EUROPEAN COMMISSION

Community research

EU RESEARCH ON SOCIAL SCIENCES AND HUMANITIES

Employment Prospects in the Knowledge Economy

EPKE

FINAL REPORT

EUR 23134

Interested in European research?

Research*eu is our monthly magazine keeping you in touch with main developments (results, programmes, events, etc.). It is available in English, French, German and Spanish. A free sample copy or free subscription can be obtained from:

European Commission
Directorate-General for Research
Communication Unit
B-1049 Brussels
Fax (32-2) 29-58220
E-mail: research-eu@ec.europa.eu
Internet: http://ec.europa.eu/research/research-eu

EUROPEAN COMMISSION

Directorate-General for Research
Directorate L — Science, economy and society
B-1049 Brussels
Fax (32-2) 2994462

http://ec.europa.eu/research/social-sciences
http://cordis.europa.eu/fp7/cooperation/socio-economic_en.html

EUROPEAN COMMISSION

EU RESEARCH ON SOCIAL SCIENCES AND HUMANITIES

Employment Prospects in the Knowledge Economy

EPKE

Final report

HPSE-CT-2001-00055

Funded under the Key Action
'Improving the Socio-economic Knowledge Base' of FP5

DG Research
European Commission

Issued in
December 2004

Coordinator of project:
National Institute of Economic and Social Research
London, United Kingdom
Mary O'Mahony
www.niesr.ac.uk/research/epke/index.html

Partners:
Zentrum für Europäische Wirtschaftsforschung, Mannheim, DE, Thomas Zwick,
The University of Groningen, NL. Bart van Ark
Oesterreichisches Institut für Wirtschaftsforschung, Vienna, AT, Michael Peneder
Centre d'Études Prospectives et d'Informations Internationales, Paris, FR, Michel Fouquin
The University of Ancona, IT, Alessandro Sterlacchini

Directorate-General for Research
2007 Citizen and Governance in a knowledge-based society EUR 23134 EN

LEGAL NOTICE

Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use which might be made of the following information.

The views expressed in this publication are the sole responsibility of the author and do not necessarily reflect the views of the European Commission.

A great deal of additional information on the European Union is available on the Internet.
It can be accessed through the Europa server (http://europa.eu).

Cataloguing data can be found at the end of this publication.

Luxembourg: Office for Official Publications of the European Communities, 2007

ISBN 978-92-79-07583-4

Printed in Belgium

PRINTED ON WHITE CHLORINE-FREE PAPER

Preface

Within the Fifth Community RTD Framework Programme of the European Union (1998–2002), the Key Action 'Improving the Socio-economic Knowledge Base' had broad and ambitious objectives, namely: to improve our understanding of the structural changes taking place in European society, to identify ways of managing these changes and to promote the active involvement of European citizens in shaping their own futures. A further important aim was to mobilise the research communities in the social sciences and humanities at the European level and to provide scientific support to policies at various levels, with particular attention to EU policy fields.

This Key Action had a total budget of EUR 155 million and was implemented through three Calls for proposals. As a result, 185 projects involving more than 1 600 research teams from 38 countries have been selected for funding and have started their research between 1999 and 2002.

Most of these projects are now finalised and results are systematically published in the form of a Final Report.

The calls have addressed different but interrelated research themes which have contributed to the objectives outlined above. These themes can be grouped under a certain number of areas of policy relevance, each of which are addressed by a significant number of projects from a variety of perspectives.

These areas are the following:

- ***Societal trends and structural change***

16 projects, total investment of EUR 14.6 million, 164 teams

- ***Quality of life of European citizens***

5 projects, total investment of EUR 6.4 million, 36 teams

- ***European socio-economic models and challenges***

9 projects, total investment of EUR 9.3 million, 91 teams

- ***Social cohesion, migration and welfare***

30 projects, total investment of EUR 28 million, 249 teams

- ***Employment and changes in work***

18 projects, total investment of EUR 17.5 million, 149 teams

- ***Gender, participation and quality of life***

13 projects, total investment of EUR 12.3 million, 97 teams

- ***Dynamics of knowledge, generation and use***

8 projects, total investment of EUR 6.1 million, 77 teams

- ***Education, training and new forms of learning***

14 projects, total investment of EUR 12.9 million, 105 teams

- ***Economic development and dynamics***

22 projects, total investment of EUR 15.3 million, 134 teams

- ***Governance, democracy and citizenship***

28 projects; total investment of EUR 25.5 million, 233 teams

- ***Challenges from European enlargement***

13 projects, total investment of EUR 12.8 million, 116 teams

- ***Infrastructures to build the European research area***

9 projects, total investment of EUR 15.4 million, 74 teams

This publication contains the final report of the project 'Employment Prospects in the Knowledge Economy', whose work has primarily contributed to the area 'Employment and unemployment in Europe'.

The report contains information about the main scientific findings of EPKE and their policy implications. The research was carried out by six teams over a period of three years, starting in September 2001

The abstract and executive summary presented in this edition offer the reader an overview of the main scientific and policy conclusions, before the main body of the research provided in the other chapters of this report.

As the results of the projects financed under the Key Action become available to the scientific and policy communities, Priority 7 'Citizens and Governance in a knowledge based society' of the Sixth Framework Programme is building on the progress already made and aims at making a further contribution to the development of a European Research Area in the social sciences and the humanities.

I hope readers find the information in this publication both interesting and useful as well as clear evidence of the importance attached by the European Union to fostering research in the field of social sciences and the humanities.

J.-M. BAER,

Director

Table of contents

Acknowledgements

This research benefited from discussion and comments from a wide range of people from the research communities and national statistics offices. In addition to colleagues within the consortium research institutes and universities we would like to specifically thank the following individuals: Prabhat Vaze, Eunice Lau and Craig Richardson (all UK Office for National Statistics); Alessandra Colecchia, Dirk Pilat and Paul Schreyer (all OECD); Mike Keoghan and Ken Warwick (UK Department of Trade and Industry); Tassos Belessiotis and Jesus Maria Irigoyen (both European Commission, DG Enterprise); Stephen Broadberry (University of Warwick); Heinz Hollenstein (ETH Zuerich); Kazuo Inaba (Ritsumeikan University, Kyoto); Dale Jorgenson (Harvard); Edward Paul Lazear (Stanford University); Nick Oulton (Bank of England and London School of Economics); Michael Pfaffermayr (University of Innsbruck); Sally Srinivasan (Bank of England); Jack Triplett (Brookings); Elke Wolf, Guy Vernon and Thomas Hempell (all ZEW); Lionel Fontagné (Director, CEPII), Isabelle Bensidoun and Guillaume Gaulier (both CEPII); Aude Sztulman (University of Paris-IX Dauphine); Isabelle Laudier (Institut CDC pour la Recherche); Jacques Mairesse (INSEE-CREST-EHESS); Gilbert Cette (Banque de France); François Magnien (INSEE), Gwenaelle Brilhaut, Stéphane Vignault (INSEE); Frédéric Lerais and Géraldine Seroussi (DARES); Dirk van den Bergen (Statistics Netherlands); Robert McGuckin and Matthew Spiegelman (both The Conference Board); Martin Weale (Director, NIESR). We would also thank ISTAT and Capitalia for providing us the Italian data used in the analysis.

Abstract

The main purpose of the Employment Prospects in the Knowledge Economy (EPKE) research project was to examine the impact of the adoption and diffusion of knowledge generating activities on economic performance in Europe. The primary focus of the research was on considering employment generation and productivity growth and the demand for skilled labour in the context of increased investment in information and communications technology (ICT) equipment, contrasting EU performance with the US. The analysis was carried out at both the industry and firm level. The project first generated an internationally comparable industry dataset used in subsequent analysis, constructing estimates for employment and labour productivity growth for all EU countries and more detailed data containing estimates of capital input and labour quality for four EU countries, namely France, Germany, the Netherlands and the United Kingdom. Industry taxonomies were developed to aid in analysing the first of these databases. The research results need to be seen against a background of accelerating productivity growth in the US since the mid 1990s which most observers now acknowledge is linked to the use of ICT. The analysis at the industry and firm levels show the EU economies have been investing rapidly in new technology but as yet have not enjoyed the same productivity benefits as observed for the United States. All countries also show evidence of increased demand for skilled labour associated with the adoption and use of ICT and reductions in the demand for unskilled labour. However, from the mid 1990s EU countries have shown a capacity to create jobs, mainly in traditional industries but there is some evidence of job creation also in ICT intensive using service sectors. There is considerable variation in performance across EU countries. The UK performance is most like the US, with productivity gains in the same service sectors that underlie the US growth spurt. Nevertheless the UK lags considerably behind the US. In general the large EU countries, particularly France, Germany and Italy, appear to be gaining less from information technology, with little evidence of productivity gains in service sectors. The US head-start in adopting information technology explains some of its lead in reaping productivity benefits from ICT. It may be the case that, to date, the poor relative EU performance merely reflects that region’s later start. However it is also possible that the competitive and regulatory environment in which firms operate in the EU will delay productivity gains. It is likely that both explanations have some validity but, since these countries are currently in the midst of the diffusion process, it may be some time before research can distinguish between the two. From a policy perspective, therefore, the relative effectiveness of policies to encourage the flow of information versus regulatory reforms will also be difficult to disentangle. Therefore a combination of both types of policies is likely to prove useful.

I. EXECUTIVE SUMMARY

1. Objectives

1) The overarching objective of the Employment Prospects in the Knowledge Economy (EPKE) research consortium was to improve understanding of economic performance in EU member states, in the context of advances in information and communications technology (ICT) and other knowledge generating activities.

2) A first main objective was to consider knowledge generating activities in a systematic quantitative way by combining data on relevant indicators from a wide range of sources and countries. The aim was to integrate available data for European countries at the industry level so as to yield a coherent, unified analysis of the impact of these innovations on economic activity.

3) A primary focus of the research using these industry data was in contrasting European performance with that in the US. The aim was to consider employment generation in general, and specifically the demand for skilled labour, and productivity change. An important objective was to analyse the position in the much less researched service sector activities and contrast this with the impact of knowledge innovations in manufacturing.

4) A second main objective was to examine evidence using firm level data to see to what extent the findings are consistent with the results using industry data. This research was to have a similar focus to the industry research, namely consideration of employment generation, the demand for skilled labour and productivity.

2. Data series

1) Two industry data sets were developed, one covering a large number of industries and all fifteen EU member states, the other concentrating on a few large EU countries, and including a smaller number of individual sectors.

2) The *Industry Labour Productivity Database for the European Union and the United States* provides a comprehensive, internationally comparable dataset on industrial performance at a detailed industry level for the fifteen EU member states, aggregate estimates for the EU-15 as a whole, and the United States. Data are provided for 56 industries in total. The industries are classified according to the International Standard Industrial Classification (ISIC) revision

3. To ensure international comparability of the data series, variable definitions and industry classifications were matched across countries. This included basing real output series on the use of harmonised US deflators for the manufacturing industries that produce information technology so as to avoid non-comparabilities arising from measurement methods. The variables included in the database are nominal value added, output deflators, persons engaged, employees, annual average hours worked and labour compensation.

3) The *Industry Growth Accounting Database* was constructed for a smaller number of industries, 26 in total, for the US and four European countries (France, Germany, The Netherlands and the UK). This enabled a division of output growth into contributions from capital, labour quality and total factor productivity. Capital was divided into two main categories - ICT capital, comprising three asset types, software, computers and communications equipment – and non-ICT capital comprising also three asset types, non-ICT equipment, structures and vehicles. As with the industry database, considerable effort was devoted to ensuring international comparability, in particular in using common methods to measure capital inputs. Thus capital was constructed as aggregates across the three types within each of the two categories, measured as service flows with the share of each type in the value of capital based on its user cost.

4) The above two data series have been made publicly available through the EPKE web-site. Additional unpublished series are being made available to researchers on request; these include annual investment series, skill proportions of the workforce, wage bill shares by skill type and proportions of the workforce in ICT occupations. A decision was made not to publish these series as the data underlying these estimates were in some cases derived from unpublished sources from national statistical offices, and in some cases the data were derived from surveys where sample sizes can be quite small.

3. Industry analysis of productivity and employment growth

1) The US acceleration in labour productivity growth since the mid 1990s has been largely concentrated in ICT producing manufacturing and ICT using services. EU countries in general also show accelerating growth in the first group but EU performance in the second group of ICT using services (distribution, financial and business services) was relatively poor. These sectors together represent a sizeable proportion of economic activity. In the 1980s, labour productivity

growth in ICT using sectors was higher in the EU than in the US and this advantage continued into the early 1990s. The period since 1995 saw a reversal of this pattern as slower growth in ICT using sectors in the EU accounted for a significant proportion of the slower aggregate growth in Europe.

2) Growth accounting estimates suggest that ICT investment has been proceeding at a rapid pace in the EU as well as in the US in recent years. Within ICT producing industries, the US clearly leads in terms of ICT investment growth in manufacturing industries, while ICT investment in the telecommunication services industry has been growing faster in the EU. In ICT using industries, both the wholesale and retail trade sectors in the US clearly invested at a faster pace in ICT assets between 1979 and 1995 but subsequently the larger EU countries had mostly closed this growth gap. However ICT capital shares are currently considerably lower in EU countries than in the US, reflecting earlier adoption in the latter. Hence ICT-capital deepening contributed considerably more to aggregate labour productivity growth in the US than in the EU countries considered. The gaps in percentage point contributions from ICT capital deepening between the US and large EU member states is greatest in ICT using sectors

3) The US labour productivity growth advantage over EU countries since the mid 1990s stems largely from higher total factor productivity (TFP) growth, and is concentrated largely in ICT using services. This suggests that the US might be benefiting from adoption and use of information technology which impacts on the efficiency of input use. Indeed econometric analysis based on these industry data confirmed the presence of excess returns to ICT compared to non-ICT assets, particularly in the US. These excess returns may originate from ICT spillovers or organizational changes. However, the data do not allow identification of these from alternative hypotheses. In particular increased TFP growth may arise from investment in organisational changes which cannot be observed in the dataset.

4) Since the mid 1990s the annual average percent growth in employment in the EU-15 rose to levels close to those achieved in the US. This is in contrast to the decade of the 1980s, and the early 1990s, when the EU-15 experienced an average growth in employment less than half the rate of US growth. Thus in the second half of the 1990s EU countries appear to have recovered a substantial capability of generating jobs. These are mostly located in more traditional manufacturing industries but there is some evidence that the EU-15 has

increased employment in recent years in the service sectors most affected by ICT.

5) There is a well-known inverse relationship between productivity and employment in the short to medium run, generally stronger in manufacturing than in services, that was confirmed using the industry data. However, during the 1990s, this relationship has turned positive in many industries, in particular in ICT-producing industries and in ICT-using industries in the service sector. Therefore as a result of increased use of ICT, high labour productivity growth is less associated with low employment growth during the second half of the 1990s, in particular in ICT-using services. This effect, however, has been stronger in the US than in the EU.

6) The industry analysis also showed that variations in industrial structure are significant determinants of aggregate income levels and growth so that growth and structural change are two inseparable elements.

7) A detailed case study of the retail trade sector showed that the marriage of technology and organisational change is at the core of the US trade sector's productivity acceleration and its superior performance relative to European countries. Over the past three decades the trade sector has been transformed from a low technology sector to one that makes extensive use of ICT. Adoption and use of ICT has been much slower in Europe than in the US.

4. The demand for skilled labour

1) The research results confirm a positive association between the use of information technology and the demand for highly skilled labour exists for EU countries as well as for the US. The timing of the impacts of new technology vary between countries, with the US showing the largest effect in the 1980s and the European countries showing a greater impact in the 1990s. This is consistent with the later adoption of ICT in Europe, compared to the United States. In all countries the lowest skilled workers have suffered a loss of employment and remuneration shares. There is also evidence that ICT has had a positive impact not only on the employment and wage bill shares of the highest skilled group, university graduates and above, but also on the higher intermediate group, third level but below degree.

2) There is considerable variation across EU countries in the impact of ICT on heterogeneous labour demand. For example in France the demand for college-

educated workers has mainly increased in sectors already intensive in skilled labour and in ICT investment while in Italy ICT appears to have its greatest impact on reducing demand for unskilled workers. In Germany the results are less consistent across studies, with those using firm level data showing increased demand for university-educated labour but less evidence for this using firm level data. The UK has shown one of the largest expansions in its university education system but concurrently shows increased wage shares for these workers associated with ICT. Hence in that country evidence for skill biased technical progress is particularly strong.

3) The research carried out as part of this project also suggests that there may be elements of the division of the labour force, other than skills, which have changed as a result of ICT. Thus there is some evidence for increased demand for younger workers, which are those most likely to have been trained in the use of ICT through the educational system. The impact of age cohort effects is one area where future research should be concentrated.

5. Firm level results

1) The research carried out in this project using micro firm level data provides ample evidence that ICT impacts positively on productivity, consistent with findings from the industry data. This is based both on an analysis of an international company accounts database and surveys carried out in individual countries.

2) The analysis using international company accounts suggests that some additional benefit from investment in R&D is occurring in services sectors in more recent years in both the US and the EU, but the effect is stronger in the former. These productivity gains tend to be concentrated in small or medium sized firms in contrast to the position in manufacturing whereby R&D tends to have its biggest impact in large firms. Combining firm data with industry information on ICT intensity supports the existence of spillover effects from ICT both in the US and the EU in the 1990s. However the dynamic pattern varies across the two regions with the results suggesting positive and significant spillover effects in both the short-run and the long-run in the US but only evidence for long run effects in the EU. This evidence confirms the suggestions based on industry data that the European countries still appear to be lagging behind the US in terms of obtaining a pay-off from investments in ICT.

3) Country specific results highlight variation within Europe. In France one study found that the increased use of computers had a positive impact on productivity growth. Also in Germany there appear to be substantial impacts from ICT investments on firm level productivity, although this effect is more apparent for manufacturing than service sectors. In Italy results show a significant and positive correlation between R&D and ICT intensity (on the one hand) and the change in TFP on the other for manufacturing firms.

4) Many of the country specific studies considered the use of particular types of information technologies on productivity. In France and the UK the results show that the use of the internet is significantly correlated with firm performance. Investigations for the UK show that there are substantial gains in productivity from buying and selling over the Internet, but these effects are strongest for service sectors.

6. The impact of regulation

1) The research considered the impact of the regulatory environment on productivity using industry data. Some evidence was found for such a link in the retail trade and utilities (gas, electricity and water). In the former industry, the case study suggested that regulation was likely to explain much of the failure of EU retail stores to reap the same benefits from ICT as enjoyed in the US. A study of labour market regulations suggest these impact mostly on the variability of employment and wages over the business cycle with little evidence for more long term structural impacts.

2) Although an important topic, the investigation into the impact of the regulatory environment yielded less satisfactory conclusions than other parts of the research project. This was largely due to very weak data available with which to carry out such an analysis and it was identified as one of the important topics for future research.

7. Summary of research findings

The EPKE project's main contribution was to take a truly international comparative perspective in evaluating the impact of ICT on economic performance, contrasting the EU with developments in the US. The industry analysis has shown that EU countries are investing heavily in the new technology. This has not translated into similar payoffs in terms of productivity growth as experienced in the US. Research using firm level data suggests positive contributions of ICT to output and productivity growth in a range of EU countries. Both industry and firm level data present evidence of a (complementary) increase in the demand for skilled labour in EU countries, mirroring similar trends in the US for an earlier period. Much of the dynamic focus of the research suggests that it may be the case that the EU is merely lagging the US and that benefits from ICT will emerge in Europe in the future. However the importance of the institutional environment in which firms operate cannot be discounted. Thus the degree of competition and regulation, are likely to impact on productivity performance, but in ways that are difficult to measure given current data.

8. Policy implications

1) If the sole reason that Europe is lagging the US is its later adoption of ICT, policies that facilitate complementary investment might be worthwhile. These policy recommendations will not be sufficient, however, if structural rigidities are the main reason for lower EU growth rates. In that case EU governments need to instigate structural reforms, stimulating competition and deregulating large areas of activity.

2) A first set of policy recommendations therefore would apply if the delayed benefits in Europe merely reflect the US first mover advantage. These would be largely concerned with developing the knowledge generating infrastructure and could include public policies and programmes intended to influence the behaviour of enterprises in terms of, for example, external knowledge search and exchange, and R&D collaboration with universities, research institutes and other enterprises. Policies might also be instigated to inform firms of developments in information technology, possibly targeted at particular sectors and/or categories of enterprise.

3) A second set of policies would be appropriate if the main break on an impact of ICT on EU performance is structural rigidities. This would include reform of the competitive and regulatory environment, particularly targeted at service sectors where the US gains have been most pronounced. These could include both deregulation of product markets and labour markets.

4) Many observers are in favour of deregulating product markets. Indeed if the main impact of this regulation is to allow producers to capture rents, then it is difficult to argue against this position. Nevertheless it is important that policy makers have a thorough understanding of why these institutional structures emerged so as to distinguish those where rent seeking has been the main motivation from those designed to address other social goals. Any such whole-

scale changes, however, need to be weighted against current and/or future potential costs.

5) In particular there may be a trade-off between labour market deregulation and human capital accumulation. In countries where there are well-established training systems which provide support for firms to upgrade the skills of their existing employees in response to technological change, any policies that undermine long term relationships between firms and their employees may have adverse consequences. Nevertheless too stringent labour market regulations are likely to have adverse consequences for productivity growth. Achieving the correct balance is likely to be difficult.

6) It is likely that policy should incorporate both types of change, developing infrastructure and some deregulation. Neither are likely to be sufficient in themselves to drive forward the European productivity agenda.

7) Regardless of the source of the EU lag, it is important that policy looks to the skill needs of the modern information technology based economy. Policies that improve the educational attainment of school children are likely to be particularly useful, especially if such improvements are targeted at the needs of the information economy.

8) However the research undertaken as part of the EPKE project suggests that care needs to be taken in attempting to predict the skill needs of the future. The concentration on university education pursued by the US in its early adoption of ICT might not be appropriate in later use phases both in that country and in Europe. University education is also relatively expensive compared with other streams of education and training. On the job training, even with a low level of education, can increase job opportunities and job stability.

II. BACKGROUND AND OBJECTIVES OF THE PROJECT

The primary objective of the EPKE project was to improve understanding of employment generation and productivity in Europe in the context of advances in information and communications technology (ICT) and other knowledge generating activities. In order to do so, the project set out to consider knowledge generating activities in a systematic quantitative way by combining data on relevant indicators from a wide range of sources and countries. The project was oriented to consider comparisons between performance in the total EU, and individual EU countries on the one hand, and the US on the other. The project set out to consider the link between total factor productivity (TFP) growth and employment generation, and a consideration of the relationship between the use of ICT capital and R&D, substitution of these with other inputs, and impacts of new technology on TFP growth. Specific objectives included a consideration of the factors leading to increased demand for skilled labour and the impact of the regulatory environment.

During the course of the project there was a reorientation towards a greater emphasis on productivity issues and less on employment. This reflected changes in the policy agenda of both national governments and the European Commission. As employment rates increased in the EU, there was less concern on raising these further. Instead the productivity surge experienced by the US, and the failure of EU countries in general to match this, placed productivity further up the policy agenda. Nevertheless, the project adhered to the broad workplan as set out in the workpackages but altered the effort devoted to each. The policy context is described in more detail in the scientific description below, with this largely following the original workpackage layout.

III. SCIENTIFIC DESCRIPTION OF PROJECT RESULTS AND METHODOLOGY

1. Introduction

This report sets out the research achievements of the project 'Employment Prospects in the Knowledge Economy' focusing on developments in European Union employment and productivity growth, comparisons with achievements in the United States and relationships with adoption and use of information technology and other knowledge generating activities. The scientific report begins by setting out the context in which the project proceeded, describing both general trends in employment and productivity and outlining the importance of information technology.

The industry dataset that formed a large part of the research effort is then described, as is the methodology employed. This is followed by a summary of the main industry analyses (section 4), divided into broad industry trends, the development of taxonomies to describe these trends, employment and labour productivity growth in the European Union compared to the US and growth accounting results. These form the results of the first four workpackages of the project. This section also summarises research on a specific sector, the distributive trades, where much of the US productivity acceleration is concentrated.

Section 5 then considers research on workpackage 5, relating to the demand for skilled labour. This section contains evidence using both industry and firm level data. Section 6 considers the impact of regulation and the institutional environment on productivity performance. Section 7 presents research using micro firm level data, comprising the results from workpackages 7 and 8.

References to research outputs that were supported by the EPKE project are shown in italics.

2. The context

2.1. Overview of employment and productivity performance in Europe

O'Mahony and van Ark (2003b) present an overview of economic performance contrasting the EU as it existed at the outset of this project, hereafter termed EU-15, with the US. Since the mid 1990s the average growth rates of real GDP, labour productivity and total factor productivity in the European Union have fallen behind those in the United States. What makes this remarkable is that this is the first time since World War II that these performance measures have shown lower growth rates for the EU-15 for several years in a row. The period from the mid 1990s was also remarkable in that employment expanded in the EU-15 at rates not seen for decades.

Table 1. shows the aggregate developments of output, employment and productivity growth in the US and the EU-15, as well as the growth rates for individual EU countries. Comparing the EU-15 with the US, the table shows that during the 1980s, real GDP growth was 3.2 per cent in the US compared to only 2.4 per cent in the EU-15. During the early 1990s GDP growth slowed in all regions, but both the US and the EU-15 saw a substantial recovery during the second half of the 1990s. However, the recovery was much faster in the US than in the EU-15. More importantly, the US recovery was accompanied by a large upswing in labour input and productivity growth. In contrast, the EU-15 realised a substantial expansion in labour input but productivity growth slowed down to a rate that was substantially lower than that achieved during the 1980s.

