DOCUMENT RESUME

ED 478 433 CE 085 009

TITLE	Impact of Technological and Structural Change on Employment. Prospective Analysis 2020. Synthesis Report. Report to the Committee on Employment and Social Affairs of the European Parliament. Technical Report Series.
REPORT NO	EUR-20131-EN
PUB DATE	2001-12-00
NOTE	54p.; Produced by the European Commission. Joint Research Centre. For the background report: ftp://ftp.jrc.es/pub/EURdoc/eur20258en.pdf. Study was carried out by the Institute for Prospective Technological Studies (part of the Joint Research Centre) in collaboration with the European Science and Technology Observatory at the request of the Committee on Employment and Social Affairs of the European Parliament.
AVAILABLE FROM	For full text: ftp://ftp.jrc.es/pub/EURdoc/eur20131en.pdf.
PUB TYPE	Information Analyses (070)
EDRS PRICE	EDRS Price MF01/PC03 Plus Postage.
DESCRIPTORS	Adjustment (to Environment); Adult Education; Demand Occupations; *Economic Change; Economic Impact; Education Work Relationship; Employment Level; *Employment Patterns; Employment Qualifications; *Futures (of Society); *Industrial Structure; Job Skills; Job Training; Labor Economics; Labor Market; Policy Formation; Postsecondary Education; *Public Policy; *Technological Advancement; Work Environment
IDENTIFIERS	*European Union; Scenarios

ABSTRACT

The possible impact of technological and structural change on employment in the European Union (EU) over the next 20 years was examined through an exploration of the following alternative policy-driven scenarios: (1) business as usual; (2) concentrated technology policy (increases in innovation and research and development [R&D] efforts are concentrated on advanced technology); (3) diversified technology policy (increases in innovation and R&D efforts are allocated to sectors currently demonstrating strong performance); and (4) uniform technology policy (innovation and R&D spending are increased uniformly throughout the economy). The study demonstrated that technological progress is a necessary though insufficient condition for the EU to achieve high economic growth and higher employment levels. Rather than threatening employment at the EU level, the increased productivity resulting from technological progress appeared to be a driver for increased competitiveness and overall economic growth. Other conclusions emerging from the study were as follows: (1) technological change will increase the demand for highly skilled workers; (2) emerging technologies will both respond to changes in work organization and further raise requirements for flexibility in work organization; and (3) technology policy strategies aimed at accelerating technological progress should lead to positive results and further economic and employment growth. (Twenty tables/figures are included. An overview of the study methodology and a bibliography listing 29 references are appended.) (MN)

European
Science and
Technology
Observatory

Impact of Technological and Structural Change on Employment

Prospective Analysis 2020

Synthesis Report

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Institute for Prospective Technological Studies

Report EUR 20131 EN

Technical Report Series

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 adopted 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 Joint Research Centre institutes.

For more information: http//:www.jrc.es ipts-secr@jrc.es

About ESTO

The European Science and Technology Observatory (ESTO) is a network based on a core group of 17 European leading organisations with expertise in science and technology assessment. ESTO provides real-time information on the socio-economic significance of scientific and technological advances. The ESTO network is directed and managed by the IPTS.

Along with the 14 initial members, another group of institutes later became associated to the ESTO network covering all the 15 EU Member States as well as Israel. Membership is being continuously reviewed and expanded with a view to meeting the evolving needs of the IPTS and to incorporate new competent organisations from both inside and outside the European Union.

The ESTO network was formally constituted in February 1997 and its principal tasks are:

- to contribute to the IPTS Report with articles on relevant topics;
- to issue, on a periodic basis, a techno-economic analysis report, which reviews socio-economic developments either arising from technological change or driving it;
- to produce input to long-range foresight studies undertaken by the IPTS in response to EU policy needs;
- to provide quick responses to specific S & T assessment queries.

For more information: http//:www.jrc.es Contacts: esto-secretary@jrc.es

Institute for Prospective Technological Studies

joint research centre
EUROPEAN COMMISSION

IMPACT OF TECHNOLOGICAL AND STRUCTURAL CHANGE ON EMPLOYMENT

PROSPECTIVE ANALYSIS 2020

Synthesis Report

Report to the Committee on Employment and Social Affairs of the European Parliament

December 2001

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Report EUR 20131 EN

European Science and Technology Observatory

Research team

IPTS

Hector Hernandez
Panayotis Christidis
Juan Carlos Ciscar
Dimitrios Kyriakou
Odd Bjorn Ure

ESTO Network

Jorma Lievonen, VTT Technical Research Centre of Finland
Anette Braun, VDI-TZ Technology Centre Duesseldorf
Eamon Cahill, Irish Productivity Centre
Nikolaos Kouvaritakis, National Technical University of Athens
Leonidas Paroussos, National Technical University of Athens
Mario Pianta, FORMAPER, Italy
Claudio Roveda, Fondazione Rosselli
Wolfgang Schade, IWW, University of Karlsruhe
Nick Von Tunzelmann, SPRU, University of Sussex
Marco Vivarelli, FORMAPER, Italy

External advisors

Robert Solow, Massachusetts Institute of Technology
Theo Dunnewijk, International Institute of Infonomics
Bart Verspagen, Eindhoven University of Technology

Printed in Spain

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.

This report is the synthesis of the main findings of the work carried out. A more detailed and technical analysis is included in the 'Background Report' that complements this report.

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, December 2001

Table of contents

Executive Summary

Scope of the study

The study addressed the following basic questions concerning the impact of technological and structural change on employment over a 20 year time-horizon:

Q.1. Which economic sectors will offer high growth potential and quality jobs?
Q.2. Which technologies will have a significant impact in those sectors?
Q.3. What kind of skills will be required to match the needs of those sectors and technologies?
Q.4. What will be the impact of emerging technologies on the organisation of work and job profiles?
Q.5. What would be the impact of selected innovation and technology policy strategies under different socio-economic conditions?

The impact of technology was analysed under four alternative policy-driven scenarios (table 1). Each scenario assumed a specific focus of technology policy that led to different results for economic growth and employment, at a sectoral and regional level.

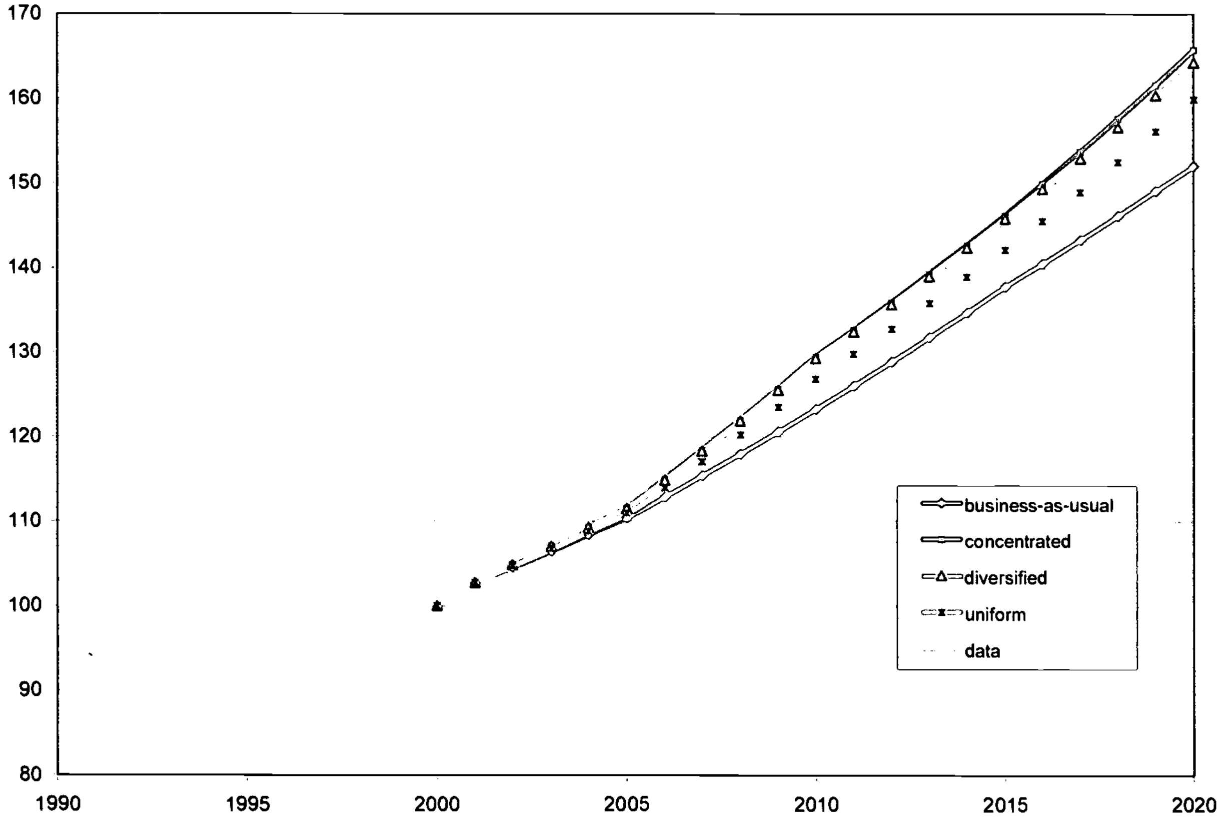
Table 1: Scenarios used in the analysis

- ***Business-as-usual scenario:*** Innovation and RTD expenditure follows current patterns and represents a constant share of GDP. Productivity growth per sector and region is in line with OECD projections.
- ***Concentrated technology policy:*** The increase in innovation and RTD efforts is concentrated on advanced technologies (electronics, telecommunications, genetic engineering, nano-technologies, aeronautics & space applications). The affected sectors that demonstrate increased productivity growth include mainly electronic equipment, services, high-tech manufacturing, transport equipment and chemicals.
- ***Diversified technology policy:*** The increase in innovation and RTD efforts is allocated to sectors that are currently demonstrating a strong performance, taking regional specialisation into account as well. Efforts are concentrated on research fields pertinent to advanced materials, biotechnology, energy and ICTs. The affected sectors include chemicals, equipment manufacturing, transport equipment, trade, transport and communication services, food industry and services.
- ***Uniform technology policy:*** Innovation and RTD spending is increased uniformly throughout the economy, affecting all technologies and sectors. Each sector increases its productivity at different rates, in proportion to its use of emerging technologies.

Main findings

The results of the study demonstrate that technological progress is a necessary though not sufficient condition in order for the EU to achieve high economic growth and higher employment levels. GDP is expected to grow between 2000 and 2020 at an average annual rate of 2.1%. An increase of innovation expenditure equal to 0.1% of GDP can raise the GDP growth rate to 2.4-2.6% per annum. Such an increase would correspond to an equivalent increase of current levels of Research and Development expenditure by 5% (i.e. from 1.9% to 2.0% of GDP), or 9 billion euros for year 2002. It is also expected that *between 9 and 14 million new jobs will be created* in the same period (figures 1 and 2).

Figure 1: Total GDP, EU-15 (constant prices, year 2000=100)



The increased productivity resulting from technological progress does not threaten employment at EU level but, on the contrary, is a driver for increased competitiveness and overall economic growth. Higher income and consumption levels compensate for the jobs lost due to labour saving processes and create new employment. However, technological progress may affect employment at a sectoral (and to a large extent regional) level, through the shift in production and consumption patterns that new processes and new products stimulate (table 2, figures 3 and 4).

It is important to note that the overall impact of technological progress is greatly influenced by the characteristics of labour supply (size, participation rates, working time, flexible contracts, responsiveness to changes in wage levels, and quality) and the demand for new products and services (final and intermediate consumption, domestic and international). A main advantage of a more responsive labour supply is the redistribution of the gains from economic growth to a wider population. However, higher flexibility of the type mentioned above may entail major structural changes in the labour markets, as well as trade-offs between economic efficiency and equity. Immigration policy is also a factor that may affect the overall balance.

Figure 2: Total employment, EU-15 (1000 full time jobs equivalent)

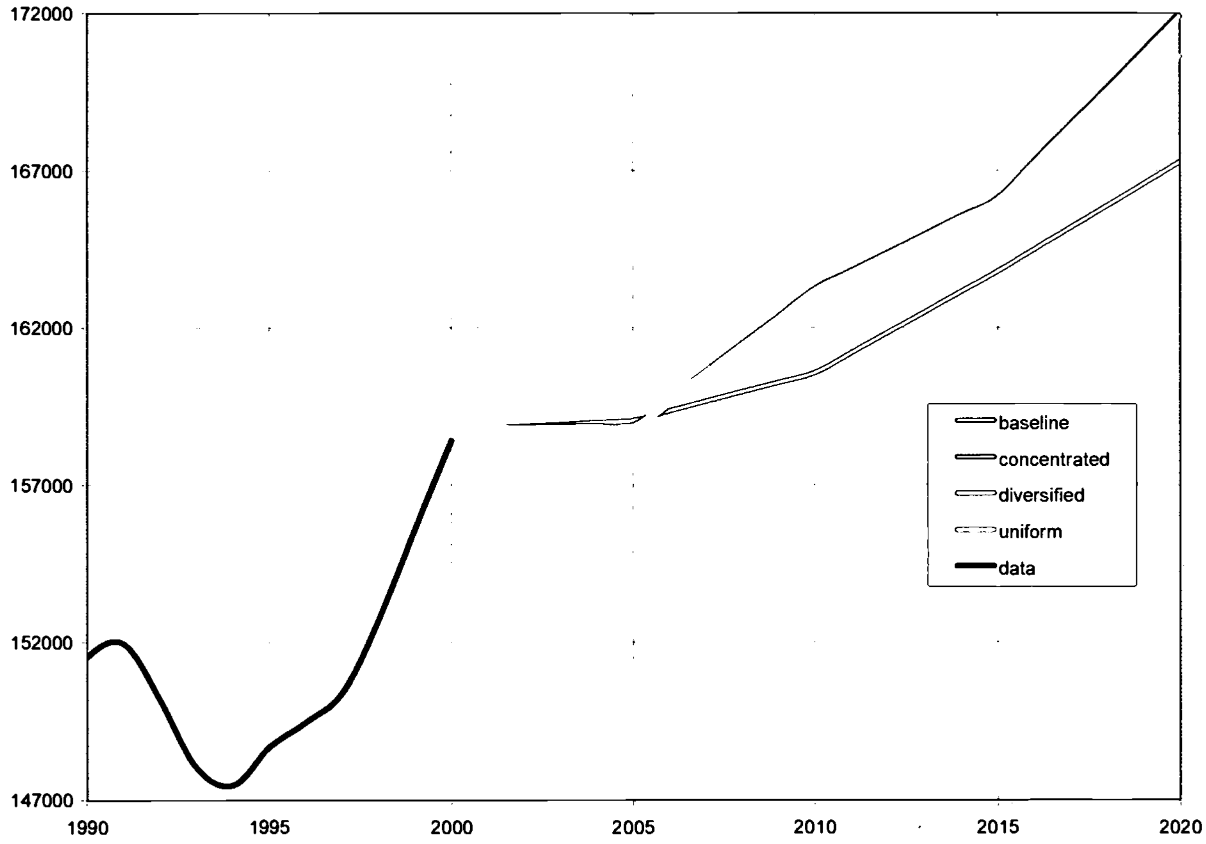


Table 2: Sectoral employment levels (000s)

Sector		business-as-usual	con-centrated	diversified	uniform
	2000	**2020**			
Agriculture	4352	4071	4224	4206	4131
Energy and metals	3771	3470	3630	3557	3545
Chemical products	6037	5998	6187	5985	6155
Other energy intensive	5179	4968	5142	5186	5093
Electronic equipment	2751	3082	3047	3236	3105
Transport equipment	4776	5179	5374	4895	5329
Other equipment goods	11880	13632	14154	13931	14018
Other manufacturing products	4125	5171	5679	5495	5437
Food industry	4654	4607	4787	4668	4668
Trade and transport	29587	30825	31692	31986	31468
Textile industry	2962	2834	2895	2708	2850
Other services and construction	49192	54001	56768	56409	55821
Non market services	35650	36297	35515	36699	36018
Total	**164915**	**174135**	**179094**	**178962**	**177639**

Figure 3: Impacts on employment at sectoral level, EU-15 (1000 full time jobs equivalent)

