into account when policy formulations are being considered.

Another important finding of the IPTS–ESTO study is that in terms of job creation and economic growth the payoff from R&D expenditures in high-technology sectors (Concentrated Scenario) and established competitive sectors (Diversified Scenario) produce the best results. However, the differences are small. Even in the case of the Baseline Scenario, where innovation expenditures are maintained at their present levels, employment is expected to increase. However, in reality Europe's competitors can be expected to increase their innovation efforts, and Europe trying to stand still would soon face a decline in competitiveness and a loss of its best talents.

The results of the study strengthen the argument that technological progress is the main option for the EU to maintain its competitiveness on the international level. Since the potential for the EU to compete in labour-intensive sectors is very limited, given the higher wages in the EU compared to those in Eastern Europe or Asia, the most viable option appears to lie in technology-intensive sectors. In addition, technological progress can lead to higher wages and improved quality of work, thus allowing a higher standard of living. Technological progress can be the key for achieving the objectives of economic, social and environmental policy, and goals of the "Knowledge-based Society" as defined in the Lisbon Summit.

The impacts of technological progress on employment are in principle positive, but are not affected only by technology policy. The responsiveness of labour supply, in both quantitative and qualitative terms, influences the outcome. In addition, the fact that the impact of technological change also depends on the levels of consumption and investment suggests that fiscal and monetary policies also play an important role. A shift towards new technology may require suitable policies aimed at increasing consumption, especially that of new products and services, and attracting new investment to finance new production facilities.

The results can be summarised by presenting the answers to the five questions set out for the study:

Which economic sectors will offer high growth potential and quality jobs? The majority of new jobs that will be created during the next 20 years are expected to be in the area of services. More than three-quarters of the new jobs in the EU will probably be in trade and commerce, business services, healthcare, entertainment and recreational services, tourism and catering services, education, transport and logistics services, and construction. Jobs in these sectors are expected to provide increased real wages and an improved overall job quality, aided by the expected developments in information and communication technologies and organisational improvements in the workplace.

Which technologies will have a significant impact in those sectors? Obviously sector-specific technologies will have important employment and job-quality implications, but it is the general-purpose technologies that will be the main drivers of technical change. Information and communication technologies, biotechnology and nanotechnology are rapidly evolving fields and will remain so during the next twenty years or so. They will form numerous combinations with sector-specific technologies enhancing productivity and creating opportunities for the emergence of new products, services and enterprises.

What kind of skills will be required to match the needs of those sectors and technologies? It will be important to ascertain the availability of highly-trained experts in general-purpose technologies. Acute shortages can be expected of people who can combine expertise in both information technology and biotechnology and of those who can combine expertise in both automation technology and nanotechnology. Europe will also need strong management and entrepreneurial skills in order to take full advantage of opportunities for job creation that arise as a result of technical change.

What will be the impact of emerging technologies on the organisation of work and job profiles? In the past the full benefits of new information and communication technologies have been obtained only after organisational changes such as the instigation of self-managing teams and decentralised decision-making have been carried out, and employees have been empowered to make critical decisions together with suppliers or customers. Biotechnology and nanotechnology will affect production processes more directly than organisational practices, but they are likely to heighten the need for close interactions with suppliers and customers, lowering further the boundaries between different organisations.

What would be the impact of selected innovation and technology policy strategies under different socio-economic conditions? The overall success depends on the coherence of the policy mix in changing socio-economic and competitive conditions. Attention needs to be devoted not only the development of new technologies but also to their diffusion. Education, labour-market, fiscal, monetary and social welfare policies all have an impact on final employment outcomes. Technology policy variations considered in our study can also be seen as expressions of more comprehensive policy strategies. Our Concentrated Scenario might be seen as a manifestation of a drive that emphasises high technology, and by necessity, globalisation. The Diversified Scenario is compatible with more inward and even protectionist attitudes. The Uniform Scenario tries to favour everyone but offers relative benefits only to sectors in which the prospects for technical change are poor.

12 References

1. Acemoglu, D. 2001. 'Directed Technical Change', *NBER Working Paper* 8287, National Bureau of Economic Research, Cambridge, Mass.
2. Adams, J. D. 1999. 'The Structure of Firm R&D, the Factor Intensity of Production and Skill Bias', *Review of Economics and Statistics*, vol. 81, pp. 499-510.
3. Aguirregabiria, V. and C. Alonso-Borrego. 2001. 'Employment, Occupational Structure, Technological Capital and Reorganisation of Production', *Labour Economics*, vol. 8, pp. 43-73.
4. Autor, D., L. Katz and A. Krueger. 1998. 'Computing Inequality: Have Computers Changed the Labor Market?', *Quarterly Journal of Economics*, vol. 113, pp. 1169-1214.
5. Baily, M. N., Haltiwanger, J. and Bartelsman, E. J. 1994. 'Downsizing and productivity growth: Myth or reality?', Center for Economic Studies, Discussion Paper 94-4, US Bureau of the Census.
6. Bart Los.2000. *Endogenous Growth and Structural Change in a Dynamic Input-Output Model.* August 2000. University of Groningen. Netherlands.
7. Bellmann, L. 1995. 'Internal and external destruction', Conference on the Effects of Technology and Innovation on Firm Performance and Employment, Washington, 2 and 3 May.
8. Berman, E., Bound, J. and Machin, S. 1997. 'Implications of skill-biased technological change: International evidence', NBER Working Paper 666.
9. Berman, E., J. Bound, and Z. Griliches. 1994. 'Changes in the Demand for Skilled Labor within U.S. Manufacturing Industries: Evidence from the Annual Survey of Manufacturing', *Quarterly Journal of Economics*, vol. 109, pp. 367-397.
10. Black, D. 1998. 'The emerging virtual workplace', *IT Careers*, Oct. 5 (URL: www.advancedskills.com).
11. Blanchflower, D. and Burgess, S. 1996. 'New technology and jobs: Comparative evidence from a two country study', Discussion Paper 285, London School of Economics.
12. Borsch-Supan, Axel. 1998. 'Capital's Contribution to Productivity and the Nature of Competition', *Brookings Papers on Economic Activity*, pp. 205-248.
13. Bresnahan, T. F., Brynjolfsson, E. and Hitt, L. M. 1998.'Information technology, workplace organisation and the demand for skilled labour: Firm-level evidence', Working paper MIT, Stanford and Wharton.
14. Bresnahan, T.F., E. Brynjolfsson and L.M. Hitt. 2002. 'Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-Level Evidence', *Quarterly Journal of Economics*, February, pp. 339 - 376.
15. Brücker, H., G. S. Epstein, B. McCormick, G. St-Paul, A. Venturini and K. Zimmerman. 2001. *Managing migration in the EU welfare state*, mimeo, Deutsches Institut für Wirtschaftsforschung (DIW), Berlin.
16. Brynjolfsson, E. and Hitt, L. M. 1998. 'Beyond the productivity paradox: Computers are the catalyst for bigger changes', Communications of the ACM, 41 (8), pp. 49-55.
17. C. Freeman, M. Sharp and W. Walker (eds), Technology and the future of Europe, Pinter Publishers, London, 1991.
18. C.M. Cooper and J.A. Clark, Employment, economics and technology, Wheatsheaf Books Ltd, 1982.
19. Caroli, E. and J. Van Reenen. 2001. 'Skill biased organizational change: evidence from a panel of British and French establishments', *Quarterly Journal of Economics*, vol. 116, pp. 1449-1492.