These growth rates should be seen in conjunction with estimates of the distance between countries in levels of GDP, labour productivity and employment rates; these levels estimates are shown in Table 2. for 1980, 1990, 1995 and 2002.[1] Starting from a higher level in 1980, and continuing through to the early 1990s, the EU GDP level fell below that of the US in the second half of the 1990s. Moreover the labour productivity gap between the EU and the US also widened at this time. This has been the first time since World War II that the productivity level in the EU did not converge to the US level for a sustained period. Thus as a result the labour productivity gap in the EU relative to the US has widened by 2 percentage points, from 96 per cent of the US level in 1995 to 94 per cent in 2000, and by another 2 percentage points to 92 per cent of the US level in 2002 (GGDC/TCB estimates). Table 2. also shows that the ratio of employment to total population improved in the EU, but it has not reached the levels in the US. Hence despite relatively high labour productivity levels, in some European countries, per capita income levels are lower due to lower labour intensity levels in the EU (McGuckin and van Ark, 2003).

[1] Estimates produced by the Groningen Growth and Development Centre/The Conference Board – available from http://www.eco.rug.nl/ggdc/homeggdc.html – see McGuckin and van Ark (2003) for details.

Table 1. Aggregate growth rates of real GDP, total hours and labour productivity, 1980-2002

	Real GDP				Total hours				GDP/hour			
	1980-90	1990-95	1995-00	2000-02	1980-90	1990-95	1995-00	2000-02	1980-90	1990-95	1995-00	2000-02
Austria	2.3	2.0	2.8	0.9	0.6	0.3	-0.5	0.1	1.7	1.8	3.2	0.8
Belgium	1.9	1.6	2.7	0.7	-0.4	-0.7	0.0	1.4	2.3	2.3	2.8	-0.7
Denmark	2.0	2.0	2.7	1.5	0.1	-0.4	1.1	0.0	1.9	2.4	1.6	1.5
Finland	3.1	-0.7	4.8	1.1	0.1	-3.4	1.9	-0.2	3.0	2.8	2.9	1.4
France	2.3	1.1	2.7	1.4	-0.6	-0.4	1.4	-0.2	2.9	1.4	1.3	1.7
Germany	2.2	2.0	1.8	0.4	-0.3	-1.9	-0.3	-0.9	2.5	4.0	2.2	1.3
Greece	1.6	1.2	3.4	4.0	0.6	0.7	0.6	-0.2	1.0	0.6	2.8	4.2
Ireland	3.6	4.7	9.8	4.7	-0.4	1.1	3.9	1.4	4.1	3.6	5.7	3.2
Italy	2.2	1.3	1.9	1.1	0.3	-1.0	1.0	1.2	2.0	2.3	1.0	-0.1
Netherlands	2.2	2.1	3.7	0.7	0.2	0.7	3.1	0.4	1.9	1.4	0.6	0.3
Portugal	3.2	1.7	3.9	1.0	1.4	-1.8	0.8	1.0	1.7	3.5	3.1	0.1
Spain	2.9	1.5	3.8	2.2	-0.1	-0.7	4.2	2.6	3.0	2.3	-0.3	-0.4
Sweden	2.0	0.7	3.3	1.5	0.9	-1.3	1.0	-0.5	1.1	2.0	2.2	2.0
UK	2.6	1.8	2.9	1.7	0.5	-1.2	1.0	0.7	2.2	3.0	1.8	1.1

EU-15	**2.4**	**1.6**	**2.7**	**1.3**	**0.1**	**-1.0**	**1.1**	**0.4**	**2.3**	**2.6**	**1.5**	**0.8**
US	**3.2**	**2.4**	**4.0**	**1.3**	**1.7**	**1.2**	**2.0**	**-0.4**	**1.4**	**1.1**	**2.0**	**1.7**

Note: Germany 1980-90 refers to West Germany only; EU-15 1980-90 excludes Eastern Länder of Germany.

Source: GGDC/The Conference Board, Total Economy Database (June 2003)

Table 2. GDP share, employment/population ratio and GDP per hour worked as % of the US, 1980-2002

	GDP as % of US GDP					Employment/population ratios					GDP per hour worked as % of US				
	1980	1990	1995	2000	2002	1980	1990	1995	2000	2002	1980	1990	1995	2000	2002
Austria	2.7	2.4	2.4	2.3	2.2	0.407	0.441	0.463	0.461	0.460	90.0	91.9	94.8	100.9	99.0
Belgium	3.5	3.0	2.9	2.7	2.7	0.371	0.374	0.366	0.384	0.386	95.2	103.5	109.8	114.1	108.8
Denmark	1.9	1.7	1.7	1.6	1.6	0.482	0.513	0.491	0.504	0.503	90.2	94.3	100.4	98.5	98.1
Finland	1.5	1.5	1.3	1.3	1.3	0.485	0.493	0.403	0.450	0.455	67.2	78.2	84.8	88.7	88.0
France	18.7	17.2	16.2	15.1	15.1	0.398	0.389	0.378	0.399	0.405	93.7	108.3	109.9	106.2	106.1
Germany	24.3	24.7	24.3	21.8	21.4	0.440	0.470	0.438	0.445	0.442	96.2	89.2	102.5	103.4	102.5
Greece	2.2	1.9	1.8	1.7	1.8	0.348	0.366	0.366	0.374	0.369	59.8	57.5	56.0	58.3	61.2
Ireland	0.7	0.8	0.9	1.1	1.2	0.335	0.328	0.353	0.439	0.447	58.2	75.1	84.6	101.2	104.2
Italy	19.2	17.4	16.5	14.9	14.8	0.379	0.399	0.384	0.400	0.411	94.6	99.4	105.3	100.3	96.8
Netherlands	5.2	4.7	4.6	4.5	4.5	0.390	0.419	0.435	0.497	0.507	108.3	113.7	115.2	107.6	104.5
Portugal	1.9	1.9	1.9	1.8	1.8	0.403	0.471	0.444	0.488	0.495	46.2	47.3	53.2	56.1	54.3
Spain	8.9	8.7	8.3	8.2	8.4	0.314	0.331	0.318	0.387	0.408	68.8	79.8	84.4	75.4	72.3
Sweden	3.0	2.7	2.4	2.3	2.4	0.508	0.527	0.459	0.478	0.486	85.3	82.1	85.5	86.7	87.1
UK	17.3	16.3	15.8	15.0	15.1	0.438	0.465	0.437	0.455	0.459	72.4	77.7	85.2	84.6	83.5

EU-15	**111.0**	**104.9**	**100.9**	**94.5**	**94.3**	**0.402**	**0.423**	**0.404**	**0.428**	**0.434**	**84.9**	**88.9**	**95.7**	**93.7**	**92.1**
US	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**0.436**	**0.475**	**0.475**	**0.489**	**0.478**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Many observers now believe that the US has experienced a structural break since about 1995, leading to somewhat faster productivity growth, which may continue into the first decade of the 21st century, see e.g. Jorgenson, Ho and Stiroh (2003). The numbers in the above tables suggest that the EU might have entered onto a low productivity growth track. In contrast to the US position, however, there is as yet less evidence that this productivity slowdown is of a structural nature. Firstly, it should be noted that the productivity growth rates experienced in recent years in the EU are no less than those in the US in the 1980s and so recent experience may largely be driven by the end of catch-up growth, before any benefits from the new technology were manifest. Many EU countries are still in the midst of an adjustment process towards a new arrangement of their economies, with less emphasis on capital-intensive manufacturing, and a greater emphasis on technology use and diffusion in services. Secondly, there is still a much greater potential in terms of underutilised resources to be employed in the EU. This latter view is consistent with the notion that the EU is merely lagging the US in the adoption of new technology and that the EU will see the benefits within the next decade. The key issue for the EU is whether these resources can be mobilised in a productive way. In the meantime productivity gains in the frontier economy, the US, will start to show diminishing returns so that the EU could eventually catch up to US levels, as it came close to doing in the early 1990s.

2.2. The role of information and communications technology

There are few who would now argue against the proposition that information and communications technology (ICT) is the key technology of the recent past. The widespread diffusion first of computer use and then of the Internet contributed to its classifications as a General Purpose Technology (GPT) that is characterised by pervasiveness, technological dynamism and innovation complementarities (Bresnahan and Trajtenberg 1995). Pervasiveness means that a GPT is used as a component input all sectors of the economy because it provides a generic function. Technological dynamism results from the GPT's ability to support continuous innovation and learning, and innovation complementarities exist because of mutually reinforcing productivity gains generated by the GPT for it downstream applications and vice-versa.

Empirical evidence, mainly for the United States highlights the importance of ICT for generating growth. Evidence first emerged of a significant impact of investment in ICT capital on output and labour productivity growth (Jorgenson and Stiroh, 2000, Oliner and Sichel, 2000). Several firm-level studies found that spillovers from ICT capital exist (Brynjolfsson and Kemerer,1996). Brynjolfsson and Hitt (2000) find evidence of a substantial relationship between computers and multi-factor productivity growth, and that these contributions rise significantly in the long-term because computers complement productivity-enhancing organisational changes carried out over a period of years. The ICT capital deepening channel also operates in the EU but with lower contributions than in the US. Real ICT investment and capital service flows in the European Union have grown almost as rapidly as in the United States, but the level of ICT investment either as a share of total equipment or as a percentage of total GDP has remained well below that of the US and it has not shown any catch-up during recent years (van Ark et al., 2002b; Timmer et al., 2003). As yet there appears to be little convincing evidence suggesting large spillovers from ICT in the EU.

As a consequence of these developments earlier concerns about the so-called 'ICT productivity paradox' in the US have now dissipated. It is now generally recognised that much of the impatience at the apparent lack of productivity pay-off to ICT investments was due to an initial lack of awareness of the lengthy timescales under which earlier technological revolutions had unfolded. At the outset of the ICT diffusion period, there was very little understanding of the fact that any new skill-intensive general-purpose technology is likely to require a substantial period of time before its full potential can be realised (David, 1990; Caselli, 1999). Thus, returns to new investments in ICT hardware are likely to be delayed until complementary investments in new software and ICT skills training have been made along with appropriate changes in work organisation and incentive structures designed to maximise the benefits to be gained from ICT (Bresnahan, Brynjolfsson and Hitt, 2002). Thus the evidence suggests visible payoffs from ICT in the US but as yet little evidence for corresponding benefits in the EU.

There remain many questions relating to the impacts of ICT in the EU compared to the US and ultimate reasons for differential impacts. The research produced in the EPKE project considered many aspects of recent economic performance in EU member states and its relationship to ICT. The analysis was carried out at both the industry and firm level. The former is considered in the next few sections while firm level results are discussed further below.

3. Building the evidence base: the industry database and research methods

3.1. Why use an industry analysis

A focus on industry is important for a number of reasons. Firstly, it is important to pinpoint in which industries the US has been achieving superior performance in order to clarify whether the US productivity acceleration is just confined to a few sectors or is more generally widespread. Gordon (2000) suggested TFP growth was confined to ICT producing sectors whereas McKinsey (2002) emphasised the important contributions of a small number of service sectors, wholesale and retail trade and financial securities. Similarly it is useful to compare EU to US performance at the industry level, as an aid in understanding the sources of the divergent performance of these two regions in recent years. For example, it is useful to know if EU productivity growth rates have improved in those industries where the US has also shown an acceleration, with the poor EU performance attributable elsewhere. Alternatively, it might be that the EU fails to match the US in its best performing sectors. Or, if the picture that emerges involves an element of both explanations, then there is need to quantify the importance of each.

The upsurge of opportunities for new technological applications may have very different implications for industries. Indeed the absorptive capacity for ICT differs greatly across industries, and has very different impacts on output, employment and productivity performance. For example, in most manufacturing industries ICT has largely contributed to rationalising the production processes, raising productivity through the use of less inputs, in particular unskilled labour. In many service industries, the introduction of ICT has had, in addition, an impact on "product" innovation, in turn implying increased use of high technology inputs. Some service industries (in particular finance and part of business services) are among the most intensive users of ICT in the economy. Thus It is useful to distinguish performance in these industries with a high propensity to invest in information technology from more 'traditional' industries.

3.2. General description of industry data

Two industry data sets were developed, one covering a large number of industries and all fifteen EU member states. The development of the database benefited from additional funding from the European Commission's DG Enterprise who were eager that the productivity results should be available at an early date. This section briefly describes these data; more detail is provided in *Inklaar et al. (2003)*.

<u>A. Industry labour productivity database for the European Union and the US</u>

This provides a comprehensive, internationally comparable dataset on industrial performance at a detailed industry level for the fifteen EU member states and the US. Aggregate estimates for the EU-15 as a whole are also provided.

Considerable effort was made to ensure international comparability of the data series, including matching variable definitions and industry classifications. One of the most important adjustments to the underlying data was to standardise methods to incorporate quality change in ICT goods. At present there are only a few countries that have an adequate system in place for measuring prices of computers and semiconductors, which take into account the fast increase in quality of these goods. To achieve international comparability, harmonised US deflators are applied for six ICT-producing manufacturing industries (comprising parts of electrical equipment and instruments as well as the entire electronic and computing equipment sectors) in all countries. US value added deflators are corrected for differences in overall inflation between each country and the US.

Data are provided for 56 industries in total. The industries are classified according to the International Standard Industrial Classification (ISIC) revision 3. see VII. 2. Table 11. provides a listing of the industries. The following variables, by industry and country can be downloaded from the EPKE web-site through a link to the University of Groningen growth and development centre web-pages (http://www.ggdc.net/index-dseries.html#top), where the data are frequently revised and updated.

Value added is current gross value added measured at producer prices or at basic prices, depending on the valuation used in the national accounts. It represents the contribution of each industry to total GDP.

Deflator is the change in the value added deflator. It can be combined with current value added to derive quantity indices of real value added at industry level.

Persons engaged comprises number of workers engaged in production, including employees as well as self-employed, working proprietors and unpaid family workers.

Employees is the number of employees.

Hours refers to average annual hours worked per employee or per person engaged.

Labour compensation is current price labour costs borne by the employer. It includes wages as well as the costs of supplements such as employer's compulsory pension or medical payments. It refers to compensation of employees only.

B. Growth accounting dataset

In addition to the Industry Labour Productivity Database, growth accounting estimates that enable a division of output growth into contributions from capital, labour quality and total factor productivity were constructed. This was carried out for a smaller number (26) of industries for the US and four European countries (France, Germany, The Netherlands and the UK). See VII 2. Table 12. shows the industries included in this part of the analysis.

Capital input is measured using a Törnqvist capital service index which comprises three assets for ICT - software, computers and communications equipment -, and three for non-ICT - non-ICT equipment, structures and vehicles. Capital inputs are measured as service flows, and the share of each type in the value of capital is based on its user cost. Capital services are defined as the flow of productive services from the cumulative stock of past investments. The flow of services from any asset in any one time period is generally assumed to be proportional to the stock. In the past these measures were aggregated by simply summing across asset types, equivalent to weighting growth rates using asset acquisition or market prices. These measures have been superseded in recent years by the calculation of volume indexes of capital services, which are (slowly) being adopted in national accounts. The new measures aggregate by using user costs or rental prices rather than market prices. Under competitive conditions user costs reflect the marginal productivity of the various assets. Employing user costs as aggregation weights is a way of incorporating the productive contribution of heterogeneous assets. User costs represent the amount of rent that would have been charged for one unit of an asset and consists of three terms. These are the cost of financing the asset (measured by the rate of return) the value of depreciation (including both physical decay and the fact that the asset's service life has declined by one year) and capital gains or losses.

Estimating labour quality requires total labour input to be divided into a number of skills categories. Unfortunately skills classifications differ across countries, but these disparities are not a major issue for examining the growth contribution, since the contribution from each skill group is weighted by its wage share (with the implicit assumption that wages equal marginal products). As long as the number of skill groups does not vary too much across the countries and the divisions are roughly equivalent, then the relative wage shares pick up differences across countries in the growth in labour quality. There are additional complications if the calculations do not control for other impacts on wages such as gender, age, minimum wages and the impact of collective bargaining. The sample size in the survey data used in this study precludes the division of workers by age and gender – in addition to skills – by industry group. Similarly there is no information to take account of other influences which may cause deviations of wages from marginal products. The number of labour skill types (based on educational attainment or qualifications) varies from three in Germany to seven in the Netherlands. See VII. 2. Table 13. summarises the categories included for each country.

The following variables, by industry and country can be downloaded from the EPKE web-pages (http://www.niesr.ac.uk/epke/), all variables are annual growth rates.

Output - Growth in value added at constant prices

Labour - Growth in total hours worked

Labour quality - Growth in skill-adjusted labour input minus growth in total hours worked

ICT capital - Growth in ICT capital services (computers, communication equipment and software)

Non-ICT capital - Growth in Non-ICT capital services (non-IT equipment, non-residential structures and transport equipment

TFP - Growth in Total factor productivity

ICT share - Share of ICT capital in total capital compensation

Labour share - Share of labour compensation in value added

C. Underlying data series

The growth accounting dataset includes a single figure for growth in both ICT and non-ICT capital and labour quality. The data underlying these estimates were in some cases derived from unpublished series from national statistical offices. This is particularly an issue for data derived from surveys where sample sizes can be quite small. Therefore these data are not posted on web-pages but are given freely to academic researchers on request.

These underlying data comprise

Annual investment series – comprising estimates in current and constant prices, for the six asset categories listed above plus residential buildings.

Skill proportions of the workforce – for the skill categories listed in VII. 2. Table 13.

Wage bill shares by skill type – corresponding to the skill types above

Proportions of the workforce in ICT occupations – based on occupational classifications as set out in *Mason et al (2003)*, divided into those with and without degrees

3.3. Research methods applied to industry data

The research methods employed in the project can be divided into four categories, nonparametric grouping of data (the creation of industry taxonomies), index number methods, econometric methods and a case study. Each are considered in turn.

A. Industry taxonomies

Classifications systematically arrange cases in terms of their similarity. They constitute a first and generic advance from mere observation and description towards systematic scientific inquiry. Substituting structural knowledge for exhaustive information about single attributes, the intractable diversity of real-life phenomena is condensed into a smaller number of salient types. Classifications thus direct attention towards a few characteristic dimensions, according to which relative similarities or differences can be identified. They allow heterogeneity to be taken into account, but simultaneously force selectivity.

From a more practical perspective, the taxonomic approach is most useful precisely when it refers to data that are not easily available in a comparable format across countries or firms. The reason is that it builds upon data from those countries, which offer the best coverage of specific attributes and then produces typical profiles of the relevant variables. The resulting classification can then be applied to other data of economic activity, which are available on a broader internationally comparable basis (for example, value added, employment, or foreign trade data).

In the field of economics, a historical example of such a classification is Carl Menger's (1871) distinction between goods of the "first order" and goods of "second"- and "higher orders". While the former refers to consumer goods, which directly serve consumers' wants and needs, the latter categories are comprised of intermediate goods, such as capital, labour or raw materials, which are used to produce goods of the first or the respective lower order. This structural separation was an important element in the formulation of Menger's theory of economic value and prices. The related separation of industries according to major end-use categories, such as "intermediate goods", "equipment", or "consumer goods" has remained popular up to the present day.

The process of classification is generally defined as the ordering of cases in terms of their similarity. In this project, the focus is on taxonomies, i.e. empirical classifications generated by quantitative identification. Furthermore, all the presented classifications are strictly interpreted as polythetic, i.e. the cases are not identical with respect to all variables, but rather are grouped according to the generally strongest similarity. In other words, the existence of large variations within individual categories are taken for granted. Also each of the classifications discovered for this survey is synchronic in the sense that it represents a static snapshot of structural characteristics, without dynamic categories for different patterns of change. Finally, the selected classifications are generally expected to be exhaustive and mutually exclusive, thereby demanding the existence of one (but only one) appropriate class for each observation.

Two general approaches to the quantitative identification of individual observations into classes can be distinguished. A 'cut-off' procedure by which a certain discriminatory edge is defined exogenously by the researcher is the more frequently applied method. The sole advantage of this approach lies in its simplicity. In choosing not to use more powerful statistical tools, the underlying structure within the data is more or less presumed, rather than explored. Although this approach can be defended as long as the classifications are built upon one or two variables only, it is generally inept for the categorisation of a data profile of larger dimensions. Statistical cluster analysis is the obvious alternative. It is a powerful technique specifically designed for classifying observations on behalf of their relative similarities with respect to a multidimensional array of variables. The basic idea is one of dividing a specific data profile into segments by creating maximum homogeneity within and maximum distance between groups. Despite its higher technical sophistication, cluster analysis is still a heuristic method, which requires the researcher to make a number of critical choices, e.g. between the various measures of distance or the kind of agglomeration algorithm. The variety of possible outcomes naturally raises concerns about the robustness of the results and calls for an extensive documentation of the work done (including information about the approaches which were dismissed). Cluster analysis also requires a clear concept of geometric space that allows for a meaningful measurement of distances between observations. Variables have to be chosen in a way that spans independent dimensions of the phenomenon under investigation. Both the cut-off procedure and cluster analysis were employed in the EPKE project.

B. Growth accounting

The growth accounting method is employed in much of the industry analysis. This method has been used to estimate the impact of ICT on productivity by Jorgenson and Stiroh (2000) and Oliner and Sichel (2000). Essentially it is a method to decompose output growth into contributions of factor inputs, weighted by their shares in the value of output, and underlying residual productivity or total factor productivity (TFP). Thus the growth in output is given by:

$$dq_t = w_l dl_t + w_l dh_t + r_i dki_t + r_n dkn_t + dtfp_t$$

where q is real output, l is labour in volume terms (hours worked), h is labour quality, ki is ICT capital, kn is non-ICT capital, w and r are input shares in value added (averaged across period t and t-1). The operator d denotes percent growth rates.The method assumes perfect markets and constant returns to scale so that the share of total capital is one minus labour's share. Subtracting total hours from both sides of the above equation, rearranging and employing constant returns to scale so that $w_l + r_i + r_n = 1$, gives a decomposition of average labour productivity growth as:

$$dp_t = w_l dh_t + r_i dkil_t + r_n dknl_t + dtfp_t$$

where *p* is labour productivity and *kil* and *knl* are ICT and non-ICT capital labour ratios. Labour quality is measured by first dividing total hours by skill level, weighting the growth in each type by their wage share and subtracting total hours.

Constant returns dictate that the weight on labour quality is equal to that on total hours.

Growth accounting gives a broad overview of sources of changes in industry output. This method has been employed in a range of applications since Solow's seminal contribution in the 1950s (Solow, 1957) and refined in many subsequent studies, e.g. Jorgenson and Griliches (1967), Jorgenson, Gollop and Fraumeni (1987) – a comprehensive overview of the development of the method is provided in Hulten (2000). The method has enjoyed a recent renaissance in the context of attributing growth to ICT.

C. Econometric methods

The growth accounting method is however constrained by its underlying assumptions. When these assumptions breakdown, econometric analysis is a useful tool to add to knowledge. Econometric methods were used in a range of applications in this project, including testing if the returns to ICT investment were in fact greater than those implied by the growth accounting method and estimating the influences on the demand for skilled labour. Thus econometric analysis was seen as complementary to growth accounting when utilising the industry dataset.

As the industry databases were constructed annually by country, panel regression methods were the obvious choice of methods and indeed much of the analysis utilises these techniques. However standard panel data analysis was developed from the consideration of datasets with a large number of cross section observations (large N) and a small number of time series observations (small T). The industry datasets developed in the program, however, were characterised by large T and small N. Increasingly researchers have realised that the problems encountered in the latter types of panels are very different from those based on microdata, namely that it is important to take account of the time series properties of these models. Thus the researchers experimented with alternative methods. For example one paper used a relatively new technique, the Pooled Mean Group (PMG) discussed in Pesaran *et al*. (1999) to examine the issue of excess returns from investing in ICT capital *(O'Mahony and Vecchi, 2005)*; this paper is discussed in more detail below. The PMG estimator extends the error-correction-modelling framework to the panel dimension by imposing homogeneity restrictions on the long-run parameters and deriving the error correction coefficient and the other short-run parameters of the model by averaging across groups.

D. Case Study

Finally the project considered a case study for one important sector, retail trade, where US productivity has accelerated rapidly since the mid 1990s but where a similar upturn is not generally observed in the EU.

4. Research at the industry level: the principal results

The EPKE project employed industry data to consider the following:

- employment and labour productivity trends in the EU versus the US;
- the relative impact of investment in physical capital– delineating both ICT and more traditional capital – labour quality and total factor productivity on output and labour productivity growth;
- evidence for external benefits from ICT;
- the demand for skilled labour;
- evidence on the impact of regulation.

The final two are considered in separate sections. Before moving to considering the first three topics listed above, the specifics of industry taxonomies created in order to analyse industry data are first discussed.

4.1. Industry taxonomies

The first paper on this topic that was produced within the EPKE project is a survey of the relevant literature (*Peneder, 2003a)*. Its main objective is to provide the practitioner of applied economic research with a brief overview for better orientation. The main body of the text is organised around the major topics pursued by the various classifications. It begins with the one-dimensional separation of high- versus low-tech industries, which frequently appears in studies on competitive performance by international organisations and governmental bodies. Then classifications that are motivated by the more differentiated notion of technological regimes and had been developed within the field of innovation research are presented. The paper then further discusses a distinct kind of classification, based upon various combinations of different factor intensities and closely associated with studies on international trade. Both conventional tangible factor intensities and intangible investment (and endogenous sunk cost) in industrial economics are analysed. An entirely different approach, which targets the distinction between 'quality'- versus 'price competition' is also briefly discussed.

Thus, a surprisingly large variety of available taxonomies, directed at different analytic questions and relying on various data, nomenclatures, and methods of identification surfaced. In principle, this diversity is welcome, as it offers researchers a wide choice. In practice, however, the range of taxonomies is greatly limited by either a lack of information and precise documentation or their adherence to outdated official nomenclatures. While some of the proposed classifications may not be ideal from a conceptual point of view, they might still provide the best solution given the availability of data.

Despite the diversity of the approaches, several problems and caveats are held in common. Above all, when implementing a taxonomic approach, one must stay alert to the hidden heterogeneity, which regularly prevails within the categories of a certain type. Apart from these general requirements, the desired mitigation of problems from hidden heterogeneity also sets the agenda for the most promising routes for the future development of industry classifications.