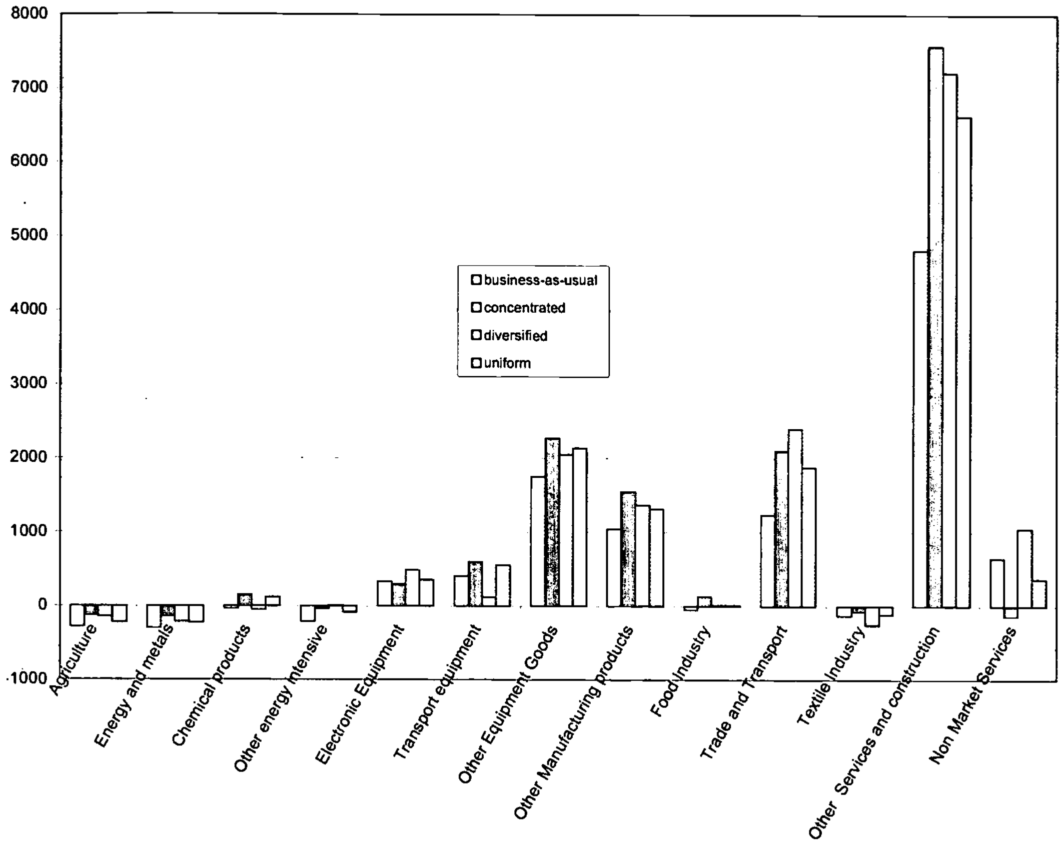
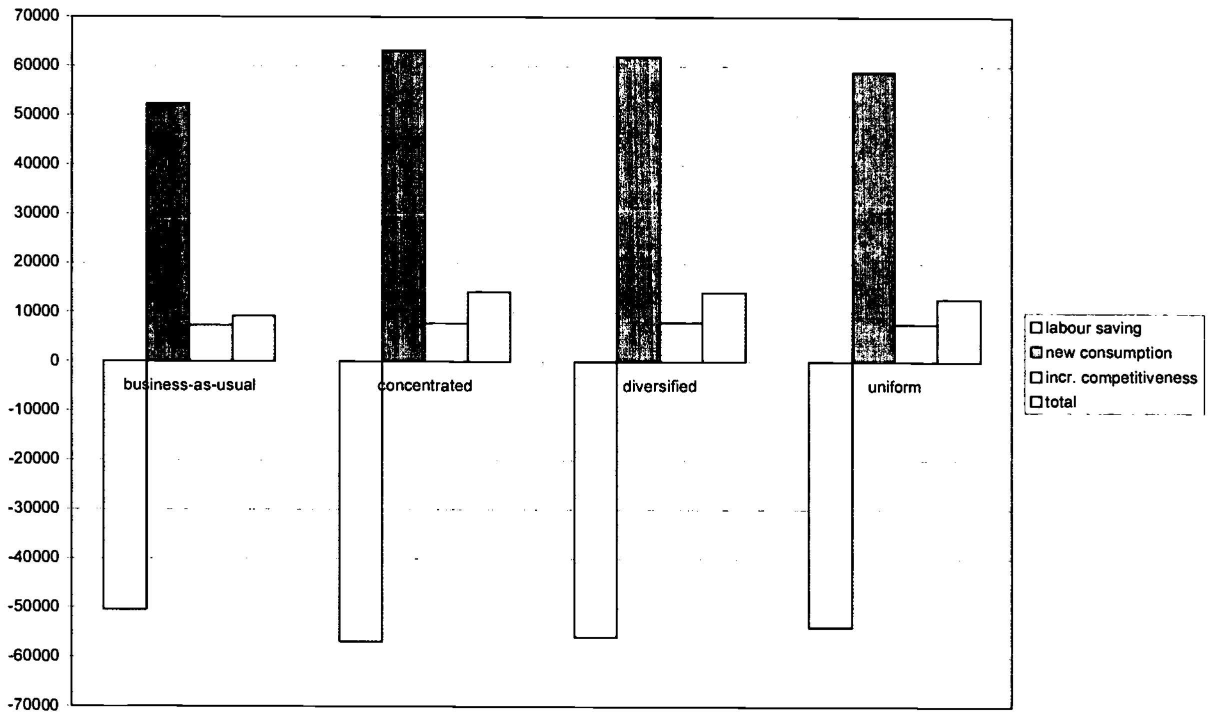


Figure 4: Decomposition of main impacts of new technologies on employment



BEST COPY AVAILABLE

11

Labour supply also affects the impacts on employment at a sectoral level. Given the evident trend towards a more services-based economy in the EU and the fact that most new jobs are expected to be created in the tertiary sector, it is important to ensure that the labour supply matches the required size and quality. Three critical issues can be identified: the availability of sufficient numbers of employees with the required skills, the conversion of the skills of employees moving from contracting to expanding sectors (skills mismatch), and the flexibility of labour supply.

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.
It should be also noted that the scope of the study has been limited to issues related to economic growth and employment. Several areas where technology will also probably have positive results, such as environmental issues, regional policy, defence and security, safety, health and quality of life, gender issues, social equity, and many others can be identified and should be normally taken into account when evaluating the impacts of technology.

The results of the study reinforce 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, the most viable option appears to be that of increasing the EU's share in the technology intensive sectors. In addition, technological progress can lead to higher wages and improved quality of work, thus allowing a higher standard of living. Seen in the context of the overall EU policies, technological progress can be the key for achieving the objectives of economic, social and environmental policy, and the main tool to reach the goals of the 'Knowledge-based Society' as defined in the Lisbon Summit.

To summarise the results, the answers to the original questions of the study can be outlined as follows:

Q.1 Which economic sectors will offer high growth potential and quality jobs?
The sectors where employment growth is expected to concentrate- though the extent of the impacts also depends on the specific technology policy- include trade and commerce, financial services & general business services, healthcare, entertainment and recreational services, catering & food and drink services, education, transport and logistics services, construction, tourism, transport equipment, communication services, social and related community services, manufacturing of special industrial machinery, and specialized manufacturing (fashion items, furniture, jewelry, scientific equipment, etc.).
Jobs in these sectors are expected to offer increased real wages and an improved overall work quality, aided by the expected developments in ICTs and other organizational improvements in the workplace.

Q.2 Which technologies will have a significant impact in those sectors?
The technologies that are expected to influence the number and quality of new jobs are mainly general-purpose technologies of a pervasive nature that can increase, directly or indirectly, the productivity of all economic sectors. The key technologies include ICTs and organisational/ managerial methods, nanotechnology and biotechnology. Nevertheless, the

whole spectrum of technological development is expected to have a positive impact on employment in the long-term. Such technologies include for example general technological areas such as advanced materials (applicable to manufacturing, construction, electronics, communications, energy production, etc.), or specific technologies such as tissue engineering (offering new solutions in the health sector).

The initial positive impacts of the introduction of a new technology are normally observed in the sectors where the new technology is first applied ("producing sectors"). As experience with past technological paradigms shows, in the long term the gains are transferred to the "user sectors". Such a transfer of benefits is currently underway in the case of ICTs, and it is expected to continue happening with the full range of technological developments in the next 20 years.

Q.3 What kind of skills will be required to match the needs of those sectors and technologies?

Technological change will increase the demand for highly skilled workers in Europe. Skills related to general-purpose technologies (ICT, biotechnology and nanotechnology) will be in high demand in the labour market, especially for the extension of those technologies to new areas of application. Acute shortages can be expected of people who have expertise in both information technology and biotechnology and of those who have expertise in automation technology and nanotechnology. The majority of jobs will require skills for the exploitation of these technologies rather than for their development. Skills related to management and entrepreneurship are also expected to become more important in the future.

Q.4 What will be the impact of emerging technologies on the organisation of work and job profiles?

Emerging technologies are expected to both respond to the need and raise further requirements for flexibility in work organisation. The productivity impacts of emerging technologies can only be realised 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 outside suppliers and customers. However, in the context of the increased flow of information exchange, the protection of the companies' key information assets is going to need heightened attention and may also result in changes in work organisation.

Q.5 What would be the impact of selected innovation and technology policy strategies under different socio-economic conditions?

Technology policy strategies aiming to accelerate technological progress are expected to lead to positive results and lead to further economic and employment growth. The success of such a strategy depends largely on whether the structural and regional characteristics of the EU economy are taken into account. In addition, technology policy has to be accompanied by suitable labour supply side policies, as well as measures in the fields of education and training, immigration, fiscal and monetary policies, investment incentives and social protection.

1 Introduction

The study has been conducted by the JRC Institute for Prospective Technological Studies (IPTS) on behalf of the Committee on Employment and Social Affairs of the European Parliament and addressed the following basic questions concerning the EU economy over the 20 years time-horizon:

Q.1. Which economic sectors will offer high growth potential and quality jobs?
Q.2. Which technologies will have a significant impact in those sectors?
Q.3. What kind of skills will be required to match the needs of those sectors and technologies?
Q.4. What will be the impact of emerging technologies on the organisation of work and job profiles?
Q.5. What would be the impact of selected innovation and technology policy strategies under different socio-economic conditions?

IPTS applied a combination of qualitative and quantitative analyses, in collaboration with ESTO[1], and with Robert Solow (MIT, Nobel prize 1987) as an external advisor. The starting point of the work in this study was the Technology Map of the IPTS FUTURES project, which identified the main emerging technological developments. The potential impact of these technologies on productivity growth and consumption patterns was estimated using theoretical and empirical evidence, results from other relevant studies, and additional expert advice. These estimates were used as input by 2 established simulation models (the general equilibrium model GEM-E3 and the system dynamics model ASTRA, described in Annexes 1 and 2) in order to quantify the impact of these technological developments in terms of economic growth and employment. Four alternative technology policy scenarios were analysed, and their impacts on the issues examined were discussed. In parallel, the implications for the quality of work and skills were discussed.

The approach that was applied in the study is rather innovative, since it combined technology foresight and research on applied economics, and linked theoretical work in the field of economics of technological change with advanced econometric modelling. The main aim of the study was to describe the general trends in economy and employment under certain assumptions as regards technological progress and the socio-economic environment. The results, especially those of quantitative nature, unavoidably depend largely on the initial assumptions. The degree of uncertainty that is inherent in the input used for the models does influence the statistical confidence levels of the final results in terms of absolute values. On the other hand, the general trends in GDP and employment growth and the relative ranking of the various scenarios demonstrated a high degree of stability during the sensitivity analysis and can be therefore considered as reliable.

[1] The European Science and Technology Observatory (ESTO) is a network of 45 Research Institutes which operate as a 'virtual institute' together with IPTS. Its core competence resides in prospective analyses of the impact of emerging technologies on the economy and society, and advice on policy options available to EU decision-makers arising therefrom.

It should be also noted that the study concentrated on the impacts of technology and innovation policy issues, other things being equal ("ceteris paribus"). Future developments in other policy areas (e.g. monetary, fiscal, labour, social, etc.) will certainly also affect economic growth and employment levels[2]. The methodology that was applied involved a number of assumptions as regards the development of the variables that may be influenced by such external factors. The impacts of changes in policy areas not directly related to technology have not been therefore analysed in the same detail, but the extent to which they may influence the impacts of technology and innovation policy has been discussed where possible.

2 Technology policy driven scenarios

An important element of the methodology applied in the study is the *analysis of scenarios* that correspond to *alternative technology policy strategies*. The scenarios were built around the various options to focus technological progress in certain directions. *The business-as-usual scenario* assumes that the current patterns will continue, i.e. the current levels of expenditure on innovation and RTD[3] as percentage of GDP will be maintained, with a similar sectoral distribution. Productivity in each sector is assumed to continue to grow in line with current OECD projections.

The *remaining scenarios* are constructed under the hypothesis *that innovation and RTD efforts are increased by roughly 0.1% of total GDP* for the EU per year -equivalent to around 9 billion euros for year 2002 (an increase of about 5% in comparison to current Research & Development levels)[4]. An equal increase is applied in all three alternative scenarios, but it is distributed in a different way among the sectors, depending on the specific technology policy. As a result, productivity growth, competitiveness and the size of new markets will differ in each case[5].

---

[2] The terrorist attacks in New York and Washington D.C. on September 11th, and the events that have followed since are obviously a development that should be taken into account. As far as the present study is concerned, the main change those events have caused is an acceleration in the drop of the confidence levels of consumers and enterprises worldwide, and increased pressures to potentially raise defence spending in the U.S.A. and possibly other countries. This may affect consumption and investment in the short term, variables that influence to a great extent the success of the introduction of new technologies. In addition, a possible increase in defence spending may prove an impeding factor for the increase in RTD and innovation spending (but may also stimulate an acceleration of defence R&D that can have spill-overs for civilian R&D). However, after the initial pessimism, there is an increasing number of signs already visible that can allow one to expect that the society and economy will recover from the shock earlier than initially anticipated, and that the overall impact in economic terms in the long-run will be limited.

[3] Innovation and RTD (Research and Technological Development) expenditure includes all expenditure related to the scientific, technological, commercial, financial and organisational steps which are intended to lead, or actually lead, to the implementation of new or improved products and processes. Intramural R&D (expenditure on Research & Development performed within the firm) represents about half of total innovation and RTD expenditure, the rest consisting of expenditure for the acquisition of disembodied technology and expenditure on machinery and equipment.

[4] As a reference, the level of R&D spending (public and private) as a percentage of GDP is equal to 1.90% in EU-15 in year 2000 (1.92% in 1999), 2.64% in the US (1999) and 3.04% in Japan (1999). It is worthwhile mentioning that all three alternative scenarios demonstrate a high multiplier value of the initial increase in spending.

[5] The input for the model simulations is the predicted productivity growth rates and the shifts in the shares of the various consumption categories. The assumptions for both variables (that are the only exogenous variables used in the modelling exercise) were the result of empirical work carried out by the European Science and Technology Observatory (ESTO) Network of IPTS. They were validated in 3 workshops with ESTO

Business-as-usual scenario
Innovation and RTD expenditure follows current patterns and represents a constant share of GDP. Productivity growth per sector and region is in line with OECD projections.

Concentrated technology policy
The increase in innovation and RTD efforts is concentrated on advanced technologies (electronics, telecommunications, genetic engineering, nano-technologies, aeronautics & space applications). The affected sectors that demonstrate increased productivity growth include mainly electronic equipment, services, high-tech manufacturing, transport equipment and chemicals.

Diversified technology policy
The increase in innovation and RTD efforts is allocated to sectors that are currently demonstrating a strong performance, taking regional specialisation into account as well. Efforts are concentrated on research fields pertinent to advanced materials, biotechnology, energy and ICTs. The affected sectors include chemicals, equipment manufacturing, transport equipment, trade, transport and communication services, food industry and services.

Uniform technology policy
Innovation and RTD spending is increased uniformly[6] throughout the economy, affecting all technologies and sectors. Each sector increases its productivity at different rates, in proportion to its use of emerging technologies.

Additional scenarios have been also tested by changing the external conditions under which the economy of the EU is examined. A number of simulations using different assumptions as regards issues such as environmental policy or EU enlargement were carried out, in order for the coherence of the results to be ensured. A more detailed analysis of these issues is beyond the scope of the current study, but could be the subject of more narrowly defined aspects of such topics in the future.

3 Technological progress, economic growth and employment levels

Technological progress is a necessary but not sufficient condition in order for the EU to achieve high economic growth and higher employment levels. *The increased productivity resulting from technological progress does not threaten employment at the aggregate level but, on the contrary, is a driver for increased competitiveness and overall economic growth that, in turn, leads to increased employment levels*. However, technological progress does affect employment at a sectoral (and to a large extent regional) level, through the shift in production and consumption patterns that new processes and new products stimulate. It is important to note that the overall impact of technological progress is greatly influenced by the characteristics of labour supply (size, responsiveness to changes in wage levels, and quality) and the demand for new products and services (final and intermediate consumption, domestic and international).

participants, external experts and Commission services, and are in line with projections of similar studies at a sectoral level .
[6] Same rate of increase for every sector.

3.1 Impact on growth

Technological progress is expected to have a positive impact on GDP growth in the European Union and can have positive impacts on employment. In all scenarios examined, the growth in productivity leads to significantly higher GDP levels and a moderate increase in employment levels.