20. Caroli, E., N. Greenan and D. Guellec. 2001. Organizational Change and Skill Accumulation, *Industrial and Corporate Change*, vol. 10, pp. 481-506.
21. Colecchia A. and P. Schreyer. 2001. 'ICT investment and economic growth in the 1990s: is the United States a unique case? A comparative study of nine OECD countries', *DSTI Working paper* 2001/7, Organisation for Economic Co-operation and Development, Paris.
22. Commission of the European Communities, Towards Enterprise Europe, Brussels, May 2000.
23. Conference Board. 1998. 'Computers, productivity, and growth', Economic Research Report 1213-98-RR, New York.
24. Coppel J., J. Dumont and I. Visco. 2001. 'Trends in immigration and economic consequences', *OECD Working Paper* ECO/WKP (2001)10, Organisation for Economic Co-operation and Development, Paris.
25. Coutrot, T. 1996. 'Les Nouveaux Modes d'Organisation de la Production: Quels Effets sur l'Emploi, la Formation, l'Organisation du Travail?', *Données Sociales*, Institut National de la Statistique et des Études Économiques (INSEE), pp. 209-216.
26. Crandall, N. F. and M. J. Wallace. 1995. 'The virtual workplace: work and rewards in the 21st century', *ACA Journal*, Spring, pp. 6-23.
27. D. Kyriakou, Technology and employment revisited : against pessimism, IPTS report, 53 (2001) 4.
28. David, P. A. and G. Wright. 1999. *General Purpose Technologies and Surges in Productivity: Historical Reflections on the Future of the ICT Revolution*, a paper presented to the International Symposium on Economic Challenges of the 21st Century in Historical Perspective, 2nd-4th July, Oxford.
29. Dirk Pilat and Frank C. Lee. 2001 Productivity Growth in ICT-Producing and ICT-Using Industries: A Source of Growth Differentials in the OECD? STI Working Paper 2001/4. June 2001. OECD.
30. DoC (1997). "Regional multipliers. A user handbook for the regional input-output modeling system (RIMS II). US Department of Commerce. Third edition.
31. Dominique Guellec & Bruno van Pottelsburghe de la Potterie. 2001. *R&D and Productivity Growth: Panel Data of 16 OECD Countries.* STI Working Paper 2001/3. June 2001 OECD.
32. Doms, M., T. Dunne and K. Troske. 1997. 'Workers, Wages and Technology', *Quarterly Journal of Economics*, vol. 112, pp. 253-290.
33. Dosi, G., C. Freeman, R. Nelson, G. Silverberg, and L. Soete (eds.). 1988. *Technical change and economic theory*. Pinter, London.
34. Dunne, M., J. Haltiwanger and K. Troske. 1996. 'Technology and Jobs: Secular Changes and Cyclical Dynamics', *NBER Working Paper* 5656, National Bureau of Economic Research, Cambridge, Mass.
35. Easterly, W. and R. Levine. 2000. *It's Not Factor Accumulation: Stylized Facts and Growth Models*, November, World Bank, forthcoming Working Paper, Washington. (URL: http://www.worldbank.org/research/growth/wpdate.htm).
36. EC. 1996. *Putting Services to Work*, Communication from the Commission to the Council, Commission of the European Communities, CSE (1996) 6 final, November 27, Brussels.
37. EC. 1998. *The Contribution of Business Services to Industrial Performance: A Common Policy Framework*, Communication from the Commission to the Council, Commission of the European Communities, COM(1998) 534 final, September 21, Brussels.

38. EC. 2001a. *Employment in Europe 2001: Recent Trends and Prospects.* Commission of the European Communities. Directorate-General for Employment and Social Affairs. Unit EMPL/A.1. July.
39. EC.2001b. *Trend Chart Data Base*.
40. EC. 2001c. Assessment of the implementation of the 2001 employment guidelines. Supporting document to the joint employment report 2001. *Commission Staff Working Paper*. November 16. Brussels.
41. EIMS. 1997. 'Exploring innovation in Europe', CORDIS Focus, 10 December 1997, European Commission, Innovation programme, the European Innovation Monitoring System (EIMS).
42. Emerging thematic priorities for research in Europe, working paper, IPTS-JRC, Seville, December 2000.
43. Entdorf, H. and Kramarz, F. 1995. 'The impact of new technologies on wages', Conference on the Effects of Technology and Innovation on Firm Performance and Employment, Washington, 2 and 3 May.
44. EU Commission The European Trend Chart on Innovation: Thematic Trend Chart Report on Innovation Finance, June 2000 - Thematic Trend Report on Research - Industry Technology Transfer ", June 2000 - Trend Report: Industry-Science Relationship Dec 2000
45. European Commission. 2001. *Employment in Europe 2001- Recent Trends and Prospects.*July 2001. DG Employment and Social Affairs. European Commission.
46. European Foundation for the Improvement of Living and Working Conditions. 1997. *New forms of work organization*, European Foundation for the Improvement of Living and Working Conditions, Dublin.
47. Eurostat. 2000. *Eurostat Yearbook: A statistical eye on Europe, Data 1988-1998*, Eurostat, Luxembourg.
48. Eurostat. 2001. *Regional Labour Force in the EU: Recent Patterns and Future Perspectives.* Theme1-2/2001. General Statistics. Statistics in Focus. KS-DN-01-002-EN-1
49. Evangelista, R. and G. Perani. 1998. *Innovation and Employment in Services: Results from the Italian Innovation Survey*, paper presented at the conference of the European Association for Evolutionary Political Economy (EAEPE), 5-8 November, Lisbon.
50. Evangelista, R. and M. Savona. 1998. *Patterns of Innovation in Services. The Results of the Italian Innovation Survey*, paper presented at the VIII Annual European Network on Services and Space (RESER) Conference, 8-10 October, Berlin.
51. Fagerberg, J. 1994. 'Technology and international differences in growth rates', *Journal of Economic Literature*, 32, September, pp. 1147-1175.
52. Falk, M. 1999. 'Technological Innovations and the Expected Demand for Skilled Labour at the Firm Level', *ZEW Discussion Paper* 99-59, Zentrum für Europäische Wirtschaftsforschung, Mannheim.
53. Falk, M. 2000. *Organizational Change, Information and Communication Technologies and the Demand for Different Educational Qualifications*, paper presented at the conference on Organizational Change and its Implications on Labour Market, November, Bonn.
54. Falk, M. and K. Seim. 1999. 'Workers' Skill Level and Information Technology – Evidence from German Service Firms', *ZEW Discussion Paper* 99-14. Zentrum für Europäische Wirtschaftsforschung, Mannheim.
55. Feenstra, R. and G. Hanson. 1996. 'Globalization, Outsourcing, and Wage Inequality', *American Economic Review Papers and Proceedings*, vol. 86, pp. 240-245.