- First of all, the fundamental heterogeneity within industries implies that the accurateness of a taxonomy crucially depends on the level of disaggregation. In many instances, more disaggregated data would be available, but are not published for reasons of confidentiality. Closer co-operation between statistical offices and the research community is therefore desirable.

- Secondly, many classifications are based only on data for one country. Due to the potential effects of heterogeneity between different economies, a broadening of the geographic coverage together with tests on the significance of between-country variation is needed. In general, data from large economies that are less exposed to distortions by local idiosyncrasies are preferable to data from small countries.

- Thirdly, the integration of services into the more elaborate taxonomies for the manufacturing sector remains a critical task. The lack of equally disaggregated data and the large degree of heterogeneity within the services sector, together with the wide range of differences in technology and the market environments with respect to manufacturing and services, suggest that in many instances separate classifications would be more appropriate. An integrated approach might nevertheless remain desirable for higher levels of sectoral aggregations.

Taxonomy 1.The employment of IT-personnel

The employment of IT-personnel was chosen to be the first target for a methodologically extended attempt to create a new taxonomy that explicitly validates the impact of heterogeneity over time and differences between countries (*Peneder*, *2003b*). This paper starts with two basic presumptions:

- First, the rapid advance of new information technologies (IT) is a major cause of qualitative transformations in modern production systems.

- Second, IT personnel is the fundamental category of human capital formation in the process of dissemination and adoption of computers and related equipment. IT personnel drives the progress in computer related technologies of the IT producing sectors while at the same time enabling the actual realisation of productivity gains among IT user industries.

Recent empirical research has paid increasing attention to the complementarity between human capital and computer technologies. For example, Falk and Seim (2001) report a positive relation between the IT investment to output ratio and the employment of high-skilled workers for a panel of German companies while Chun (2003) demonstrates a positive interaction of demand for educated workers with IT adoption and use for a US industry panel from 1960 to 1996. Bresnahan, Brynjolfsson and Hitt (2002) argue that the demand for labour skills is embedded in a three-way system of complementarities among IT capital, new products and services, and new organisational practices. It should be noted, however, that all these studies are concerned with the educational composition of the workforce at large.

In contrast, this article focuses more narrowly on IT labour. The reason is that the "digital revolution" leaves some pronounced imprints on the overall formation of human capital in at least two dimensions. First, it favours the growth of specific computer related occupations. Second, it raises the demand for higher levels of workforce education. Together, occupational and educational attributes characterise the IT labour intensity of a firm, an industry, or the aggregate economy.

The paper then develops a new taxonomy based on sectoral characteristics of IT-labour intensity, which is defined, first, by the occupational attribute of an industry's share of IT personnel in the total workforce and, second, by the share of higher education among its IT labour as an educational attribute. Both employment and wage shares represent workforce composition. The data cover 39 sectors in the US and the United Kingdom from 1979 until 2000. The taxonomy is established by a three-staged statistical cluster analysis, using the dynamic profile of prior cluster identifications for the final partition. Cluster validation by means of boxplot charts helped to interpret the outcome. In a series of 3-way ANOVA regressions with additional country, time, and interaction effects, the industry types explain substantial portions of the overall variation. Further inspection of the interaction terms suggests the overall robustness of the taxonomy with respect to differences between the two countries and over time.

The new taxonomy consists of four classes (see VII 2. Table 14). First, computer services and, second, computer manufacturing are both IT producing industries with the highest IT-labour intensity. Being extreme outliers, each establishes a category of its own. The third group comprises 17 IT user industries, which are characterised by a comparatively high and dynamic profile of IT-labour intensity. For them the advance and diffusion of new information technologies has left a strong imprint on the workforce, both in terms of occupations and the rising share of persons with higher education. A certain characteristic of the fourth category of other IT user industries sharply contrasts popular believes about a more or less uniform dissemination of new information technologies in all sectors. The 20 industries belonging to this class, not just display lower levels in the educational attributes, but also exhibit a surprising lack of dynamics in the occupational attribute. While the share of IT labour in the total workforce grew steadily in all other sectors, these industries show no signs of catching-up from low initial levels but fall further behind. Two possible explanations seem plausible. First, these industries might be intrinsically less inclined towards information processing activities and therefore need less IT personnel. Secondly, they might systematically outsource more of their IT-related tasks to the specialised IT producing services. It is, however, likely that both causes interact. That is to say that in the group of other IT user industries outsourcing might be more important, because the demand for information processing activities remains below a critical scale, where internal production would pay-off.

<u>Taxonomy 2. Educational intensity</u>

Apart from the cultural values of education to the individual and society at large, the economic interpretation of education emphasizes its nature as a special input to production. This 'human capital revolution' was triggered by Theodore W. Schultz (1960), who proposed that education is an investment in people that generates a distinct class of productive assets – labeled human capital, because it distinctly becomes part of the person receiving it. Schultz also pointed at the particular importance of human resources in the process of economic development and presented empirical evidence for the continual rise of this investment. Although such evidence is naturally based on the individual characteristics of the people occupying the jobs, it also reflects the labor skill requirements of firms, which in part depend on the characteristics of markets and industries. The second new industry classification produced within this project focuses on this aspect of sector-specifity in the demand for human resources, presenting a new sectoral taxonomy of educational intensity and is available in *Peneder (2004a)*.

The data are for the US, Germany, France, the UK and Austria and (with considerable variations between countries) cover the period from 1979 to 2000. The annual data were pooled to comprise two consecutive years. Except for Germany, all the data were extracted from national labor force surveys, which are based on large-scale household interviews of individuals, and include information on educational qualifications and occupations (of employees and the self-employed) and also the codes of the industries where the people work. By virtue of multivariate statistical cluster analysis, a differentiated breakdown of up to seven categories, that range from 'very low' to 'very high' educational intensity was produced. If required, these can also be reintegrated into a smaller number of larger groups (e.g. 'low', 'medium', 'high').

Considering the enormous differences in both the educational and data systems, the initial plan to harmonize the categories of educational attainment in the various countries had to be dropped. Instead a tedious, but more rewarding approach is chosen, first creating independent national taxonomies for each country, and then using these to synthesize a common consensus classification. While, for instance, the national classifications are applicable, and indeed preferable, for the analysis of micro-data in the particular countries, the consensus classification establishes an analytic tool for international comparative studies (see VII 2. Table 15 for details of the taxonomy created).

In an elaborate section on cluster validation, it is investigated whether the final taxonomy is reasonably robust with respect to time and spatial boundaries. Necessarily, the common consensus classification must be less accurate than the national taxonomies. Similarly, its discriminatory power is expected to decrease with the passage of time. Two kinds of loss of information are assessed by means of simple OLS regressions with educational workforce composition as dependent and only the industry classifications as independent variables. First the specific identification of industries for each country in the national taxonomies are used and then a second regression is run with each sector categorized uniformly across countries according to the consensus classification. Table 3. compares the share of explained between group variation to the total variation. Substituting the consensus classification for the national taxonomies, the explained between group variation drops from about 69% to 57% for people with higher education as well as no formal degrees, and from 52% to 37% for intermediate degrees. If the dependent variable is standardised, the explained variation naturally becomes higher. Applying its identification to data for the earliest year available for each country, it is also possible to assess what impact the passage of time has on the accurateness of the classification. Table 3. shows a further drop in explanatory power of only four to eight percentage points. While this finding underscores the need for regular reviews, it also suggests that much change over time remains within the broad boundaries of the given industry types. In conclusion, this validation confirms the expected loss of information but overall is quite encouraging. Even after synthesizing the individual country results into one common classification and going back in time up to twenty years, the new taxonomy is able to capture a considerable part of the total variation.

Table 3. Share of variation explained by industry types in total variation (in %)

Classification	**Employment share of people with:**					
	Higher education		Intermediate degrees		No formal degrees	
	x	z(x)	x	z(x)	x	z(x)
National taxonomy, latest year	68.72	83.13	52.47	53.53	68.59	69.38
Consensus taxonomy, latest year	57.42	80.29	37.12	41.92	56.49	59.23
Consensus taxonomy, earliest year	54.31	79.70	29.17	31.15	52.52	61.79

Taxonomy 3. ICT capital

It was also considered useful to develop a taxonomy based on the production or use of ICT capital. This groups industries based on whether they produce ICT goods and services, whether they intensively use ICT or if they do not use ICT intensively. Sufficiently detailed data were only available for one country, the US, so the less sophisticated cut-off procedure was employed when considering ICT use. Industries were divided into the following seven groups; 1. ICT Producing Manufacturing; 2. ICT Producing Services; 3. ICT Using Manufacturing; 4. ICT Using Services; 5. Non-ICT Manufacturing; 6. Non-ICT Services; and 7. Non-ICT Other industries. ICT producing industries are those that directly produce ICT goods or services. This set of industries includes amongst others the computer, semiconductor, telecommunication and software industries. This distinction is based on a classification from the OECD (see, for example, OECD, 2002). As well as distinguishing ICT producing industries, this taxonomy also aims to separate the industries that make intensive use of ICT from those that do not. This is a less straightforward undertaking since nearly every part of the economy uses some ICT. Nevertheless, research for the US has shown that a binary classification based on ICT intensity has its uses, mainly when the underlying capital data are very noisy.[2] The share of ICT capital in total capital services in the United States is used as a measure of ICT intensity, as derived from Stiroh (2002).

There are two reasons for applying the classification based on ICT intensity in the US to all countries. The first has to do with the very limited availability of data on ICT investment by detailed industry outside the US, let alone capital stocks and capital services measures.[3] Apart from that, given the leading role of the US, it is reasonable to assume that the distribution of ICT use in the US presents a set of technological opportunities, which may or may not have been taken up in other countries. Van Ark *et al.* (2002a) show that the ranking of ICT intensity across industries is reasonably similar in the US and the EU. Based on this, the top half of the ranked ICT using industries is classified as ICT-user and the bottom half as non-ICT.[4] This cut-off point is obviously arbitrary, but alternative cut-off points have few implications for the results on productivity growth, except for retailing which has been included with intensive using industries. A distinction is also made between manufacturing and services industries and

---

[2] See McGuckin and Stiroh (2001).
[3] See van Ark *et al.* (2002b) for some of the difficulties in acquiring ICT investment even for the aggregate EU economies.
[4] The exceptions are education and health which, despite the high share of ICT in total capital services, are allocated to non-ICT services. Using alternative measures, namely ICT capital per worker or capital per unit of output, both these two industries rank near the bottom.

a group of other industries that include agriculture, mining, utilities and construction. Industries classified according to the ICT taxonomy are shown in VII 2. Table 16.. Further details on construction are given in Van Ark et al (2002a) and *Robinson et al. (2003).*

4.2. Trends in employment and labour productivity

A. Employment trends

From the mid-1990s there are signs that the EU began a process of catching up with the US in terms of employment growth. In the decade of the 1980s, the EU-15 saw an average growth in employment of 0.64% per annum, less than half the rate of US growth. The EU-15 unemployment rate remained quite high and rose further during the first half of the 1990s (with a peak of 10.5% in 1994). In contrast, in the years 1995-01, the annual average percent growth in employment in the EU-15 rose to an average rate of 1.35%, compared with 1.6% for the US, a much smaller gap than in previous periods. Thus in the second half of the 1990s European countries seem to have recovered a substantial capability of generating jobs and this have led researchers to speak about a "European job machine" (European Commission, 2002).

Employment trends by industry in the EU-15 compared to the US were analysed in *O'Mahony, Stokes and Stuivenwold (2004)*. An examination of the pattern across broad sectors showed that the business services sector experienced the highest employment growth since 1979 in both the US and EU-15, with employment growth greater in the EU-15 since 1995, reversing a previous US lead. Market service sectors such as distribution, financial and personal services also show growth in employment in both regions, with again some general narrowing of the gap between the EU and the US since 1995. However financial services were an exception to this rule, with US employment growth higher in the post 1995 period. In the 1980s falling employment was the norm in agriculture, mining and quarrying, and manufacturing and this decline continued throughout the 1990s. From 1995 the utilities joins these three sectors in seeing negative employment growth. Manufacturing employment declined much more rapidly in the EU-15 than in the US from 1979 to 1995, but the decline was greater in the US thereafter. In fact from 1995 to 2001 manufacturing employment did not change in the EU-15 whereas it declined at an annual average rate of nearly one percent in the US.

O'Mahony, Stokes and Stuivenwold (2004) employ the industry taxonomies created as part of the EPKE project to highlight the main differences between the EU-15 and the US. Table 4. shows employment growth according to the ICT taxonomy. ICT producing industries displayed positive employment growth in 1979-1990 in both the EU-15 and the

US, and followed a pattern of slowing employment growth in the second time period, indeed, negative growth in the EU; this middle period was affected by the early 1990s recession. Employment then increased in the period 1995-2001, to rates of 3.2% and 3.8% in the EU-15 and US respectively. This positive growth has been driven by relatively high employment growth in ICT producing services. Of all the groups in the ICT-7 taxonomy, ICT producing services experienced the greatest employment growth in the final period for both the EU-15 and the US. Indeed, this group has consistently seen the highest growth in persons engaged in all three periods for the US. Employment in ICT producing manufacturing industries is lower than the services part of the larger group and the EU-15 marginally outperforms the US in the final period.

Table 4. Employment growth of ICT-producing, ICT-using and non-ICT industries in the EU and the US (persons based)

	1979-1990		1990-1995		1995-2001	
	EU	US	EU	US	EU	US
ICT Producing Industries	1.1	1.4	-1.2	0.7	3.2	3.8
ICT Producing Manufacturing	*-0.2*	*0.2*	*-3.7*	*-1.8*	*0.6*	*0.2*
ICT Producing Services	*1.9*	*2.6*	*0.1*	*2.5*	*4.3*	*5.7*
ICT Using Industries	1.0	1.7	-0.4	0.3	1.4	0.8
ICT Using Manufacturing	*-0.7*	*-0.5*	*-3.3*	*-1.6*	*-0.4*	*-1.4*
ICT Using Services	*1.8*	*2.3*	*0.6*	*0.7*	*1.9*	*1.2*
Non-ICT Industries	0.5	1.7	-0.4	1.5	1.2	1.8
Non-ICT Manufacturing	*-1.3*	*-1.3*	*-2.5*	*0.3*	*0.1*	*-0.8*
Non-ICT Services	*2.1*	*2.6*	*1.1*	*1.9*	*2.0*	*2.1*
Non-ICT Other	*-1.6*	*0.6*	*-2.8*	*0.3*	*-0.6*	*2.1*

ICT intensive using industries have witnessed lower employment growth in the final period than ICT producing industries in both the EU-15 and the US. In the first two periods, the US experienced higher employment growth than the EU in ICT using industries, but this pattern was reversed in the final period, with EU-15 employment growth at 1.4%, compared to 0.8% in the US. The split between ICT using manufacturing and ICT using services reveals that while growth in ICT using services has been positive across the three time periods, this has been offset by negative employment growth in ICT using manufacturing. ICT intensive using services are an important sector in the explanation of productivity growth differentials across the two regions (see below).

Non-ICT industries have consistently demonstrated higher employment and hours worked growth in the US than in the EU-15. In 1979-1990, both the EU-15 and the US witnessed negative employment growth in non-ICT manufacturing. Following this, in the EU-15 the growth rate fell further to -2.5%, while in the US, it rose to 0.3%. In the final period, however, employment growth fell in the US by -0.8%, while increasing in the EU by 0.1%. Employment growth in non-ICT services has been positive for both countries in all three time periods, with slightly higher growth in the US, although the difference in the final period is very small, with growth rates of 2.0% and 2.1% in the EU and US respectively. In other non-ICT industries, employment growth has been negative in all three periods in the EU, but positive in the US. Both however experienced declines in 1990-1995, before rising in the final period.

Although very useful insights are obtained from observing the pattern of employment growth within this taxonomy, in order to put these trends into perspective, the employment shares of the various groups also need to be considered. Thus in 2000, non-ICT industries account for the majority of employment in both countries, with a share of 69.2% in the EU and 65.8% in the US in 2000. In both countries, this proportion has remained fairly stable over time. Within this group, non-ICT services account for the most employment, and in both countries these industries have been increasing their share over time, rising from 35% in 1979 to 46% in 2000 in the EU-15, and from 43% to 50% in the US over the same period. In contrast, non-ICT manufacturing has witnessed a decline in its employment share over time, to levels of 10.9% in the EU and 6.8% in the US by 2000. The same applies for other non-ICT industries. While non-ICT service industries account for a slightly greater share of employment in the US in 2000, the EU has a greater proportion of non-ICT manufacturing and other non-ICT industries.

ICT producing industries account for a much smaller proportion of employment, although this is slightly greater in the US (4.6%), than in the EU (3.9%) in 2000. In 2000, ICT using industries accounted for 27% of employment in the EU and 29.7% in the US. The US has experienced a small decline in this sector’s share from 1990 to 2000. ICT using services account for most of this group. ICT using manufacturing has witnessed a fall in its employment share over time, although this remains higher at 6% in the EU, compared to 4.4% in the US.

Combining the growth rates and shares suggests therefore that the EU-15 relatively favourable performance in generating employment growth since the mid 1990s is mostly explained by more traditional manufacturing industries, although there is some suggestion that the EU-15 has increased employment in recent years in the service sectors most affected by ICT.

The second taxonomy used to consider patterns of employment change is the educational intensity one developed in *Peneder (2004a).* Table 5. shows employment growth for this taxonomy. In both regions the highest skill groups show by far the greatest employment growth. The EU-15 has narrowed the employment generation gap with the US in industries that intensively use intermediate skills. The EU-15 turnaround has been greatest in the intermediate sub group, which consists mainly of manufacturing industries such as printing & publishing, mechanical engineering, electrical equipment and motor vehicles. But the very low skill group has also shown a large change in the EU from negative rates of more than 1% per annum in the 1980s to positive growth rates in the late 1990s. This group consists of traditional manufacturing industries (such as textiles) and hotels & catering. In terms of employment shares, the US outperforms the EU-15 in terms of employment accounted for by industries with the highest skill intensity, matched by lower shares in the low skill intensive groups.

Considering trends in employment growth by the occupational taxonomy also yields some interesting results. Thus the 'dynamic IT user' group has seen greater employment growth in the US in all three time periods than in the EU, although both countries experienced a decline in the rate of employment growth in 1990-1995. But employment growth in the 'IT user other' group has remained fairly stable in the US throughout the three time periods, while this group has seen an increase in employment and hours worked growth in the final period in the EU.

Table 5. Employment growth by educational intensity taxonomy in the EU and the US (persons based)

	1979-1990		1990-1995		1995-2001	
	EU	**US**	**EU**	**US**	**EU**	**US**
Highest skilled	2.96	3.51	1.59	2.02	3.45	3.12
Very High	*2.73*	*2.97*	*1.59*	*1.68*	*3.11*	*2.86*
High	*3.41*	*4.74*	*1.60*	*2.71*	*4.08*	*3.61*
Intermediate skilled	1.00	1.62	-0.25	0.92	1.18	1.04
Medium-High	*1.58*	*2.22*	*0.36*	*1.12*	*1.27*	*1.42*
Intermediate	*0.27*	*0.77*	*-1.56*	*0.29*	*1.16*	*0.24*
Medium Low	*0.68*	*1.26*	*-0.11*	*1.07*	*1.02*	*0.94*
Lowest Skilled	-0.83	0.54	-1.72	0.79	0.36	1.55
Low	*-0.49*	*0.18*	*-1.42*	*0.20*	*0.59*	*2.85*
Very Low	*-1.18*	*0.83*	*-2.04*	*1.23*	*0.08*	*0.53*
Total	**0.64**	**1.70**	**-0.40**	**1.11**	**1.35**	**1.60**

Thus in general employment generation in Europe owes much to expansion in more traditional industries, intensive in the use of low skilled labour. Nevertheless this is not the complete story since there is also some suggestion that some high technology industries (ICT producing services, ICT using services, and high skill intensive industries) do show convergence of employment growth in the EU to rates in the US in the late 1990s. This is a reversal of the position in the decade of the 1980s when employment expansion was considerably greater in high technology industries in the US than in the EU.

An analysis of the link between the growth in employment and labour productivity is contained in *van Ark et al. (2003)*, dividing industries according to the ICT taxonomy. The authors find an inverse relationship between productivity and employment in the long run, which is generally stronger in manufacturing than in services. However, during the 1990s, this relationship has turned positive in many industries, in particular in ICT-producing industries and in ICT-using industries in the service sector. Therefore as a result of increased use of ICT, high labour productivity growth is less associated with low employment growth during the second half of the 1990s, in particular in ICT-using services. But the negative association between productivity and employment growth has remained much more persistent in Europe than in the US.

Matteucci and Sterlacchini (2003) consider in some more detail employment generation in Italian industries and its association with ICT. Italian employment trends over the 1990s are consistent with those of the EU, even though, in the first part of this decade, the decrease in the working population was more severe and, in the second part, the employment revival less pronounced. In particular, Italian data show that the phase of employment expansion starting in 1995 is driven by the service sector as a whole and there is a staggering increase (almost 5% per annum) of people working in financial and business services.

The authors review the two main explanations for the differing employment experience in the EU and the US. The mainstream approach has largely emphasised the rigidities of the European labour markets which have determined higher wages and lower employment (cf. Bertolila and Bertola, 1990, Layard et al., 1991, OECD, 1994). According to this approach, the European employment resurgence of the late 1990s is mainly the outcome of a variety of policy interventions, recently introduced in most European countries, which have relaxed a number of institutional rigidities affecting their labour markets (see OECD, 2002). However, the mainstream approach fails to provide a convincing explanation of the extremely different patterns of employment growth across sectors. Evolutionary approaches have instead stressed the importance of structural and technological changes, which, over the last decade, have been driven by ICT. This approach (based on the Schumpeterian view of capitalist development) departs from the standard market equilibrium framework by stressing that employment expansions and reductions are driven by different paths of technological change (Petit and Soete, 2001). A relevant example is provided by the US where ICT, along with their positive impact on productivity, have contributed to an expansion of employment via new products, services and business opportunities. According to this approach, ICT spread through European countries with substantial delays and only in the late 1990s fostered an employment resurgence.

Matteucci and Sterlacchini (2003) investigate if there is a positive relationship between the recent employment revival and the intensity of ICT investment by combining the above two different approaches. In fact, most of the evidence concerned with employment changes in the EU and Italy neglects the role of technological change, uses aggregated data and applies a standard framework for labour demand (in which wage and output changes play a crucial role). On the contrary, empirical studies focussing on structural and technological changes (such as ICT) have not always controlled for the impact exerted by wages. They use a newly available statistical source (the Survey on Firms' Account), representative of the Italian economy, which provides data disaggregated up to the third digit level for value added, employment, labour costs and investment (total and ICT).

First they perform a descriptive analysis of the relation between ICT investment intensity and employment growth, using the same classification of industries proposed by Stiroh (2002). The authors find a broad association between ICT intensity (particularly "ICT producing sectors") and employment growth. However, when industries are disaggregated between secondary and tertiary industries, the ICT-employment relation is confirmed only within the latter. This result is however likely to be specific to the Italian case, since the employment reduction of Italian ICT producers is explained by the loss of competitiveness of the national manufactures of electronics and IT during the 1990s.

In the second step of the analysis, *Matteucci and Sterlacchini (2003)* estimate across 173 three-digit industries a comprehensive equation for employment growth for the period 1997-2000. The estimating equation, involving long difference specification, allows the exclusion of the bias of idiosyncratic industry effects, includes a continuous variable for ICT intensity as well as output and the cost of labour. The results suggest that, no matter how labour input is measured (employees or hours worked), the employment changes over the period 1997-2000 are closely associated with the changes in value added and labour costs. In particular, the elasticity of employment with respect to value added is around 0.7 (OLS estimate, and slightly decreasing with the WLS estimate), while the negative coefficient of the unit labour costs is significant and remarkable (around -0.4/-0.5). The service sector dummy, alone and in interaction with the two regressors, indicates that there are no significant differences in the behaviour of secondary and service industries. These results seem to indicate that the "labour market rigidities" explanation is valid for Italy. However, the estimate of the coefficient of the ICT investment intensity says that also this factor cannot be neglected. When the ICT variable is inserted alone, the coefficient is negative and barely significant; this is due to secondary industries, where a greater intensity of ICT is associated with a loss of employees and hours worked. In fact, the interaction of the ICT intensity variable and the service dummy confirms that within service industries a higher ICT investment per unit of labour affects positively and significantly employment growth. Thus, the advantage in terms of employment growth is not generalised to service industries but confined to those with a greater intensity of ICT investment. So, the considerable net employment generation registered in Italian tertiary sectors over the years 1997-2000 is not completely explained by output (or demand) changes and labour costs reduction, but also by the diffusion of the ICT paradigm.

B. Labour productivity trends

A comprehensive description of labour productivity growth was presented in *O'Mahony and van Ark (2003a).* Labour productivity growth, defined as the growth in value added at constant prices minus the growth in hours worked, is the performance indicator most readily associated with increases in standards of living. *O'Mahony and van Ark (2003b)* summarised labour productivity growth at the broad sector level. This suggests that the worsening in the EU-15 position relative to the US from 1995 was due mainly to a combination of decelerating labour productivity growth in manufacturing, distribution and business services and a failure to reach US growth rates in financial services. These broad sector trends, however, hide considerable diversity within each sector.

As an aid to describing these diverse trends, *Inklaar, O'Mahony, Robinson and Timmer (2003)* relate the sectoral breakdowns to industry taxonomies. Their summary however begins with a consideration of growth rates for all 56 industries contrasting the total EU-15 and the US (shown in VII. 2. Table 17.) for the same three time periods considered for employment generation. There appears immense diversity in performance between industries within each region, across the two regions and over time. Average annual growth rates range from over 50% per annum in electronic valves and tubes in both regions in the final period to –11% in the US fishing industry in the early 1990s. These very large or small numbers appear largely in smaller industries, which is a common finding in productivity studies. Thus electronic valves and tubes represent about 0.3% of aggregate employment in the US and less than 0.2% in the EU. When larger industries are considered, in particular in service sectors, most growth rates occur in the plus to minus 4%-points range.