The business-as-usual scenario predicts an increase of GDP by 52.1% and of total employment by 5.6% (9.2 million new jobs) between 2000 and 2020. All three alternative scenarios predict that the additional investment in innovation and RTD, and the subsequent increase in productivity will result in further gains as regards both GDP and employment. GDP is expected to grow by between an additional 7.8 percentage points in the uniform scenario to 13.6 percentage points in the concentrated scenario, compared to the prediction for the business-as-usual scenario. As far as employment is concerned, 1.9 to 5 million additional new jobs are expected to be created respectively. *Expressed on an annual basis, the benefit brought by the increase in innovation and RTD spending ranges between 0.25 percentage points (uniform scenario) to 0.44 percentage points (concentrated scenario) of additional GDP growth.*

It is interesting to note that the average annual growth of GDP in EU-15 between 1983 and 2000 was 2.24%. In the business-as-usual scenario a slower GDP growth is expected (2.12% per annum), although RTD and innovation intensity is assumed to remain at the same level.

Table 1: Percentage changes 2000-2020

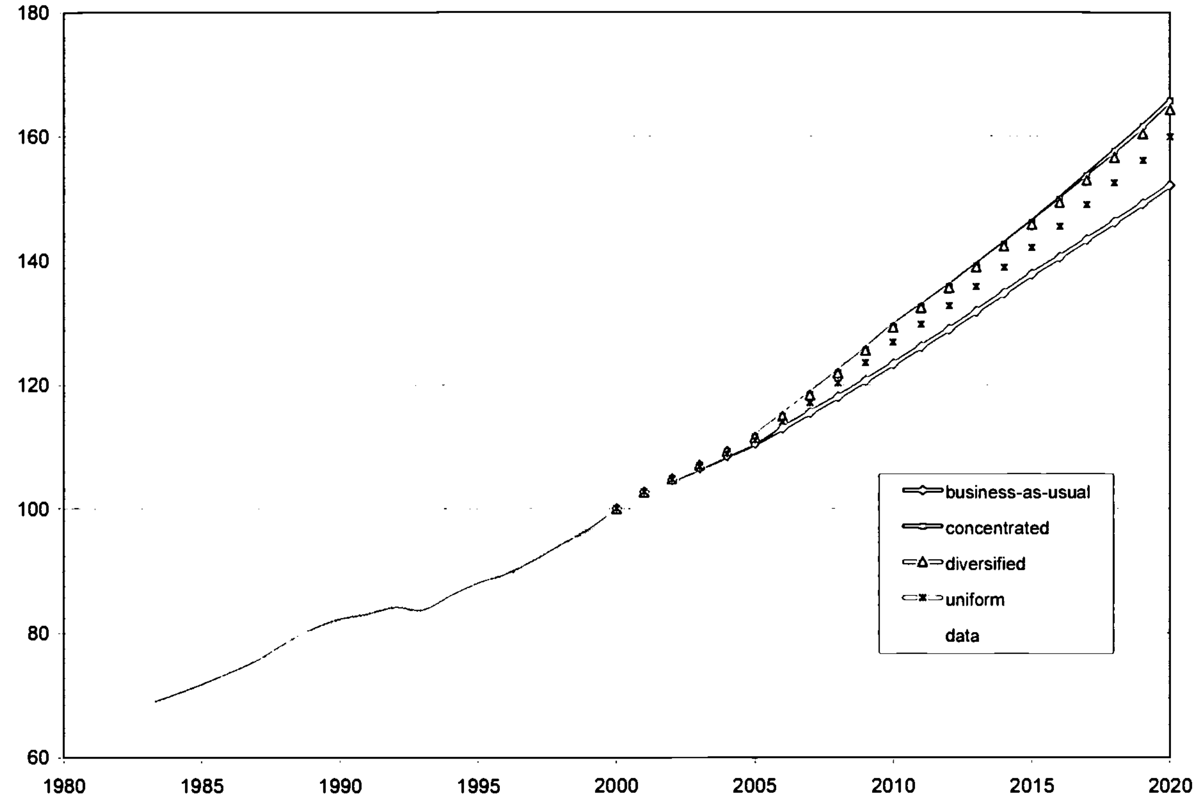
	business-as-usual	**con-centrated**	**diversified**	**uniform**
GDP	52.1	65.7	64.3	59.9
Eq. annual growth of GDP	2.12	2.56	2.51	2.37
Investment	49.8	89.9	83.5	72.2
Consumption	55.0	68.9	66.9	62.8
Exports	49.8	56.0	57.3	53.7
Imports	33.0	48.2	46.1	41.4
Employment[7]	5.6	8.6	8.5	7.7

Table 2: Comparison of alternative scenarios and business-as-usual scenario

	concentrated	**diversified**	**uniform**
GDP	13.6%	12.2%	7.8%
Employment (000s)	4959	4826	3504

[7] Unemployment rates also depend on population growth, immigration, participation rates, etc. and cannot be therefore directly extracted from the projections concerning employment levels. Since GEM-E3, the main model used for the simulations, is a general equilibrium model, no unemployment is envisaged in the employment projections. Therefore the results on employment for each scenarios should be considered as the upper ceiling of alternative potential employment paths, rather than predictions of unemployment levels.

Figure 1: Total GDP, EU-15 (constant prices, year 2000=100)



New technology is expected to help economic growth accelerate during the whole period covered (figure 1). *The highest increases are expected to result from the concentrated and the diversified technology policies*, which lead to a comparable growth in GDP[8]. The uniform scenario demonstrates a moderate improvement compared to the business-as-usual scenario, a fact that reinforces the argument that increased investment in technology and innovation, and the subsequent acceleration of productivity growth, will have positive impacts on the economy.

3.2 Impact on employment

The increase in productivity induced by technology leads to higher income and consumption levels that compensate for the jobs lost due to labour saving processes. Although higher productivity at a sectoral level has a labour saving effect assuming the same level of production, the increased productivity results at the same time at higher real wages for the employees of the sector. This higher income is transformed into new consumption that generates employment in other sectors. A second, though weaker, compensation mechanism is the increased consumption of a sector's products as a result of the lower prices because of higher productivity. All simulations show that these are the two main compensation mechanisms for the EU economy as a whole and imply that productivity growth does not, in principle, reduce overall employment levels.

[8] However, the 2 scenarios differ considerably as regards their sectoral and regional impacts, as well as in relation to their dependency on increased domestic and international demand for new products and services.

In the business-as-usual scenario, total employment levels are expected to demonstrate a moderate growth in the next 20 years and to increase by 5.6%. This increase corresponds to a (long-term) ratio of employment growth to total GDP growth of about 0.1, comparable to the respective figure for the EU economy in the period 1980-2000[9]. This relatively low level has been a key characteristic of the EU economy, especially if compared to the much higher one of the US (on the other extreme, that of Japan is almost zero).

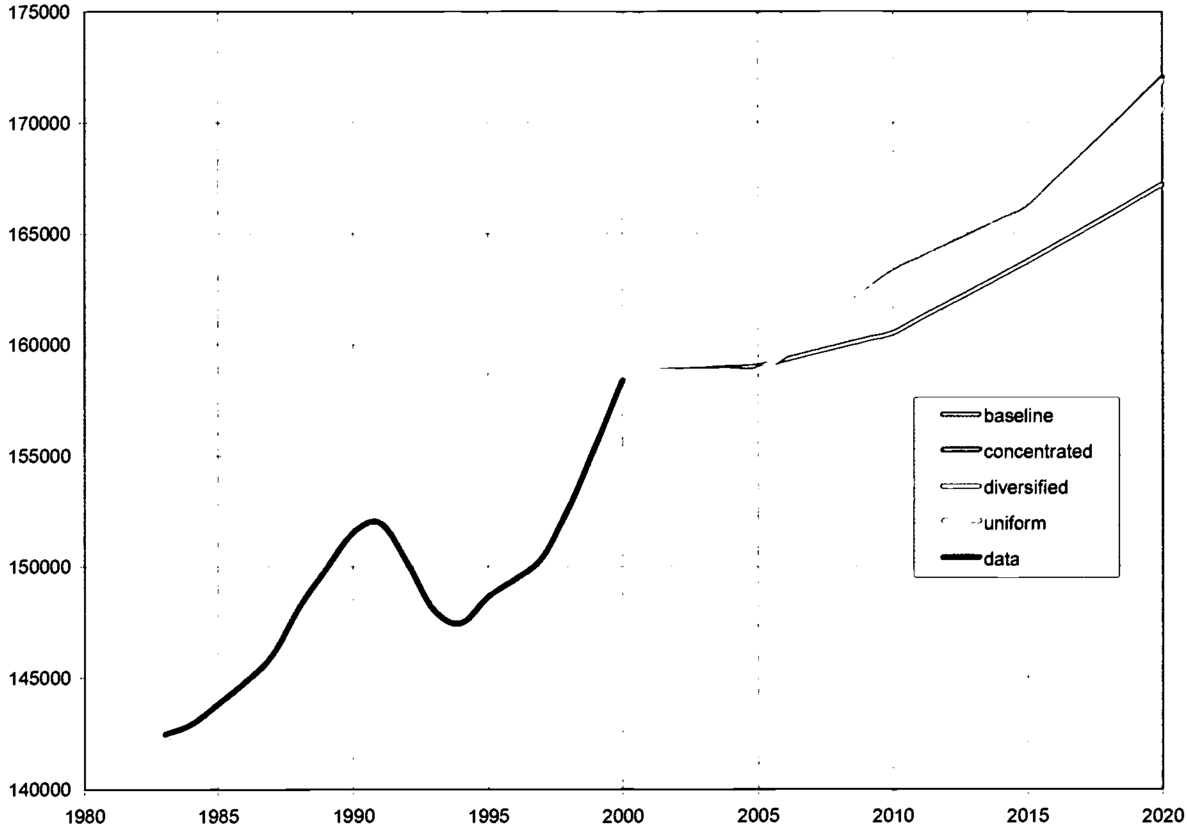
The 3 alternative scenarios suggest a further increase of the number of jobs with respect to the business-as-usual scenario. Although the impacts on employment at a sectoral level do differ (tables 4, 5 and 6), *the impact on total employment is still relatively low* compared with the employment levels of year 2000. The total labour supply is to a large extent independent of the technology policy; the labour supply and demand reach an equilibrium that corresponds to the level of real wages. Real wages are expected to increase in 2020 compared to 2000, and are expected to be higher in all alternative scenarios in comparison with the business-as-usual, as a consequence of higher productivity. The extent to which productivity growth will be reflected in real wage growth depends on the labour market structure and regulation, bargaining processes, etc. The concentrated and diversified scenarios demonstrate this more clearly: they are expected to lead to an increase of employment levels by 2.85 percentage points and 2.77 percentage points respectively compared to the business-as-usual scenario (table 2).

Given the methodological limitations of the models used, the ranking of the different scenarios - in terms of employment performances - is more important than absolute figures. From this respect, *the concentrated and diversified scenarios look better both in terms of economic growth and employment generation.* This confirms the hypothesis that a targeted innovation policy can have better employment impacts than a uniform increase in R&D and innovation spending in all economic sectors.

The way that the positive impacts on growth are transformed into increased levels of employment depends to a large extent on the responsiveness of labour supply that, in turn, can be influenced by labour supply side policies. Technology policy can affect the growth of the economy, but issues affecting labour supply and labour market organisational and regulatory issues (e.g. participation rates, working time, flexible contracts, etc.) play a crucial role. If labour supply becomes more responsive to changes in wages[10], overall participation rates can rise further and satisfy the higher labour demand. A main advantage of a more responsive labour supply is the redistribution of the gains from economic growth to a wider population. However, higher flexibility of the type mentioned above may entail major structural changes in the labour markets, as well as trade-offs between economic efficiency and equity. Immigration policy is also a factor that may affect the overall balance.

[9] If only the period 1990-2000 is taken into account, the ratio for the EU is 0.2, but as it can be observed in figure 2, this higher value was mainly due the fact that the economy was recovering from a previous slowdown.
[10] In this context, responsiveness of the labour supply corresponds to the so-called labour supply elasticity with respect to wages.

Figure 2: Total employment, EU-15 (1000 full time jobs equivalent)



Labour supply, in terms of both size and quality, also affects the impacts on employment at a sectoral level. Given the evident trend towards a more services-based economy in the EU and the fact that most new jobs are expected to be created in the tertiary sector, it is important to ensure that the labour supply matches the required size and quality. Two critical issues can be identified: the availability of sufficient numbers of employees with the required skills, and the conversion of the skills of employees moving from contracting to expanding sectors (skills mismatch). An issue that deserves further study is the responsiveness (elasticity) of skill conversion to changes in wages.

The demand for skilled workers is expected to increase faster than that for non-skilled workers. Indeed, the *technology induced skill bias* has caused increasing unemployment rates of unskilled workers in continental European countries and stronger effects on the wage dispersion between the skilled and unskilled in the US and - to a lesser extent - in the UK. *There is already evidence of a growing skill-bias in manufacturing, and research suggests that future growth in services will also demonstrate that tendency.* A main impact of the skill-bias that should be taken into account is the worsening social and economic position of the unskilled.

3.3 Economic sectors and employment growth

The impacts of technology and innovation on employment at the sectoral level are presented in tables 4, 5 and 6, and figure 3. It is evident that in all scenarios employment growth is expected to concentrate in services. Agriculture is expected to continue to lose its share of total employment, while manufacturing seems to be stabilising, with some sub-sectors even increasing their share of employment. Electronic equipment, often considered a promising sector, is not expected to gain an important role as regards employment levels, since the predicted impact of labour productivity growth in the sector is higher than the predicted impact of growth in consumption of its products.

Table 3: Production per sector, year 2020 (constant prices, year 2000=100)

Sector	business-as-usual	Concentrated	diversified	uniform
Agriculture	122.2	128.9	127.8	126.6
Energy and metals	125.9	134.6	134.0	131.3
Chemical products	129.7	138.5	139.8	135.1
Other energy intensive	125.6	137.5	135.6	132.7
Electronic Equipment	145.6	174.1	160.5	161.3
Transport equipment	144.0	159.2	163.6	152.8
Other Equipment Goods	148.4	164.0	163.9	157.5
Other Manufacturing products	161.9	180.4	178.0	173.6
Food Industry	130.7	138.4	137.1	135.3
Trade and Transport	135.5	146.0	144.8	141.7
Textile Industry	123.6	128.3	129.4	126.9
Other Services and construction	141.7	157.9	155.5	150.8
Non Market Services	125.9	129.2	128.9	127.8
Total	**136.6**	**148.7**	**147.4**	**143.6**

Table 4: Sectoral employment levels (000s)

Sector	2000	business-as-usual	concentrated	diversified	uniform
		2020			
Agriculture	4352	4071	4224	4206	4131
Energy and metals	3771	3470	3630	3557	3545
Chemical products	6037	5998	6187	5985	6155
Other energy intensive	5179	4968	5142	5186	5093
Electronic Equipment	2751	3082	3047	3236	3105
Transport equipment	4776	5179	5374	4895	5329
Other Equipment Goods	11880	13632	14154	13931	14018
Other Manufacturing products	4125	5171	5679	5495	5437
Food Industry	4654	4607	4787	4668	4668
Trade and Transport	29587	30825	31692	31986	31468
Textile Industry	2962	2834	2895	2708	2850
Other Services and construction	49192	54001	56768	56409	55821
Non Market Services	35650	36297	35515	36699	36018
Total	**164915**	**174135**	**179094**	**178962**	**177639**

Table 5: Percentage change in sectoral employment levels, 2000-2020

Sector	business-as-usual	con-centrated	diversified	uniform
Agriculture	-6.5%	-2.9%	-3.4%	-5.1%
Energy and metals	-8.0%	-3.7%	-5.7%	-6.0%
Chemical products	-0.6%	2.5%	-0.9%	2.0%
Other energy intensive	-4.1%	-0.7%	0.1%	-1.7%
Electronic Equipment	12.0%	10.7%	17.6%	12.9%
Transport equipment	8.4%	12.5%	2.5%	11.6%
Other Equipment Goods	14.8%	19.1%	17.3%	18.0%
Other Manufacturing products	25.3%	37.7%	33.2%	31.8%
Food Industry	-1.0%	2.8%	0.3%	0.3%
Trade and Transport	4.2%	7.1%	8.1%	6.4%
Textile Industry	-4.3%	-2.3%	-8.6%	-3.8%
Other Services and construction	9.8%	15.4%	14.7%	13.5%
Non Market Services	1.8%	-0.4%	2.9%	1.0%
Total	**5.6%**	**8.6%**	**8.5%**	**7.7%**