56. Gera, S., W. Gu and Z. Lin. 1999. 'Technology and the Demand for Skills: an Industry Level Analysis', Working Paper 28, *Industry Canada Research Publications Program*.
57. Goldin, C. and L. Katz. 1998. 'The Origins of Technology-skill Complementarity', *Quarterly Journal of Economics*, vol.113, pp. 693-732.
58. Gordon, Robert J. 2000. *Interpreting the "One Big Wave" in U. S. Long-term Productivity Growth*, April 22, a revision of a paper published in Bart van Ark, Simon Kuipers, and Gerard Kuper (eds), 2000. *Productivity, Technology, and Economic Growth*, Kluwer Publishers, Dordrecht (http://faculty-web.at.northwestern.edu/economics/gordon/338.html).
59. Goux, D. and E. Maurin. 2000. 'The Decline in Demand for Unskilled Labor: an Empirical Analysis and its Application to France', *Review of Economics and Statistics*, vol. 82, pp. 596-607.
60. Griliches, Z. 1964. 'Research Expenditures, Education and the Aggregate Agricultural Production Function', *American Economic Review*, 54 (6), pp. 961-974.
61. Griliches, Z. 1995. 'R&D and productivity: econometric results and measurement issues', In Stoneman, P. (ed.) *Handbook of the economics of innovation and technological change*, Blackwell, London.
62. Grossman, G. M. and E. Helpman. 1991. *Innovation and Growth in the Global Economy*, The MIT Press, Cambridge, Mass.
63. Guellec D. and B. van Pottelsberghe de la Potterie. 2001. 'R&D and productivity growth: panel data analysis of 16 OECD countries', *DSTI Working paper* 2001/3, Organisation for Economic Co-operation and Development, Paris.
64. Guo D. and G. J. D. Hewings (2001). "Comparative analysis of China's economic structures between 1987 and 1997: an input-output prospective". Discussion paper of REAL. Downloaded from www.uiuc.edu/unit/real.
65. Capron H., Economic quantitative methods for the evaluation of the impact of R&D programmes, CEC report EUR 14864 EN, 1992.
66. Hannan M. and J. Freeman. 1997. 'The Population Ecology of Organizations', *American Journal of Sociology*, vol. 82, pp. 929-964.
67. Haskel, J. and Y. Heden. 1999. 'Computers and the demand for Skilled Labour: Industry and Establishment-level Evidence for the UK', *Economic Journal*, vol. 109, pp. C68-C79.
68. Howell, D.R. and E.N. Wolff. 1992. 'Technical change and the demand for skills by U.S. industries', *Cambridge Journal of Economics*, vol. 16, pp. 127-146.
69. ILO. 2001. *World Employment Report 2001: life at work in the Information Economy*, International Labour Organization, Geneva.
70. IPTS. 1999. *IPTS Futures Project, Synthesis Report*, (EUR 19038 EN), IPTS, Seville.
71. IPTS/ESTO. 2001 *Impact of Technological and Structural Change on Employment: Prospective Analysis 2020.*Study for the European Parliament, Committee on Employment and Social Affairs. Implementation Plan. May 2001
72. Alaminos J. D., The inter-relation between technology and total employment, IPTS Report, 34 (1999) 30.
73. Jarmin, R. S. and Motohashi, K. 1997. 'Technology and productivity: Insights into employment from firm level datasets in France, Japan and the United States', International Conference on Comparative Analysis of Enterprise Data, Bergamo, Italy, 15 to 17 December.
74. Jorgenson, D. W. and K. J. Stiroh. 2000. 'Raising the Speed Limit: U.S. Economic Growth in the Information Age', *Brookings Papers on Economic Activity*, vol. 2 (1), pp. 125-212.

75. Jovanovic, B. 1979. ‘Job matching and the theory of turnover’, Journal of Political Economy, 87, pp. 972-990.
76. Pavitt K., The inevitable limits of EU R&D funding, Research Policy, 27 (1998) 559.
77. Kölling, A. 1997. ‘Employment dynamics by different skill groups: Are there shifts in labour demand against the unskilled?’, European Low-Wage Conference, London School of Economics, London, 12 and 13 December.
78. Kraemer, K. L. and Dedrick, J. 1998. ‘Information technology and economic development: Results and implications of cross-country studies’, the UNU/WIDER Meeting, Helsinki, 12 and 13 June.
79. Krueger, A. 1993. ‘How Computers Have Changed the Wage Structure: Evidence from Micro Data 1984-1989’, *Quarterly Journal of Economics*, vol.108, pp. 33-60.
80. L.B. Joergensen et al, Evaluation of the MONITOR programme (1989-1993), EC report EUR 15782 EN, 1994.
81. Laaksonen, S. 1998, ESTO TECHNO ECONOMIC INTELLIGENCE REPORT 1998, http://esto.jrc.es/tar/1998-2.html 10/06/99, 100000 bytes
82. Laaksonen, S. and Teikari, I. 1999. ‘Analysis of effects of reconstructed business units on employment and productivity’, in Biffignandi, S. (ed.), Micro and macrodata, statistical analysis and international comparison, Physica Verlag, Germany, pp. 373-392.
83. Licht, G. and Moch, D. 1997. ‘Innovation and information: Technology in services’, ZEW Working Paper 97/20, Mannheim.
84. Lipsey, R. G., C. Bekar, and K. Carlaw. 1998. ‘What Requires Explanation?’ In E. Helpman (ed.). *General Purpose Technologies and Economic Growth*, The MIT Press, Cambridge, Mass.
85. M. Meyer, Start-up support and company growth, IPTS report, 51 (2001) 27.
86. M.B. Wallerstein, M.E .Mogee and R A Schoen (eds), Global dimensions of intellectual property rights in science and technology, National Academic Press, Washington DC, 1993.
87. Machin, S. 1996. ‘Changes in the Relative Demand for Skills in the UK Labor Market’, in A. Booth and D. Snower (eds.), *Acquiring Skills: Market Failures, Their Symptoms and Policy Responses*, Cambridge University Press, Cambridge.
88. Machin, S. and J. Van Reenen. 1998. ‘Technology and Changes in the Skill Structure: Evidence from Seven OECD Countries’, *Quarterly Journal of Economics*, vol.113, pp. 1215-1244.
89. Maddison, A. 1991. *Dynamic forces in capitalist development: a long-run comparative view*, Oxford University Press, Oxford.
90. Mairesse, J. and P. Mohnen. 1994. ‘R&D and Productivity Growth. What Have We Learned From Econometric Studies?’ In *Proceedings of the EUNETIC Conference on Evolutionary Economics of Technological Change: Assessment of Results and New Frontiers*, Communauté urbaine, Strasbourg, pp. 817-888.
91. Mairesse, J., N. Greenan and A. Topiol-Bensaïd. 2001. ‘Information Technology and Research and Development Impacts on Productivity and Skills: a Comparison on French Firm Level Data’, *NBER Working Paper* 8075, National Bureau of Economic Research, Cambridge, Mass.
92. Mansfield, E. 1965. ‘Rates of Return from Industrial R&D’, *American Economic Review*, 55, pp. 310-322.
93. McMorrow, K. and W. Roeger. 2001. *Potential Output: Measurement Methods, “New” Economy Influences and Scenarios for 2001-2010 - A Comparison of the EU15 and the US*, ECFIN/249/01-EN, n.150, April 2001, European Commission, Brussels.

94. Milgrom, P. and J. Roberts. 1990. 'The Economics of Modern Manufacturing: Technology, Strategies and Organization', *American Economic Review*, vol. 80, pp. 511-528.
95. Millard, J. 1999. 'Foreword', in *Proceedings of the Sixth European Assembly on Telework and New Ways of Working*, 22-24 September 1999, Aarhus, Denmark.
96. Mortensen, D. T. and Pissarides, C. A. 1995. 'Technological progress, job creation and job destruction', Centre for Economic Performance, Discussion Paper 264, London.
97. Motohashi, K. 1997. 'Technology adoption, organisational change and human resource strategy: Some observations in Japanese firms', International Conference on Comparative Analysis of Enterprise Data, Bergamo, Italy, 15 to 17 December.
98. Musick, N. 1998. 'Heroic plants — Persistently-rapid job creators in the longitudinal research database', Center for Economic Studies, Discussion Paper, Washington.
99. Kastrinos N., The impact of EC R&D programmes on corporate R&D practice in Europe: a knowledge-base approach, R&D Management, 25 (3) (1995) 269.
100. Nadiri, I. 1993. 'Innovations and Technological Spillovers', *NBER Working Paper* 4423, National Bureau of Economic Research, Cambridge, Mass.
101. Neil Jennings & Ben Gardiner.1999. *Robustness of Industrial Projections and Simulation Properties.* Working Paper for Task 2. Industrial Benefits and Costs of Greenhouse Gas Abatement Strategies: Applications of E3ME. Cambridge Econometrics Dec, 1999.
102. Nickell, S. and B. Bell. 1995. 'The Collapse in Demand for the Unskilled and Unemployment across the OECD', *Oxford Review of Economic Policy*, vol.11, pp. 40-62.
103. Nyholm, J. 1995. 'Information technology, productivity and demand for skills in Danish manufacturing', Conference on the Effects of Technology and Innovation on Firm Performance and Employment, Washington, 2 and 3 May.
104. OECD. 2001. *OECD Productivity Manual: A Guide to the Measurement of Industry Level and Aggregate Productivity Growth.* Statistics Directorate & DSTI. March 2001. OECD. Paris.
105. OECD. 2000a. *Science Technology and Industry Outlook*, Organisation for Economic Co-operation and Development, Paris.
106. OECD, 2000b, *A new economy? The role of innovation and information technology in recent OECD economic growth*, Organisation for Economic Co-operation and Development, Paris.
107. OECD. 1999a. Economic Opening and the Demand for Skills in Developing Countries – A Review of Theory and Evidence, *Technical Paper* 149, Organisation for Economic Co-operation and Development, Paris.
108. OECD. 1999b. *Towards More Sustainable Household Consumption Patterns Indicators to Measure Progress*, Environment Directorate, October, Organisation for Economic Co-operation and Development, Paris.
109. OECD. 1999c. *Trends in International Migration*, SOPEMI, Organisation for Economic Co-operation and Development, Paris.
110. OECD. 1998. 'OECD Data on Skills: Employment by Industry and Occupation,' *STI Working Paper* 4, Organisation for Economic Co-operation and Development, Paris.
111. OECD. 1996, *Technology, productivity and job creation: vol. 2 Analytical Report,* Organisation for Economic Co-operation and Development, Paris.
112. Oliner, S. D. and D. E. Sichel. 2000. 'The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?', *Journal of Economic Perspectives*, 14 (4), pp. 3-22.