There are similarities between the US and EU-15 in the main ICT producing sectors in manufacturing, both in magnitudes of the growth rates and the pattern across time of industries. In these industries the US only marginally leads the EU in the earliest period and the EU catches up subsequently, although not fully. There are also some similarities in the time pattern in 'traditional' industries such as food, drink and tobacco, leather, fabricated metals and hotels and other services with declining growth rates through time in both regions, but on the whole productivity growth rates in EU manufacturing industries remain somewhat above that of the US counterparts. But differences across regions and time dominate the picture, in particular the finding that the US acceleration in wholesale trade, retail trade and auxiliary financial services in the second half of the 1990s is not matched in the total EU-15.

Table 6. shows labour productivity growth rates for the ICT taxonomy described above. This clustering shows considerable variation across the groups, apart from ICT producing manufacturing. In the latter group labour productivity growth rates in both the US and EU-15 are considerably greater than all other sectors and show a similar time pattern with accelerated growth in the late 1990s, although at a higher rate in the US. In contrast, ICT producing service sectors experienced high growth rates in the EU, outperforming the US, in particular in the later period. This is the only ICT group for which the EU shows an acceleration from the mid 1990s whereas the US shows a deceleration, which is mainly due to the negative productivity growth rates in US computer services. But overall this group represents only a small share of total economy value added, about 5% in both the US and EU in 2001.

The two ICT using sectors generally show considerably lower growth rates than the corresponding ICT producing sectors with the important exception of the ICT using services group in the US which from 1995 onwards shows a sharp acceleration not matched in the EU-15. This was mainly due to a major increase in productivity and output growth in distribution and financial securities in the US as shown in VII. 2. Table 17. Equally important is the pronounced deceleration in the EU in non-ICT industries, which occurs in all three subcomponents. In non-ICT manufacturing, labour productivity growth decreases in the final period in both the US and the EU-15 with a greater decline in the US. However the US shows a marginal improvement in non-ICT services, and since this comprises over 60% of the non-ICT group, the overall percentage point reduction in US non-ICT industries since 1995 is lower than in the EU. Nevertheless productivity growth rates in the non-ICT sectors are much lower in the US than in the EU.

Table 6. Labour productivity growth of ICT-producing, ICT-using and non-ICT industries in the EU and the US

	1979-1990		1990-1995		1995-2001	
	EU	**US**	**EU**	**US**	**EU**	**US**
Total Economy	**2.2**	**1.3**	**2.3**	**1.1**	**1.7**	**2.2**
ICT Producing Industries	7.2	8.7	5.9	8.1	7.5	10.0
ICT Producing Manufacturing	*12.5*	*16.6*	*8.4*	*16.1*	*11.9*	*23.7*
ICT Producing Services	*4.4*	*2.4*	*4.8*	*2.4*	*5.9*	*1.8*
ICT Using Industries	2.2	1.2	2.0	1.2	1.9	4.7
ICT Using Manufacturing	*2.4*	*0.5*	*2.4*	*-0.6*	*1.8*	*0.4*
ICT Using Services	*2.1*	*1.4*	*1.8*	*1.6*	*1.8*	*5.3*
Non-ICT Industries	1.8	0.5	2.1	0.3	1.0	-0.2
Non-ICT Manufacturing	*3.0*	*2.1*	*3.6*	*2.7*	*1.6*	*0.3*
Non-ICT Services	*0.6*	*-0.2*	*1.2*	*-0.5*	*0.5*	*-0.3*
Non-ICT Other	*3.4*	*2.0*	*3.2*	*1.2*	*2.1*	*0.7*

Notes: For industries 30-33 (NACE) the US deflators have been used for all countries. *Italics* indicate ICT-7 taxonomy, remaining groups refer to the ICT-3 taxonomy.

Sources and methods: see Inklaar et al. (2003).

In looking at the position across EU countries it is useful to combine the above groups into the three main groups, that is, ICT producing, ICT using and non-ICT. In the ICT producing sectors Ireland and Germany show the most pronounced growth between the two halves of the 1990s, with their very large ICT manufacturing sectors. But accelerating growth is also apparent in the ICT producing sector of a further six EU countries. The UK shows a deceleration but from a relatively high base. In the ICT using sectors there are again differences in the experiences of individual countries with eight of the EU-15 showing accelerating growth. However these are mainly the smaller countries and their performance is counter-balanced by poor relative performance in three large EU member states, namely Germany, France and Italy. Finally in the non-ICT sectors, which together generally make up about two thirds of economy wide value added, there is a pronounced deceleration in all countries except Greece, Ireland, Portugal and Sweden. These small countries were those with some of the largest productivity gaps relative to the US in the 1980s. Since the non-ICT group is largely made up of traditional mature industries, conventional convergence trends are more apparent. In the period up to 1995 labour productivity growth rates in these sectors were considerably above those in the US in most EU countries, but in many countries the growth advantage over the US diminished over time.

Up to this point industries have been considered as single observations, but not their importance in accounting for the changes in aggregate economy wide labour productivity growth. The impact of each industry group on labour productivity at the aggregate level depends not only on the average productivity growth rate of each industry, but also on the relative size of that industry. Hence labour productivity for the total economy can be perceived as the sum of the productivity contributions of each industry group, weighted by their labour shares.[5]

Table 7. shows the contributions of industries to the percentage point difference in aggregate economy labour productivity growth in the US and EU-15, cross-classified by the ICT taxonomy. In the period 1979-1990, nearly three quarters of the one percentage point higher EU average labour productivity growth was due to higher growth in more traditional non-ICT industries, with the EU maintaining a productivity advantage in these sectors through to 2001. In the 1980s ICT using sectors accounted for about 40% of the EU higher growth and this advantage continued into the early 1990s. The final period saw a reversal of this pattern as slower growth in ICT using sectors in the EU accounted for –0.6 percentage points slower aggregate growth in Europe. This was confined to service industries although the contribution to the EU-US differential growth from ICT using manufacturing also declined somewhat from its level in the 1980s. The US outperformed the EU in all periods in ICT producing manufacturing and this difference has been increasing over time. In contrast in all periods ICT producing services made a positive contribution to the EU-15-US differential and this became significant but still small by the latest period.

[5] Based on Fabricant (1942).

Table 7. Contributions of industry groups to differences between EU and US aggregate labour productivity growth

	Productivity growth differential EU-15 over US Average annual percentage points		
	1979-1990	**1990-1995**	**1995-2001**
Total economy	**0.99**	**1.19**	**-0.54**
ICT Producing Industries	-0.13	-0.25	-0.45
ICT Producing Manufacturing	*-0.31*	*-0.29*	*-0.60*
ICT Producing Services	*0.08*	*0.04*	*0.15*
ICT Using Industries	0.38	0.44	-0.61
ICT Using Manufacturing	*0.19*	*0.18*	*0.14*
ICT Using Services	*0.19*	*0.26*	*-0.75*
Non-ICT Industries	0.73	0.99	0.44
Non-ICT Manufacturing	*0.27*	*0.01*	*0.24*
Non-ICT Services	*0.41*	*0.88*	*0.32*
Non-ICT Other	*0.06*	*0.10*	*-0.11*

Contributions by detailed industry group to growth in each region were also calculated separately. This shows that much of the high growth in labour productivity in the US in the late 1990s is accounted for by a small number of industries. In the final period, the largest contributors to the US advantage were office machinery and electronic manufacturing in ICT producers, and wholesale, retail and auxiliary financial services (securities) in ICT using sectors. Financial intermediation (banking) and other business services also make a significant contribution. Together these industries contribute 2.1 percentage points to aggregate US growth. The same group of industries account for only 0.7 percentage points in the EU. Indeed the industry contributions to EU growth were found to be more spread out.

Inklaar, O'Mahony, Robinson and Timmer (2003) also consider labour productivity trends using alternative industry taxonomies. These in general concur with the above observations that the US labour productivity acceleration tends to be concentrated in ‘high technology sectors’, i.e. those which intensively use high skilled labour. These labour productivity trends are useful for broad descriptive analysis, in particular for getting a handle on trends in the total EU-15 versus the US, and within EU variation. However, further analysis requires a more sophisticated approach, the cost of which is a reduction in both country coverage and disaggregation by industry. The next section considers one such approach - the growth accounting method.

4.3. Growth accounting

Growth accounting estimates were calculated for four European countries, France, Germany, the Netherlands and the UK. Table 8. provides a decomposition of aggregate labour productivity growth into the contributions from labour quality, ICT and non-ICT capital deepening and TFP growth for an aggregate across the four European countries (EU-4) and the US. The main source of the EU-4 slowdown is a deceleration of non-ICT capital deepening and, in contrast to the U.S., a lack of acceleration of TFP growth. Although in this summary, the focus is mostly on the EU-4 versus the US, analysed in *Inklaar, O’Mahony and Timmer (2003)*, it is important to realise that in some cases the EU-4 results hide considerable cross-country variation. Although the individual countries differ in their growth experience, a few common observations stand out. First of all, the four European countries all had higher labour productivity growth than the US before 1995 and all except the U.K. had lower growth after 1995. Even in the latter country labour productivity growth decelerated after 1995. Furthermore, the contribution of ICT capital deepening is lower than in the US in all European countries throughout the period. Some additional detail on France is discussed below. Additional country results are described in *Inklaar, O’Mahony and Timmer (2003).*

Table 8. Sources of labour productivity growth in the EU-4 and the United States, 1979-2000

	1979-1995			1995-2000		
	EU-4	**US**	**US-EU**	**EU-4**	**US**	**US-EU**
Labour productivity	2.30	1.21	-1.09	2.02	2.46	0.43
Contribution of						
Labour quality	0.31	0.28	-0.03	0.22	0.22	-0.01
Reallocation of hours	0.02	-0.15	-0.16	-0.04	-0.09	-0.05
ICT capital deepening	0.33	0.46	0.12	0.53	0.86	0.33
Non-ICT capital deepening	0.70	0.35	-0.35	0.25	0.43	0.18
TFP growth	0.94	0.26	-0.67	1.07	1.05	-0.02

Notes: EU-4 includes France, Germany, Netherlands and the UK, which makes up 70% of EU-15 GDP. Labour productivity growth is defined as the growth in real value added per hour worked. Labour quality takes account of changes in the skill composition of the workforce. Reallocation of hours reflects shifts in employment to or from high productivity industries. Capital deepening is the change in capital services per hour worked.

Source: see Inklaar, O'Mahony and Timmer (2003), Appendix A.

Previous studies discussing differences in labour productivity growth between the US and EU countries have shown that the key to understanding the acceleration in US labour productivity growth and the lack of it in the EU is the difference in performance of industries that intensively use ICT and those that do not (van Ark, Inklaar and McGuckin 2002). This naturally raises the question whether this is due to lagging ICT investment in Europe, especially in ICT intensive industries. In fact it turns out that ICT capital deepening has been progressing at double-digit growth rates since 1979 in both regions. Although growth has been faster in the U.S., the differences are relatively minor. This picture extends quite well to each of the industry groups, but at the industry level, notable differences start to appear. Within ICT producing industries, the US clearly leads in terms of ICT investment growth in manufacturing industries, while ICT investment in the telecommunication services industry grows much faster in the EU-4 in both periods. In ICT using industries, both the wholesale and retail trade sectors in the US clearly invested at a faster pace in ICT assets between 1979 and 1995 but subsequently the EU-4 had mostly closed this growth gap. In business services, on the other hand, the EU-4 showed considerably stronger investment growth in both periods than the US. In non-ICT industries, the most noticeable difference between the two regions is faster EU-4 ICT investment growth in non-ICT manufacturing between 1979-1995.

When combining ICT capital deepening in industry groups with their shares in the value of output, one arrives at the contribution of ICT capital deepening in each industry to aggregate labour productivity growth. The results are shown in Table 9. The first row shows the contribution to aggregate labour productivity growth of ICT capital deepening in all industries, reproduced from Table 8. Subsequent rows decompose the contributions given in the first row by industry. So for example the entry 0.35 for ICT using industries in the EU-4 for the 1995-2000 period indicates that ICT-capital deepening in the ICT-using industries in the EU-4 contributed 0.35 percentage points to aggregate labour productivity growth in this period. In contrast, ICT capital deepening in ICT producing industries only contributed 0.07 percentage points. The gap in percentage point contributions from ICT capital deepening between the US and the EU-4 is greatest in ICT using sectors.

Table 9. Contributions to aggregate labour productivity growth of industry ICT capital deepening, EU-4 and US

	1979-1995			**1995-2000**		
	EU-4	**US**	**US-EU**	**EU-4**	**US**	**US-EU**
Total economy	**0.33**	**0.46**	**0.12**	**0.53**	**0.86**	**0.33**
ICT producing industries	*0.04*	*0.06*	*0.02*	*0.07*	*0.11*	*0.04*
Electrical and electronic equipment & instruments	0.01	0.04	0.02	0.02	0.05	0.04
Communications	0.03	0.02	0.00	0.05	0.05	0.00
ICT using industries	*0.21*	*0.28*	*0.07*	*0.35*	*0.57*	*0.22*
ICT using manufacturing	0.02	0.02	0.01	0.03	0.03	0.01
Wholesale trade	0.03	0.08	0.05	0.07	0.13	0.06
Retail trade	0.01	0.04	0.03	0.03	0.05	0.02

Financial intermediation	0.08	0.11	0.03	0.10	0.27	0.17
Business services	0.07	0.04	-0.03	0.12	0.09	-0.04
Non-ICT industries	*0.08*	*0.11*	*0.03*	*0.11*	*0.18*	*0.07*
Agriculture, forestry and fishing	0.00	0.00	0.00	0.00	0.00	0.00
Mining and quarrying	0.00	0.01	0.01	0.00	0.00	0.00
Non-ICT manufacturing	0.04	0.04	0.00	0.04	0.05	0.01
Transport & storage	0.00	0.01	0.00	0.01	0.02	0.01
Social and personal services	0.01	0.01	0.01	0.01	0.03	0.02
Non-market services	0.01	0.03	0.01	0.02	0.04	0.03
Other non-ICT	0.02	0.02	0.00	0.03	0.03	0.00

Note: An industry's contribution is calculated as industry ICT capital deepening weighted by the share of the industry's ICT capital compensation in aggregate value added. ICT using manufacturing includes paper, printing & publishing, machinery and furniture and miscellaneous manufacturing. Non-ICT manufacturing includes food, textiles, wood, petroleum, chemicals, rubber & plastics, non-metallic mineral, metal products and transport equipment. Other non-ICT includes utilities, construction and hotels & restaurants.

Source: see Inklaar, O'Mahony and Timmer (2003), Appendix A.

Differences in labour quality growth are relatively unimportant in terms of explaining the aggregate labour productivity growth differential between the EU-4 and the US However, the results at the industry level do point to some noticeable differences between the two regions. Throughout the period the EU-4 had a somewhat higher contribution from labour quality, but not significantly so. Between 1979 and 1995, non-ICT manufacturing in the EU-4 shows particularly large contributions. These are sectors that intensively use craft level skills, a traditional area of focus of European upskilling. Together with the larger contribution from non-market services, these contributions more than account for the aggregate differential. After 1995 the differential in these industries between the EU-4 and the US mostly disappeared, largely due to a large drop in labour quality contributions in non-ICT manufacturing in the EU-4. In the US on the other hand, the labour quality contribution of finance and business services was noticeably higher than in the EU-4. These industries intensively use university graduates, which has long been an area of strength of the US skill acquisition system. In business services, this position was reversed after 1995 with the EU-4 showing a larger contribution. In terms of labour quality contributions, in the period 1995 –2000 the EU-4 converged on the US in ICT producing and ICT using industries. Furthermore, the earlier lead of the US in these industries points to possible ICT-skill complementarities. However, the issue of factor complementarities cannot be handled in a growth accounting framework and needs factor demand analysis as outlined in section 5 below.

*Inklaar, O'Mahony and Timmer (2003), h*owever, highlight the important role played by reductions in non-ICT capital deepening in explaining the slowdown in labour productivity growth, at least in the four large EU countries studied. The striking finding is that the deceleration in non-ICT capital deepening in the EU-4 has been very widespread with almost all industries showing declines in the contribution of this input after 1995. A number of industries stand out. First of all, manufacturing (ICT producing, ICT using and non-ICT manufacturing) is responsible for around one-third of the aggregate deceleration, which is much bigger than its share in GDP. More than a quarter of the aggregate deceleration can be traced to business services where non-ICT capital per hour worked was actually declining after 1995. Finally, mining makes up another 20 percent of the deceleration. This industry showed a similar decline in contribution in the US. One likely candidate for explaining such a development is slower (nominal) wage growth in the EU-4 as this may well have induced a substitution of labour for non-ICT capital. This explanation is considered further below.

Although the differences in quantity and quality of input use are quite important for explaining the aggregate labour productivity growth differential, TFP growth also has a substantial role to play as was shown in Table 8.. While aggregate TFP growth in the EU-4 increased only slightly after 1995, US growth accelerated strongly. Which industries were responsible for this acceleration? In contrast to the extent of ICT investment, the industry pattern of TFP performance is much more heterogeneous. ICT producing industries make the largest contribution to TFP growth in both the EU-4 and the US. In the US most of the contribution can be traced to ICT producing manufacturing while in the EU-4 communications services play a much more important role. After 1995, ICT producing industries still make the largest contribution to overall US TFP growth, but the contribution of ICT using industries is almost as large. The acceleration in the TFP contribution of ICT using industries in the US is mostly related to accelerations in three industries: wholesale trade, retail trade and financial intermediation. The US findings broadly confirm those of Jorgenson, Ho and Stiroh (2002) and Triplett and Bosworth (2003).

In contrast, in the EU-4 none of these industries is an important contributor to aggregate TFP growth. The only reason that aggregate TFP in the EU-4 is still on par with the US is due to the much higher contribution from TFP growth in non-ICT industries. During the 1995-2000 period it added 0.35 percentage points to aggregate labour productivity growth in the EU-4, but it contributed negatively in the US. This mainly involved contributions from transport and storage, non-market services and other non-ICT industries in the EU-4. In contrast, in the US the contributions from non-ICT sectors were small or even negative. These were largely driven by the substantial negative values in non-market services. But there is a large question mark regarding the reliability of output measurement in these sectors and it is unclear whether these differences between the US and Europe are due to differences in output measurement methodologies or reflect underlying differences in performance.

Table 10. Industry contributions to aggregate total factor productivity growth, EU-4 and US

	1979-1995			**1995-2000**		
	EU-4	**US**	**US-EU**	**EU-4**	**US**	**US-EU**
Total economy	**0.94**	**0.26**	**-0.67**	**1.07**	**1.05**	**-0.02**
ICT producing industries	*0.30*	*0.35*	*0.06*	*0.53*	*0.71*	*0.18*
Electrical and electronic equipment & instruments	0.21	0.36	0.15	0.27	0.63	0.35
Communications	0.09	-0.01	-0.10	0.26	0.08	-0.18
ICT using industries	*0.17*	*-0.15*	*-0.31*	*0.19*	*0.68*	*0.50*
ICT using manufacturing	0.03	-0.07	-0.11	0.03	-0.01	-0.05
Wholesale trade	0.11	0.04	-0.07	0.08	0.35	0.27
Retail trade	0.06	0.10	0.05	0.03	0.39	0.36
Financial intermediation	0.00	-0.19	-0.19	0.06	0.08	0.02
Business services	-0.03	-0.02	0.01	-0.02	-0.12	-0.11
Non-ICT industries	*0.48*	*0.06*	*-0.42*	*0.35*	*-0.34*	*-0.69*
Agriculture, forestry and fishing	0.09	0.13	0.04	0.06	0.16	0.10
Mining and quarrying	-0.01	0.00	0.01	0.01	-0.02	-0.04

Non-ICT manufacturing	0.21	0.17	-0.04	0.08	-0.07	-0.15
Transport & storage	0.09	0.05	-0.04	0.13	0.05	-0.08
Social and personal services	-0.02	0.00	0.02	-0.02	-0.11	-0.09
Non-market services	0.07	-0.24	-0.31	0.07	-0.30	-0.37
Other non-ICT	0.04	-0.05	-0.09	0.02	-0.05	-0.07

Note: An industry's contribution is calculated as industry TFP growth weighted by the industry's share in aggregate value added. ICT using manufacturing includes paper, printing & publishing, machinery and furniture and miscellaneous manufacturing. Non-ICT manufacturing includes food, textiles, wood, petroleum, chemicals, rubber & plastics, non-metallic mineral, metal products and transport equipment. Other non-ICT includes utilities, construction and hotels & restaurants.

Source: see Inklaar, O'Mahony and Timmer (2003), Appendix A.

In *Melka and Nayman (2004)*, a similar accounting assessment of hourly labour productivity growth in an international perspective is used to highlight the particular issues for France. This highlights particularly poor performance in the ICT using sector in France. TFP gains were found to originate outside the ICT linked industries in France, mainly in the traditional manufacturing sectors. While the contribution of labour quality in the nineties is more or less equivalent in the four countries, the underlying conditions contrast sharply. Concerning France and Germany, the deceleration in labour quality is mostly due to age, whereas education explains the deterioration that occurred in the US. Labour quality reflects the workings of social policies introduced in France.

Venturini (2004) considers growth accounts for Italy, discussing where the Italian productivity story has diverged from the EU pattern. Overall, ICT capital deepening in Italy has been close to the lower end of the distribution in EU countries. However the decline in total factor productivity is found to play a more important role in the deceleration of Italian labour productivity growth. In Italy there is a widespread deterioration in TFP growth in service sectors. This finding is worrying for the future growth of Italy, more than slowed capital deepening that, by contrast, can be partly attributed to temporary factors. In addition, by scrutinizing the industry performance, this paper shows the rising weakness of traditional sectors. These are the bulk of Italian economy, where it enjoys the major comparative advantages in international trade but is more vulnerable to Asian competitors.

4.4. Other industry results

This section considers two additional strands of industry research undertaken as part of the EPKE project, i.e. Evidence on excess returns from ICT capital and the impact of industry structure.

<u>A. The returns to ICT investment</u>

Using industry data for the US and the UK, O'Mahony and Vecchi (2004) provide new evidence on the impact of ICT capital on real output growth. The traditional industry panel data analysis fails to find a positive contribution. This paper argues that this is due to heterogeneity across industries, particularly in the time dimension. Pooling the data for the two countries and using a dynamic panel data estimation method, the pooled mean group (PMG) estimator, yields a positive and significant effect of ICT on output growth.

The gain from using the PMG estimator, as opposed to the standard panel data analysis, is to allow for heterogeneous dynamic adjustments towards a common long run equilibrium. This is likely to be a better representation of the way ICT capital investments are affecting both manufacturing and non-manufacturing industries. The heterogeneous way in which ICT capital has spread across the different sectors of the economy, and the way in which it is still growing, suggests that this is a dynamic process, whose features are better captured using dynamic econometric methods. This is consistent with the notion of ICT as a general purpose technology which increases the long run growth rate (Helpman 1998).

The results have confirmed the presence not only of positive returns to ICT capital but also excess returns to ICT compared to non-ICT assets, particularly in the USA. This suggests the possibility that standard growth accounting exercises may understate the contribution of ICT to output growth and TFP. The null of equal returns on the two capital assets can be rejected in the estimates. This suggests that the marginal returns to ICT capital are significantly higher than those on non-ICT and the estimated coefficient on ICT is nearly twice as high as would be observed if there were zero excess returns. These greater returns to ICT compared to other types of capital justify the intensive investment in ICT during the last 10-15 years. It also suggests that firms have not invested enough on ICT, possibly because of the time needed to reorganise the production process. Individual country estimates suggest a strong impact in the US while results are less conclusive in the UK. However these results are only indicative of the differences between the UK and the US because, being based on a smaller sample, are likely to be less efficient.

B. Tracing empirical trails of Schumpeterian development

Peneder (2004b) considers the impact of industry structure on growth. This paper starts with the presumption that Schumpeterian *development* is characterised by the simultaneous interplay of growth and the qualitative transformation of the economic system (Schumpeter, 1911, 1942). At the sectoral level, such qualitative transformations become manifest as variations in the sectoral composition of production, i.e. structural change. In contrast to Schumpeter's broader notion of development, theories of economic growth tend to focus exclusively on macroeconomic phenomena. For the sake of analytic tractability and clear identification of the steady state equilibrium solutions, the meso-level of industrial structure is bypassed by the assumption of balanced steady-state growth, uniformly spread across all industries.

The paper presents an empirical validation of this evolutionary emphasis on Schumpeterian development, focusing on variations in industrial structure and its impact on aggregate income and growth. It traverses three different layers of visibility. Within the first layer of easily recognisable trails, an apparent co-movement in time involving aggregate income and certain selected types of industry motivated further investigations. In the second layer, the application of Harberger's visualisation not only demonstrated that differential productivity growth is an undeniable fact, but also revealed some interesting time patterns in its relationship to aggregate development. Specifically, the boom in the US New Economy in the late 1990s, preceded by a phase of painful but creative destruction in the years prior to 1992, invites a very Schumpeterian interpretation. In the final layer, (dynamic) panel estimations of a standard empirical growth model augmented by various structural variables for 28 OECD countries during the period 1990 to 2000, revealed that variations in industrial structure do have a significant impact on both aggregate income levels and growth. While (consistent with Baumol's cost disease argument) the share of the services sector in total value added exerted a negative influence, the coefficients for the value added share of business services and the export shares of particularly technology driven manufacturing industries were positive and significant. Potential explanations range from differential growth between industries to their different propensities to generate producer-related spillovers. For technology-driven industries, a positive impact of relative import shares is additionally found, indicating the presence of user-related spillovers from embodied technology flows.

The essential message in *Peneder (2004b)* is that variations in industrial structure are significant determinants of aggregate income levels and growth. The empirical evidence thus substantiates the importance of Schumpeterian *development*, which in addition to the endogeneity of innovation in Schumpeterian *growth* models, comprises growth and structural change as two inseparable elements.