Table 6: Change in sectoral employment levels, number of jobs, 2000-2020

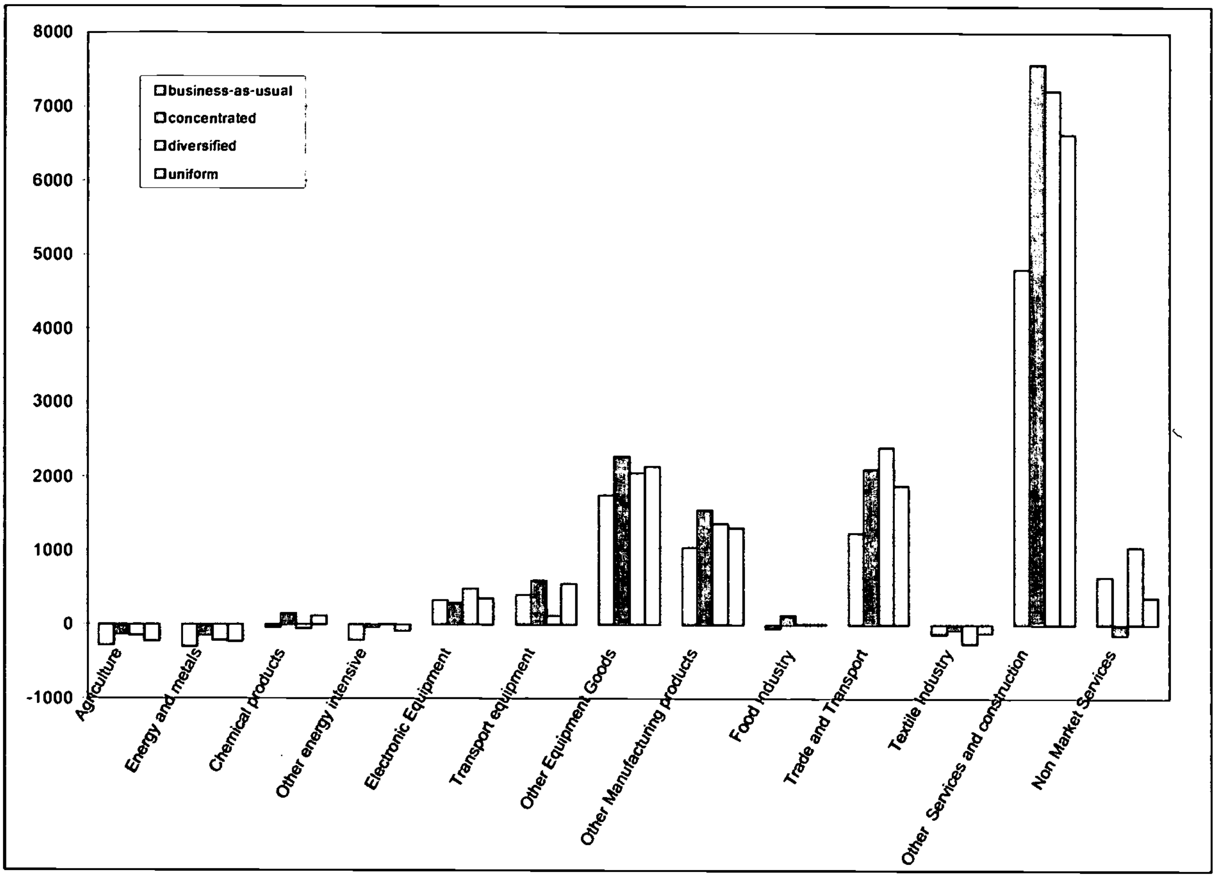
Sector	business-as-usual	con-centrated	diversified	uniform
Agriculture	-281	-128	-146	-221
Energy and metals	-301	-141	-214	-226
Chemical products	-38	151	-52	119
Other energy intensive	-211	-37	8	-86
Electronic Equipment	331	296	485	354
Transport equipment	403	598	119	553
Other Equipment Goods	1752	2275	2051	2139
Other Manufacturing products	1046	1554	1369	1312
Food Industry	-48	132	13	13
Trade and Transport	1238	2105	2400	1881
Textile Industry	-128	-67	-253	-111
Other Services and construction	4809	7576	7217	6629
Non Market Services	647	-135	1050	368
Total	**9220**	**14179**	**14047**	**12724**

At a more detailed level, the sub-sectors where employment growth is expected to be more significant -though the extent of the impacts also depends on the specific scenario- include the following:

- Trade and commerce
- General business services (including data processing, advertising and general technical services)
- Healthcare
- Entertainment (including electronic media and recreational services)
- Catering and other food and drink services (restaurants, cafes, etc.)
- Education
- Transport services, storage, warehousing and logistics
- Construction
- Tourism
- Financial services, insurance and legal services
- Transport equipment
- Communication services

- Social and related community services
- Manufacturing of special industrial machinery
- Specialized manufacturing (fashion items, furniture, jewelry, scientific equipment, etc.)

Figure 3: Impacts on employment at sectoral level, EU-15 (1000 full time jobs equivalent)



3.4 Regional impacts

The results of the simulations demonstrate that the impacts of technological progress may vary considerably at a national or regional level. GDP growth in all scenarios is expected to be slower in Germany, the UK and the Nordic countries than in the other 10 Member States (figure 4)[11]. A similar picture can be drawn as regards the impacts on employment (table 6, figure 5). There is however a difference in the degree to which each region benefits, when comparing the alternative scenarios. A concentrated technology policy would bring more benefits for the group of 10 Member States ('rest of EU'), while Germany and the UK would benefit more from a diversified technology policy. The Nordic countries would benefit equally from either the concentrated or the diversified technology policies.

[11] The level of regional analysis was limited by the available information of the models used for the simulations. The level of aggregation in GEM-E3 is rather unbalanced (3 Nordic countries, Germany, UK, and 10 other Member States are considered as one group that includes large economiés such as France, Italy and Spain). The second model used, ASTRA, has a slightly different aggregation, but still not enough to allow more country-specific conclusions to be drawn.

Increased innovation and RTD expenditure can accelerate the 'catch-up' effect for the regions lagging in terms of productivity, economic growth and employment. An increase in regions with lower productivity, which in most cases also spend less on innovation and RTD, can bring higher returns than a comparable increase in regions that already have high productivity levels. In addition, lagging regions can benefit further from the spill-over effects that an increase of innovation and RTD in more technologically advanced regions would stimulate. Productivity levels can increase through the application of new technologies developed in other regions ('technology transfer'), an effect that will be facilitated by the continuing integration of the EU economy.

Technology policy is a main part of regional policy. As a policy instrument it can stimulate economic growth and employment generation. It is however important that measures aiming to stimulate innovation at a regional level are accompanied by suitable measures to reduce regional disparities and take the specific regional characteristics and needs into account. In that sense, regional development policies are also an important part of technology policy.

Table 7: Increase in total employment levels per region, number of jobs, 2000-2020

	business-as-usual	con-centrated	diversi-fied	uniform
Denmark, Finland and Sweden	4.1%	5.4%	5.3%	4.9%
Germany	3.3%	5.9%	6.1%	4.9%
United Kingdom	4.0%	4.4%	6.3%	4.3%
Group of 10 Member States (Austria, Belgium, France, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain)	7.4%	11.7%	10.8%	10.5%
Total EU	**5.6%**	**8.6%**	**8.5%**	**7.7%**

Figure 4: GDP growth per region, business-as-usual (constant prices, year 2000= 100)

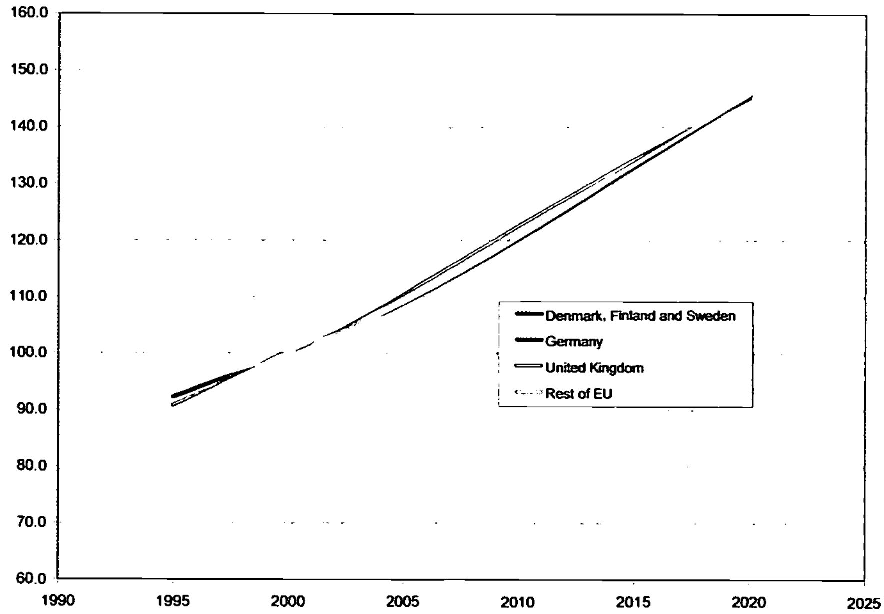
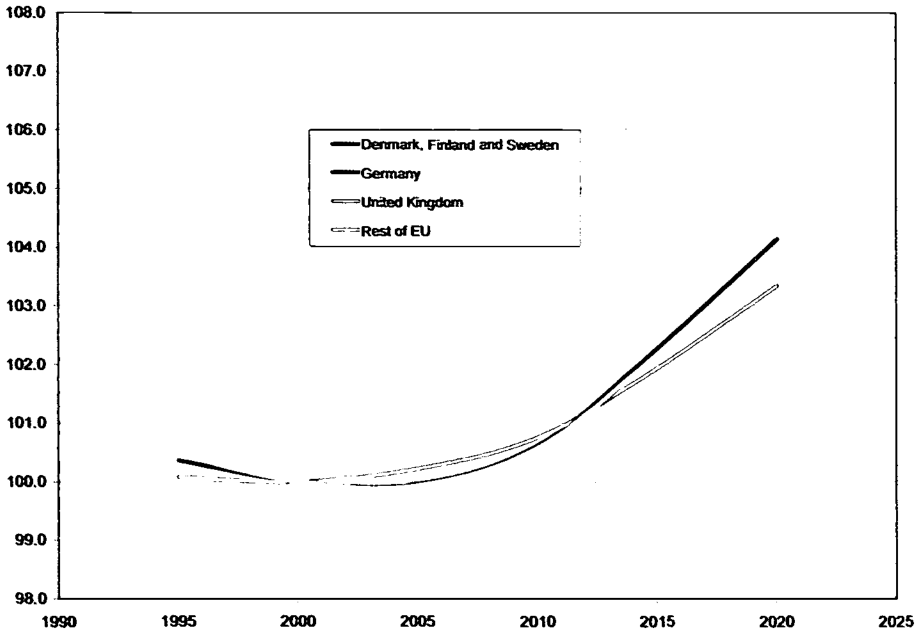


Figure 5: Impacts on employment at regional level, business-as-usual, EU-15 (year 2000 level= 100)



3.5 Spill-over effect on Candidate Countries

Innovation and RTD are expected to have positive results for the enlarged EU. New technologies in either the EU-15 or the enlarged EU will probably benefit all member states in terms of economic growth, since the increasing level of integration of the national economies will facilitate the *spill-over effects*.

The case that was tested in the context of this study referred to the economies of a subgroup of candidate countries only, due to data availability (the countries covered are Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia and Slovenia). The enlargement process was simulated through the variables of the models that describe the level of economic integration and the freedom of capital movement. The impact that a change in technology policy in EU-15 would have on economic growth and employment in candidate countries was investigated by comparing the respective levels under each scenario. According to the business-as-usual projections, the GDP of the selected candidate countries is expected to increase by 75% between 2000 and 2020 (i.e. 2.8% per annum). In the three alternative scenarios, GDP in these countries is expected to grow by an additional 1.5 percentage points (uniform scenario) to 3.1 percentage points (concentrated scenario) in the course of the next 20 years. On the other hand, employment levels are not expected to change considerably as a result of the alternative technology policies in the EU-15. An overall increase of employment by 15% is expected in all scenarios[12].

The case of an increased innovation and RTD spending scenario for the candidate countries has not been tested due to the lack of data concerning the current and potential technological

[12] It is interesting to note that both GDP and employment are expected to grow faster in the candidate countries than in the EU-15 (the respective figures in the business-as-usual scenario for the EU-15 are 52.1% increase in GDP and 5.6% in employment). Candidate countries are expected to have a ratio of employment change to GDP change of 0.2, double that of EU-15. It should also be noted that the impacts of immigration are not taken into account.

level of the various economic sectors in these countries, and because of the high degree of uncertainty as regards the structural changes that the enlargement process will lead to. It is however expected, based on the results available, that innovation and RTD should have positive impacts on economic growth and employment in the candidate countries as well.

3.6 Impact on exports

Technology and innovation, and subsequently higher productivity, can play an important role for the international competitiveness of EU products and services. Exports from the EU to the rest of the world are expected to increase in all alternative scenarios.

As the analysis of the decomposition of the impacts on employment also shows, the EU is largely self-sufficient and exports correspond to a small part of GDP. Subsequently, consumption within the EU is a stronger driver for GDP growth than exports. This is evident in the comparison of GDP and export growth for the various scenarios (table 1). However, exports play an important role at a sectoral level and stimulate growth for the economy as a whole.

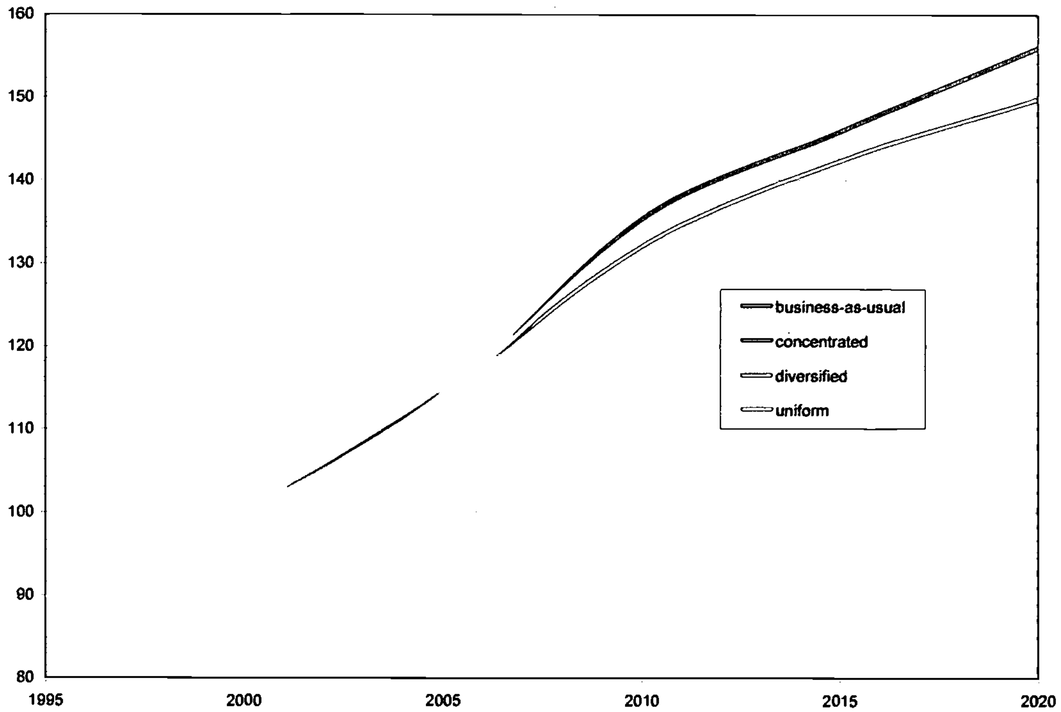
Depending on the specific scenario, the export potential of various EU products can increase significantly (table 8). For example, a concentrated technology policy can facilitate the production of new or more competitive products in electronics and increase the exports of the sector. In a similar fashion, a diversified technology policy can increase the export potential of transport equipment and manufacturing products. The exports of chemicals, food products and textiles are not affected as much by technology policy.

Table 8: Increase of value of exports of characteristic products, 2000-2020, constant prices

	business-as-usual	concentrated	diversified	uniform
Chemical products	30%	35%	38%	33%
Electronic equipment	55%	79%	69%	68%
Transport equipment	57%	67%	75%	62%
Industrial machinery and specialized manufacturing products	72%	77%	81%	77%
Food industry products	38%	42%	42%	41%
Textile products	26%	27%	30%	27%

The total volume of exports and their sectoral distribution depends to a large extent on the economic developments at an international level. Given the assumptions of the study (average GDP growth for the rest of the world equal to 3% per annum), a diversified technology policy is expected to lead to slightly higher export levels than the concentrated technology policy (figure 6). However, if the economy of the rest of the world grows even faster, the demand for high-tech products is expected to rise and the exports under a concentrated technology policy could be higher.

Figure 6: Total exports from EU-15 to rest of the world (constant prices, year 2000=100)



3.7 Decomposition of impacts on employment

The impact of productivity growth on employment can be divided in three parts: the immediate impact due to labour saving processes[13], the impact of increased consumption of existing and new products and services[14], and the impact of increased exports as a result of increased competitiveness[15]. As can be seen in figure 7, in all scenarios the employment generated by the increase in domestic consumption is sufficient to compensate for the labour saving processes. In addition, the increased international competitiveness that leads to additional exports allows a further increase in total employment levels.