113. Osmo Forssell & Hans Gunther Vierweg. 1999. *Incentives for Industrial Energy Efficieny*. Working Paper for Task 5. Industrial Benefits and Costs of Greenhouse Gas Abatement Strategies: Applications of E3ME. University of Oulu & IFO, Munich, Germany.Dec 1999.
114. Osterman, P. 1994. ‘How Common is Workplace Transformation and Who Adopts It?’ *Industrial and Labour Relations Review*, vol. 47, pp. 173-188.
115. Moncada P. et al, The management of intellectual property in publicly funded research, Research Policy, 26 (1998) 18.
116. David P.A. et al, Is public R&D a complement or substitute for private R&D? A review of the econometric evidence, ibid, 497.
117. Pasinetti, L. 1981. *Structural Change and Economic Growth*, Cambridge University Press, Cambridge.
118. Schreyer P.,2000. *The Contribution of Information and Communication Technology to Output Growth: A Study of the G7 Countries.* STI Working Paper 2000/2. OECD.
119. Pianta, M. 2001. ‘Innovation, demand and employment’, in P. Petit and L. Soete, (eds.) *Technology and the future of European employment*, Elgar, Aldershot.
120. Pianta, M., 2000, ‘The impact of product and process innovations’. In M. Vivarelli and M. Pianta (eds.), *The Employment Impact of Innovation: Evidence and Policy*, Routledge, London.
121. Prescott, E. C. 1997. ‘Needed: A Theory of Total Factor Productivity’, Federal Reserve Bank of Minneapolis, *Staff Report* 242, Minneapolis.
122. Cyert R. M. and Mowery D.C. (eds), The impact of technological change on employment and economic growth, Ballinger Publishing Co, 1988.
123. Hawkins R. W. and Sinclair T. J., A methodology for assessing the impact of the Marie Curie fellowships scheme, report to the European Commission, January 2000.
124. Roach, S. 1987. ‘America’s technology dilemma: A profile of the information economy’, Economics Newsletter by Morgan Stanley, 22 April.
125. Martin S. and Scott J.T., The nature of innovation market failure and the design of public support for private innovation, ibid, 437.
126. Sakurai, N., G. Papaconstantinou, G. and E. Ioannidis. 1997. ‘Impact of R&D and technology diffusion on productivity growth: empirical evidence for 10 OECD countries’, *Economic Systems Research*, 9, pp. 81-109.
127. Sakurai, N., Papaconstantinou, G. and Ionnidas, E. 1995. ‘The impact of R & D and technology diffusion on productivity growth: Evidence for 10 OECD countries in the 1970s and 1980s’, Conference on the Effects of Technology and Innovation on Firm Performance and Employment, Washington, 2 and 3 May.
128. Schreyer, P. 2000. ‘The Contribution of Information and Communication Technology to Output Growth: A Study of the G-7 Countries’, *STI working paper* 2000/2, Organisation for Economic Co-operation and Development, Paris.
129. Schumpeter, J. A. 1942. Capitalism, socialism and democracy, Harper and Row, New York.
130. Siegel, D. 1995. ‘The impact of technological change on employment’, Conference on the Effects of Technology and Innovation on Firm Performance and Employment, Washington, 2 and 3 May.
131. Smolny, W. 1998. ‘Innovations, Prices and Employment: A Theoretical Model and an Empirical Application for West German Manufacturing Firms’, *Journal of Industrial Economics*, vol. 46, pp. 359-381.
132. Statistics on Science and Technology in Europe, Eurostat, March 2001.

133. Stefano Scarpetta, Andrea Bassanini, Dirk Pilat and Paul Schreyer. 2000. *Economic Growth in the OECD Area: Recent Trends at Aggregate and Sectoral Level.* ECO/WKP(2000)21. June 2000. Economics Department. OECD.
134. Sylos-Labini, P. 1969. *Oligopoly and Technical Progress*, Harvard University Press, Cambridge.
135. Luukkonen T., Additionality of the EU framework programmes, Research Policy, 29 (2000) 711.
136. Luukkonen T., The difficulties in assessing the impact of EU framework programmes, ibid, 599.
137. Terleckyj, N. 1958. 'Factors Underlying Productivity: Some Empirical Observations', *Journal of the American Statistical Association*. 53, June, p. 593.
138. Terleckyj, N. 1980. 'Direct and Indirect Effects of Industrial Research and Development on the Productivity Growth of Industries', in Kendrick, J. W. and B. N. Vaccara (eds.), 'New Developments in Productivity Measurement and Analysis', *Studies in Income and Wealth*, vol. 44, The University of Chicago Press, Chicago.
139. Thesmar, D. and M. Thoenig. 2000. 'Creative Destruction and Firm Organization Choice: a New Look into the Growth Inequality Relationship', *Quarterly Journal of Economics*, vol. 115, pp. 1201-1237.
140. Trajtenberg, M. 1990. *Economic Analysis of Product Innovation: The Case of CT Scanners*, Harvard University Press, Cambridge, MA.
141. Vainiomäki, J. and Laaksonen, S. 1997. 'The effects of technology on job creation and destruction in Finnish manufacturing, 1986-93', in Laaksonen, S. (ed.), 'Evolution of firms and industries', Statistics Finland Research Reports 223, Helsinki, pp. 234-251.
142. Van den Berg, G. J., Gautier, P. A., van Ours, J. C. and Ridder, G. 1998. 'High unemployment rates for low-skilled workers: Does that mean there is crowding out?', Conference of Linked Employer-Employee Data, Washington, 21 and 22 May.
143. Van Reenen, J. 1997. 'Employment and Technological Innovation: Evidence from U.K. Manufacturing Firms', *Journal of Labor Economics*, vol. 15, pp. 255-284.
144. Verspagen B. (2001). "Structural change and technology. A long view". Mimeo.
145. Vivarelli, M. 1995. *The Economics of Technology and Employment: Theory and Empirical Evidence*, reprinted 1997, Elgar, Cheltenham.
146. Vivarelli, M., Evangelista, R. and Pianta, M. 1995. 'Innovation and employment: Evidence from Italian manufacturing', Conference on the Effects of Technology and Innovation on Firm Performance and Employment, Washington, 2 and 3 May.
147. von Tunzelmann, G. N. 2000. 'Technology generation, technology use and economic growth', *European Review of Economic History*, vol. 4, pp. 121-146.
148. von Tunzelmann, N. 1999. 'Growth and supply in Europe since the Second World War', in D. Dyker (ed.), *The European Economy*, Longmans, London.
149. Piper W. S and Naghshpour S., Government technology transfer: the effective use of both push and pull marketing strategies, Int J Technology Management, 12 (1996) 85.
150. Wolff, E.N. 1996. 'Technology and the demand for skills', *STI Review*, vol. 18, pp. 95-123.
151. Wood, A. 1994. *North-South Trade, Employment, and Inequality: Changing Fortunes in a Skill-driven World*, Clarendon Press, Oxford.