4.5. The distribution sector – a case study

McGuckin, Spiegelman and Van Ark (2003) consider the distributive trades sector where US efficiency has grown so much faster than in Europe since the mid 1990s. They employ a unique approach of combining growth accounting analysis for the sector with a business case study approach. The latter is based on business cases and commercially available data.

As discussed in previous sections of this report, the US combined wholesale and retail sector was a major driver of the US productivity acceleration, and this trend was not matched in Europe. The growth accounting analysis showed a significant acceleration in productivity growth around 1995 in this sector in the US, almost doubling the trend growth rate of the previous twenty years. Retail trade jumped from 2.5% average labour productivity growth per year between 1979 and 1995 to 7.9% between 1995 and 2002. Wholesale trade moved from 2.7% to 7.1% over the same period. The US has remained on this higher productivity growth track through both the recession and subsequent recovery. European performance, on the other hand, stalled with very slow post-1995 wholesale and retail productivity growth in France, Germany, Spain, Belgium, the Netherlands, and Portugal. The US trends were apparent also when productivity was measured by TFP growth so that not all the upsurge is due to use of inputs.

The authors suggest that the marriage of technology and organisational change is at the core of the US trade sector's productivity acceleration and its superior performance relative to European countries. Over the past three decades the trade sector has been transformed from a low technology sector to one that makes extensive use of ICT. The most important improvements in the US were:

- **Better information about customers –** Retailers, wholesalers, and manufacturers can now use detailed real-time information about customer purchases to make business decisions.
- **Faster information flow** – Information gathering and reporting is highly automated and flows almost instantaneously between business units and companies.
- **Smaller and more accurate inventories** – At all stages of the value chain participants boost efficiency by keeping lower inventories on hand.

- **Sharp declines in operating margins and real consumer prices** – These are the ultimate rewards of the investment, and many of the gains are passed on to the consumer.

- **Increased firm and store size** – The technology rewards scale and scope, enabling large centralized chains and "big box" stores to expand rapidly.

The authors suggest that these improvements were far from instantaneous but rather reflected decades of investment. US progress was slow for a number of reasons including:

- **Network effects** – Benefits could only be realized once a large number of manufacturers and stores were using the technology.

- **Learning effects** – Companies had to reorganize their entire operations around the new technology to realize its benefits.

- **Complementary changes** – Deregulation of the trucking industry in the 1980s was a major enabler of the gains, and this adjustment took time.

- **Industry diffusion** – There were substantial delays as the technology moved from the food sector, to general merchandise, and then outward to other retail sectors like apparel and electronics.

- **High investment barriers** – Inventory control systems have very high fixed costs, and the investment barrier is high, especially for smaller firms. This has been mediated over time as computer prices have fallen.

Once these obstacles were overcome the rewards were great. The authors suggest that the EU could also potentially reap similar rewards and could learn from the mistakes made in the US. While retailers on both sides of the Atlantic have followed suit in adopting Wal-Mart's innovations, US retailers had a substantial head-start over European firms in making the changes required to successfully exploit these technologies. European retailers and wholesalers are investing heavily in ICT capital. Nevertheless there may be reasons why the European lag may be prolonged. These include:

- Regulatory obstacles;

- Slower complementary change;

- Culture and taste – Differences in language and culture make it more difficult to streamline operations across borders in Europe;

- Scale – Since ICT in the trade sector is a technology of centralized management, information processing and analysis, reduced opportunity for cross-border scale has lowered the incentive for investment in Europe relative to the United States.

The impact of the first two factors on productivity performance is considered further in section 6 below. In terms of cross-border trade, there is evidence that Europe is changing. Cross-border taxes are now much simpler than they were in the past. Cross-border mergers and acquisitions soared in the late 1990s as firms began moving out of their home countries. Furthermore, Western European retail companies have aggressively pushed into the new Eastern European markets of the ten new EU member states. Nevertheless there are culture and taste differences that might persist, e.g. the shopping behaviour of consumers with Americans prepared to drive relatively long distances to shop whereas Europeans show a preference for more local shopping facilities. Thus the authors conclude that the European 'lean-retailing' model may ultimately turn out to be somewhat different from the American model.

5. The demand for skilled labour

5.1. The demand for skilled labour: industry analysis

There is increasing evidence that the past 30 years have witnessed a dramatic change in the way goods are produced. During this period input factors such as information and communication technologies, imported materials, purchased services, skilled labour as well as capital have been increasingly used in production. In particular firms began to replace low-skilled or unskilled workers by more skilled workers.

There are a number of possible explanations for the shift in labour demand towards skilled labour and away from unskilled labour. First, the diffusion of information and communication technology is often emphasized as one of the most important factors explaining the shift in labour demand towards highly skilled workers and away from unskilled workers (see Autor, Katz and Krueger, 1998; Bresnahan, Brynjolfsson and Hitt, 2002). Capital-skill complementarity may also contribute to the shift in the skill structure of labour demand. This hypothesis states that (general) physical capital is complementary to skilled labour, but a substitute for unskilled labour. On the theoretical side, Caselli (1999) presents a formal model on interactions between technological change and the labour market. The author suggests that if educated workers face smaller costs in the use of new machines than do unskilled workers, it is more likely that new machinery will be assigned to educated workers, who will in turn increase their productivity and hence the demand for educated workers.

Second, organizational change is also a possible explanation for these shifts in demand for types of workers (see Snower 1999; Aghion, Caroli and Garcia-Penalosa, 1999). In particular, the move towards flatter organizational structures with more individual responsibility and autonomy increases the demand for skilled labour. On the theoretical side, Bresnahan (1999) and Snower (1999) present a theoretical analysis of the impact of the information and communication technologies as well as of organizational change on the skill structure of the workforce. Bresnahan (1999) suggests that ICT-enabled changes in work organizations may be more important than the direct effects of computers on employment.

Third, increasing international trade is seen as another factor explaining the shift in the skill structure of labour demand. This hypothesis claims that opening trade with newly industrialized countries puts pressure on the wages of low-skilled workers and shifts aggregate demand to skill-intensive industries. However, it is well-known that the shift in demand towards skilled labour can be explained by within-industry shifts rather than by between-industries shifts. This holds not only for manufacturing, but also for non-manufacturing industries.

International comparisons of the demand for skilled labour were considered by *O'Mahony, Robinson and Vecchi (2004).* This paper presents a cross-country comparative perspective on the impact of information technology on the demand for skilled labour. Over the past 30 years the wage differential between high and low skilled workers has increased in the US and, to a lesser extent, in Europe. At the same time, the number of students entering higher education has been increasing in most developed economies worldwide. These two factors together have led many economists to the conclusion that the skills premium has increased because the demands for skills by modern technology has increased faster than the supply. This paper considers the complementarities between human capital, technology use and technology adoption. This paper examines the relationship between human capital and technology at a disaggregated skill level, across four countries (the UK, the US, France and Germany), using both employment and wage share equations.

This paper uses uniquely diverse and disaggregated data at the industry level in each country, covering the period 1979-2000. These data cover the service sectors, in addition to manufacturing, where the impact of ICT is thought to have been greater. The skills data used in this paper are constructed on a more disaggregated level than found in the existing literature allowing the consideration of the role of technology on the demand for intermediate skills, previously a 'black box' of labour demand. One might expect to see a gradual shift in the demand for labour through the intermediate categories as ICT knowledge becomes more codified and accessible as adoption takes place.

O'Mahony, Robinson and Vecchi (2004) estimate wage and employment share equations, derived from cost and production functions, respectively. Although employment share equations are strictly not capable of identifying skill biased technical progress, they convey some information on the relative demands for different types of workers and their correlation with information technology. In particular, wage share equations may fail to show any relationship with ICT if institutional rigidities or wage setting institutions constrain workers in greater demand from reaping the benefits from their increased demand. Both the employment and the wage shares for each skill group are modelled as a function of the capital-output ratio, which captures the degree of capital skill complementarity, and the ratio of ICT capital to total capital, which captures the impact of ICT capital intensity. Additionally, the wage share equation includes an adoption term, the proportion of IT workers over total employment. It is assumed that these occupations (computer programmers, software engineers etc) are specifically linked to adoption of ICT since they involve very specific skills. But they are less likely to be the skills required to instigate organisational changes in using the new technology. Therefore their impact is expected to decrease over time. The equations are estimated for the full time period and for two subsets dividing into the period up to 1989 and the period thereafter.

The results suggest that employment and wage shares of skilled workers have generally been increased as a result of ICT. Overall employment share equations offer some insights into the pattern of skill use within each country, while the wage share equations do not always provide clear evidence on the impact of technology on skills. Both equations show heterogeneity across different skill groups and changes in the responses of skills to technology over time.

In all countries the lowest skilled workers have suffered a loss of share both in employment and wage terms from the introduction of new technology. These workers have no more than the very basic educational qualifications. The sole exception is the US in the 1990s where the results show a decrease in the rate of relative demand for skilled workers associated with ICT, accompanied by the disappearance of the negative impact on the less skilled workers.

There is also evidence that ICT has had a positive impact not only on the employment and wage bill shares of the highest skilled group, university graduates and above, but also on the higher intermediate group, third level but below degree. The timing of the impacts of new technology vary between countries, with the US showing the largest effect in the 1980s and the European countries showing a greater impact in the 1990s. This is consistent with the later adoption of ICT in Europe, compared to the United States.

Overall, this paper emphasises the fact that skill requirements are likely to change through time. Acemoglu (2002) suggests that the employment structure of the US was so high-skill intensive in the 1960s and 1970s that it created the impetus for high-tech capital adoption, so as to best utilise America's abundant skill resources. In this sense technical progress is endogenous. But it may also be endogenous in the sense that the technology itself may adapt over time to skill endowments and this is likely to vary across country.

The main contribution of *Falk and Koebel (2002)* is a more thorough investigation of the determinants of the demand for heterogeneous labour in Germany. In particular, they aim to identify several determinants of heterogeneous labour demand: the price sensitivity of labour by different skill classes, factor substitution, the impact of both output and capital, the impact of exports as well as technological change measured as the computer hardware capital stock. They use two-digit manufacturing industry data for Germany. Labour is dived into three groups: (i) university graduates, (ii) workers with a certificate from the dual vocational system plus masters and technicians and (iii) unskilled workers.

The main result is that unskilled labour tends to be considerably more responsive to wage rate changes compared with both medium-and high-skilled labour. Furthermore, the results show a strong substitutability relationship between unskilled workers and total materials. There is also evidence on capital-skill complementarity, but capital accumulation only accounts for a small proportion of the employment change of highly skilled workers. In general, the results are robust with respect to the choice of the functional form of the cost function. The translog functional form resulted in higher price elasticities compared with the quadratic functional form or the generalized Leontief.

Falk and Koebel (2002) also analyze the impact of the increased use of purchased services and imported materials on the demand for heterogeneous labour in German manufacturing. A seven-equation factor demand system based on a variant of the generalized Box-Cox function with total capital as fixed factor is specified. The estimates are based on two-digit manufacturing industries from the period 1978-1990. The authors find that the effects of output and capital growth are more important in explaining the demand for heterogeneous labour than substitution effects between either purchased services or imported materials with different skill groups of labour.

Falk and Koebel (2004) present new empirical estimates of the impact of computer capital on the demand for heterogeneous labour. The data consists of panel data on 35 two-digit German industries for the period 1978 -1994. A four-equation input demand system with three types of labour and total intermediate materials as variable factors as well as two types of capital (office machinery and computer capital and general capital) as quasi-fixed factors is derived and estimated. Since functional forms are often data-specific and empirical results sensitive to the choice of the functional form of the cost function, elasticities are calculated using different flexible forms of the cost function such as the generalized Box-Cox, the generalized Leontief, the normalized quadratic as well as the translog functional form. Furthermore, the specifications combine the factor demand systems with a general dynamic adjustment process of each input factor. In particular, multi-equation error-correction models suggested by Anderson and Blundell (1982) are estimated. As noted by Anderson and Blundell (1982), the advantage of these models is that it nests simpler dynamic specifications, such as the partial adjustment model as well as the static model or the model in first differences. To the authors' knowledge, this is the first application of a multi-equation error-correction model assuming a generalized Box-Cox functional form of the cost function. Workers are classified according to whether they have a university degree, a certificate from the dual vocational system including masters and technicians and workers without any formal degree. In this paper the authors also develop new estimates of the office machinery and computer capital stock. US price indices (adjusted for exchange rate changes) are used as deflators for investment in office machinery and computers. The sensitivity of the key elasticities with respect to the deflator for investment in office machinery and computers are examined. Questions concerning the choice of the functional form of the cost function, the choice of the dynamic specification and the stability of the impact of office machinery and computer capital across industries were also addressed.

Estimates using French and US deflators for investment in office machinery and computer imply that the growth in the German office machinery and computer capital stock based on the official office machinery and computer investment deflators is significantly underestimated by about 10 percentage points per year. The empirical results indicate that the accumulation of the office machinery and computer capital is the major factor contributing to the shift in labour demand towards highly skilled workers. Accumulation of office machinery and computer capital accounts for between 60 and 72 percent of the expanding employment of university graduates in manufacturing industries from 1978 to 1994. In non-manufacturing industries, both office machinery and computer capital and general capital accounted for nearly all of the change in the employment of university graduates. Contrary to expectation, the results also show a positive impact of the office machinery and computer capital stock on the demand for unskilled workers. Furthermore, accumulation of general capital tends to reduce unskilled workers. Wage effects and substitution effects between labour and material inputs play a minor role in explaining employment changes of highly skilled and medium-skilled workers, but these effects are more important in explaining the demand for unskilled workers. Finally, the results of the effects of the office machinery and computer capital stock are somewhat sensitive to the choice of the deflator of office machinery and computer investment, which is used to construct the office machinery and computer capital stock. Estimates based on the German deflator significantly underestimate the effect of office machinery and computer capital on the employment of highly skilled workers.

Melka and Nayman (2005) consider the issue of the demand for skilled labour in France. The shift in the share of more educated workers has been explored for France over the 1982-01 period. It was first shown that differentiating supply and demand changes across different categories of labour mattered on account of important composition effects. Thus female and younger educated workers have increased their share of hours worked over the 1995-01 period, reflecting demographic structure changes. The analysis of demand favouring college-educated labour across sectors brings also some insight into the debate about the factor/sector bias of the demand for different types of labour. Demand for college-educated workers has, indeed, mainly increased in sectors already intensive in skilled labour and in ICT investment. This in turn suggests that the sector bias of technological change has driven up the share of college-educated labour.

The econometric analysis provides evidence of skill biased technical change (SBTC) over the 1990-01 period. The model is estimated by the use of Generalised Least Squares applied to panel data from 1990 to 2001 and for two sub-periods: 1990-95 and 1996-2001.The estimation results, significant at the 1 per cent level, support the SBTC thesis. Technological progress, represented by the R&D stock and ICT capital stock, increases the college-educated wage bill share by 2% and 6% respectively. In contrast, non-ICT equipment capital has a negative effect on the college-educated wage bill share. This result (significant at the 1 per cent level) indicates that investment in ICT or non-ICT equipment will not have the same impact. In the first case, the wage bill share of college-educated workers is likely to increase, whereas in the second case, the relative non college-educated share is due to increase.

When fixed effects are introduced, results show that the college-educated wage bill share is higher *ceteris paribus* in some ICT producer and ICT user industries: office accounting and computing machinery, business activities, education, health and social services, printing and publishing. In the office accounting and computing machinery industry, the share of higher college-educated wage bill is the highest. Also, the skill biased technological change is four times as important in ICT producer industries as in other industries. Sectorwise, the impact of SBTC was strongest in the non producing sector in the first period, 1990-95 while the ICT producer sector experienced a larger SBTC effect in the second period the 1996-01 years.

Across education types, ICT capital accumulation and the R&D stock impact favourably the share of college-educated labour, but differently in the producing and using sectors. In the producing sector, the ICT capital stock has a significant and very strong impact on the wage bill share of baccalaureate educated workers. The relationship between the wage bill share and technological change is even higher for this education category than for the highest skill group. On the contrary, in the using industries, the ICT capital stock has a stronger impact on the two year of college group.

A complementary explanation to the increase in skilled wage bill share is international trade. In order to estimate the trade impact on the skilled wage bill share, imports and exports variables are introduced in the regression. The explanation according to which international trade brings about a decrease in the share of unskilled labour does not seem to hold over the nineties. However, allowing for the changing nature of the international trade environment, with growing outsourcing transactions, it would be interesting to add an outsourcing variable to complete the analytical framework.

5.2. The demand for skilled labour: firm level analysis

Falk (2002) provides further evidence for Germany on the relationship between the past introduction of new organisational practices as well as new ICT and employment change. In order to proxy actual employment growth by educational qualifications, employment plans for different skill levels are used. In order to ensure that the results are not affected by potential endogeneity of organizational change in the labour demand equation, a selection equation explaining organizational change is added to the labour demand model. Since the ratio of training expenditures to total wage costs does not directly affect labour demand, it is used as an identifying variable. The results suggest that organisational change has a significant and positive impact on expected employment for all skill groups except for unskilled labour. Controlling for endogeneity of organisational change in the labour demand equations resulted in a larger organisational change effect on employment expectations. Estimation results for the equation explaining organisational change indicate that the introduction of new ICT and the ratio of training expenses to total wage costs are the primary explanatory factors.

Bratti and Matteucci (2005) consider the demand for skilled labour in Italy. The empirical literature on SBTC in Italy is very limited, the main reason being the lack of suitable data. In fact, official supply-side statistics (like the Labour Force Survey) provide a disaggregation of employment by skill levels, but miss the sectoral dimension. On the demand side, instead, the National Accounts data on employment and labour costs, although fairly disaggregated by macro-industry, lack the skill dimension. As a result, for Italy a detailed sectoral test of the skill bias cannot be performed with the data provided by official statistics.

The situation changes partially for micro-data statistics. Among the few contributions, Casavola et al. (1996) have created a panel of 35,174 firms representing the non-agricultural private sector for the period 1986-1990 matching two different datasets: the INPS (National Institute for Social Security) and the private (banking) dataset CADS. Technological capital is expressed by a (perhaps too) comprehensive measure of firm's "intangible assets", which includes software, patents, R&D expenditures and other financial assets; the main dependent variable is the wage bill share of the white-collars. The results seem to point to the specificity of the Italian case for SBTC, whose presence, in any case, is confirmed. First, the "shift and share" analysis highlights that the earnings dispersion of the Italian workforce is mainly explained by the variability of wages within the group of the white-collar workers, and that the white-collar "within" dispersion grows particularly among the most technologically advanced firms. The causal explanation of this evidence is further refined with a regression analysis, with "intangible capital", industry and location dummies and size as regressors. In the cross-section, it emerges that there is a positive impact of technology on the wage bill share of the skilled and that this is mainly driven by changes in employment shares (wage inflexibility). The panel specification confirms that white-collar workers are increasingly demanded in conjunction with a higher technological profile assumed by firms. The authors suggest a few explanations for the limited magnitude of the wage premium for the skilled: a contemporary increase in the supply of skilled labour, the traditional inflexibility of the Italian centralised wage setting systems, and other institutional factors.

Several papers have been based on the (private) Capitalia (formerly Mediocredito Centrale) dataset, covering and representative of manufacturing firms, e.g. Piva and Vivarelli (2002a,b). These papers suggest that no up-skilling trend occurs in Italian manufacturing during 1991-97, but rather a deskilling one. These authors also suggest that the only explanatory variable for SBTC (as measured by the skill ratio of white-collar to blue collar workers) is the occurrence of organisational change. Given the characteristics of Italian manufacturing, *Bratti and Matteucci (2005)* suggest the need to reconsider some problematic aspects of the methodology used by previous literature, which may have crucially impinged on the empirical test of SBTC. Often the variables that should measure technological capital are patently inadequate for capturing a potential SBTC phenomenon, like the use of a simple dummy for the occurrence of R&D activity, which cannot discriminate between innovative and non-innovative firms. Other explanatory factors for the missing evidence on SBTC could also be the "delay" hypothesis (the consideration of an appropriate time period to detect SBTC – David, 1990), and problems of sample distortions or lack of representativeness (for example, it is hard to believe that over the Nineties Italy has experienced an overall deskilling trend).

The point of departure of *Bratti and Matteucci (2005)* has been a detailed reconstruction and update of some basic characteristics of Italian manufacturing. The authors surveyed some descriptive statistics on productive specialization, R&D activities, ICT investment and skill endowments of the workforce in Italy. This examination confirms that the long-term characteristics of the Italian model of specialisation have not changed, and in some cases are even reinforced. Thus due to its persistent specialisation in mature, low-medium R&D intensive sectors and its industrial demography of small and medium sized firms, often located in industrial districts, Italy is a poor absorber of skilled workers. Faced with this background, it is not surprising that the previous literature has not found a pattern of SBTC similar to that detected for other countries. In fact, the subsequent regression analysis has found a number of interesting results.

Bratti and Matteucci (2005) used the same Capitalia dataset (enriched by its most recent wave 1998-2000, see Capitalia, 2002) used by Piva and Vivarelli (2002a,b), and decided to perform the test on the most recent period (1997-2000), so as to end up with a larger (and more representative than before) number of observations (832). This choice also allows the use of monetary variables for both R&D and ICT investment. The econometric framework builds on previous literature. They estimate both long difference and seemingly unrelated regression (SUR) specifications of an employment-share equation, where the skill ratio (non production over production workers) is related to some proxies of the technological intensity of the firms, together with controls for output and total capital. The technological intensity is measured by two different variables: the firm's R&D and ICT investment over turnover. The time-series specification in long differences and the lagged values of the technological intensity helps to minimise the endogeneity and reverse causality bias. The employment share specification shows that R&D and ICT are not significantly related to changes in the skill-ratio. However, when R&D is interacted with Pavitt (1984)'s taxonomy (and disaggregated by destination), the coefficients become significant and different in sign, calling for a differentiated impact of technologies according to Pavitt sectors (and R&D destination)[6].

This analysis is further refined with the SUR estimation, which allows an assessment separately of the effects of technology on the two different components of the skill ratio. In fact, the significance of the previous relation mainly works through the denominator: both the controls (output and capital, positively) and the R&D variable (negatively) are significantly correlated with the production workers stock only. This correlation can be further disentangled with the interaction of R&D with Pavitt sectors: the impact of R&D is negative with respect to traditional (Supplier Dominated) sectors, while it is positive for Scale intensive and Specialised Suppliers. Further, looking at R&D by destination, it is correlated with BC negatively (labour saving effect) if it is devoted to the introduction of new (digital) processes (as typically happens with Italian mature traditional sectors), while it is correlated positively (labour increasing) if it is devoted to the improvement of old processes.

Moreover, ICT is globally not significant, except for Science Based sectors, for which it is positively related to the skill-ratio. Again, given the structural decline of Italian high tech sectors, which are mostly subcontractors or non performing-R&D units of foreign operators, this evidence is not surprising. In fact, the R&D coefficient is not significantly related to the white-collar stock, while the ICT regressor is significant and positive only when interacted with the Science Based sector.

Lucchetti, Staffolani and Sterlacchini (2005) consider the relationships between wages, working hours and the use of computers in the Italian labour market. For this purpose, they use the survey carried out by the Bank of Italy on Italian household budgets which, in the 2000 edition, asked Italian households some questions on computer use at work and computer skills. Such information was not previously available at the individual level, so this is the first attempt to estimate the above relationships for Italy. Their econometric analysis refers to a sample of 3,931 Italian employees.

In the authors' opinion, the estimation methods used so far in the literature (see, in particular, Kreuger, 1993; Author *et al.*, 1999; Freeman, 2002) have to be revised in order to obtain soundly interpretable evidence. Some of the points that were explicitly considered when setting up the empirical models were: better modelling of unobserved heterogeneity between workers in order to avoid spurious effects; possibly different

[6] The Pavitt (1984) taxonomy classifies III-digit sectors according to the kind of innovative activities performed. Four types of industry sectors are found: Supplier Dominated (mainly traditional sectors), Specialized Suppliers (mechanic capital goods sectors), Science Based and Scale Intensive sectors.

impact on computer usage across industries, firm size and qualifications; different levels of computers skills between individuals; possible simultaneity between wages and hours worked. With respect to the issue of unobserved heterogeneity, the cross-sectional dimension of their data set does not allow controlling for whether the changing status of a worker from non-user to user of a computer at work exerts a significant impact on its wage (DiNardo and Pischke,1997; Entorf and Kramarz, 1997 and 1999). However, the authors have tried to take this problem into consideration by inserting into their regressions some controls for ability that that were not used, at least all together, in previous empirical studies.

After analysing the Italian data by statistical procedures similar to those used in the literature, *Lucchetti, Staffolani and Sterlacchini (2005)* found that both the wage premium (5%) and the increase in working time (0.8%) associated with computer use are much lower than those estimated for other countries. However, from a different specification of the wage equation — including control variables for workers' ability and the provision of different effects of computer usage across job types — it emerges that the impact on wages of using a computer at work becomes substantial for higher-level white-collar workers, namely cadres and technicians (14%) and managers (16%). The fact that computer skills are also significant in determining wage differentials reflects a picture in which the outcome of computer usage on wages is less clear-cut than previously thought. Moreover, there is ample evidence that individual characteristics, such as unobserved ability, are a fundamental factor in explaining wage differentials: failure to take this into account may lead to serious biases of the impact of computer-related variables on wages.

6. The impact of regulation on employment and productivity growth

The central issue of this workpackage is whether international differences in the state and pace of market regulation relates to differences in economic performance. This question is posed against the background of the increasing gap between the European Union and the USA in productivity growth of the past decade

From an analytical perspective there are two categories of explanations for these differences in productivity growth rates. Firstly one can look at the direct proximate sources of growth, which include differences in labour force participation, differences in capital intensity, and – within the category of physical capital – the share of ICT versus non-ICT capital. These issues have been treated in previous sections. Secondly, the efficiency by which the factor resources are used, helped by technological and organisational innovation, can play a key role in understanding differences in productivity performance. Efficient use of factor resources relates to the extent of regulation of product, labour and capital markets, competition rules, and supply side policies concerning the physical infrastructure. This second aspect is addressed in this section.