The order of magnitude of the impact of new consumption in comparison to that of the increased competitiveness is impressive (a factor of 5). However, it should be noted that the latter also stimulates multiplier effects that are depicted in the results as increased consumption. The extent of the impact of each compensation mechanism also changes in each of the 4 scenarios. As a general principle, in all alternative scenarios the change in technology policy increases the number of jobs lost due to labour saving processes, but on the other hand leads to even higher employment growth due to new consumption. The impact of increased exports on employment does not differ considerably between the alternative scenarios.

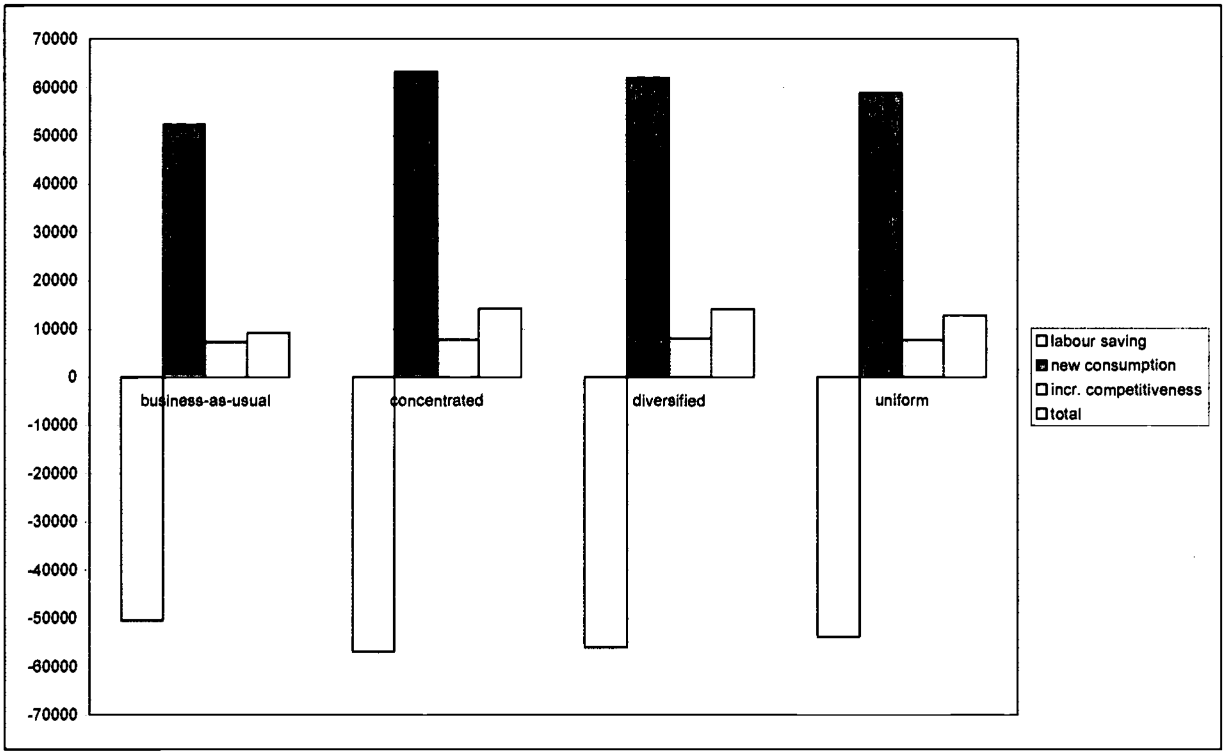
New technology can lead either to the introduction of new products to the market (product innovation) or to the improvement of existing work methods and production procedures (process innovation). The simulation results imply that although product innovation is

[13] Calculated as the difference in employment caused if the level of domestic consumption for year 2000 is satisfied with the productivity of year 2020. The underlying hypothesis that is tested is that productivity increases without an increase in output.
[14] The difference in domestic consumption between years 2000 and 2020.
[15] The difference in exports between years 2000 and 2020.

important at a firm level (empirical evidence) or at a sectoral level (the model provides partial evidence), it is of lower importance for the economy as a whole than process innovation.

In the context of the study, the limits on the total level of consumption (that itself depends on total income) have as a result an increase in the substitution effect in consumption. Product innovation could have a more positive impact on the economy as a whole if it led to a higher share of income being used for consumption instead of being used for saving (i.e. product innovation causing a higher marginal propensity to consume). However, although this share differs among countries, tends to change over time and is affected by economic cycles, the extent to which it is affected by product innovation remains an open question.

Figure 7: Decomposition of changes on employment levels, EU-15, 1000s of full time equivalent jobs



BEST COPY AVAILABLE

4 Key technologies for future employment

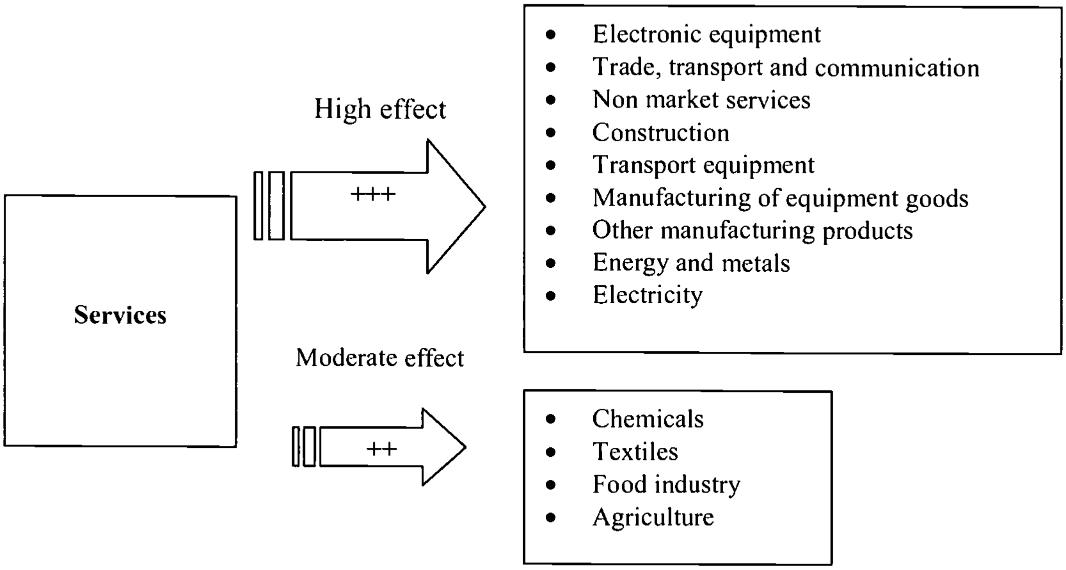
An important aspect of the study was the connection of past work on technology foresight, most notably the work carried out in the IPTS FUTURES project, with the quantitative economic analysis. The Technology Map of the FUTURES project provided an outline of the main trends in technology and one of the objectives of the current study was to investigate the extent to which these technologies influence economic growth and employment. This was done through the analysis of the interaction of the economic sectors in quantitative terms and the identification of the technologies that can increase productivity, or stimulate new demand, in the sectors that affect the overall economy the most.

4.1 Technology flows between sectors

Technological progress is expected to lead to structural changes in the economy, as a result of the different productivity growth in each sector. The various sectors of the economy are strongly inter-linked, and a change in a sector's productivity may influence the intermediate demand for its products and the productivity of the sector that uses them[16].

Changes in productivity of (market) services and trade, transport and communication affect the other sectors the most. Since they represent a large share of the input for the majority of the sectors, technologies improving the productivity of these specific sectors can have far-reaching impacts for the whole economy. Moreover, since the size of the service sectors themselves is large, a potential increase in their productivity can lead to direct benefits. Other sectors, such as manufacturing, chemicals and agriculture, given here as examples, may demonstrate significant gains in productivity as a result of new technology, but their impact on the economy as a whole is more limited.

Figure 8: Sectors benefiting from technological progress in services



[16] The structure of economic activities can change as a result of the changes in relative prices of capital and labour due to new technology.

Figure 9: Sectors benefiting from technological progress in trade, transport and communication

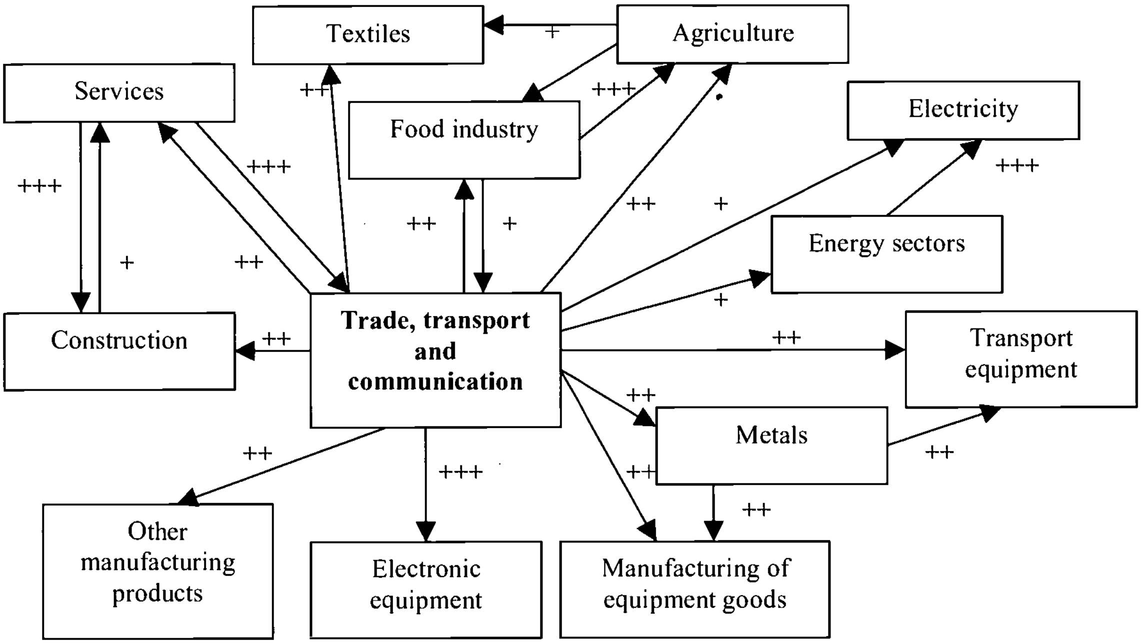


Figure 10: Sectors benefiting from technological progress in equipment goods manufacturing

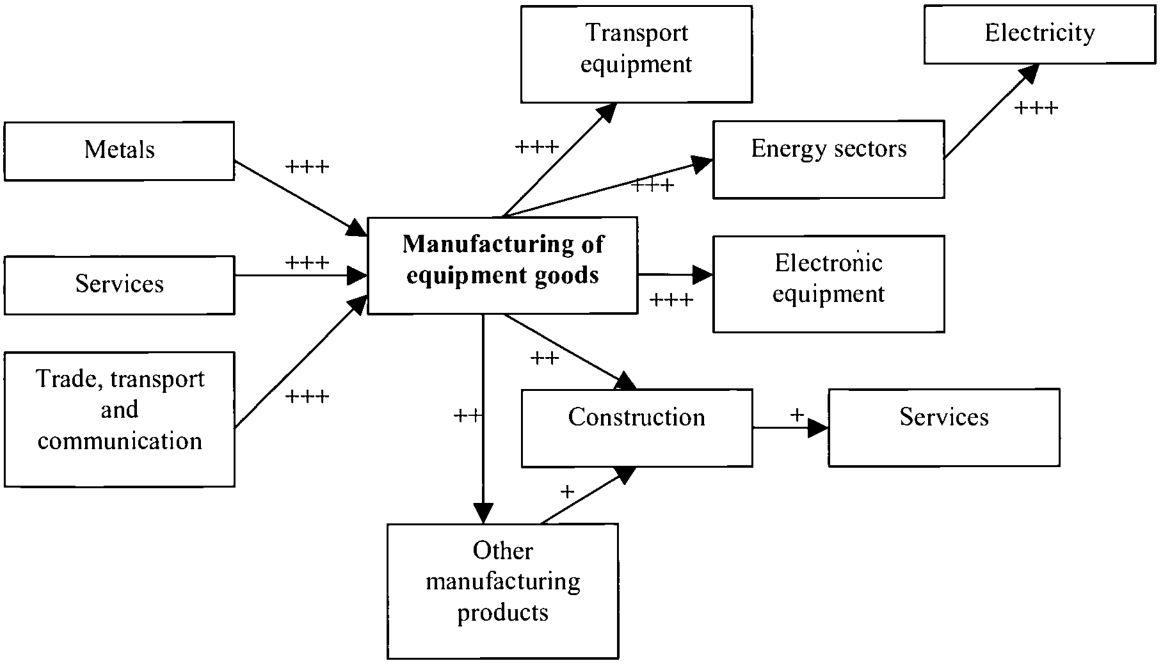


Figure 11: Sectors benefiting from technological progress in chemicals

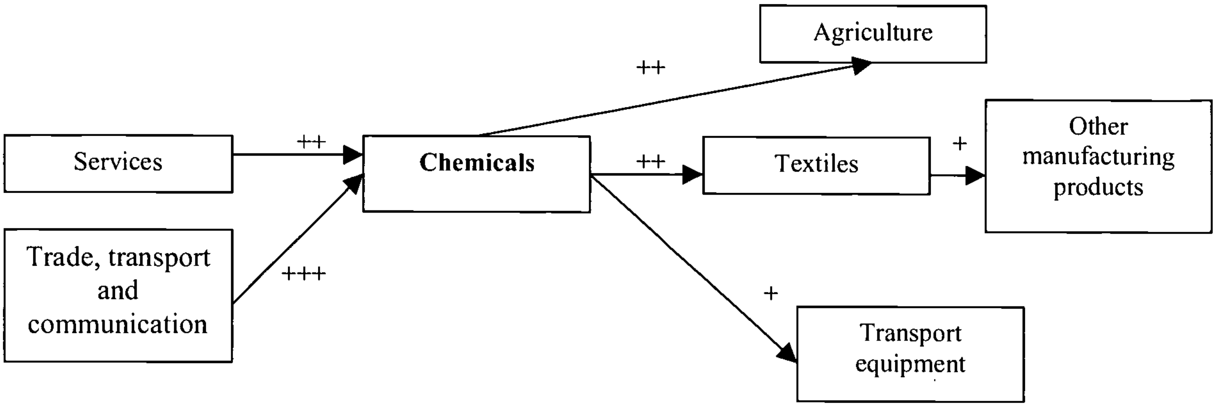
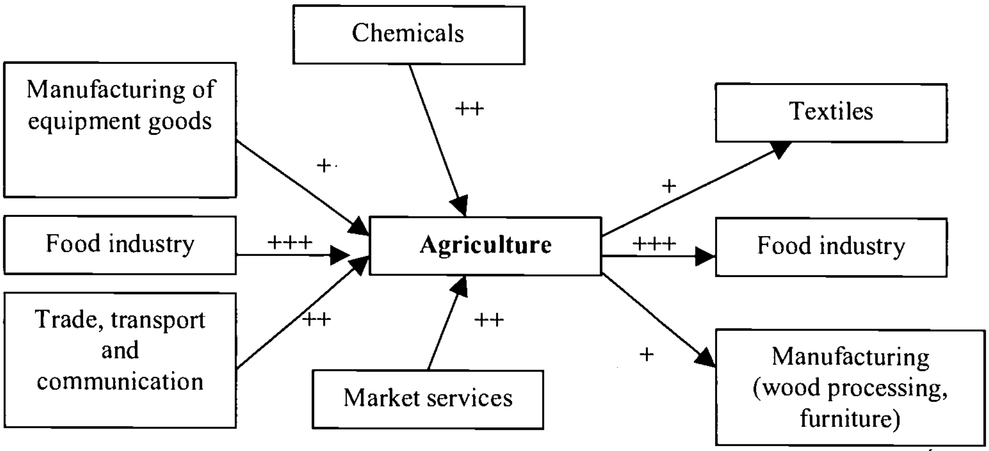


Figure 12: Sectors benefiting from technological progress in agriculture



4.2 Technologies with a significant impact on employment

The results of the quantitative analysis and the identification of the key sectors and intersectoral flows suggest that the best outcome in terms of GDP growth and employment can be achieved in trade, transport, communication and other services. As part of the methodology of the study, the main technological developments identified in the technology foresight literature were considered, and the technologies affecting the above sectors were identified as those being the most promising in terms of employment generation[17].

General-purpose technologies

Three sets of technologies are expected to produce major impacts in a large range of economic activities: Information and Communication Technologies (ICTs), nano-technologies[18] and biotechnologies.

[17] A more detailed analysis of emerging technologies is included in the Background Report, containing the full map of sectors and relevant technologies, the expected impact on productivity, demand and employment, as well as the expected time of introduction.