Annex 1 Emerging sector-specific technologies

Simulations of employment in Europe in 2000-2020 were carried out in this study by using the GEM-E3 and ASTRA models. The simulations were based on specific assumptions about future productivity of labour and consumption demand. The assumed growth rates of labour productivity and shares of consumption demand shares for different sectors of the European economy are presented in Appendices 2 and 3. The assumptions have been derived on the basis of informal analyses of long-term trends in the different sectors of the European economy. One part of the analysis identified emerging technologies that are likely to affect sectoral employment levels. This Annex presents those emerging technologies; the presentation shown is based on the division of the economy into 12 sectors along the lines of the ASTRA model.

The presentation includes only those emerging technologies that are expected to have a High (H) or Medium (M) impact on employment by the year 2020. For each emerging technology the presentation also gives an estimate of the year by which the technology concerned is expected to become widely diffused in Europe. Needless to say, employment in each sector is also going to be affected by incremental changes in existing technologies that already are widely used. Moreover, developments in general-purpose technologies, particularly information and communication technologies, can be expected to influence employment levels simultaneously in many sectors of the economy.

The identification of the emerging technologies was carried out by means of an analysis of the results of technology foresight studies recently accomplished in many industrially advanced countries and consultations of scientific and technical experts in the public (universities, research organisations) as well as the private (research laboratories of firms) sector. For the 5th sector "Steel products, machinery, transport equipment, office equipment", the analysis was carried out in more detail. The productivity effects of new technology (1) substituting human labour and old technology were distinguished from those resulting (2) from the substitution of just a technology of a previous generation. Similarly regarding consumption a distinction was made here between consumption effects on (3) old and (4) new products.

Table A1.1. Employment impacts of emerging technologies on 12 sectors of the European economy.

1. Agriculture, forestry and fishery.	**Impact on employment**		
Emerging technology	Produc-tivity	De-mand	Diffu-sion
Gene manipulation of plants.	H	H	2005
Bio-mimetic farm machines.	H	L	2012
Embryonic stem cells in livestock production.	H	L	2011
Genetic engineering and protein engineering of synthetic vaccines.	M	H	2010
Decomposition of animal waste.	M	H	2009
Gene manipulation and cell fusion for tree breeding.	M	H	2009
Remote sensing systems for pest outbreaks, landslides and other disturbances to forests.	M	H	2010
Life cycle assessment for forestry and forest products.	H	M	2005
Gene manipulation and cell fusion for traits in aquatic organisms advantageous to cultivation.	H	M	2009

Deep sea fishing technologies.	H	….	2013
Modeling and simulation for long term marine resource prediction.	H	….	2016

2. Energy, water-, mining products, crude oil.	**Impact on employment**		
Emerging technology	Produc-tivity	De-mand	Diffu-sion
Biotechnology produced low cost methane from waste treatment.	M	….	2007
Solar cells for domestic power.	M	H	2009
Microgeneration with microturbines and fuel cells.	H	H.	2005
Energy efficient buildings.	H	….	2011
Long distance transportation of natural gas through new materials and high pressure.	H	H	2005
Distributed electric power generation with fuel cells.	H	….	2017
High efficiency biomass energy production.	M	….	2016
Hybrid systems with microturbines and fuel cells.	H	H	2010
High temperature gas turbine combined cycle power generation.	H	….	2009
CO_2 capture and sequestration.	H	H	2010
Very high yield heavy oil conversion.	H	H	2005
Artificial rainmaking,	H	….	2014
Elimination of leakage in water distribution networks.	H	H	2009
International water transfer systems.	M	H	2020
Biotech-based water treatment.	….	M	2011
Solution mining.	H	H	2019
Semi-quantitative prospecting technology using artificial satellites.	H	….	2012
Ultra-deep drilling and excavating technologies.	H	….	2016
Water jet based hard rock tunnel drifting.	H	….	2008
Unmanned mining robots.	H	….	2012

3. Chemical-, mineral-, plastic- and petroleum products.	**Impact on employment**		
Emerging technology	Produc-tivity	De-mand	Diffu-sion
Mass-synthesizing technology for fullerene carbon compounds.	….	M	2010
Photo-catalysts for organic synthetic processes.	….	M	2010
Artificial high performance catalysis for manufacture of chemicals at near normal temperatures and pressures.	H	….	2010
Organic ferro-magnetic materials.	….	H	2010
Bio-plastics, Polymer conductors.	….	M	2010
Self-healing high polymers.	….	M	2005
Selective catalytic cracking technology for naphtha.	H	….	2008
Direct synthesis of phenol from benzene.	….	M	2006
Combinatorial chemistry.	….	M/H	2006
Chiral chemistry and asymmetric catalysis.	….	M/H	2004
Advanced enzyme evolution techniques.	….	M	2004
RNA catalysis.	….	H	2010
Biomimetic catalysis.	….	H	2010
Advanced zeolite catalysis.	….	H	2003
Polymer functionalization.	….	H	2003

4. Ferrous and non-ferrous ores and metals.	**Impact on employment**		
Emerging technology	Produc-tivity	De-mand	Diffu-sion
Economical manufacturing process for ultra high purity steel with 6-N.	H	M	2005
Long life high strength, high temperature alloys.	L	H	2007
Biotech-based extraction and separation of metals.	H	L	2016
Cost of refining process for titanium on a par with aluminium.	M	L	2010
Magnetic force for non-ferrous metal casting.	H	H	2005
Thin strip casting of steels: pilot plant setup, product properties, process reliability.	M	H	2005
Nanostructural and submicrostructural metals: bulk processing and properties.	H	H	2010
Formability of metal matrix composites: high temperature properties and deformation behaviour.	L	M	2005
New materials by molecular scale engineering.	M	H	2005

5. Steel products, machinery, transport equipment, office equipment.	Impact on employment				
Emerging technology	Produc-tivity		De-mand		Diffu-sion
	(1)	(2)	(3)	(4)	
Super heat-resistant inter-metallic compounds.	….	M	….	M	2015
Maintenance robots for diagnosing and repairing machinery.	….	H	….	….	2003
Automobiles powered by hydrogen in hydrogen occlusive alloy storage tanks.	….	M	….	H	2015
Automobiles with fuel efficiency increased by 30%.	….	M	….	H	2020
Fully automatic ships which can navigate and dock automatically.	H	….	….	….	2010
Quiet, energy-saving VTOL passenger aircraft.	….	….	….	H	2010
Formability of metal matrix composites: high temperature properties and deformation behaviour.	….	….	M	H	2006
Surface engineering for improved corrosion, wear, strength: special coatings produced by thermal spray or by arc deposition methods.	….	M	….	H	2008
Material increasing forming technologies.	M	M	H	H	2013
Microfluidics, microelectromechanical devices, micromachines and microassembly.	….	….	….	H	2013
Agile and reconfigurable plug and play production cells.	….	M	H	H	2013
Agent based production systems.	M	M	M	M	2013
Web based integrated manufacturing.	M	M	H	H	2013
PKM robots. Bio and clean manufacturing.	M	M	M	M	2013
Return manufacturing. Reconfigurable systems.	….	M	H	H	2013
Process design and ramp-up tools.	….	….	M	H	2013
Online systems monitoring.	H	H	H	H	2013
Digital mock-up of product and processes.	H	H	H	H	2013
Near net and net shape forming technology.	M	H	H	L	2013