6.1. History of structural reform

Since the early 1980's structural reform programs have been implemented in all OECD countries. Structural reforms refer to regulatory changes and changes in the institutional setting of a country that affect the fundamentals underlying the way in which economic agents operate. Although varying in scale and scope, a common aim of these reforms was, and still is, to improve overall efficiency and flexibility of the economy, i.e. enhancing the adaptability of firms and markets in the face of major economic shocks.

The trend in overall regulatory policy in OECD countries has moved in the last two decades towards deregulation, with an increasing emphasis on promoting competition. It became well accepted that traditional regulatory instruments resulted in severe losses in efficiency due to the entry barriers and possible limitations to innovation they induced.[7] Second, the rapid changes in technology have led policy makers to re-evaluate the traditional regulatory and institutional settings towards regulating natural monopolies.[8] Third, globalisation forced economies to adapt and adjust to changing circumstances. The emergence of free trade areas, like the EU and the NAFTA, added to these circumstances.

In fact, the current regulatory reforms have had three dimensions: (i) liberalisation of prices and market access, (ii) state retrenchment, i.e. returning to the private sector activities that were previously run or controlled by the government and (iii) new regulatory design. Structural reforms in this setting have been the key to shaping competition particularly for service industries, as many services were not exposed to the same extent of competition as manufacturing. Service industries that are notably affected by these reforms are utilities (electricity, gas and water), telecommunications, railways, air travel, road freight and retail trade.

---

[7] It is still an open question whether regulation is indeed detrimental to innovations. The lack of competition induced by regulation may lead to slack within the firm, thereby hampering innovations from being carried out. On the other hand, a regulated environment may provide sufficient resources and create the necessary stable surroundings for a firm to innovate, in comparison to fully competitive markets. Which one of these relations prevails in reality is difficult to assess empirically.

[8] Changing technology in telecommunications for example has brought down entry costs substantially. Here new technology may have been giving rise to deregulation, instead of the other way around. In any case, the deregulation did make it possible for new entrants to stand up and challenge incumbent monopolists, thereby creating both a demand and a supply of new information services (innovations).

6.2. Empirical Evidence

The regulatory environment and its effect on innovation and performance has already received much attention, particularly at the OECD - see Pilat (1997, 2001), Nicoletti (2001), Ahn (2002), Bassanini and Ernst (2002) and Scarpetta et al. (2002). The OECD established a database with internationally comparable data on regulation by country and industry. Nicoletti and Scarpetta (2003) make use of this database to relate the regulatory environment of OECD countries to their productivity growth performance. They provide empirical evidence in favour of a negative relation between product market regulations that curb competition and productivity growth. Regulation is interpreted as privatisation and entry liberalisation. When a similar exercise is performed on manufacturing and service industries in OECD-countries, they find this negative relation mainly pertains to manufacturing and not so much to service industries.

The mechanism behind this negative relation is technology catch-up to international best-practice. Countries lagging in both regulatory reforms and technology adoption are likely to reap the largest productivity gains from deregulation. This means that in order to close the productivity growth gap with the US, European countries should aim at further deregulation of entry restrictions and state control.

Using a different set of regulation indicators, Gust and Marquez (2004) also find that adoption of ICT, which in its turn determines productivity growth, is negatively affected by regulations, particularly in the labour market. Indicators of product market regulation were drawn from the World Economic Forum and labour market regulations were those of the OECD (1999).

Aghion et al. (2002) provide both theoretical and empirical support for the existence of an inverted U-shaped relation between competition and innovation. Since policies of deregulation are designed to enhance competition and since innovation boosts productivity growth, this implies that this U-shaped relation also exists between regulation and productivity growth. In other words, there is some optimal level of competition at which innovation flourishes, or there is an optimal level of regulation to stimulate productivity growth. In this paper the degree of product market competition is measured by the price-cost margin, defined as one minus the Lerner index. Since marginal costs are not observed, price-cost averages are used instead, defined as the operating surplus divided by sales. The number of patents measures innovation.

The mechanism behind this inverted U-shape is the fact that two opposite forces are at work. On the one hand, competition may foster innovations and growth when it reduces a firm’s pre-innovation rents more than the post-innovation rents are reduced. This effect is likely to take place in so-called 'neck-and-neck' industries, i.e. in industries in which oligopolistic firms face similar production costs. The firm with the lower unit costs is referred to as the leader; the higher unit cost firms are the followers. When competition increases in such industries, firms may innovate in order to 'escape' competition. On the other hand more competition may also reduce innovation if the reward for lagging firms is reduced, which is the case in less neck-and neck industries. These two effects lead to an inverted U-shaped relation between competition and innovation.

All studies mentioned so far basically study the effect of regulation on productivity growth on an economy wide scale, while analysis at an industry level is a more promising route to follow. Regulations and changes in regulations differ not only between countries, but also between industries and countries. In an economy-wide study industry-specific effects may easily cancel out.

Another drawback is the fact that the internationally comparable product market regulation data from the OECD Regulation Database refer to only one year. This makes it hard to look at effects of deregulation on innovation and (hence) productivity growth. Other regulation databases have no industry-specific data and were therefore not used. In addition, when industry regulation data are used it is also essential to have an adequate industrial performance indicator corresponding to the same industry detail as regulations relate to. Such internationally comparable performance indicators are not readily available.

Broersma and van Ark (2004) consider cross section evidence based on 15 OECD countries relating regulations in retail trade and aviation in the early 1990's to real output growth in the second half of the 1990's. The results show that deregulation corresponds to higher output growth rates. For a number of other industries that were put to the test comparable performance measures, in terms of output growth or productivity growth, were not available. Of some of the alternative performance measures only deregulation in mobile telecommunication was positively related to real revenue growth.

The industry labour productivity database referred to in section 3 above was used in an attempt to get more time series information on internationally comparable regulation data. The regulatory status of an industry was measured by the price-cost average, like Aghion et al (2002), defined as the operating surplus divided by production, and performance was measured as real productivity growth. In order to avoid simultaneity bias, industry labour productivity growth was regressed on industry price-cost averages lagged two periods. It is natural to assume a substantial period of time before deregulations start to have an effect.

The authors wanted to test whether there was any evidence of an inverted U-shaped relation between regulation and future productivity growth. They found that only for retail trade and utility services there is some evidence of this U-shape. For the other industries they did not find evidence of a strong relationship between regulation and productivity. The main reason for this is the fact that there are hardly appropriate data with which a relation between regulation and performance at industry level can adequately be tested. The price-cost average used is a crude measure, which in a broad sense relates to the extent of competition on the market that the industry operates on. Moreover, the level of detail for which data are available is still not enough to represent the state of regulation in a specific market. Industries beneath the 2-digit industry ISIC level, like telecommunications, road freight or electricity generation cannot be distinguished when price-cost averages are calculated, while these industries do face deregulation specific to them. Thus better data are required to pick up these effects.

6.3. Regulation in the trade sector

McGuckin, Spiegelman and Van Ark (2003) consider the details of the regulatory issues that might explain the differing productivity performance in the US and European distributive trade sectors. These include general regulatory obstacles and those that have slowed complementary change. First the authors suggest that European firms in this sector are less competitive, hindering the adoption of new technology. The authors also suggest that Europe’s regulatory environment has slowed productivity growth in distribution through two channels: regulation within individual countries restricts competition and *differences* in regulation inhibit smooth cross-border operations in distributive trades and the associated gains from scale.

The authors identify a number of specific regulations that impact on adoption of technology and hence productivity improvements in Europe. Chief of these are regulations regarding store opening hours and land use. Restricted store opening hours make it less attractive for customers to use new modern retail formats and therefore cuts the incentives to build them. The US had largely taken a decentralised market driven approach to retail development, with new shopping centres frequently opening and old ones closing. European countries tend to be generally more restrictive in allowing land to be used to create new shopping outlets. There are two major channels by which restrictions on land use impact on productivity. The first is that it limits entry and exit. In the US there is evidence that nearly all of the increased growth in retail productivity is from new stores replacing old ones. In addition, less productive old stores are less likely to go out of business. Secondly land use regulations impact on the ability to exploit economies of scale. Large store size is required for the most efficient use of capital and labour and adoption of new technologies as discussed above.

In terms of slower complementary change the authors identify the fact that Europe's trucking industry was deregulated only in the mid-1990s, which slowed many of the shipping adjustments made in the US in a much earlier period. The adoption of scanners and bar codes enabled more frequent inventory measurement and stores could use this information to rapidly construct orders that matched what was being sold. This led to a demand for more frequent delivery. Deregulation of the trucking industry was important in facilitating this process.

6.4. Labour market regulations

Inklaar and Timmer (2004) investigate the job-rich growth in Europe in the late 1990s in the context of employment regulations. In most European countries, GDP growth has been coupled with sluggish employment growth and high unemployment rates since the early 1970s. But since the 1990s employment outcomes have diverged sharply. Countries can be split between those that have increased the labour-intensity, or job-richness, of growth and those where it remains persistently low or even negative. The latter group notably includes the three largest continental economies, France, Germany and Italy. At the same time, some of the smaller European countries were more successful and have vigorously introduced labour market reforms. Therefore it seems natural to ask how much of the divergence in labour-intensity of growth among European countries can be explained by differences in labour market institutions. A large body of literature exists that identify labour market institutions as an important source of differences in unemployment rates across countries (Nickell and Layard, 1999). Less attention has been devoted to explaining countries' relative performance in terms of employment growth. In a recent study, Garibaldi and Mauro (2002) argue that high employment growth after 1995 was not due to a cyclical upswing, but instead reflects structural improvements in the functioning of labour markets in Europe, although they do admit that these twin effects are hard to disentangle. *Inklaar and Timmer(2004)* present evidence that allows for somewhat sharper conclusions. Specifically, the paper shows that some portion of the employment acceleration after 1995 is indeed likely to be cyclical. This cyclical effect is strengthened in liberalising countries. The paper presents evidence that lower levels of employment protection may have contributed to increased cyclical variability of employment. The authors also find a minor role for wage moderation. This means that in countries with higher levels of employment protection legislation (EPL) labour demand is less responsive to both wages and output growth. These findings leave less room for structural reforms as an explanation. This is important as in the structural reform view accelerating employment growth will be permanent. In the cyclical view, reforms have only led to increased volatility of labour demand with no medium-term effect on employment. These results suggest that especially EPL reduces the responsiveness of employment to changes in economic circumstances. Hence countries with lower EPL will have higher employment growth during expansions, but lower employment growth during recessions.

7. Analysis based on microdata

While industry data are useful in developing the overall picture, the level of detail in micro data sets can provide a wider and more complete picture of the way firms have responded to changes in the economic environment and to the ICT revolution. The availability of information on R&D investment and firm size, for example, will allow a closer examination of whether the productivity slowdown has been a general phenomenon or whether it has affected R&D and non R&D performers to a different extent. Matching surveys at the microeconomic level on e.g. use of e-commerce, employment of skilled labour etc. can bring out relationships obscured by industry analysis. Two strands of research using micro firm level data were undertaken in the EPKE project, the first using international companies accounts data and the second matching firm data sets within countries. These are considered in turn.

7.1. Analysis of company accounts data

Rincon and Vecchi (2003) analyse productivity change at the micro-economic level using a large sample of companies across different industries and countries (US, EU-15 and Japan). The first objective of this research was to ascertain if the results are broadly consistent with industry analyses undertaken in other parts of the project. The second objective was to determine if focusing on the firm dimension can highlight additional factors explaining productivity growth not apparent in industry data. The level of detail in the company accounts data set used in this study can provide a broader and more complete picture of the way firms have responded to changes in the economic environment and to the ICT revolution.

The availability of information on R&D investment and firm size, for example, allows a closer examination of whether the productivity slowdown has been a general phenomenon or whether it has affected R&D and non R&D performers to a different extent. There is a large literature on the relationship between R&D and productivity, with the general conclusion that R&D investments affect productivity positively, both directly, that is via the firm’s own investments, and indirectly via spillover effects. Information on R&D is complemented with information on the size distribution of the companies in the sample. This is in order to have a more in-depth analysis of the industry structure in the various countries and to see whether size matters, in terms of productivity performance and R&D investments. Small enterprises are generally more flexible and so might be more able to adapt to changes in technologies and in the general economic environment. On the other hand, larger firms have more resources to devote to R&D investments and therefore the interaction between R&D and size can underline some interesting patterns.

The analysis at the company level also uses information at the industry level on ICT intensity, innovation and skills by using the taxonomies developed in other parts of the EPKE project. Better performance of companies operating in say ICT intensive sectors can be considered evidence of the presence of technological spillovers/externalities. A range of methods to account for spillovers can be found in the literature. Here the approach of Griliches (1992) is followed, considering the technical similarities across firms as a source of externalities. According to this, all companies in the data set are mapped into the various taxonomies. Companies belonging to the same taxonomy group can be defined as similar and this can aid in identifying spillover effects. The essence of a spillover effect is that the research carried out by other firms may allow a given firm to achieve results with less investment effort (Jaffe 1986). If a firm operates in a high technology environment, it is more likely to absorb new developments quickly and to boost productivity further.

The analysis of the impact of R&D on productivity growth indicates that in the US the returns to R&D capital are high and positive in all sectors, including services. In manufacturing, as well as in services a 1% increase in R&D invested by the companies produces roughly a 0.16% increase in output growth. This result is consistent with existing estimates for the US (Schankerman, 1981; Griliches and Mairesse, 1984; O’Mahony and Vecchi, 2002). Estimations were carried out both for the entire EU-15 sample of companies, and for those located in the three largest economies (Germany, France and the UK), hereafter termed EU-3. In the estimations for the EU, positive returns to R&D were found only for the EU-3 group of countries. The return to R&D in the manufacturing sector is nearly 20% whereas in the service sector the R&D capital did not have a significant impact on productivity. These conclusions change when tests were carried out for a possible structural break after 1995, which gives a more comprehensive picture of EU relative performance across the two halves of the 1990s. The results show a post-1995 decrease in productivity in the manufacturing sector in the EU but no negative impacts in the EU-3 countries. As for the service sector, there is some improvement in productivity after 1995 and a significantly higher R&D coefficient in the

EU-15. This shows that some additional benefit from investment in R&D is occurring in services in the more recent years, probably fostered by the more intensive use of ICT. This result is consistent with the notion that the EU is in the process of catching up with the US in the ICT revolution. Also, this change emerges only for the total EU-15, and not for the EU-3 group of larger countries, so it is likely to be driven by countries like Sweden and Finland that have highly invested in R&D and in ICT. In the US, there was a decrease in productivity in manufacturing after 1995, but not in the service sectors. The US results also show a significantly higher impact of R&D on productivity in the service sector after 1995. The results for Japan differ from those for the EU and US, primarily the non-significant impact of R&D on productivity. This seems at odds with Japan's well-known reputation as a high R&D investor, especially in the high tech sectors of the economy. However, similar results have already been found in previous studies (Sassenou 1988, Mairesse and Sassenou 1991).

Rincon and Vecchi (2003) also consider the impact of firm size on productivity. In the EU, the size variables do not show any particular pattern in manufacturing. In the service sector, the size dummies do pick up a higher productivity growth in the small (less than 250 employees) and intermediate companies (between 250 and 1000 employees) compared to the large ones, when considering the basic production function with no R&D capital. When R&D is included in the specification, intermediate sized firms enjoy higher productivity compared to the other two size groups in both EU-15 and EU-3. In the US, small companies and intermediate companies are more productive in manufacturing while only the small ones enjoy productivity gains in the service sectors. The different returns to R&D, capital and employment by size group were also analysed. In manufacturing, the returns to R&D in the large establishments are particularly high in the EU-3 and US. Also there are significantly negative returns to R&D in the intermediate companies in the EU-3 countries. In services, in the US the groups of intermediate companies experience very high returns to R&D, suggesting that innovative activity among these firms is an important driver of US productivity growth. In terms of achieving productivity gains, small to intermediate size firms seem to be more successful than larger firms, especially in the service sector. These findings are in accordance with the literature on firm dynamics that suggest that a substantial part of the productivity growth within an industry are generated by factors outside the firm, such as the dynamics of entry and exit of firms. The entering firms are usually more productive although their market shares are generally low, and the exiting firms are the most inefficient ones.

As regards the role of industry taxonomies, the results indicate that companies operating in the ICT production industries enjoy quite substantial productivity gains of around 4%.

Considering the total sample of companies, in the US and Japan the returns are higher in ICT producing manufacturing than in the ICT Producing services, while for EU-15 and EU-3 the returns are higher in ICT Producing services than in ICT Producing manufacturing. No significant gain, or even a negative impact, is experienced by those companies operating in the ICT using services sectors. Only when engaging in R&D activities, do US firms in ICT using services appear to have a productivity advantage.

Rincon and Vecchi (2004) extend this analysis further to consider the impact of ICT spillovers on company performance. There is increasing evidence that ICT investments have fostered important organisational changes within firms and such changes have had an important impact on productivity performance (Brynjolfsson and Hitt 1996, 2000, Black and Lynch 2001). Also, recent models of growth resulting from general-purpose technologies point to ICT as a source of generating spillover effects (Bresnahan and Trajtenberg 1995, Helpman 1998).

This paper analyses the impact of ICT spillovers on companies' performance using company account data for the US and four European countries (UK, Germany, France and Netherlands) for the period 1991-2001, which includes the period of the United States productivity surge. As stated above the literature to date has emphasised the considerable impact on output growth from ICT capital deepening. More recently the debate has moved beyond the narrow focus on ICT capital deepening to consider the nature of this new technology and its relationship to complementary investments. ICT is now seen as an example of a general purpose technology (GPT), which requires substantial investment in complementary capital or new intermediate inputs, such as training and work re-organisation (Aghion and Howitt 1998). Computers have not just changed the way production works but many day-to-day activities have been transformed by the 'ICT revolution'.

The GPT story stresses the importance of ICT spillovers and the different ways in which they originate. For example, the re-organisation of the production process within firms can be considered the result of a learning-by-doing process. The more is invested in ICT, the more firms learn about their potential applications which makes it possible to re-organise production in a more efficient way. ICT is also a source of 'pecuniary spillovers' (Griliches 1990) as the combination of innovation in the ICT producing sector and competition has allowed computer-using industries to benefit from lower costs. In addition to these 'vertical' externalities it is also possible to identify 'horizontal' ones, related to the sharing of the GPT among a large number of sectors. This links "the interests of players in different application sectors, and is an immediate consequence of generality of purpose" (Bresnahan and Trajtenberg 1995). An additional source of spillovers is the increased efficiency of transactions among firms using ICT technology. Rowlatt (2001) and Criscuolo and Waldron (2003) argue that the use of Electronic Data Interchange (EDI), internet-based procurement systems and other inter-organisational information systems produce a reduction in administrative costs, search costs, and better supply chain management. While the theoretical importance of ICT spillovers has been widely recognised, the empirical evidence only offers a few examples (Brynjolfsson and Hitt 2000, Van Leeuwen and van der Wiel 2003).

In their paper, Rincon and Vecchi (2004) adopted a traditional approach in measuring spillover effects, which consists of modelling the output of a single firm as a function of its own inputs and an index of aggregate activity (Helpman 1984, Caballero and Lyons 1989,1990, Vecchi 2000). It evaluated whether companies' productivity performance is affected by the total stock of ICT capital within each industry and whether different ICT aggregates produce different results. Aggregate ICT at the industry level represents spillovers within the industry (vertical spillovers). In order to account for the presence of spillover across different industries (horizontal spillovers), a wider ICT aggregate was constructed. The latter grouped industries based on whether they produce ICT or use ICT more or less intensively, following the taxonomies discussed in section 3. This measure aims at capturing spillover effects across companies operating in different industries but sharing a common ICT adoption pattern. The results support the existence of both vertical/horizontal spillover effects both in the US and EU, as emphasised in the GPT literature (Bresnahan and Trajtenberg 1995). However, while in the US the vertical spillovers are stronger than the horizontal ones, the reverse conclusion was found for Europe.

This paper also investigated if the difference in productivity performance in the EU and US can be attributed to the different timing in the implementation of ICT technology and a different impact of ICT spillovers. It may take some time for ICT to impact on production because of the complementary investments involved in the implementation of this technology. The lags might be even longer for the generation of spillover effects. The results suggest that in the US both the short-run and the long-run spillover effect is positive and significant, with a larger impact in the long run, particularly in the manufacturing sector. As in previous related studies, the authors find evidence that the European group of the follower countries in implementing the new technology, might still be lagging behind the US in terms of obtaining a pay-off from investments in ICT. This is shown in the short run estimates, where the impact of ICT spillovers was not found to be significantly different from zero. The lack of spillover effect in Europe is consistent with the later adoption of ICT compared to the US. Despite the catching-up in ICT diffusion in Europe, the existing evidence shows that there have been few productivity gains (Daveri

2002). However, in the long-run results, ICT spillovers are positive and significant, especially when considering the spillovers from the US. Therefore the results show that ICT spillovers affect productivity differently in the US and in Europe in the short run but in the long run such differences are less profound.

This paper thus introduced some dynamics in the evaluation of the spillover effect and the results support the GPT implication about the timing of the impact of a new technology on productivity. Specifically it suggests that in the long run more can be gained by increasing the stock of ICT capital in the economy, which creates important spillover effects. Considering the dynamics of external impacts, rather than the conventional focus on the contemporaneous effect (e.g. Sena 2004), yields interesting conclusions. Thus it supports findings from other analyses carried out in the EPKE project on the need to model the dynamics of process of the adoption and diffusion of ICT.

7.2. Analysis of country specific firm data

This section considers firm level evidence to answer a number of questions. First it is concerned with evidence on the productivity impacts of the usage of information technology. It then considers what are the mechanisms through which increases in productivity are achieved and what is the impact on input use. Specifically it looks at issues relating to complementary investment and the demand for skilled labour and the productivity impacts of inputs of the use of internet and other electronic connections. The evidence presented relates to four of the partner countries, France, Germany, Italy and the UK

Firm level evidence: France

Biscourp et al. (2002) address the issue of ICT and productivity in France under the interesting angle of the impact of a decrease in computer prices on the marginal cost of firms (a measure of firm productivity), the demand for aggregate labour and the skill structure. Contrary to most studies that use labour demand equations to assess the complementarity between computers and skills, they derive their panel estimates from a translog production function, based on a large sample of French firms (around 5000) followed between 1994 and 1997. Several tests are performed in order to choose a preferred estimation method among the within, between, long differences and GMM estimators. More plausible results were obtained using the within estimator and so it was chosen as the estimating method.

The results are presented in terms of quantiles of the measure of the supply shock associated with the variation in the price of computers - a fall in the price of computer by fifteen per cent per year between 1990 and 1999 involves a decrease in the marginal cost of the median firm by 0.75%. The elasticity of production to computers relative to the elasticity of scale (that is the sum of all elasticities of production to the various inputs) is much lower than this elasticity divided by its share: it could mean according to the authors that excess returns to computers are important or that the effect of unobserved variables such as reorganisation is bundled with the elasticity to the computer price.

The authors find that the price elasticity is not very different from –1. Since the elasticity of unskilled labour to the price of computers is significantly positive (the median value is at 0.15) and the one of skilled labour is negative (median value is –0.08), the decrease in the price of computers then means that firms increase the intensity of production in computers and skilled workers and simultaneously decrease the use of unskilled workers. The effect on aggregate labour of a fall in the price of computers shows then that capital accumulation is biased towards capital against labour. Moreover, this effect is negative for the median firm.

In France, the ratio of skilled to unskilled labour has increased by 2.2% per year between 1990 and 1999 and the relative cost of skilled to unskilled has slightly decreased by 0.03% per year on average. The shift in the relative demand for skills can then be evaluated at 2.1%. It is also shown that the skill bias is greater when estimated with a production function than with labour demand equations. Moreover, the skill bias is larger in the manufacturing sector than in the non manufacturing one.

To sum up, the impact of IT on firm productivity is rather small but the redistributive effect is notably strong within the workforce. Moreover, the elasticity of production to computers is above their cost share suggesting the presence of unobserved inputs correlated with computer stocks such as an organisational change or new technologies incorporated in capital goods.

These results are consistent with other firm level evidence for France. For example Mairesse, Greenan and Topiol-Bensaid (2001) examine five IT and R&D indicators in four panel data samples of French manufacturing and services firms (about 5500 firms in the whole sample) over the 1986-90 and 1990-94 periods. They find that the IT and R&D estimates are significant in the cross-sectional dimension of the data but not so in the time dimension. One significant finding is the decrease in the share of blue workers induced by an increase in IT labour in manufacturing and also in services. Nonetheless, in the cross-sectional dimension (between effect), there exists some strong evidence of a positive and significant correlation between productivity and average wage on the one hand and the five IT and R&D indicators on the other hand.

These authors suggest that the impact of IT on wages amounts to 6.9% over the 86-90 period and 8.8% over 1990-94 and to 10.9% and 14% respectively on TFP in the manufacturing sector. In the service sector, the impact of IT on TFP increases to 16.2% and 18.8% over the two periods respectively. The impact of R&D is much smaller and of about the same magnitude on wage and TFP: around 4.5% in the manufacturing sector and 2.6% in services. There is also significant evidence of a correlation with the skill composition, as IT impacts on the blue collar workers range from –12% in manufacturing to –8% in services and as R&D impacts reach 7% in manufacturing and –1% in services.

Overall, these cross-sectional results are consistent with those found in the literature on American firms (Lichtenberg, 1995; Brynjolfsson and Hitt, 1995; Lehr and Lichtenberg, 1999; Greenan and Mairesse, 2000; Black and Lynch, 2001; Doms, Dunne and Troske, 1997; Dunne, Foster, Haltiwanger and Troske, 2000) as to the impact of the use of ICT on productivity. In the time dimension, results generally found in other studies (unlike the ones by Brynjolfsson and Hitt, 1995; Lehr and Lichtenberg, 1999; Siegel, 1997) confirm the lack of evidence on the link between IT indicators and productivity growth whereas the finding of significant and negative correlations between IT indicators and the share of blue collars is not shared in all studies. Goux and Maurin (1997) for example find an opposite result on French industry data.