[18] Capacity to analyse, understand and manipulate matter at the nanometer scale, to eventually produce materials and systems with considerable functional gains (from the size of the atom up to some tens of nanometers, $1nm=10^{-9}m$).

ICTs are likely to continue making substantial contribution to improving the efficiency of the production system over the medium term (despite the current slowdown in demand due to unsustainable investment rates of recent years). Exploitation of ICTs will propagate throughout the whole economy, shifting the benefits from producers to users, leading to significant changes such as higher flexibility, cost reductions, relocation and increased knowledge intensity of all economic activities (see par. 5.2). Nanotechnologies and biotechnologies are still in their early phases of development, but are expected to follow a similar pattern to that of ICTs in terms of penetration in the economy.

Application- specific technologies

Apart from the general-purpose technologies, the whole spectrum of technological development is expected to have a positive impact on employment in the long-term. New products and services, or the improvement of production procedures and processes that new technology can lead to, can influence the productivity and the competitiveness of the sectors the technologies are applied in. Due to the flows between the sectors, the whole economy will benefit. Based on the analysis of the main sectors (figures 8-12), the following application-specific technologies that can have positive impacts for employment in the whole economy have been identified:

- Advanced logistic systems for value chains; advanced software applications for sales, logistic and distribution; fully automated container yards; automation of air traffic control; fully automatic all weather take-off, landing and taxiing systems; advanced road telematics; shared-connection vehicle systems
- Advanced communication systems; laser-based space-earth communication technology; fluoride glass fibers for optical communication; digital optical logic circuits; semiconductor lasers
- Nationwide networks of telemeters for meteorology, road and fleet traffic control, environmental monitoring, distributed via satellite
- High quality speech synthesizing technologies
- Superconductors
- Distributed learning management systems; virtual institutes for training and education, libraries and databases of learning objects
- Multi-device information networks; multifunctional portable/wrist-watch communication devices / personal assistants
- Technologies for medicine: gene therapy; non-invasive cell-level diagnostic imaging; cellular therapy; bio-artificial organs; nano-technologies and micro systems; 3D imaging for medical applications
- e-learning; e-Healthcare; e-Administration
- Integrated/ combined applications/ services: Joint use ducts for cable broadcasting, vacuum garbage collection, regional heating and cooling and general distribution.
- Biosensors
- High-speed mobile terminals; solar-powered portable computers; 3D television sets
- High density optical memories; parallel computing with more than 10^6 processors
- Virtual computer networks
- Advanced gene chip technologies
- Organic semiconductors

5 Labour supply and quality of work issues

Labour force projections demonstrate the following main trends that are expected to affect labour supply in the next 20 years:

- declining birth rates
- increasing levels of educational attainment[19]
- growing numbers of the elderly in the population
- increasing immigration flows towards EU-15 countries
- declining weekly/yearly working hours
- changing proportions in part-time work

One of the key parameters in this regard is the changing composition of households and the impact of the increasing female participation in the workforce. For both men and women, changes in wages, earnings and incomes, together with the effects of changing levels of employment and unemployment, can be expected to have significant impacts on the potential size of labour supply. *The main policy issue is whether the supply of appropriately skilled labour will match the needs of the EU economy.*

Demographic and economic factors will have impacts on the composition of the workforce. Apart form the gender issue, the age composition is also a key issue, with the impact of falling birth rates in recent times bound to lead to an ageing composition of the workforce, and a reduction in the numbers of entrants in the labour market equipped with new skills. Similarly changes in the length of the working week, such as the introduction of the 35-hour week, will affect the supply relative to demand (assuming that there is no commensurate fall in annual earnings); similarly, changes in number of days taken as holidays etc. can provide some adjustment.

A variable that is influenced by changing demand conditions is that of migration of labour. Intra-EU labour migration, EU enlargement and immigration from third countries can definitely balance mismatches in labour supply and demand and alleviate skill shortages.

One of the policy issues that arise from these trends is the impact of flexible contracts and part-time work on equity. Technology has some bearing on this, since ICTs make it easy for people to work at home or be less dependent on location.

5.1 Skills requirements

The analysis of the relation between technology and skills has identified four trends that may influence the future skill requirements:

- The demand for sectors that currently require predominantly low-skilled employees is expected to rise. The most characteristic examples are construction, tourism, transport services, commerce, as well as part of the health care and social services sectors.
- Technical change tends to be skill-biased. The introduction of new technologies in the workplace favours skilled employees and threatens the ones with lower skills. The share

[19] Although not an accurate indicator of skill levels, data on the educational attainment level of the working population of the EU can be used as a guide for the underlying trends. The share of employed persons aged 25-59 that have completed lower secondary education, upper secondary education and tertiary education corresponds to 34%, 44% and 22% of the total respectively. For the age group 25-34 only, the respective shares are 26%, 49% and 25%. The shares of tertiary and upper secondary education are expected to continue to grow.

of skilled employees is therefore expected to rise in the sectors where technology improves.
- The definition of low- and high- skill is changing in the long term. Abilities that allow one to be considered highly skilled today, e.g. computer literacy, may be prerequisites for what will be considered low-skill jobs in 2020.
- Second order effects of the changing social fabric and the increased participation of women in the workforce may create a gap for services requiring low skills (e.g. housekeeping, childcare and catering). In general, every increase in the demand for high skills is expected to stimulate a secondary demand for low skills as well.

There is clearly a falling demand for manual labour and a rising demand for mental labour (requiring cognitive and interactive skills, e.g. managerial jobs). As regards the level of skills, new technologies require new skills during the first period following their introduction, e.g. in IT (computer literacy) – 'up-skilling'. Our findings suggest that a common long-term pattern is one of up-skilling followed by down-skilling, or an inverse-U shape. This implies *greater inequality in the early stages of a new technology (which benefits the few with the 'right' skills), followed by greater equality as time goes on (when the new technology becomes much more widely accessible).*

In the long run, achieving higher levels of education and continuing to update them during one's career (*life-long learning*) seems to be the surest way of securing employment both for individuals and the economy as a whole.

General-purpose technologies can be applied in a wide range of industries, and skills related to them will be highly valued in the next 20 years. Managerial skills, especially those related to entrepreneurship will be also probably in higher demand in the future.

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. Acute shortages can be expected of people who have expertise in both information technology and biotechnology and of those who have expertise in automation technology and nanotechnology. While highly educated specialists will constitute only a small proportion of the total workforce, their significance to the economy of the EU is likely to 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, economic growth and employment generation.

5.2 Work organisation and job profiles

The following trends are expected to emerge concerning the impact of emerging technologies on the organisation of work and job profiles:
- ICTs add to the flexibility of carrying out and organising work
- the Internet makes it possible to reorganise collaboration with suppliers and customers
- the productivity impacts of ICTs can only be realised if combined with organisational changes that help decentralise decision making, reduce layers of management, and empower employees to make critical decisions together with outside 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 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. 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.

Other changes in work organisation may be influenced by changes in technology. Among companies that have adopted information and communication technologies (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 brought in old organisational structures. The need for organisational change can be expected to remain in place at least for the next two decades. Another urgent task is the definition of proper balance between the increased comfort of work-related communication made possible by ICTs and associated work stress and strain on families of white-collar and maintenance workers.

6 Conclusions

The results of the study confirm that technology and innovation can have a positive role on economic growth and employment. Emerging technologies accelerate economic growth and can lead to the creation of new jobs. Technological change also influences the structure of the economy and raises the need of higher skills in the workforce.

Although the development of a number of variables that influence the long-term impacts cannot be predicted with certainty, the overall trends identified can be still described with a certain degree of confidence.

The results of the study reinforce 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 some of its competitors (e.g. in Eastern Europe or Asia), the most viable option appears to be that of *increasing the EU's share in the technology intensive sectors.* In addition, technological progress can lead to higher wages and improved quality of work, thus allowing a higher standard of living. Seen in the context of the overall EU policies, technological progress can be the key for achieving the objectives of economic, social and environmental policy, and the main tool to reach the 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.

It should be also noted that the scope of the study has been limited to issues related to economic growth and employment. Several areas where technology will also probably have positive results, such as environmental issues, defence and security, safety, health and quality of life, gender issues, social equity, and many others can be identified and should be normally taken into account when evaluating the impacts of technology.

To summarise the results, the answers to the original questions of the study can be outlined as follows:

Q.1 Which economic sectors will offer high growth potential and quality jobs?
More than three quarters of the projected 9 to 14 million new jobs in the EU in the next 20 years 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 offer increased real wages and an improved overall work quality, aided by the expected developments in ICTs and other organizational improvements in the workplace.

Q.2 Which technologies will have a significant impact in those sectors?

The technologies that are expected to influence the number and quality of new jobs are mainly *general-purpose technologies* of a pervasive nature that can increase, directly or indirectly, the productivity of all economic sectors. The key technologies *include ICTs and organisational/ managerial methods, nanotechnology and biotechnology*. Nevertheless, the whole spectrum of technological development is expected to have a positive impact on employment in the long-term. Such technologies include for example general technological areas such as *advanced materials* (applicable to manufacturing, construction, electronics, communications, energy production, etc.), *or specific technologies such as tissue engineering* (offering new solutions in the health sector).

The initial positive impacts of the introduction of a new technology are normally observed in the sectors where the new technology is first applied ("producing sectors"). As experience with past technological paradigms shows, in the long term the gains are transferred to the "user sectors". Such a transfer of benefits is currently underway in the case of ICTs, and it is expected to continue happening with the full range of technological developments in the next 20 years.

Q.3 What kind of skills will be required to match the needs of those sectors and technologies?

Technological change will increase the demand for highly skilled workers in Europe. *Skills related to general-purpose technologies (ICT, biotechnology and nanotechnology)* will be in high demand in the labour market, especially for the extension of those technologies to new areas of application. Acute shortages can be expected of people who have expertise in both information technology and biotechnology and of those who have expertise in automation technology and nanotechnology. The majority of jobs will require skills for the exploitation of these technologies rather than for their development. Skills related to management and entrepreneurship are also expected to become more important in the future.

Greater inequality can be expected in the early stages of a new technology (which benefits the few with the 'right' skills), followed by greater equality as time goes on (when the new technology becomes much more widely accessible).

Q.4 What will be the impact of emerging technologies on the organisation of work and job profiles?

Emerging technologies are expected to both respond to the need and raise further requirements for flexibility in work organisation. The productivity impacts of emerging technologies can only be realised 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 outside suppliers and customers*. However, in the context of the increased flow of information exchange, the *security issue* as regards the protection of the companies' key information assets is going to need heightened attention and may also result in changes in work organisation.

Q.5 What would be the impact of selected innovation and technology policy strategies under different socio-economic conditions?

Technology policy strategies aiming to accelerate technological progress are expected to lead to positive results and lead to further economic and employment growth. The success of such a strategy depends largely on whether the structural and regional characteristics of the EU economy are taken into account. In addition, technology policy has to be accompanied by suitable labour supply side policies, as well as measures in the fields of education and training, immigration, fiscal and monetary policies, investment incentives and social protection.

The three alternative technology policy strategies (concentrated, diversified and uniform) have a number of differences that can increase or decrease their success depending on the development of the international socio-economic context. A *concentrated technology policy* would benefit more from an acceleration of international growth of economic activity and trade, in particular as regards high-tech products and services. However, although such a policy would be advisable in the case of a prolonged "boom", it would entail many risks in the case of a world-wide slowdown. A *diversified technology policy* would depend more on the self-sufficiency of the economy of the EU and would be less exposed to fluctuations of international trade. Such a strategy could provide sufficiently high GDP and employment growth rates and could optimise the resource allocation in the EU, but would possibly not allow the EU to become a world leader in a potential new technological revolution. A *uniform technology policy* would spread the benefits of technological development across the whole economy and would create fewer sectoral imbalances, but would not be as efficient as the more focused strategies.

7 Issues for further research

The methodology applied in the study could be extended in order for additional issues of policy interest to be investigated. The combination of technology foresight, economic policy modelling and economics of technological change applied here could be also useful for the analysis of the impacts of other forms of innovation or policy intervention on employment. Subsequent studies with more narrowly defined aspects of the issues involved could allow for more detailed analyses. Examples include focused analysis of specific policies, technologies, sectors, geographical areas, or socio-economic trends.

As regards specific policies, such an approach could be applied in order to investigate the impacts of tighter environmental regulatory frameworks and related technological options. The relevant scenarios could include options of additional innovation and RTD spending channelled to technologies related to environmental protection. A more detailed analysis of the environmental dimension of technology policies would also consider the environmental and social benefits.

As regards labour policy, examples of possible areas for further analysis include issues such as the reduction of working time (e.g. the 35-hour week), part time work and temporary contracts. Such developments affect both the efficiency of the economy and the equity in the distribution of the benefits and the analysis of the trade-offs involved deserves a more detailed investigation.

Specific technologies, or new technological paradigms in general, can be also examined in more detail. It would be interesting to investigate further the impact of Information and Communication Technologies on the form, organisation and quality of employment. Biotechnology and nanotechnology could be also examined with a combination of foresight analysis and quantitative methods. A more detailed sectoral analysis is also possible. IPTS is currently carrying out quantitative analyses of the energy and transport sectors and is planning to develop similar activities in a number of industrial sectors.

This approach could be also applied to examine the impact of alternative technology policies at the regional level, focusing on the specific characteristics and needs of the economy at a more detailed geographic level. Concerning the EU enlargement process in particular, similar scenarios can be analysed with respect to the impact of alternative investment strategies on economic growth and employment in Candidate Countries and the subsequent impact on the enlarged EU as a whole. The IPTS Enlargement Futures project has successfully completed its first phase, where the main challenges and priorities have been identified. In the second phase, a more detailed analysis of these issues is foreseen.

Finally, another interesting issue that could be further examined is the indirect effect of the increasing knowledge intensity of economic activities. The present work concentrated on direct implications of technological change and related higher demand for high skilled workers. However, at the same time, demographic and social trends will raise the need for back-up services such as caring and other personal services. This mostly concerns low-pay and low-status jobs, and involves further social and economic issues, that should be addressed in future studies.

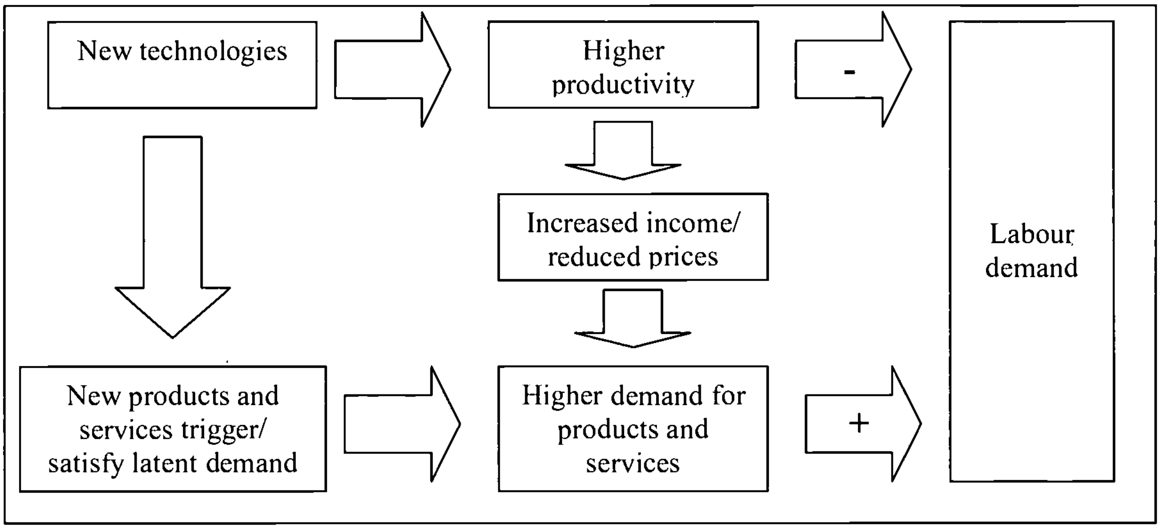
Annexes

Annex 1: Overview of the methodology of the study

The following summarises the methodology applied in the study. A more detailed description addressing technical issues is included in the 'Background Report'.

The impact of new technologies on the demand for labour can be summarised in figure A.1. New technologies tend to increase overall productivity and subsequently reduce the demand for labour, for a given level of output. On the other hand, the new products and services can create new markets than in turn will require new labour. Additionally, the increase in productivity can increase competitiveness, allowing larger market shares that can also lead to a higher labour demand.

Figure A.1: Summary of impacts of new technologies on labour demand



The net impact of new technologies on employment depends on the impact the new technologies have on the supply and demand systems. From the supply side, new technologies increase productivity and, subsequently, the production capacity.