Key: (1) New “machine substituting” man and machine – (2) New “machine substituting” previous generation machine – (3) Traditional products – (4) New products

6. Electrical-, optical goods, office and data processing, toys.	Impact on employment		
Emerging technology	Produc-tivity	De-mand	Diffu-sion
DNA and RNA Biochips.	H	H	2009
Biosensors.	H	H	2016
3D television sets.	….	H	2009
Mobile terminals with 10 Mbps reception and transmission.	….	H	2006
Fluoride glass fibers for optical communication.	….	M	2008
Digital optical logic circuits.	H	….	2007
Semiconductor lasers with oscillation wavelength independent of temperature.	….	M	2009
Optical memories with recording densities of 10^{11} b/cm2.	H	H	2015
Parallel computing with more than 10^6 processors.	H	H	2008
>10 TFlops computer.	H	M	2007
Solar-powered portable computers.	M	M	2006
Computer networks with shared virtual space for many unspecified persons anywhere.	M	H	2007
Complex polymer and supramolecular assemblies for electronic molecular scale devices.	….	H	2005

7. Textiles, clothing, paper, wooden goods.	Impact on employment		
Emerging technology	Produc-tivity	De-mand	Diffu-sion
Crosslinked polyol fibrous substrates as multifunctional and multi-use intelligent materials.	M	H	2010
Application of nonionic polymer gel and elastomers for artificial muscles.	….	M	2012
Smart textile composites integrated with fiber optic sensors.	….	M	2007
Dyeable polypropylene via nanotechnology.	M	….	2006
Magnetic ring-spinning.	M	….	2006
Biomimetic manufacturing of fibers.	H	M	2012
Biostoning.	M	H	2003
Enzyme based setting.	M	….	2003
Equipment for volumetric body measurement using lasers and image analysis techniques.	H	….	2004
DNA profiling and micro-biological techniques for unambiguous identification of natural fibres.	M	L	2008
Machine vision for e.g. robotic manipulation of fabric plies.	M	….	2008
Wood and non-wood composite material integration technology.	H	H	2007
Environmentally friendly wood protection, coating and gluing.	L	H	2007
Stem modelling and simulation of sawmill outputs.	H	L	2005

8. Food, beverages, tobacco.	Impact on employment		
Emerging technology	Produc-tivity	De-mand	Diffu-sion
Ultra-high pressure hydrostatic processing.	M	M	2004
Ohmic processing.	M	M	2005
High intensity light pulses and high energy field pulses for food processing.	M	M	2005
Thermosonication.	M	M	2006
Radiofrequency (RF) heating.	M	M	2004
Modified atmosphere packaging (MAP) and active packaging.	M	M	2003
Edible films and coatings.	M	M	2004
Intelligent packaging devices.	M	M	2005
Under vacuum packaging & cooking of ready meals.	M	H	2005
Irradiation for very long shelf life products.	H	M	2004
Hurdles technology.	L	….	2010
Osmotic dehydratation.	M	L	2005
High pressure food sterilisation.	M	H	2005
Electro-magnetic waves food sterilisation.	M	H	2020

9. Building and construction	Impact on employment		
Emerging technology	Produc-tivity	De-mand	Diffu-sion
Concrete whose strength deterioration is predictable.	L (1 m^3/hr)	L	2010
Long service-life (>100years) concrete and steel in buildings.	H (50 m^3/hr)	M	2005
AI and virtual reality technologies applied to architectural design systems.	L	….	2003
Self-Compacting Concrete (SCC).	H (100 m^3/hr)	H	2003
Concrete for a Sustainable Development (CSD).	H (50 m^3/hr)	M	2010

10. Services for repair, wholesale and retail, transport, communication	Impact on employment		
Emerging technology	Produc-tivity	De-mand	Diffu-sion
Advanced logistic systems for value chains.	H	….	2005
Superconductivity, fully automated container yards.	M	M	2005
Radical automation of air traffic control.	H	….	2020
Fully automatic all weather take-off, landing and taxiing systems.	M	M	2010
Shared-connection vehicle systems.	H	H	2005
A/D converters using high temperature superconductors, 10Gbps laser-based space-earth communication technology.	M	M	2006
Nationwide network of telemeters for meteorology, road and fleet traffic control, environmental monitoring, distributed via satellite.	H	M	2005
High quality speech synthesizing technologies.	….	M	2004

11. Other market services e.g. lodging, catering, credit, insurance.	Impact on employment		
Emerging technology	Produc-tivity	De-mand	Diffu-sion
Full range of information, communication and computer based technologies which enable product/ service development and real time customised response and delivery.	H	L	2003
Intelligent monitoring systems (captators) for insurance services	L	H	2003
Intelligent guidance of vehicles for better safety	L	M	2003
Virtual reality applications for tourism	M	M	2003

12. Non-market services: Education, Healthcare	Impact on employment		
Emerging technology	Productivity	Demand	Diffusion
E-learning: distributed learning management systems, virtual institutes for training and education, libraries and databases of learning objects.	….	H	2005
Information networks by numerous devices, multifunctional wrist-watch communication devices / personal assistants.	H	H	2005
Advanced e-solutions for sales, logistics and distribution.	M	….	2010
Healthcare: bio-technologies for bio-artificial organs, cellular therapy for neurological and genetic diseases, nanotechnologies and microsystems for medical use and research.	H	H	2008
Knowledge of contracting mechanisms in auto-immune diseases.	H	H	2008
Scientific guidelines for adult disease preventing life styles.	H	H	2005
3D imaging for cancer spread diagnosis.	H	H	2005
Non-invasive cell-level diagnostic imaging.	H	H	2005
Gene therapy.	H	H	2012
Preventive technologies, understanding the mechanisms of immune response at the level of molecular biology.	H	H	2012
E-healthcare: use of ICT for medical and chirurgical applications and services, health telematics.	H	H	2008
E-administration: use of ICT for civil services and web based public applications.	M	H	2004

Annex 2 Productivity growth assumptions 2000-2020

Table A2.1. Average annual productivity growth rates in the EU in 1994-2020, data and assumptions for the GEM-E3 model, per cent.