Crépon, Heckel and Riedinger (2003) investigate the respective link between the use of internet, the adoption of a computer network and the performance of Electronic Data Interchange with suppliers or customers on the one hand and the Solow residual and the individual input productivities on the other hand by using a panel of about 3700 firms between 1994 and 1997. Heterogeneity is then allowed for: IT adoption does not homogeneously impact on inputs' efficiency. Moreover, the interaction of IT use with organisational changes is introduced in the regressions since the adoption of IT and organisational may be complementary.

The research was implemented on the *Changements Organisationnels et Informatisation* (COI) survey described at length in Gollac, Greenan and Hamon-Cholet (2000). This survey was merged with a firm level file *Bénéfices Réels Normaux* (BRN) and with a file documenting employees *Déclarations Annuelles de Données Sociales* (DADS). A number of different specifications were estimated. IT adoption variables were estimated either separately or together. Regressions were also performed either with or without control variables (firm size, industry to which the firm belongs, the Herfindahl index of the industry concentration, the share of production exported and a dummy variable indicating whether the firm belongs to a group).

The result that stands out is that only internet is significantly correlated with firm performances. For example, the increase in internet use induces a change in the Solow residual by 1.3%, in capital productivity by 7%, in the K/L ratio by –5% and in the labour quality ratio by 3% without control variables whether the regressions are pooled or separate. Including control variables, the correlation is then positive between internet and labour (5%) and capital (6%) productivities and not material productivity suggesting internet does not affect inputs in the same way.

As network or EDI effects are not significant, the paper then considers whether there exists a complementarity between IT and new organisation practices. The Solow residual is then augmented with two additional variables: the type of organisation and the type of organisation interacted with IT adoption. As none of the parameters is significantly positive, the assumption that gains from IT adoption depend on the type of organisation within the firm is not confirmed in this study.

IT adoption variables are then interacted with input shares. Internet improves labour efficiency by ten per cent and the Solow residual by about three per cent. The use of a network increases capital efficiency by about 12% at a 10% level of confidence. The efficiency of age, skills and gender categories are then regressed on the three IT adoption variables. The impact is strongly heterogeneous across the workforce. Internet adoption increases the efficiency of skilled (by 25%) and female workers (by 12%) and decreases the one of unskilled workers (by 36%). The use of a network increases the efficiency of older workers by 43% and the one of the unskilled by 19%. As to EDI, it impacts positively on the efficiency of the youngest (under 30 years old) and has a negative effect on the one of the 30-40 age bracket. To sum up, in this paper too, the effect of IT adoption on the Solow residual is found to be small, and only through adoption of the internet. The efficiency of skilled and female workers is mainly affected by the use of internet and the one of young workers by the adoption of EDI.

Firm level evidence: Germany

Zwick 2003 considers firm level evidence for Germany. After the advent of the representative German establishment and firm data sets that include relevant information on ICT investments and production, several authors investigated the impact of ICT investments on establishment or firm productivity. The main data sets used for these analyses are the IAB establishment panel (see Kölling, 2000 for further information) and the Mannheim Innovation Panel (see Janz et al., 2001).

Zwick (2003) finds substantial effects of ICT investments on establishment productivity using a Cobb-Douglas production function: the fact that an establishment invested in ICT in 1996/97 increased average establishment productivity in 1997-2000 by almost 100%. In contrast to the bulk of the literature also establishments without ICT capital are included and lagged effects of ICT investments are analysed in this paper. In addition, a broad range of establishment and employee characteristics are taken account of in order to avoid omitted variable bias. It is shown that taking into account unobserved heterogeneity of the establishments by using system GMM panel estimation techniques increases the estimated lagged productivity impact of ICT investments. Also the endogeneity of ICT investments is corrected by introducing an instrumental variables estimation with external instruments. This correction also increases the estimated productivity impact of ICT. *Zwick* uses the waves 1997-2001 of the IAB establishment panel for this analysis. Hempell (2004a) also finds a high net-rate of return to ICT investments of more than 50% on the basis of the Mannheim Innovation Panel in Services. He uses a translog production function including non-ICT capital, ICT capital and labour, and corrects the endogeneity of ICT intensity and unobserved heterogeneity by using system GMM estimations. Controlling for unobserved heterogeneity reduces the coefficient of ICT capital and it is no longer significant. When endogeneity is also taken into account, however, the measured productivity effect increases again. Also on the basis of the Mannheim Innovation Panel, Licht and Moch (1999) find a very high impact of personal computers on productivity, while the impact of ICT investments on productivity is smaller. Bertschek and Kaiser (2004) find similarly high impacts of ICT investments on productivity in a comparable econometric setting using the German "Service Sector Business Survey" (see Kaiser, Kreuter and Niggemann, 2000 for further information).

Wolf and Zwick (2002) and *Zwick (2003)* do not find positive interaction effects on productivity between training, reorganisations that increase employee participation and decentralize decisions on the one hand, and ICT investments on the other hand. This may be a consequence of imprecise measurement, however, because only dummies are available for training, changes in organisation and ICT investment. Hempell (2003) shows that training aimed at the usage of recent ICT investments increases the productivity impact of ICT investments. This effect is confined to firms with a high share of highly qualified employees, however. Hempell (2004b) argues that ICT investment is closely linked to complementary non-ICT innovations and most productive in firms with innovative experience.

Using firm or establishment level data, EPKE members pursued some related research on the productivity effects of certain management measures. The following research is all based on the IAB establishment panel. *Zwick (2002a)* demonstrates that an increase in training intensity from no employees participating in training to all employees participating in training in 1997 would increase average productivity by 17% in the years 1997-2000. In this paper, again unobserved establishment heterogeneity and endogeneity of the training decision is corrected for. The effect is mainly driven by the positive productivity impact that can be realized in establishments with a works council *(Zwick, 2004b)*. Works councils have a say in who gets training and how much training is offered and obviously this increases the effectiveness of training measures. *Zwick (2005)* shows that not all training forms have positive productivity effects. The highest productivity impact can be observed for external formal training measures followed by internal formal training measures and quality circles. Self-induced learning, participation at seminars and talks, and job rotation do not enhance productivity while training on the job even has a negative productivity impact.

Wolf and Zwick (2002) show that an increase in the participation of employees such as a reduction in hierarchies, or the introduction of teamwork or autonomous work groups increases establishment productivity while financial incentives do not have any impact on establishment productivity. *Zwick (2004a)* stresses that the positive impact of higher employee participation on productivity is mainly enjoyed by establishments with a works council. The reason may be that works councils can help to reduce anxieties and employee resistance against organizational changes. Employee resistance is higher against organizational changes than against other innovations such as product or process innovations (*Zwick, 2002b*). Both papers take account of endogeneity in the introduction of measures and time-invariant unobserved establishment heterogeneity.

<u>Firm level evidence: Italy</u>

Matteucci and Sterlacchini (2004) review the literature on this topic for Italy. Longitudinal micro-datasets providing evidence on ICT investment are still in short supply for Italy. The most representative truly longitudinal firm-level dataset is that drawn from the Survey on Firms Accounts maintained by ISTAT, but its data are not released in a disaggregated form to external researchers. Milana and Zeli (2004) have used this dataset to perform a firm-level analysis on the causes of the purported TFP slow-down of Italy in the last decade. For a descriptive industry-level assessment, they construct a TFP growth index for each industry over 1996-99, which is measured as a weighted average of the firms' TFP growth rates - technically, a Malmqvist index of TFP constructed with DEA techniques. In theory this index can be decomposed into the shift of the technological frontier (technological change) and the changes in the firms' distance from this frontier (technical efficiency). However, based on Milana and Zeli (2004) evidence, for the Italian economy this would imply that over 1996-99 the average TFP has decreased (-0.0039); this should be manly due to the technological change component (-0.0096), which has been only partially compensated by the technical efficiency increase (0.0057).

With the exception of the Milana and Zeli (2004) study, for Italy it is not possible to reconstruct a reliable indicator of ICT capital stock at the firm-level. Consequently, the only alternative, still unexplored in the literature, is that of using intensity measures of ICT investment, as previously done with R&D. In this way, one can interpret the coefficients of R&D and ICT as "excess rate of return".

Matteucci and Sterlacchini (2004) use the Capitalia dataset, previously known for those studies assessing the impact of R&D on productivity. At the descriptive level this shows over the period 1995-00 a small decline in the R&D and ICT intensities (both calculated over value added). Moreover, between the period 1995-97 and that of 1998-2000, the internal composition of the ICT investment shifts towards the telecommunications component, both on average and across sectors.

They then calculate the firm's TFP index of productivity imposing constant returns to the two conventional inputs (capital and labour), and perform regression analysis on two different samples. First, they exploit the times-series dimension of the data (data in long-differences) maximising the number of observations. In the estimated equation the log variation of TFP is regressed over the intensity of R&D and that of ICT investment. Additionally, controls are included for size (log workers), the occurrence of corporate transformations (like mergers and acquisitions) and industry effects (sectoral dummies).

The results show a significant and positive correlation between the change in TFP and the R&D intensity; instead, ICT is barely significant, and its coefficient is very low. However, in this formulation the problem of endogeneity of ICT investment and reverse causality could be non negligible, since data on ICT investment refer de facto to the same wave in which the variation in the TFP is observed.

To minimise this possible bias, the authors then estimate a similar long-difference equation only for the firms which are present in both waves of the Survey, so that the dependent variable is referred to the 1998-2000 period while both the explanatory variables are lagged (and hence predetermined). The result previously found for R&D is confirmed, while the ICT investment intensity becomes significant at the 5% level (and bigger in size), even after controlling for industry effects. To sum up, the provisional evidence available for Italy shows that there is a significant correlation between the firm’s effort devoted to technological capital and its TFP performance, independently from individual and industry fixed effects.

The main purpose of *Lucchetti and Sterlacchini (2004)* was to carry out an empirical analysis on the adoption and effective use of Information and Communication Technologies (ICT) among a sample of Italian SMEs. Different indicators are used and discussed and, by means of firm-level regression analyses, an attempt is made to built a taxonomy of ICT based on their typical function and the main determinants of their usage. Under the label ‘ICT’ there is a wide range of technologies which are different in terms of cost and skill requirements and, as a consequence, a comprehensive set of adoption indicators are needed. In fact, there are a number of studies based on simple measures of ICT adoption, but only a few (see e.g. Bakker, 2000; Falk, 2001) have used comprehensive and sophisticated indicators such as those employed in this paper.

Data are derived from a survey concerned with the firms located in the Ancona Province (Central Italy, Marche Region). The reference population amount to 514 firms: 456 in manufacturing and 58 in business services. Small and medium sized enterprises account for 95% of the population. Although not fully representative in a statistically rigorous sense, this study provides a good representation of the manufacturing and business services activities located in Northern and Central Italy, which include the most developed regions of the country.

The questionnaire submitted to the sampled firms – which followed very closely that used earlier by Statistics Canada (1999) – was composed of three sections. The first was devoted to the firm's characteristics whereas the second referred specifically to ICT and different indicators of adoption and effective use are collected. Moreover, in order to have a realistic picture of the Web sites' presence and features, the answers of the firms were checked ex-post by visiting their sites. Finally, the third section was concerned with the occupational structure of the firms: data on employees was broken down not only by level of education but also by firm function.

After a descriptive analysis of the results and some international comparisons, principal component and Tobit regressions analyses were carried out with firm level data in order to build a taxonomy of different ICT and find the main determinants of their adoption. Thus, from a theoretical point of view, this study follows a rank (or probit) model of technology diffusion (Karshenas and Stoneman, 1995; Geroski, 2000). This assumes that potential adopters differ from each other in many characteristics so that the expected benefits from (and, thus, the probability of) adopting a new technology may differ significantly.

Tobit regressions were chosen to take into account the fact that many SMEs did not adopt any ICT more complex than those of general use (e-mail and Internet access). From a methodological point of you, it was found that a good indicator of the effective use of e-mail and the Internet is provided by the share of non production workers having access to them rather than the share of total workers; the latter measure, in fact, is influenced by the functional and educational distribution of employees (cf. Berman *et al.*, 1994). The main findings of the empirical analysis can be well summarised by the following taxonomy of ICTs.

General-use ICT: include e-mail and Internet; simple rates of adoption are very high and do not depend on size (i.e. number of employees) and industry. When the rate of effective use is measured by the share of total employees with access to these ICTs, the percentages of educated workers exert a positive effect and, in the case of the Internet, a negative impact of size emerges. However, when the occupational structure of the firms is taken into account - by defining the rate of effective use as the percentage of non production workers with access to e-mail and the Internet - the influences of size and education vanish and only industry effects are relevant.

Production-integrating ICT: include LAN, EDI and Intranet; these ICT are linked to production processes either carried out within the firm or based on inter-firm relationships; they are more expensive than general-use ICT and require relevant technological skills (often internal to the firms). A composite indicator of production-integrating ICT, used as the dependent variable of a Tobit regression, turns out to be significantly and positively associated with firm size, the use of CAD and CAD-CAM technologies, the nature of the firm as subcontractor and the share of employees with secondary and, especially, university education.

Market-oriented ICT: they are jointly identified by the presence and the content of a firm's Web site; analysis of the content show that Web sites are mainly used to improve the firms' visibility and to provide detailed information on their products, with a view to enlarge potential customers. On the other hand, e-commerce in a strict sense (identified by the possibility of on-line ordering) is extremely rare. Tobit estimates show that the use of market-oriented ICT does not depend on a firm's size or its productive or technological features, but raises when the firm is an exporter, is present in foreign markets with commercial branches and employs a relevant share of workers with university education.

<u>Firm level evidence: UK</u>

*Rincon, Robinson and Vecchi (*2004) turn to the evaluation of the indirect or network impact that ICT has on productivity. The use of computers have radically changed the way of undertaking businesses, for example by making available a large amount of information, improving commercial communication through access to wider markets and improving the efficiency of business processes (Clayton and Criscuolo 2002). This study specifically focuses on the impact of e-commerce on the productivity of enterprises in the UK, using survey data from two sources: the Annual Business Inquiry (ABI), which contains financial information on 'reporting units' in both the manufacturing and service sectors, and the 2001 e-commerce survey. The latter has been specifically designed to elicit information about reporting units' use of the internet in their production processes. The paper looks at the way firms use the internet, the factors that affect their choice to carry out transactions over the Internet and how the choice of operating via the Web affects sales

The use of computers and websites is very widespread in UK enterprises, but not a very large percentage uses the Internet for placing or receiving orders. Around 35.48 percent of production companies and 39 percent of service enterprises are engaged in buying over the internet, while the figure for selling over the internet is much lower, 14 and 21.44 per cent, respectively for production and services. However, looking at trading on the Internet is of particular interest for at least two reasons: it is an area of considerable expansion in some industries and is indicative of innovative behaviour.

The data also show a strong and positive correlation between productivity performance and the decision of trading on the Internet. Those companies that choose to trade on the Internet in the year 2001 were characterised by a good productivity performance in the 1998-2001 period. The productivity gains have been particularly high in 2001 and firms that have chosen to buy and sell on the Internet have experienced the highest productivity growth.

To investigate the causal relationship between e-trade and productivity an econometric approach is required. Using a production function framework, gross output is modelled as a function of the total numbers of employees, the capital stock, the value of intermediate material and an indicator of trading on the internet. When the production function is estimated using Ordinary Least Squares (OLS) the results do not show any significant effect of trading on the Internet on productivity. However, when the authors correct for the endogeneity of the decision to trade on the Internet, using a treatment effect estimator, the impact of e-trade on productivity becomes positive and significant in both the production and the service sector.

Following Atrostic and Nguyen (2004), the authors compare the productivity impact of trading on the Internet on firms at two predicted probabilities of doing e-trade. The results show that in the total sample, for example, firms in the 99th percentile of the probability distribution (more likely to trade on the Internet) have over 29% higher productivity compared to firms on the 1st percentile (less likely to trade on the Internet). The productivity gain is stronger in the Service than in the Production sector where the difference between the 1st and the 99th percentile is 35.91% and 24.79% respectively.

Micro-evidence: a synthesis

Finally *Matteucci, O'Mahony, Robinson and Zwick (2005)* bring together industry evidence for the US and large EU countries and firm level evidence for the Germany, Italy and the UK, in an attempt to draw some general conclusions on the impact of ICT on productivity. Both sources of information suggest that there appear to be some productivity impacts from investment in ICT in the larger European countries, but there is little evidence to suggest that these impacts are as yet close to those found for the US. The analysis also highlights differences within Europe. The industry analysis suggests that of the European countries studied, the UK experience is closest to the US, in terms both of its adoption of ICT and the industrial location of productivity benefits. In contrast the evidence presented suggests little evidence of a significant impact from ICT on service sectors in the Continental European countries, a finding that is confirmed by the micro analysis for Germany. In Germany, ICT investments lead to a significant productivity increase for several years in manufacturing, while the available evidence suggests service establishments have not yet increased their value added by investing in ICT.

IV. CONCLUSIONS AND POLICY IMPLICATIONS

1. Conclusions

1.1. Analytical conclusions

The impact of ICT on economic performance arguably has been one of the most important research topics in the past decade. The dotcom bubble at the time was seen as likely to diminish interest in this topic but this turned out not to be the case. In fact interest in the economic consequences of the information technology revolution accelerated since then, driven by evidence that the US continued to enjoy high rates of productivity growth in the first few years of the new century. There are few commentators, if any, who would now argue that information technology is unimportant.

Much of the research to date has been carried out for the US, with some contributions for other countries. The main contribution of the EPKE consortium was to take a truly international comparative perspective, contrasting EU performance with developments in the US. This complements research carried out by researchers at OECD, with whom the consortium has had close links.

To briefly summarise the conclusions:

- The industry analysis has shown that EU countries are investing heavily in the new technology.
- This has not translated into similar payoffs in terms of productivity growth as experienced in the US.
- These findings are reinforced by analysis at the firm level that in general shows positive contributions of ICT to output and productivity growth in a range of EU countries.
- The analysis suggests in general that there has been a (complementary) increase in the demand for skilled labour in EU countries, mirroring similar trends in the US for an earlier period.
- The environment in which firms operate, in particular the degree of competition and regulation, is likely to impact on productivity performance, but in ways that are difficult to measure given current data.

The results need to be seen against a background of accelerating labour productivity in the US since the mid 1990s but decelerating growth in the EU. In detail the following conclusions emerged.

<u>Industry productivity</u>

The US acceleration in labour productivity growth since the mid 1990s has been largely concentrated in ICT producing manufacturing and ICT using services. EU countries in general also show accelerating growth in the first group (computing equipment, electronic components, communications equipment and scientific instruments) and the EU performs better than the US in ICT producing services (communications and computer services). Where the EU falls down relative to the US is in ICT using services (distribution, financial and business services), which together represent a sizeable proportion of economic activity. In the past these sectors have shown some of the largest gains in employment; they now show large gains in labour productivity, noticeably in the US but also potentially in the EU. In non-ICT manufacturing, labour productivity growth decreases in the final period in both the US and the EU-15 with a greater decline in the US. However the US shows a marginal improvement in non-ICT services, and since this comprises over 60% of the non-ICT group, the overall percentage point reduction in US non-ICT industries since 1995 is lower than in the EU. Nevertheless productivity growth rates in the non-ICT sectors are much lower in the US than in the EU.

Weighting industry growth rates by their shares of value added brings out the importance of these trends in explaining aggregate economy changes in productivity. Nearly three quarters of the one percentage point higher EU average labour productivity growth was due to higher growth in the 1980s in more traditional non-ICT industries, with the EU maintaining a productivity advantage in these sectors through to 2001. In the 1980s ICT using sectors accounted for about 40% of the EU higher growth and this advantage continued into the early 1990s. The period since 1995 saw a reversal of this pattern as slower growth in ICT using sectors in the EU accounted for a significant proportion of the slower aggregate growth in Europe.

The method of growth accounting was employed to pinpoint the sources of labour productivity growth. The first conclusion from this is that ICT investment has been proceeding at a rapid pace in the EU as well as the US in recent years. Within ICT producing industries, the US clearly leads in terms of ICT investment growth in manufacturing industries, while ICT investment in the telecommunication services industry has been growing faster in the EU. In ICT using industries, both the wholesale and retail trade sectors in the US clearly invested at a faster pace in ICT assets between

1979 and 1995 but subsequently the larger EU countries had mostly closed this growth gap. ICT capital shares are currently considerably lower in EU countries than in the US, reflecting earlier adoption in the latter. ICT-capital deepening in the ICT-using industries contributed considerably more to aggregate labour productivity growth than did ICT producing industries in both the EU and US since the late 1990s. Nevertheless the gaps in percentage point contributions from ICT capital deepening between the US and large EU member states is greatest in ICT using sectors.

Econometric analysis based on industry data confirmed the presence not only of positive returns to ICT capital but also excess returns to ICT compared to non-ICT assets, particularly in the US. This suggests the possibility that standard growth accounting exercises may understate the contribution of ICT to output growth. Thus there may be spillover effects from ICT to residual productivity or TFP growth, although the data do not allow identification of this from an alternative hypothesis that increased TFP growth arises from investment in organisational changes which cannot be observed in the dataset.

The US labour productivity growth advantage over EU countries since the mid 1990s stems largely from higher total factor productivity (TFP) growth, and is concentrated largely in ICT using services. In addition, the labour productivity deceleration in the EU can be to some extent attributed to reductions in the rate of growth of traditional non-ICT capital intensity, which in turn probably reflects changes in the relative costs of capital and labour.

Industry analysis also shows that variations in industrial structure are significant determinants of aggregate income levels and growth. The empirical evidence thus substantiates important insights from theories of Schumpeterian development, which emphasise that growth and structural change are two inseparable elements. This is in contrast to standard neo-classical models which analyse growth in terms of balanced steady-state growth, uniformly spread across all industries.

Finally the project considered a case study for one particular industry, the distributive trades sector, where there has been a significant divergence of performance comparing the US and Europe in recent years. This showed that the marriage of technology and organisational change is at the core of the US trade sector’s productivity acceleration and its superior performance relative to European countries. Over the past three decades the trade sector has been transformed from a low technology sector to one that makes extensive use of ICT. Adoption and use of ICT has been much slower in Europe than in the US.

Employment generation

Employment generation has become less of a policy priority in recent years. In the decade of the 1980s, and the early 1990s, the EU-15 saw an average growth in employment less than half the rate of US growth. In contrast, in the years 1995-01, the annual average percent growth in employment in the EU-15 rose to levels close to those achieved in the US. Thus in the second half of the 1990s European countries seem to have recovered a substantial capability of generating jobs. Looking at the industry concentration of employment growth, this project shows a relatively favourable EU performance in generating employment growth since the mid 1990s in more traditional manufacturing industries. However there is some evidence that the EU-15 has increased employment in recent years in the service sectors most affected by ICT.

The EU-15 has narrowed the employment generation gap with the US in industries that intensively use intermediate skills. The industries largely employing low skilled workers in the EU has experienced a large turnaround, from negative rates of more than 1% per annum in the 1980s to positive growth rates in the late 1990s. Nevertheless in both the EU and the US employment growth has been highest in industries intensive in the use of very highly skilled labour. An econometric analysis for one country (Italy) suggests that the employment generated in service sectors in the late 1990s is not completely explained by output (or demand) changes and labour costs reduction, but also by the diffusion of ICT.

Employment and productivity

Bringing together trends in labour productivity and employment generation confirms the well-known inverse relationship between productivity and employment in the long run, which is generally stronger in manufacturing than in services. However, during the 1990s, this relationship has turned positive in many industries, in particular in ICT-producing industries and in ICT-using industries in the service sector. Therefore as a result of increased use of ICT, high labour productivity growth is less associated with low employment growth during the second half of the 1990s, in particular in ICT-using services. But the negative association between productivity and employment growth has remained much more persistent in Europe than in the US.

The demand for skilled labour

The increase in the demand for skilled labour in the US associated with the adoption and use of information technology is well documented in the literature. This project confirms that such an association also exists for EU countries but that there is considerable variation both across countries and in the timing of the effects. In one international comparison using employment and wage share equations, in all countries the lowest skilled workers have suffered a loss of shares. There is also evidence that ICT has had a positive impact not only on the employment and wage bill shares of the highest skilled group, university graduates and above, but also on the higher intermediate group, third level but below degree. The timing of the impacts of new technology vary between countries, with the US showing the largest effect in the 1980s and the European countries showing a greater impact in the 1990s. This is consistent with the later adoption of ICT in Europe, compared to the United States.

Looking at country specific results, the empirical results for Germany indicate that the accumulation of office machinery and computer capital is the major factor contributing to the shift in labour demand towards highly skilled workers. Wage effects and substitution effects between labour and material inputs play a minor role in explaining employment changes of highly skilled and medium-skilled workers, but these effects are more important in explaining the demand for unskilled workers. In France the demand for college-educated workers has mainly increased in sectors already intensive in skilled labour and in ICT investment. Evidence for increased use of skilled workers is weaker in Italy. One study shows little evidence for such an effect outside Science Based sectors, while a second suggests that the wage premium and the increase in working time associated with computer use are much lower than those estimated for other countries. However, when allowance is made for differences in workers' ability and the provision of different effects of computer usage across job types, it emerges that the impact on wages of using a computer at work becomes substantial for higher-level white-collar workers, namely cadres and technicians and managers.

The research carried out as part of this project also suggests that there may be elements of the division of the labour force, other than skills, which have changed as a result of ICT. Thus evidence for France in particular suggests increased demand for both female and younger workers. Recent US literature also emphasises the importance of age cohort effects, with increased demand for younger workers, again in an earlier period than seems to be the case in Europe.

Overall the research results suggest that skill requirements are likely to change across country and through time. Existing literature for the US emphasises the endogenous nature of technical progress, pointing to the skill-intensive nature of the US employment structure in the 1960s and 1970s that may have created an impetus for high-tech capital adoption. But it is also possible that information technology may adapt over time to skill endowments so that the demand for the most highly skilled group may not lead to as large returns as enjoyed by American skilled labour in the ICT adoption phase of the 1980s.