The ratio of GDP per capita is one indicator of economic growth. In order to analyse its relation with employment, it can be decomposed in the following way:

$$GDP/POP = GDP/H \times H/L \times L/LF \times LF/WAP \times WAP/POP$$

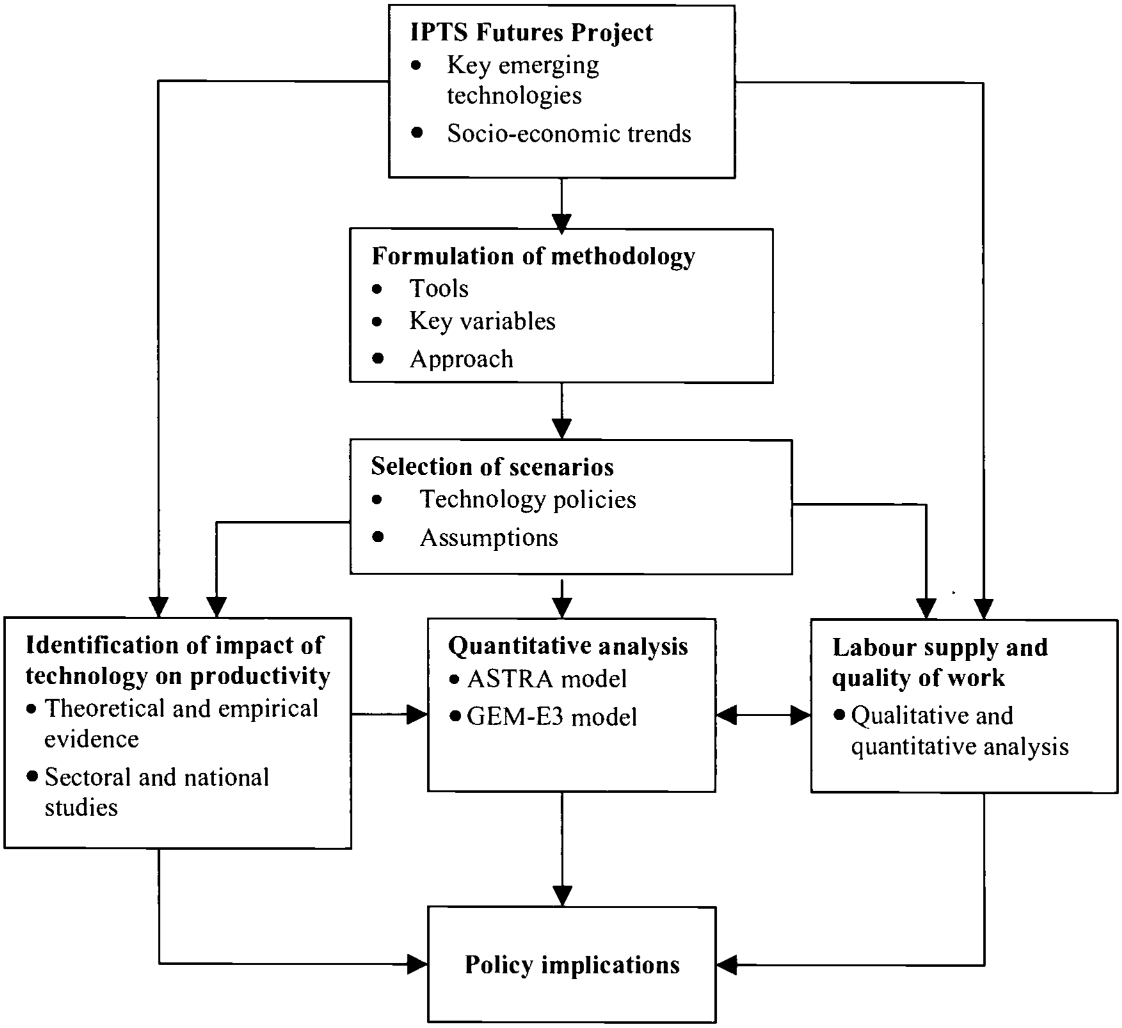
H is total hours worked, L is employment, LF is the labour force, WAP is the working age population, POP is the total population.
Thus, growth in terms of GDP per capita can be explained as a combination of changes in hourly productivity (GDP/H), and labour inputs, i.e. the average working time (H/L), the employment rate (L/LF), the participation rate (LF/WAP) and the demographic characteristics (WAP/POP).

Economic theory distinguishes between increases in the capital/ labour ratio (movement along a production function) where the technology is unchanged and changes in technology (shifts in the production function) where the capital/ labour ratio is constant. However, in practice it is difficult to distinguish the two effects because technical progress is often embodied in capital equipment. A large part of technical change is embodied in new capital equipment, such as machinery or computers. This also implies that investment is a key component of technical progress.

In advanced economies the main determinant for GDP growth in the long run is total factor productivity growth rather than capital accumulation and labour force growth. Total factor productivity is often identified with technical progress, broadly speaking. The massive introduction of ICT, for instance, and the organisational changes it brings about, permit to raise economy-wide productivity. Additional technological areas with large potentials for growth include biotechnology, advanced materials, and alternative energy sources. All these technological areas are skill biased and require a highly skilled and educated labour force.

A main challenge of the study was to connect innovation and RTD, productivity, economic growth and employment. This was made feasible through a combination of qualitative and quantitative methods. The methodology applied in the study can be outlined in figure A.2:

Figure A.2: Outline of methodology



Workshops and meetings

The methodology and the assumptions of the study were presented to, and validated by, a large number of experts in the various fields covered. About 40 scientists in the fields of economics, technology foresight and modelling have contributed with comments during the various stages of the study's progress. The most important milestones of this process were the following:

- **Presentation to the 'High Level Economist Group'** of IPTS (R. Solow, W. Branson, D. Ulph, J.-J. Laffont, C. von Weizsacker): validation of the methodology and interim report (Seville 22nd March 2001)

- **1st ESTO Workshop:** validation of assumptions for business-as-usual scenario (Seville, 25th April 2001)
- **Presentation of a working document** to the co-ordinators of the E.P. Committee on Employment and Social Affairs (Strasbourg, 17th May 2001)
- **2nd ESTO Workshop:** validation of assumptions for alternative scenarios (Rome 13th July 2001)
- **3rd ESTO Workshop:** validation of results of quantitative analysis (Brussels, 28th September 2001)
- **Final ESTO Workshop:** validation of final results (Brussels, 26th October 2001)

In addition, the interim report and the draft final report of the study were submitted to DG EMPL, DG ECFIN, DG ENTR, DG TREN and DG RTD for comments.

Assumptions for labour productivity growth rates

The assumptions for the future growth of productivity for each sector and zone in the business-as-usual scenario were carried out by combining historical data, the main trends identified in the IPTS Futures Project 'Technology Map' and sectoral and national forecasts whenever available. These assumption were widely discussed among the participants of the study and external experts, and were validated in a workshop in Seville in April 2001. The assumption for the alternative scenarios were developed using theoretical and empirical evidence concerning the relation of innovation, Research and Development and productivity, taking sectoral and regional issues into account. These assumptions were also discussed with a wide range of experts, and were validated in a dedicated workshop in July 2001. The results of the quantitative analysis as a whole were presented and validated on two occasions, in September and October 2001.

Average annual productivity growth rates (%): Business-as-usual scenario, GEM-E3 model

	Nordic EU		**Germany**		**UK**		**REU**	
	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020
Agriculture	1.5	1.4	1.5	1.4	0.0	1.2	2.0	1.8
Coal	1.6	1.4	1.6	1.4	1.3	1.1	1.8	1.6
Oil	3.3	3.0	1.8	1.8	3.2	2.9	2.0	2.0
Gas	2.2	2.0	1.6	1.6	2.8	2.5	1.8	1.6
Electricity	2.0	1.8	2.0	1.8	2.5	2.2	2.0	1.8
Ferrous and non ferrous	0.5	0.6	2.0	2.0	0.4	0.3	1.0	0.9
Chemicals	2.0	2.0	3.3	3.3	2.2	2.2	2.3	2.2
Other energy intensive	2.6	2.4	1.3	1.1	0.5	0.5	1.7	1.5
Electronic	8.0	4.0	2.0	1.8	1.6	1.6	3.8	3.5
Transport	2.3	2.1	2.0	1.8	1.3	1.1	3.0	2.7
Other equipment	1.9	1.9	3.3	3.3	0.0	0.8	1.8	1.8
Other Manufacturing	2.0	2.0	0.5	0.5	0.0	0.4	2.3	2.3
Construction	2.3	2.1	2.0	1.8	2.2	2.2	2.0	1.8
Food	1.8	1.6	0.0	1.0	-1.0	0.5	1.5	1.4
Trade and transport	2.1	2.1	1.8	1.8	1.8	1.8	2.0	2.0
Textile	1.6	1.4	1.6	1.4	1.2	1.0	1.9	1.7
Other Market services	2.2	2.2	2.0	2.0	2.2	2.2	2.0	2.0
Non Market services	1.8	1.8	1.8	1.8	1.5	1.5	1.8	1.8

Average annual productivity growth rates (%): Concentrated scenario, GEM-E3 model

	Nordic EU		Germany		UK		REU	
	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020
Agriculture	1.5	1.4	1.5	1.4	0.0	1.2	2.0	1.8
Coal	1.6	1.4	1.6	1.4	1.3	1.1	1.8	1.6
Oil	3.3	3.0	1.8	1.8	3.2	2.9	2.0	2.0
Gas	2.2	2.0	1.6	1.6	2.8	2.5	1.8	1.6
Electricity	2.0	1.8	2.0	1.8	2.5	2.2	2.0	1.8
Ferrous and non ferrous	0.5	0.6	2.0	2.0	0.4	0.3	1.0	0.9
Chemicals	2.2	2.0	3.8	3.5	2.5	2.4	2.5	2.3
Other energy intensive	2.6	2.4	1.8	1.4	0.5	0.5	2.2	2.0
Electronic	10.0	6.0	4.0	3.5	2.2	2.2	5.0	5.0
Transport	2.3	2.1	2.5	2.3	1.5	1.5	3.6	3.0
Other equipment	2.2	1.9	3.8	3.5	0.0	0.8	2.5	2.5
Other Manufacturing	2.0	2.0	0.5	0.5	0.0	0.4	2.3	2.3
Construction	2.3	2.1	2.0	1.8	2.2	2.2	2.0	1.8
Food	1.8	1.6	0.0	1.0	-1.0	0.5	1.5	1.4
Trade and transport	2.1	2.1	2.2	2.0	2.5	2.5	2.3	2.3
Textile	1.6	1.4	1.6	1.4	1.2	1.0	1.9	1.7
Other Market services	2.6	2.6	2.4	2.4	2.6	2.6	2.4	2.4
Non Market services	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

Average annual productivity growth rates (%): Diversified scenario, GEM-E3 model

	Nordic EU		Germany		UK		REU	
	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020
Agriculture	1.5	1.4	1.5	1.4	0.0	1.2	2.0	1.8
Coal	1.6	1.4	1.6	1.4	1.6	1.4	1.8	1.6
Oil	3.5	3.3	1.8	1.8	3.6	3.4	2.0	2.0
Gas	2.7	2.5	1.6	1.6	3.2	3.0	1.8	1.6
Electricity	2.2	2.0	2.0	1.8	2.7	2.5	2.0	1.8
Ferrous and non ferrous	0.5	0.6	2.0	2.0	0.4	0.3	1.8	1.6
Chemicals	2.4	2.2	4.7	4.3	2.8	2.8	2.6	2.4
Other energy intensive	3.0	2.8	1.8	1.6	0.5	0.5	1.7	1.5
Electronic	9.0	6.0	2.0	1.8	2.6	2.4	3.8	3.5
Transport	2.3	2.1	3.2	3.0	1.3	1.1	5.0	4.6
Other equipment	1.9	1.9	4.0	3.7	0.0	0.8	2.8	2.6
Other Manufacturing	2.0	2.0	0.5	0.5	0.0	0.4	2.8	2.6
Construction	2.3	2.1	2.0	1.8	2.2	2.2	2.0	1.8
Food	1.8	1.6	0.0	1.0	-1.0	0.5	2.0	1.8
Trade and transport	2.1	2.1	2.2	2.0	2.4	2.2	2.0	2.0
Textile	1.6	1.4	1.6	1.4	1.2	1.0	2.9	2.7
Other Market services	2.6	2.6	2.4	2.4	4.2	4.0	2.0	2.0
Non Market services	1.8	1.8	1.8	1.8	1.5	1.5	1.8	1.8

Average annual productivity growth rates (%): Uniform scenario, GEM-E3 model

	Nordic EU		Germany		UK		REU	
	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020
Agriculture	1.5	1.4	1.5	1.4	0.0	1.2	2.0	1.8
Coal	1.6	1.4	1.6	1.4	1.3	1.1	1.8	1.6
Oil	3.3	3.0	1.8	1.8	3.2	2.9	2.0	2.0
Gas	2.2	2.0	1.6	1.6	2.8	2.5	1.8	1.6
Electricity	2.0	1.8	2.0	1.8	2.5	2.2	2.0	1.8
Ferrous and non ferrous	0.5	0.6	2.0	2.0	0.4	0.3	1.0	0.9
Chemicals	2.1	2.0	3.6	3.4	2.3	2.3	2.4	2.4
Other energy intensive	2.6	2.4	1.6	1.3	0.5	0.5	1.9	1.8
Electronic	9.0	5.0	3.0	2.7	1.8	1.8	4.0	4.0
Transport	2.3	2.1	2.3	2.1	1.4	1.3	3.3	2.9
Other equipment	2.0	1.9	3.6	3.4	0.0	0.8	2.2	2.1
Other Manufacturing	2.0	2.0	0.5	0.5	0.0	0.4	2.4	2.4
Construction	2.3	2.1	2.0	1.8	2.2	2.2	2.0	1.8
Food	1.8	1.6	0.0	1.0	-1.0	0.5	1.5	1.4
Trade and transport	2.1	2.1	2.0	1.9	2.2	2.2	2.2	2.1
Textile	1.6	1.4	1.6	1.4	1.2	1.0	1.9	1.7
Other Market services	2.4	2.4	2.2	2.2	2.4	2.4	2.2	2.2
Non Market services	1.9	1.9	1.9	1.9	1.7	1.7	1.9	1.9

Average annual productivity growth rates (%): Business-as-usual scenario, ASTRA model

	Germany & Austria		Belgium, France, the Netherlands and Luxembourg		Greece, Italy, Spain and Portugal		Denmark, Finland, Ireland, Sweden and UK	
	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	2.5	2.5	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

Description of the GEM-E3 model

The GEM-E3 model is developed and maintained by the National Technical University of Athens. It is an applied general equilibrium model in which the world is divided into 18 zones that are linked together with endogenous trade. Each of the zones has the same model structure, but parameters and variables are zone specific.

The economy is divided into 18 sectors. Four of the sectors are involved in the supply and distribution of energy and 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 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 and the producer behaviour 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. 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 further assumed that the stock of capital is immobile between sectors and countries.

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, the remaining part of government activities (expenditures, investment demand and tax levels) are exogenous. 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. Firstly the household allocates its resources between future and present 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 from those from 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, as discussed above. 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.

The main types of issues that the model has been designed to study are:

- The analysis of market instruments for energy-related environmental policy, such as taxes, subsidies, regulations, pollution permits etc., at a degree of detail that is sufficient for national, sectoral and Europe-wide policy evaluation.

- The evaluation of European Commission programmes that aim at enabling new and sustainable economic growth, for example the technological and infrastructure programmes.
- The assessment of distributional consequences of programmes and policies, including social equity, employment and cohesion targets for less developed regions.
- The consideration of market interactions across Europe, given the perspective of a unified European internal market, while taking into account the specific conditions and policies prevailing at a national level.
- Public finance, stabilisation policies and their implications on trade, growth and the behaviour of economic agents.
- The standard need of the European Commission to periodically produce detailed economic, energy and environment policy scenarios.

Policies that attempt to address the above issues are analysed as counterfactual dynamic scenarios and are compared against baseline model runs. Policies are then evaluated through their consequences on sectoral growth, finance, income distribution implications and global welfare, both at the single zone level and for the EU taken as a whole.

The model is designed to support the analysis of *distributional effects* that are considered in two senses: distribution among European countries and distribution among social and economic groups within each country. The former issues involve changes in the allocation of capital, sectoral activity and trade and have implications on public finance and the current account of member states. The latter issues are important, given the weakness of social cohesion in European member-states, and regard the analysis of effects of policies on consumer groups and employment. The assessment of allocation efficiency of policy is often termed "burden sharing analysis", which refers to the allocation of efforts (for example taxes), over member-states and economic agents. The analysis is important to adequately define and allocate compensating measures aiming at maximising economic cohesion. Regarding both types of distributional effects, the model can also analyse and compare coordinated versus non coordinated policies in the European Union.