	Nordic EU									Germany									UK									REU								
	1994-1999	2000-2010				2010-2020				1994-1999	2000-2010				2010-2020				1994-1999	2000-2010				2010-2020				1994-1999	2000-2010				2010-2020			
		B	U	D	C	B	U	D	C		B	U	D	C	B	U	D	C		B	U	D	C	B	U	D	C		B	U	D	C	B	U	D	C
Agriculture	n.a.	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	n.a.	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	n.a.	0.0	0.0	0.0	0.0	1.2	1.2	1.2	1.2	n.a.	2.0	2.0	2.0	2.0	1.8	1.8	1.8	1.8
Coal	n.a.	1.6	1.6	1.6	1.6	1.4	1.4	1.4	1.4	n.a.	1.6	1.6	1.6	1.6	1.4	1.4	1.4	1.4	n.a.	1.3	1.3	1.6	1.3	1.1	1.1	1.4	1.1	n.a.	1.8	1.8	1.8	1.8	1.6	1.6	1.6	1.6
Oil	n.a.	3.3	3.3	3.5	3.3	3.0	3.0	3.3	3.0	n.a.	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	n.a.	3.2	3.2	3.6	3.2	2.9	2.9	3.4	2.9	n.a.	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Gas	n.a.	2.2	2.2	2.7	2.2	2.0	2.0	2.5	2.0	n.a.	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	n.a.	2.8	2.8	3.2	2.8	2.5	2.5	3.0	2.5	n.a.	1.8	1.8	1.8	1.8	1.6	1.6	1.6	1.6
Electricity	n.a.	2.0	2.0	2.2	2.0	1.8	1.8	2.0	1.8	n.a.	2.0	2.0	2.0	2.0	1.8	1.8	1.8	1.8	n.a.	2.5	2.5	2.7	2.5	2.2	2.2	2.5	2.2	n.a.	2.0	2.0	2.0	2.0	1.8	1.8	1.8	1.8
Ferrous and non-ferrous	0.3	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.2	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.8	1.0	1.0	1.8	1.0	0.9	0.9	1.6	0.9
Chemicals	2.2	2.0	2.1	2.4	2.2	2.0	2.0	2.2	2.0	4.7	3.3	3.6	4.7	3.8	3.3	3.4	4.3	3.5	2.2	2.2	2.3	2.8	2.5	2.2	2.3	2.8	2.4	2.8	2.3	2.4	2.6	2.5	2.2	2.4	2.4	2.3
Other energy intensive	3	2.6	2.6	3.0	2.6	2.4	2.4	2.8	2.4	1.0	1.3	1.6	1.8	1.8	1.1	1.3	1.6	1.4	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2.0	1.7	1.9	1.7	2.2	1.5	1.8	1.5	2.0
Electronic	13	8.0	9.0	9.0	10.0	4.0	5.0	6.0	6.0	1.5	2.0	3.0	2.0	4.0	1.8	2.7	1.8	3.5	1.3	1.6	1.8	2.6	2.2	1.6	1.8	2.4	2.2	5.0	3.8	4.0	3.8	5.0	3.5	4.0	3.5	5.0
Transport	2.5	2.3	2.3	2.3	2.3	2.1	2.1	2.1	2.1	1.8	2.0	2.3	3.2	2.5	1.8	2.1	3.0	2.3	1.5	1.3	1.4	1.3	1.5	1.1	1.3	1.1	1.5	5.0	3.0	3.3	5.0	3.6	2.7	2.9	4.6	3.0
Other equipment	1.9	1.9	2.0	1.9	2.2	1.9	1.9	1.9	1.9	4.0	3.3	3.6	4.0	3.8	3.3	3.4	3.7	3.5	-1.7	0.0	0.0	0.0	0.0	0.8	0.8	0.8	0.8	1.8	1.8	2.2	2.8	2.5	1.8	2.1	2.6	2.5
Other Manufacturing	2.3	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	-2.6	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	2.3	2.3	2.4	2.8	2.3	2.3	2.4	2.6	2.3
Construction	n.a.	2.3	2.3	2.3	2.3	2.1	2.1	2.1	2.1	n.a.	2.0	2.0	2.0	2.0	1.8	1.8	1.8	1.8	n.a.	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2		2.0	2.0	2.0	2.0	1.8	1.8	1.8	1.8
Food	2.2	1.8	1.8	1.8	1.8	1.6	1.6	1.6	1.6	-1.2	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	-1.1	-1.0	-1.0	-1.0	-1.0	0.5	0.5	0.5	0.5	1.2	1.5	1.5	2.0	1.5	1.4	1.4	1.8	1.4
Trade and transport	n.a.	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	n.a.	1.8	2.0	2.2	2.2	1.8	1.9	2.0	2.0	n.a.	1.8	2.2	2.4	2.5	1.8	2.2	2.2	2.5	n.a.	2.0	2.2	2.0	2.3	2.0	2.1	2.0	2.3
Textile	2.2	1.6	1.6	1.6	1.6	1.4	1.4	1.4	1.4	1.9	1.6	1.6	1.6	1.6	1.4	1.4	1.4	1.4	1.3	1.2	1.2	1.2	1.2	1.0	1.0	1.0	1.0	1.9	1.9	1.9	2.9	1.9	1.7	1.7	2.7	1.7
Other Market services	n.a.	2.2	2.4	2.6	2.6	2.2	2.4	2.6	2.6	n.a.	2.0	2.2	2.4	2.4	2.0	2.2	2.4	2.4	n.a.	2.2	2.4	4.2	2.6	2.2	2.4	4.0	2.6	n.a.	2.0	2.2	2.0	2.4	2.0	2.2	2.0	2.4
Non Market services	n.a.	1.8	1.9	1.8	2.0	1.8	1.9	1.8	2.0	n.a.	1.8	1.9	1.8	2.0	1.8	1.9	1.8	2.0	n.a.	1.5	1.7	1.5	2.0	1.5	1.7	1.5	2.0	n.a.	1.8	1.9	1.8	2.0	1.8	1.9	1.8	2.0

B = Baseline Scenario, U = Unified Scenario, D = Diversified Scenario, C = Concentrated Scenario, REU = Rest of the EU
Sources for data on years 1994-1999: OECD STAN database.

A single set of productivity growth rates assumptions, shown in the next table, was used for the world outside of the EU in all of the GEM-E3 simulations.

Table A2.2. Assumed average annual productivity growth rates in the rest of the world in 2000-2020, GEM-E3 model, per cent.

	Other OECD		CEA		Asia		South	
	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020
Agriculture	2.3	1.6	2.0	1.8	2.9	2.5	2.0	1.8
Coal	1.6	1.4	1.8	1.8	1.6	2.1	1.5	1.4
Oil	3.0	2.5	3.2	2.9	2.9	3.1	1.6	1.6
Gas	1.6	1.6	3.2	2.9	2.9	3.2	1.6	1.6
Electricity	1.5	1.7	3.1	3.0	3.0	3.3	2.0	2.5
Ferrous and non ferrous	2.6	1.6	2.0	2.0	2.8	2.6	2.6	2.6
Chemicals	2.4	2.0	3.1	2.8	3.1	3.0	2.8	3.1
Other energy intensive	2.1	1.6	3.1	2.8	2.9	2.6	2.6	2.8
Electronic	3.9	3.4	2.4	2.2	3.0	3.0	2.2	2.4
Transport	2.8	2.4	3.3	3.3	3.5	3.2	2.6	2.6
Other equipment	1.8	1.5	1.9	2.0	2.8	2.6	1.8	1.5
Other Manufacturing	2.0	1.6	2.3	2.3	2.6	2.4	2.4	2.4
Construction	2.0	1.6	2.8	2.6	2.2	2.2	2.0	1.8
Food	2.2	1.7	3.5	2.8	3.4	2.8	3.4	3.2
Trade and transport	1.6	1.4	3.0	2.5	2.0	2.4	2.0	2.1
Textile	1.9	1.6	3.5	3.0	3.5	3.2	3.5	3.2
Other Market services	2.5	2.5	2.0	2.0	3.0	2.8	1.5	1.5
Non Market services	1.8	1.8	1.4	1.4	1.5	1.5	1.3	1.2

CEA = Central European associates
Other OECD = U.S., Canada, Japan, Australia, New Zealand
Asia = East Asia and China only
South = rest of the world

Table A2.3. Assumed annual average productivity growth rates between 2000 and 2020, ASTRA model, Baseline Scenario, per cent.

Sector	Region of the EU							
	E1		E2		E3		E4	
	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020
Agriculture	1.5	1.4	2.0	1.8	2.0	1.8	0.6	1.3
Energy	1.6	1.6	1.8	1.6	1.6	1.4	2.8	2.5
Chemicals	3.2	3.0	2.2	2.0	2.0	1.9	2.1	2.1
Ferrous and non ferrous	2.0	2.0	0.9	0.7	1.1	1.0	0.4	0.3
Steel Transport	2.2	2.0	2.7	2.5	2.5	2.3	1.7	1.5
Electronic	2.0	1.8	3.8	3.5	3.8	3.5	1.6	1.6
Textile	1.6	1.4	1.7	1.5	2.3	2.1	1.4	1.2
Food	0.0	1.0	1.5	1.4	1.6	1.5	1.0	1.1
Construction	2.0	1.8	2.2	2.0	2.0	1.8	2.2	2.2
Trade and transport	1.8	1.8	2.0	2.0	1.8	1.6	1.9	1.9
Other Market services	2.0	2.0	2.0	2.0	2.0	2.0	2.2	2.2
Non Market services	1.8	1.8	1.8	1.8	1.8	1.8	1.5	1.5

Region E1 = Germany, Austria
Region E2 = France, Netherlands, Belgium, Luxembourg
Region E3 = Italy, Spain, Portugal, Greece
Region E4 = United Kingdom, Sweden, Denmark, Ireland, Finland

Annex 3 Consumer demand assumptions 2000-2020

Table A3.1. Shares of consumption demand in the EU in 1995-2020, data and assumptions for the GEM-E3 simulations, per cent.