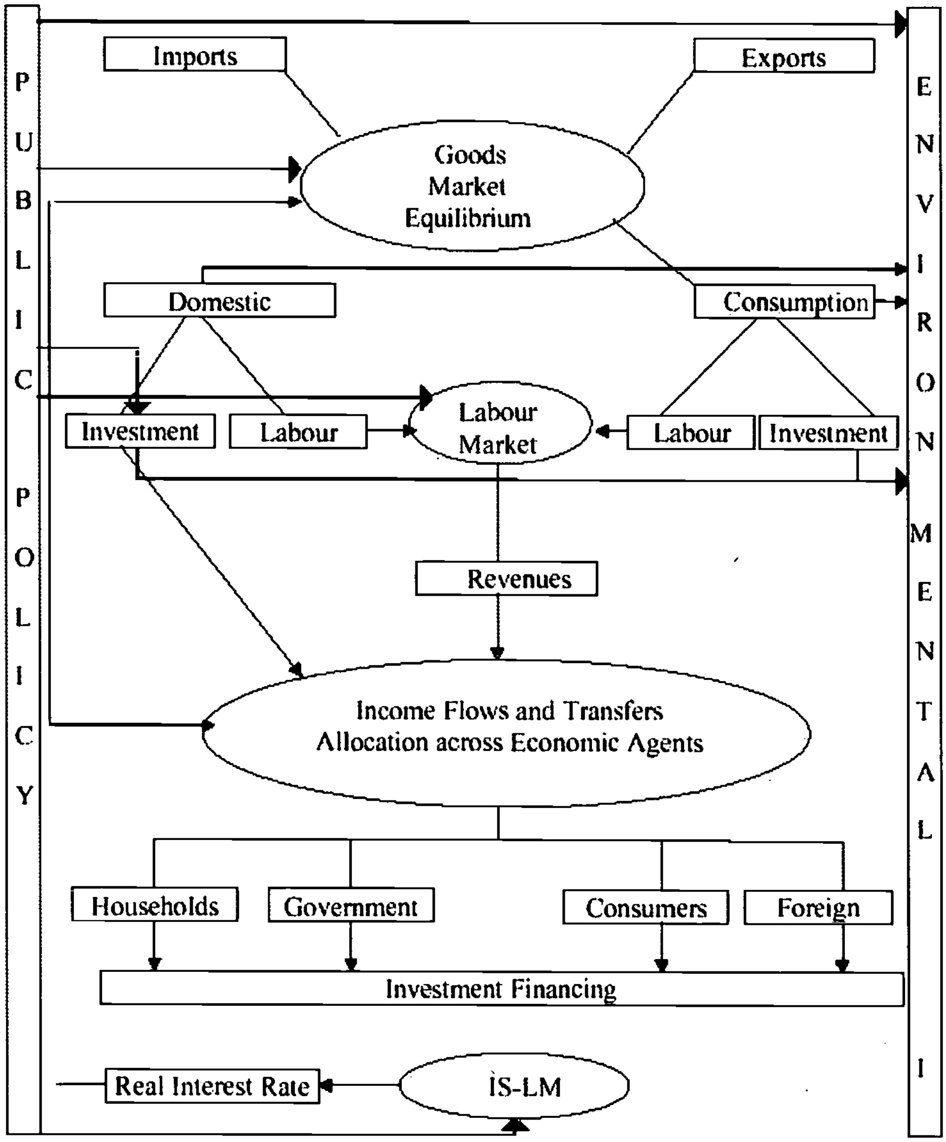
Technical progress and infrastructure can convey factor productivity improvement to overcome the limits towards sustainable development and social welfare. For example, European RTD strategy and the development of pan-European infrastructure are conceived to enable new long-term possibilities of economic growth. The model is designed to *support analysis of structural features of economic growth related to technology and evaluate the derived economic implications for competitiveness, employment and the environment.*

Selected examples of recent applications of GEM-E3/ NTUA

- 2001-2002: "CCGT-Climate Change Policy and Global Trade" for DG RTD. The objective of the project is to provide advice to European policy makers about the best strategy for climate change mitigation, within the framework of the Kyoto protocol and the proposed flexibility instruments, focusing on the interrelationships with global trade agreements (under WTO and others) (on-going).
- 2000-2003: "LREM – Long Run Energy Modelling and Analysis for Europe", DG TREN. Long-term (up to 2020 and 2030) quantitative energy projections and their evaluation and analysis for all member-states of the European Union (on-going).
- 2000-2001: "SAPIENT – Systems Analysis Promoting Induced Energy Technology progress". DG TREN.
- 2000-2001: "TCH-GEME3 - The Role of Innovation and Policy Design in Energy and Environment for a Sustainable Growth in Europe", DG RTD.
- 2000: "Scenarios Related to the Energy Security of Supply at the European Level", a study commissioned within "LREM – Long Run Energy Modelling and Analysis for Europe" framework contract for DG TREN.

- 1997: "A Macro-Economic Baseline Scenario for the EU 1995-2030": construction of a sectoral growth scenario for the EU by using the GEM-E3 model. The scenario has been used as reference to several activities within the European Commission.
- 1998-1999: "Shared Analysis" activity for DG XVII/A2, aiming at providing a new set of energy scenarios for the EU member-state energy system 1995-2020. The "EU Energy Outlook" was published in 1999.
- 1998-1999: "Evaluation of marginal cost abatement curves for CO2 emission reduction by sector and Member State of the EU", project for DG XI.
- 1995-1996: "General Equilibrium Macro-Economic Ex-post Evaluation of the EU Single Market Programme", for DG-II and DG-XV. This study corresponds to the concluding volume of the series on "Single Market 1996" study of the EC submitted to the EU inter-governmental panel.
- 1995-1997: "Macro-economic analysis for CO2 reduction policies", DG-XII.

Figure A.3: Structure of the GEM-E3 model



Description of the ASTRA model

The ASTRA model was developed in the project on Assessment of Transport Strategies (ASTRA) financed by the European Commission DG TREN, and is maintained by the Institut fuer Wirtschaftspolitik und Wirtschaftsforschung (IWW) of the University of Karlsruhe. The objective of ASTRA was to develop a tool for analysing the long-term impacts of the European common transport policy (CTP). The spatial scope for ASTRA covers the EU15 countries and the time horizon is the year 2026. ASTRA is an integrated system dynamics model comprising four modules, based on state-of-the-art models of four different research disciplines: macroeconomics (MAC), regional economics and land use (REM), transport (TRA) and environment (ENV). The aim of the ASTRA MAC module is to provide an aggregate macroeconomic environment in which the REM, TRA and ENV modules are embedded. The main advantage of the modelling technique used is the existence of feedback loops; a change in an element at any level causes changes in the whole system.

The model divides EU into 4 macro regions. These have been chosen to provide regions of approximately the same size and containing national economies with roughly similar characteristics:

- Macro region 1: Germany and Austria.
- Macro region 2: France, Belgium, the Netherlands and Luxembourg.
- Macro region 3: Italy, Spain, Portugal and Greece.
- Macro region 4: UK, Ireland, Sweden, Denmark and Finland.

Each of the four regions is modelled using the same macroeconomic framework, which is adapted to regional specifics through different parameters. All monetary values are calculated in real values of 1995 euros.

The MAC module is constructed as an extended Keynesian model. It follows a similar approach as the macroeconomic module within the ESCOT model, which has been developed as part of the project on Environmentally Sustainable Transport (EST) of the OECD. It consists of three major elements:

- supply side model based on supply of production factors,
- demand side model based on the elements of final demand and
- sectoral interchange model based on input-output tables.

The interaction between supply and demand side can be adjusted such that the model can simulate supply-demand balanced economies but also either a supply side driven or a demand side driven economy. In the base run both sides are treated as their influence is of the same importance. The basic structure of the MAC module is presented in the following figure A.4.

The boxes with the bold (blue) frames indicate the major exogenous variables that are used by the model. Especially "Employment per GVA" and "Sectoral Split Consumption" are applied to define the differences in the policy scenarios analysed in the study.

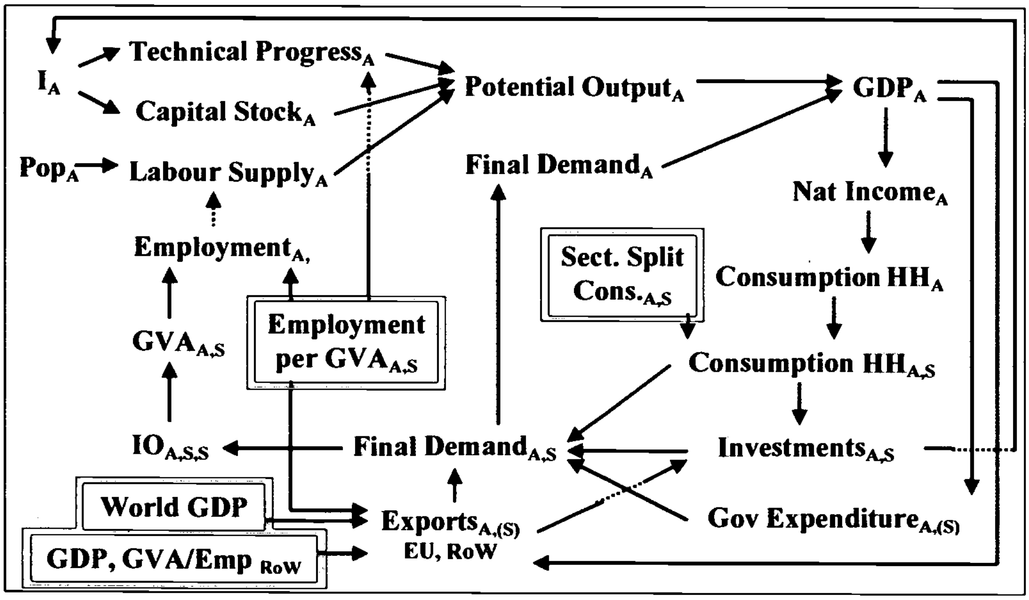
The basic element of the supply side is a Cobb-Douglas production function that incorporates the three major production factors (labour supply, capital stock and natural resources) as well as technological progress. Labour supply, capital stock and technical progress are calculated endogenously. The influence of natural resources is considered exogenously. Final demand is driven by consumption, investments, government expenditures and export-import balance. Government expenditures develop proportionally to GDP, while export is driven by the aggregated demand for the three other variables in the original ASTRA model. The export-import model was updated in the context of this study and includes the impact of relative differences in sectoral productivity and GDP growth of the importing countries and world GDP growth.

The sectoral interchange model considers the indirect effects of the sectoral developments e.g. of final demand in the ASTRA model. Its basic element is an aggregated input-output-table (I-O-table) with the following twelve economic sectors:

- Agriculture, forestry and fishery.
- Energy, water-, mining products, crude oil.
- Chemical-, mineral-, plastic- and petroleum products.
- Ferrous and non-ferrous ores and metals.
- Steel products, machinery, transport equipment.
- Electrical-, optical goods, office and data processing, toys.
- Textiles, clothing, paper, wooden goods.
- Food, beverages, tobacco.
- Building and construction.
- Services for repair, wholesale and retail, transport, communication.
- Other market services like lodging, catering, credits, insurance.
- Non-market services.

The data for the I-O-table is taken from the harmonised EUROSTAT R25 I-O-tables for 1995. The structure of the tables changes over time, as a result of technical change.

Figure A.4: Basic structure of the models in the MAC module in ASTRA



Index: A = 4 European Regions; S = 12 Economic Sectors; RoW = 13 Rest-of-the-world Regions

Recent applications of the ASTRA project in European Commission research projects

- STEMM - Strategic European Multi Modal Modelling
- SORTIT - Strategic Organisation and Regulation in Transport - Inter Urban Travel
- PETS - Pricing European Transport Systems
- SCENARIOS - Scenarios for Trans-European Networks
- SCENES - Successor of SCENARIOS
- ASTRA - Assessment of Transport Strategies
- FISCUS - Cost Evaluation and financing schemes for urban transport systems
- SOFTICE - Survey on Freight Transport including a Cost-Comparison for Europe
- EUROMOS - European Road Mobility Scenarios

Annex 2: Selected references

1. Cambridge Econometrics (2000): Sectoral Economic Analysis and Forecasts up to the Year 2005, DG ECFIN.
2. CEDEFOP (2001): Anticipating occupational and qualificational developments, Thessaloniki.
3. CEDEFOP (1999): European trends in the development of occupations and qualifications, Thessaloniki.
4. European Commission (2001a): Employment in Europe 2001: Recent Trends and Prospects, DG EMPL/A.1, July 2001
5. European Commission (2001b): Towards a European Research Area. Indicators for benchmarking of national policies, Key figures 2001.
6. European Commission (2001c): European Competitiveness Report.
7. European Commission (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.
8. IPTS (2001): Employment and Societal Change, Enlargement Futures Report series 2, EUR 20117 EN
9. IPTS (2000a): The IPTS Futures Project. Synthesis Report. EUR 19038 EN. European Commission.
10. IPTS (2000b): IPTS-ESTO Techno-Economic Analysis Report 1999-2000, EUR 19626 EN.
11. IPTS (1999a): The Futures Project: Synthesis Report, EUR 19038 EN.
12. IPTS (1999b): The Futures Project Technology Map, EUR 19031 EN.
13. IPTS (1999c): Employment Map: Jobs, skills and working life on the road to 2010, EUR 19033 EN.
14. IPTS (1999c): Demographic and social trends panel report, EUR 18729 EN.
15. 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. London, Blackwell.
16. Kyriakou D. (1996): Technology and employment: against pessimism, IPTS Report, n. 9, Nov. 1996.
17. Lipsey, Richard G, Cliff Bekar, and Kenneth Carlaw (1998): What Requires Explanation?, In Elhanan Helpman (ed.), General Purpose Technologies and Economic Growth. The MIT Press. Cambridge, Massachussetts, The United States.
18. Mairesse, J. - Greenan, N. - Topiol-Bensaïd, A. (2001): Information Technology and Research and Development Impacts on Productivity and Skills: a Comparison on French Firm Level Data, NBER Working Paper 8075.
19. McMorrow, K. and Roeger, W. (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, Bruxelles, European Commission.
20. Nickell, S. - Bell, B. (1995): The Collapse in Demand for the Unskilled and Unemployment across the OECD, Oxford Review of Economic Policy, vol.11, pp.40-62.
21. OECD, (2000a): A new economy? The role of innovation and information technology in recent OECD economic growth. Paris, OECD.
22. OECD (2000b): Science Technology and Industry Outlook. Organisation for Economic Co-operation and Development. Paris.
23. OECD (2000c): Innovation and economic performance, DSTI/STP 2, Paris, OECD.

24. OECD (1999a): Towards More Sustainable Household Consumption Patterns Indicators to Measure Progress, Environment Directorate, October 1999, Paris, OECD.
25. OECD (1999b): Economic Opening and the Demand for Skills in Developing Countries – A Review of Theory and Evidence, Technical Paper 149.
26. OECD (1998a): Technology, productivity and job creation. Best Policy Practices..
27. OECD (1998b): OECD Data on Skills: Employment by Industry and Occupation, STI Working Paper 1998/4.
28. Verspagen, B. (2000): 'Economic Growth and Technological Change: An evolutionary Interpretation.' Paper prepared for the OECD, ECIS and Merit. April.
29. Vivarelli M., Pianta M., eds. (2000): The Employment Impact of Innovation: Evidence and Policy, Routledge Studies in the Modern World Economy.

8 Acknowledgements

This work has been directly supervised by Jean-Marie Cadiou, Director of IPTS. Antoine Cahen had an important role in the communication with the E.P. services and provided useful input to the research team. The IPTS research was co-ordinated by Hector Hernández and Panayotis Christidis and included extensive input from Juan Carlos Císcar, Dimitris Kyriakou and Odd Bjorn Ure.

The ESTO team coordinated by Jorma Lievonen (VTT, Finland) consisted of Nick Von Tunzelmann (SPRU, UK), Annette Braun (VDI-TZ, Germany), Eamon Cahill (IPC, Ireland), and Claudio Roveda (Fondazione Roselli, Italy). The expertise of the group was enhanced by external experts on modelling and economic analysis, namely Mario Pianta (CNR) and Marco Vivarelli (UCP), Nikolaos Kouvaritakis (NTUA, Greece) and Wolfgang Schade (IWW, Germany).

We are especially grateful to Prof. Robert Solow, and the other members of the IPTS High-Level Economists group (W. Branson, D. Ulph, C. von Weizsacker, J.J. Laffont) for their useful comments and the many suggestions that helped to improve the quality of this work. We also warmly thank Prof. Bart Verspagen and Theo Dunnewijk who have provided valuable input during the validation workshops.

We also thank our colleagues from other European Institutions that have followed this work and participated to the validation workshops providing helpful comments: Aisling Quirke (DG ENTR), David Young (DG ECFIN), Lothar Bauer (EP-Research Directorate) and Manfred Tessaring and Burkart Sellin (CEDEFOP).

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

NOTICE

Reproduction Basis

☐ This document is covered by a signed "Reproduction Release (Blanket)" form (on file within the ERIC system), encompassing all or classes of documents from its source organization and, therefore, does not require a "Specific Document" Release form.

☒ This document is Federally-funded, or carries its own permission to reproduce, or is otherwise in the public domain and, therefore, may be reproduced by ERIC without a signed Reproduction Release form (either "Specific Document" or "Blanket").