	1995*				2000				2010				2020			
	Nordic EU	Germany	UK	REU	Nordic EU	Germany	UK	REU	Nordic EU	Germany	UK	REU	Nordic EU	Germany	UK	REU
Food, beverage and tobacco	19	20	20	20	18	18	18	19	14	15	15	16	11	12	12	13
Clothing and footwear	5	8	6	7	5	7	6	7	5	6	5	6	4	5	4	5
Housing and water charges	19	18	16	14	19	18	17	14	19	18	17	16	20	18	18	16
Fuels and power	6	5	5	4	6	5	5	4	6	5	5	4	6	5	4	4
Househ. equipm. and operation	3	4	4	4	3	4	4	4	3	4	4	3	3	3	4	3
Heating and cook. appliances	2	5	2	4	2	5	2	4	2	5	2	4	2	5	2	4
Medical care and health	5	4	2	7	6	4	3	8	7	5	4	9	9	8	6	11
Transport equipment	2	6	3	3	2	6	3	3	2	6	3	3	2	6	3	3
Operation of transport	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1
Purchased transport	11	8	9	9	11	8	9	9	11	8	9	9	11	8	9	9
Communication	5	1	3	2	5	2	3	2	6	3	4	3	7	4	5	4
Recreational services	11	10	11	8	11	10	11	8	12	11	12	9	12	12	13	9
Misc. goods and services	10	10	17	17	10	12	17	17	11	13	18	17	11	13	18	18
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

* Source: Elaborations of OECD 1999, Eurostat 2000 and original coefficients in the GEM-E3 model.

Table A3.2. Assumed shares of consumption demand in the EU in 2000-2020, ASTRA simulations, per cent.

	Food,beverages and tobacco	Clothing and footwear	Gross rent, fuel and power	Furniture, furnishings and household operation	Medical care and health expenses	Transport and communication	Recreation, entertainment, education & cultural	Miscellaneous goods and services	Total
E1 2000	18	7	23	9	4	17	10	12	100
E1 2010	15	6	23	8	6	18	12	12	100
E1 2020	11	5	23	7	10	18	13	13	100
E2 2000	16	5	22	7	12	16	8	14	100
E2 2010	14	4	22	6	14	16	9	15	100
E2 2020	11	4	22	6	16	16	9	16	100
E3 2000	20	8	16	8	6	14	8	20	100
E3 2010	17	7	17	7	8	14	9	21	100
E3 2020	13	6	18	7	10	14	9	23	100
E4 2000	18	6	22	6	3	17	11	17	100
E4 2010	16	5	22	5	6	17	12	17	100
E4 2020	12	4	22	5	9	17	12	19	100

Region E1 = Germany, Austria
Region E2 = France, Netherlands, Belgium, Luxembourg
Region E3 = Italy, Spain, Portugal, Greece
Region E4 = United Kingdom, Sweden, Denmark, Ireland, Finland

Annex 4 Correlations between Employment variables and Economic variables, 1991-2000

Table A4.1: Slopes of Employment variables regressed on Economic variables

SLOPES	RGDP	LPRY	HPRY	RCED	RULC	AVHW	PTE	UNSR
EMPR	**0.3798**	**-0.1960**	-0.0298	-0.0587	0.0643	-0.0999		
	0.068	**0.069**	0.052	0.059	0.055	0.074		
EMPM	**0.4207**	**-0.2194**	-0.0410	-0.0603	0.0758	-0.1056		
	0.083	**0.082**	0.063	0.070	0.065	0.089		
EMPF	**0.3429**	*-0.1618*	-0.0078	-0.0532	0.0506	-0.1072		
	0.068	*0.067*	0.049	0.057	0.053	0.069		
SEMR	-0.0351	0.0305	0.0051	0.0068	-0.0117	0.0058		
	0.025	0.022	0.015	0.019	0.018	0.022		
SEMM	*-0.0822*	0.0256	-0.0198	0.0243	0.0061	0.0442		
	0.034	0.032	0.021	0.027	0.025	0.030		
SEMF	0.0198	0.0450	0.0280	-0.0241	*-0.0465*	-0.0192		
	0.034	0.031	0.022	0.026	*0.024*	0.031		
PTER	-0.0408	0.0128	*0.0653*	*-0.0878*	*-0.0792*	*-0.1162*		
	0.053	0.048	*0.031*	*0.039*	*0.036*	*0.044*		
PTEM	-0.0534	0.0041	0.0306	*-0.0606*	-0.0515	-0.0447		
	0.039	0.036	0.024	*0.029*	0.027	0.034		
PTEF	-0.0102	0.0423	*0.1137*	-0.1057	-0.1109	**-0.1969**		
	0.089	0.080	*0.052*	0.067	0.062	**0.074**		
FTCR	-0.0559	0.0282	0.0326	-0.0091	-0.0216	-0.0388	*0.2750*	
	0.053	0.048	0.035	0.041	0.038	0.050	*0.109*	
FTCM	-0.0645	0.0334	0.0554	0.0064	-0.0112	-0.0685	*0.3532*	
	0.051	0.047	0.032	0.040	0.037	0.047	*0.143*	
FTCF	-0.0226	0.0224	0.0116	-0.0264	-0.0330	-0.0245	*0.2067*	
	0.069	0.063	0.044	0.053	0.049	0.064	*0.084*	
FTER	**0.2300**	-0.1566	0.0047	*-0.1738*	-0.0459	-0.1182		
	0.113	0.082	0.057	*0.069*	0.067	0.081		
FTEM	*0.3265*	-0.1558	0.0195	*-0.2283*	-0.0919	-0.1666		
	0.144	0.107	0.076	*0.089*	0.086	0.109		
FTEF	0.1084	*-0.1677*	-0.0146	*-0.1489*	-0.0189	-0.0680		
	0.103	*0.072*	0.048	*0.062*	0.060	0.069		
YEMR	**-0.8048**	0.2785	0.0372	0.0659	-0.1065	0.1820		**1.8486**
	0.149	0.150	0.102	0.130	0.116	0.145		**0.125**
UNSR	**-0.3911**	0.0565	0.0249	-0.0326	-0.0712	-0.0012		
	0.054	0.063	0.050	0.060	0.056	0.072		

Key: All variables measured in terms of changes (first differences). Country and time dummies allowed for in all regressions.

NB: Bold = significant at 1% level; Italics = significant at 5% level; Standard errors shown below coefficients.

EMPR = employment rate, total M/male, F/female (% of each population aged 15-64 in employment)
SEMR = self-employed rate, total/male/female (ditto)
PTER = part-time employment, total/male/female (ditto)
FTCR = fixed-term contracts, total/male/female (ditto)

FTER = full-time equivalent (FTE) employment rate, total/male/female
YEMR = youth unemployment rate (% of the labour force aged 15-24)
UNSR = unemployment rate (% of the labour force aged 15+)

Economic variables in columns:
RGDP = real GDP;
LPRY = average labour productivity (per year);
HPRY = average hourly productivity;
RCED = real compensation per employee (GDP deflator, as an index of real wage rates);
RULC = real unit labour costs; and
AVHW = average hours worked.
PTE = part-time employment
UNSR = unemployment rate (% of the labour force aged 15+)