Firm level productivity

The research carried out in this project using micro firm level data provides ample evidence that ICT impacts positively on productivity, consistent with findings for the US. Analysis of international company accounts databases suggest that some additional benefit from investment in R&D is occurring in services sectors in more recent years in both the US and the EU, but the effect is stronger in the former. These productivity gains tend to be concentrated in small or medium sized firms in contrast to the position in manufacturing whereby R&D tends to have its biggest impact in large firms. These findings are in accordance with the literature on firm dynamics that suggest that a substantial part of the productivity growth within an industry is generated by factors outside the firm, such as the dynamics of entry and exit of firms. The entering firms are usually more productive although their market shares are generally low, and the exiting firms are the most inefficient ones.

Combining firm data with industry information on ICT intensity supports the existence of spillover effects from ICT both in the US and the EU in the 1990s. Again there appear to be differences in the dynamic pattern of change across the two regions. The results suggest that in the US both the short-run and the long-run spillover effects are positive and significant, with a larger impact in the long run. The evidence suggests that the European group of the follower countries in implementing the new technology, might still be lagging behind the US in terms of obtaining a pay-off from investments in ICT. This is shown in the short run estimates, where the impact of ICT spillovers was not found to be significantly different from zero. However, in the long-run results, ICT spillovers are positive and significant in the EU.

Country specific results highlight some variation within Europe. In France one study found that the increased use of computers decreased the marginal cost (a measure of firm productivity) of the median firm. As with the industry studies, this could mean that excess returns to computers are important or that it is the effect of unobserved variables such as reorganisation. In Germany there appear to be substantial impacts from ICT investments on firm level productivity, although this effect is more apparent for manufacturing than service sectors. In Italy results show a significant and positive correlation between R&D and ICT intensity (on one side) and the change in TFP for manufacturing firms. Thus evidence for Europe at the firm level confirms the results of earlier studies for the US.

Many of the country specific studies considered the use of particular types of information technologies on productivity. In France the results show that the use of the internet is significantly correlated with firm performances but network or electronic data interchange effects are not significant. Investigations for the UK show that there are substantial gains in buying and selling over the Internet for both production and service companies, but other forms of electronic exchange have little impact. A study of small to medium sized enterprises for Italy also highlights the differences in usage of types of ICTs across firms.

The existing literature emphasises the importance of organisational changes as being necessary to gain the greatest benefits from ICT. Studies carried out in this project for France, Germany and Italy, using indicators of organisational changes found little evidence for any joint impacts on firm productivity, however. Links between organisational changes and productivity growth are likely to be complex and related to complementary investments such as skilled labour. Hence evidence on direct effects from the type of organisational indicators currently available in firm level data sets may not be sufficient to capture the impact of reorganisation. Instead such changes may be captured through changes in demand for different types of labour. Hence one study for Germany suggests that organisational changes have a significant and positive impact on expected employment for all skill groups except for unskilled labour. Finally, the studies for France emphasise the strong redistributive effects of IT within the workforce.

Regulation

The discussion to this point has been largely about direct proximate sources of growth, differences in labour force skills, differences in capital intensity, and – within the category of physical capital – the share of ICT versus non-ICT capital in understanding differences in productivity performance. If these were the only factors justifying the EU lag, it is reasonable to assume that eventually the EU will follow the US productivity performance. However, when particular structural features have created obstacles to the diffusion of ICT in the EU it cannot be expected that the EU will realise a similar performance as the US, unless such structural rigidities are removed. Therefore the project also considered the impact of competition and regulation on productivity performance.

Theory suggests the possibility of an inverted U-shaped relationship between deregulation and innovation. Since innovation is assumed to boost productivity growth, this gives rise to the possible existence of an inverted U-shaped relation between deregulation and productivity growth. In terms of product market regulations, the existence of such a U-shape was considered in some industries. Service industries, notably retail trade, aviation, telecommunication, electricity generation/distribution and trucking, have in recent years been exposed to large-scale deregulation. Evidence for an inverted U-shaped relation between regulation and productivity growth was only found for retail trade and the utilities. The optimal level of industry regulation in retail is much closer to a competitive market than for utilities. The U-curve for utilities is also much flatter than for retail, so the reaction of retail firms to changes in industry concentration is stronger than a similar change in concentration for utility firms. There was no strong effect of regulation on productivity growth in any of the other industries studied.

The more detailed case study of the retail trade sector did suggest an important role for regulations in affecting productivity. It specifically identifies direct effects from store opening hours and land use regulation and indirect complementary changes such as the slower pace of deregulation in Europe’s trucking industry. Such regulations constrain Europe from adopting the retail trade model, based on large-scale stores, that benefits most from information technology.

The research suggests a role for employment regulations as well, but with very different implications from those for product markets. Thus evidence is presented that lower levels of employment protection may have contributed to increased cyclical variability of employment. This means that in countries with higher levels of employment protection legislation, labour demand is less responsive to both wages and output growth. Hence countries with low levels of regulation will have higher employment growth during expansions, but lower employment growth during recessions. These findings leave less room for structural reforms as an explanation, suggesting that reforms will not lead to a permanent increase in employment growth.

Finally, bringing together evidence at the industry and firm level for the four largest EU member states, leads to the suggestion that in the information technology age, the performance in the UK looks much more like that in the US than France, Germany or Italy. In particular the pace of adoption of information technology appears faster in the UK and productivity improvements are most apparent in the ICT using service sectors, where US growth is also concentrated. Since the UK is widely perceived as one of the least regulated EU countries, both in terms of product and labour market regulations, this may be seen as indirect evidence on the importance of structural rigidities. However this cannot be taken as conclusive evidence since the UK also had lower levels of productivity than these other EU countries and hence may be merely benefiting from catch up growth.

1.2. Methodological conclusions

Growth accounting

Theoretical refinements of the growth accounting methodology, the basis of much of the industry analysis, were developed in the 1960s and 1970s. Its use as a tool of empirical analysis waned in the 1980s but it has had a renaissance in the information technology age. This project helps to bring to the fore the powerful nature of this tool, showing its usefulness in drawing out the salient features of trends in sources of output and labour productivity growth. However the research also emphasises the need to ensure international comparability in applying the method in practice. Thus it is important to understand the measurement methods that underlie the data series in each country and to adjust these where appropriate so as to avoid conclusions that are based purely on measurement differences.

Dynamics

One of the important methodological contributions of the project was in highlighting the need to consider the dynamics associated with the adoption and diffusion of new technology. The analysis of industry productivity focused on the inadequacy of the standard panel data techniques when using an industry data set characterised by a long time dimension and a relatively small number of cross sections. First, these datasets are not dealing with a true panel, where the same unit, such as a company or an individual, is observed through time, but rather are analysing industries whose structure may change over time. Secondly, the long time dimension of these types of data sets requires an investigation of the dynamic properties of the series used in the estimation, in order to avoid spurious results. Imposing the same coefficients across all industries and not allowing for any short-run dynamic adjustments imply strong restrictions on the data that should at least be tested. The analysis of the demand for skilled labour using industry data also highlights the need to go beyond traditional panel regression methods.

Econometric analysis at the firm level

Several studies in this project have discussed the problems related to the analysis of firm level data, from either company accounts or survey data. It is not easy to detect empirically if investments in ICT increase firm productivity because firms may tend to invest in ICT depending on their economic situation. Two sources of selectivity of ICT investments should be distinguished: those caused by temporary shocks (endogeneity) and those caused by unobserved structural differences (unobserved time-invariant heterogeneity). Both sources of endogeneity might have an impact on the estimated productivity effects of ICT investments. Unobserved structural differences can be taken into account by using adequate panel estimation techniques that isolate firm fixed effects. The endogeneity issue remains a problem in many firm level data sets, such as those based on company accounts. One solution is the use of a Generalised Method of Moment (GMM) estimator, which uses lagged values of the dependent and independent variable as instruments. However, these 'internal instrument' are characterised by a very low correlations with the variables they are instrumenting and therefore they are likely to generate biased results. In some instances, instruments can be found in survey data. Then endogeneity of ICT investments can be cured by instrumental variable estimation techniques that explicitly model the decision process of the firm to invest in ICT.

Many firm-level datatsets do not yet provide truly longitudinal quantitative data on technological variables, suitable for a proper test of the medium-run effects of new technology adoption on employment and productivity. While for firm heterogeneity several remedies could be envisaged (the most common being time-differencing - the basic method to get rid of sector or firm specific effects), for endogeneity the solution often could be considered only partial. For example, with firm-level data the shortness of the time-series dimension of the technological variables and the lack of good instruments prevented in a few cases the use of more elaborate methodologies aimed at addressing endogeneity and sample selection. One strategy was to use predetermined technological variables, which are often used as instruments in the literature.

Finally, as with industry analysis, it should be taken into account that ICT investments increase productivity with lags. Survey data, however, are frequently available for only a few years so firm level data currently tend to be of limited use for understanding the dynamics of adoption and diffusion. This situation will change as more data become available for a run of years.

1.3. Future Research

The research project identifies a number of areas where further research is required. These include:

The need to understand the dynamics of the growth process. Given the earlier adoption of ICT in the US, the benefits naturally appeared first in that country. However, understanding the lagged response in Europe, how that varies across countries and industries, and its links to institutional structures is an important area of future research. The development of techniques appropriate to dynamic panels, including tests for structural breaks, is at the heart of recent and ongoing theoretical innovations in econometric methods. As these methods are refined they will be available to future researchers and so will aid in understanding the dynamic responses to the introduction of new technologies. The dynamics of the growth process are intrinsically linked with organisational changes. Many papers in the literature argue that the adoption and diffusion of ICT are not instantaneous but rather require considerable changes in the organisation of production. Many go further than this and suggest that the initial stages of the use of ICT may be associated with reductions in productivity growth due to the disruption caused by changes in organisational structure. In the long run, however, such changes should increase productivity. Thus understanding the processes of organisational changes should be an important focus of future research.

The need to extend the industry and firm level analysis to more countries (see discussion below).

The need to gain a much greater understanding of the way institutions impact on employment generation and productivity growth. In addition to econometric analysis this probably requires an in-depth examination of the historical evolution of institutional structures, including why regulations were instigated and the costs and benefits of reform. Such an analysis is also likely to be best carried out industry by industry and so is likely to require considerable research effort.

Further research needs to be done in the area of labour demand. Human capital theory implies that a worker's productivity depends not only on his or her educational qualification level but also on work experience. There is some empirical evidence that the hypothesis regarding the superior ability of educated workers to adopt new technology does not hold for older workers as it does for younger workers. Future work should provide results of the substitution patterns between different age groups for a given educational qualification level.

While methodological improvements are necessary, convincing results will only be obtained with better data. Research on refining the industry data and extending to additional countries is in progress through a 6^{th} framework funded project, EUKLEMS, which involves many of the EPKE consortium. The past few years have seen an increase in the rate at which micro firm level datasets are becoming available, with greater availability of survey data which are increasingly being matched to financial data underlying business censuses. Many of the researchers involved in the current project will continue researching using these datasets.

Data availability has hampered firm level analysis on labour demand in some European countries. Usually, firm-level panel data does not contain information on quantities and wages of different types of labour. The analysis of heterogeneous labour demand models will become more important as more data become available. The preferred type of data should be at the establishment level, in particular on linked employer-employee data. These data will allow analysis of the effects of technological change on either the wage dispersion or the skill structure within and between firms. There is also a need to analyse further the interdependence of the influence if ICT investments on productivity and the human capital endowment of the firm. The small effects between both elements measured may be a consequence of measurement error. Using linked employer-employee data sets that better characterise the human capital endowment of each employee could reduce this error.

Probably the least developed area, but arguably one of the most important from a policy perspective is the relation between regulation and economic performance at the industry level. Here there are serious deficiencies in the quality of existing data. First, the OECD International Regulation Database, which is the sole source for internationally comparable regulation data at industry level, needs to be updated for more years. Second, performance indicators need to be available at the same level of industrial detail as the regulation indicators. Third, deregulation is a lengthy process that does not have instantaneous effects; a sufficient number of observations in time of both regulation and performance are essential when a relationship between the two is being studied.

2. Policy implications

In broad terms the research discussed in this report highlights two possible explanations for the failure of EU countries to match performance in the US in terms of both productivity growth and employment generation. The first is that the EU is merely lagging the US, following much earlier adoption of information technology in that country. The second is that the institutional environment in Europe, in particular structural rigidities, hampers the realisation of the benefits from the new technology. An extreme version of the latter would suggest that Europe would never realise the benefits enjoyed in the US. However there are few who would subscribe to this position, given that European countries are investing heavily in ICT and in the long run there will be diminishing returns to ICT as there have been to every major technological change. Rather the argument is that structural rigidities will seriously delay US style benefits from ICT in Europe, although Europe will eventually catch up.

The reasons for earlier adoption of ICT in the US are not well understood but are likely to have been associated with externalities from defence expenditures and large endowments of skilled labour. If the sole reason that Europe is lagging the US is its later adoption of ICT, the policy implications are very different from those in the second scenario above. Thus policies that facilitate complementary investment might be worthwhile in the first case. These policy recommendations will not be sufficient, however, if structural rigidities are the main reason for lower EU growth rates. In that case EU governments need to instigate structural reforms, stimulating competition and deregulating large areas of activity.

The first set of policies provides a rationale for public policies and programmes intended to influence the behaviour of enterprises in terms of, for example, external knowledge search and exchange, and R&D collaboration with universities, research institutes and other enterprises. Policies might also be instigated to inform firms of developments in information technology. In this respect policies targeted at particular sectors and/or categories of enterprise may be effective tools in meeting public policy objectives. Examples are sector-specific improvements in technologies with wide applications in other industries, and two-way knowledge flows along product supply-chains in the course of new product development. However, the design of alternative policies intended to speed up the rate of technological change typically requires a strong element of judgement and therefore there is considerable scope for government error in formulating and implementing such policies. Hence there is the need for caution against any hint of policy makers returning to previous efforts to 'pick winners'. Rather the aim should be to encourage winners to emerge by strengthening the innovation process in general. Additionally policy makers could target improvements in education to ensure schoolchildren are taught the correct skills for use in the information age.

The second set of policies suggests that most EU member states need to subject their existing market regulations to detailed scrutiny with a view to identifying and cutting out unnecessary administrative burdens and barriers to competition. To understand the US productivity acceleration it is important to focus on services industries that use ICT intensively. These industries, mainly distribution and finance, are responsible for most of the acceleration in ICT capital deepening and TFP growth alike. Policies designed to free EU service sectors from the burden of excessive regulation may be particularly useful.

Firm level evidence indicates that policy not only should focus on stimulating growth and performance within existing firms, but also on eliminating restrictions to the process of experimentation and creative destruction. More restrictive product and labour markets in many European countries may discourage entry and posterior growth of new firms, reduce innovative efforts, technology spillovers, and competitive pressures, which affects negatively productivity growth. In the US the administrative start-up costs and labour adjustment costs are relatively low, which stimulates entrepreneurs to start on a small scale and if successful grow to reach the minimum efficient scale. This process of experimentation can be especially important in highly innovative sectors, (like ICT related industries), where the entry of firms, which are likely to adopt the latest technologies, can make a significant contribution to technological progress and growth.

However the benefits from reform need to be set against the costs of achieving their goals. For example in the case of labour market regulations, there may be long term trade-offs between ensuring a more flexible labour market and human capital accumulation. For example, there is some evidence that labour market regulations have a relatively small impact on productivity and R&D intensity in countries such as Germany and Austria with centralised wage bargaining procedures and well-established apprenticeship and continuing training systems which provide support for firms to upgrade the skills of their existing employees in response to technological change. The negative effects of labour market regulations on productivity may be strongest in countries such as Belgium, France or Portugal 'where the adjustment costs associated with the regulations are not offset by the possibility of adjusting wages or the use of internal training.

In terms of product market regulations policies to reform the institutional structure face a potential trade-off given the possibility that policy designed to intensify product market competition may have a negative impact on incentives to innovate. It is still an open question whether regulation is indeed detrimental to innovations. The lack of competition induced by regulation may lead to slack within the firm, thereby hampering innovations from being carried out. On the other hand, a regulated environment may provide sufficient resources and create the necessary stable surroundings for a firm to innovate, in comparison to fully competitive markets. Which one of these relations prevails in reality is difficult to assess empirically. Nevertheless there appears to be more agreement in the literature that product market reforms, especially in service sectors, are likely to yield benefits than is the case for labour market reforms.

In practice both polices to improve the research infrastructure and flow of information and regulatory reform are probably needed. The many examples of diversity among EU countries in the extent and impact of regulatory practices serve as reminders that policy inferences in the area of de-regulation need to be similarly diverse and attuned to the specific nature of each country's institutional and market structures and the patterns of industrial specialisation and comparative advantage which are associated with those structures. Similarly, policies to improve flows of information are likely to be country and sector specific.

In terms of employment generation specifically, from a policy perspective, the employment generation potential of manufacturing industries which are ICT intensive seem to be inferior to that showed by the corresponding service industries. This is particularly true for the EU where the patterns of innovation, ICT investment and R&D activities are focused on process innovations, which, in comparison with product innovations, display a more pronounced labour substituting and labour saving character.

The research on small and medium sized enterprises (SME) also highlights the need for policy makers to understand the types of ICT that should be encouraged. If the objective is to help these firms increase their productivity, then the development of production-integrating ICT should be given priority; if, on the contrary, the policy is aimed at enhancing market opportunities, then the focus should be on market-oriented ICT. In either case, a key factor is the improvement of the human capital within SMEs, which can be achieved by lowering, through different types of policy instruments, the hiring and training costs of educated workers, and especially university graduates.

One of the many roles of policy is to identify the skill needs of a growing economy in order to ensure that the right skills are available at the right time. For this to be achieved, a better understanding of the skill requirements of the new technological environment is necessary. This project presented ample evidence that all EU countries included in the analyses have experienced some degree of skill biased technological change in the past two decades. The adoption process of a new technology implies that the whole range of different skill groups may be affected at different points in time. Hence it is not easy to predict the skill requirements of new technology in the future. A cursory look at the American evidence suggests a focus on increasing the stock of university graduates and equivalents in Europe. However this is very costly and greater benefit may be had by increasing information technology skills within the existing education and training systems in Europe. This is especially likely to be the case if the technology itself becomes easier to use and hence requires lower skill levels in the future. There is little doubt that information technology has developed over time so as to be usable by the average intelligent person with a reasonable level of educational attainment.

The research on the demand for heterogeneous labour does however point to a reduction in the use of workers with very low or no skills associated with information technology. An alternative to increasing graduate education might therefore be attempting to train these workers up to a minimum basic skill level. The adoption of computers in the workplace is no magical recipe, which improves job quality and compensation under any circumstances. Some workers benefit more than others from computers introduction;

some do not benefit at all. Generalised gains from ICT adoption are foreseeable only if coupled with appropriate improvements in work organisation, especially those aimed at upgrading the tasks and competencies and increasing the decisional autonomy of the employees with lower qualifications.

Finally the importance of industry structure also needs to be highlighted. For example the research results for Italy are particularly illuminating. The results identify some country-specific paths, which can be easily reconciled with the structural characteristics of Italian manufacturing. As a consequence, no straightforward labour market policy implication seem to be appropriate for Italy, since the low skill absorbing potential of manufacturing acts as a main structural constraint. In Italy, skill biased technical progress materialises mainly as a phenomenon of reduction of the use of the low skilled, and new technology does not seem to increase the employability of the skilled, as happens elsewhere. Because of that, the most effective policy intervention might be industrial policy, addressed to the reorientation of the country specialization towards more high-tech sectors.

Such a reorientation in industrial structure can have a significant impact on a country's level of income and growth. However, the empirical finding, that industrial structure matters, is not the same as to say that this variable is a sound target for policy intervention. First, sectoral specialisation is highly persistent and largely based upon processes of self-organisation. Second, industrial structure is also affected by a number of presumed horizontal policies. Education and training, R&D support, or the effectiveness of competition policy are only three examples that can enhance opportunities and overall entrepreneurial capabilities, affecting some types of industry (especially those that are particularly knowledge intensive) more than others.

V. DISSEMINATION AND EXPLOITATION OF RESULTS

During the lifetime of the EPKE project, a variety of approaches have been taken to disseminate the results. The EPKE website (www.niesr.ac.uk/epke/) has played a crucial role in this dissemination. This not only provides background information about EPKE, including details of the objectives of the project, the methodology used, and the consortium members, but also links to the database, presentations and papers from the final EPKE conference and EPKE working papers.

Indeed, the EPKE working paper series has itself been a major means for dissemination of project results. Working papers have been produced and made available on the website throughout the course of the project, resulting in a total of more than 30 papers, plus two technical notes. A full list of the working papers produced is available in VII. 1. . In addition, results have also been published in numerous other forms, including as journal articles and book chapters. Again, full details are listed in VII. 1.

One of the major outputs of the second year of EPKE-funded research was the publication of a Special Issue of the *National Institute Economic Review* in April 2003. This focused on the impact of recent advances in ICT and their effect on output and productivity growth in the last few years. An evaluation of the impact of ICT inputs can be carried out at the industry or company level using a number of methods. The four papers in the special issue (listed in VII. 1.) contribute to a growing body of literature inspired by developments in new technology utilising many of these various methods.

Two books have also been produced in relation to this project. *EU Productivity and competitiveness: An industry perspective. Can Europe resume the catching-up process?* (O'Mahony and van Ark, *eds*., 2003a) summarised much of the research at the industry level, together with research using company accounts data. This book, by researchers at NIESR, University of Groningen and the Conference Board, gives an overview of productivity trends in the EU relative to the US, detailed analyses and policy conclusions.

ICT, Mercato del lavoro, Produttività (ICT, Labour Market and Productivity) (Sterlacchini, ed., 2005, forthcoming) contains contributions by the members of the EPKE research group at Marche Polytechnic University (previously the University of Ancona). It analyses new empirical evidence on production and adoption of ICT, addressing its productivity and labour market consequences. It focuses on Italy and elaborates on work done at the industry and micro (firm and individual) level; it also provides an overview of the broader macro-trends of ICT in that country, combining the main conclusions of previous literature. Finally, the chapters discuss the main implications for a policy aimed at raising the technological level in Italy, including ICT production and adoption. Details of the chapters of both of these books are available in VII. 1.

Another important output has been the development of the database. EPKE has completed the generation of a harmonised European dataset, which has been available on the EPKE website (http://www.niesr.ac.uk/epke/database.html) since late 2003.

The EU industry database contains three databases as outlined in the scientific report above. The first database (Industry Labour Productivity Database) is an industry database on labour productivity including series on value added and labour input covering 56 industries for all 15 EU member states and the US allowing output and labour productivity growth comparisons. The second database (Industry Growth Accounting Database) was constructed for four European countries (France, Germany, Netherlands and UK) and the US allowing calculation of the contribution to growth from labour skills, (ICT and non-ICT) capital and total factor productivity. The third database (Manufacturing Productivity and Unit Labour Cost Database) contains relative measures of levels of productivity and unit labour cost in manufacturing, with relative levels being derived on the basis of unit value ratios (UVRs).

Numerous presentations of the project results have provided another significant means of dissemination. Throughout the project, partners have been actively engaged in presenting results. This has included presentations at both national and international conferences, as well as internal seminars and workshops, reaching a wide variety of audiences, including academics, members of the business community and policymakers. A full list of presentations is provided in VII. 1.

Four conferences have taken place during the course of the project. In May 2003, the EPKE 18 month conference, 'Employment, Productivity and Skills in the Knowledge Economy', was held at Carre des Sciences, Paris. This one-day conference was attended by around 50 participants, from universities, research centres and government departments. Papers were first presented by EPKE consortium members. These were then followed by presentations from invited guest speakers: Professor Karin Wagner (Fachhochschule für Technik und Wirtschaft, Berlin); Nathalie Greenan (Centre d'Etudes de l'Emploi, Paris), and Thomas Coutrot (DARES, Ministère de l'emploi, Paris). The conference concluded with a roundtable session.

In April 2004 a Conference Board Workshop on "Benchmarking Reforms in a Renovating Economy" was held in London. The aim of this small workshop was to have an open exchange between participants from academia, government and business on the state of our knowledge and experience with structural reforms on markets in the light of recent surge in technological progress and diffusion. There were three main sessions, on 1) macro-relation between ICT and structural reform; 2) technological opportunities and organizational change in retailing; 3) business and policy experiences with structural reforms in retailing.

In October 2004, a conference was organised by CEPII and Banque de France on 'The challenges and economic outlook of the American elections'. Catherine Mann presented work on global sourcing: economic gains and policy challenges. Although technological change is the most important driver of IT price declines, globalisation and international trade made IT hardware some 10 to 30% less expensive. Globalization of IT hardware led to 0.3% point to real GDP growth per year from 1995 to 2002.

The final EPKE conference, 'Information Technology, Productivity and Growth,' took place in London on the 28th and 29th October 2004. Investigating the impact of information technology use on productivity, employment and growth, the papers presented at this conference provided empirical evidence at both the firm and industry level for both Europe and the US. As with the 18 month conference, the papers presented included those by consortium members and invited outside speakers. The latter include Professor Dale Jorgenson (Harvard), Dirk Pilat (OECD), Nick Oulton, (London School of Economics), Professor Eric Bartlesman (Amsterdam) and Professor John Van Reenen (London School of Economics). Further details of all four conferences are provided in VII. 1.

Meetings of the network took place throughout the project in London, Mannheim, Paris, Groningen and Ancona. These were restricted to members of the consortium and were designed to discuss research results, progress in the project and future planning.

In terms of deliverables, the project kept largely to the summary list shown below, but disseminated results as EPKE working papers rather than reports. An edited version of the final report will be posted in due course. In terms of publication dates, a decision was made to combine many of the outputs in the early stages into the book published by the European Commission in October 2003 (O'Mahony and Van Ark, 2003). This was driven by the needs of DG Enterprise who provided additional funding so that the dataset and research findings could be disseminated early. This book is already getting wide coverage in the media, among policy makers and academics. A decision was also made, therefore not to produce a second book at the end of the project as this would of necessity involve replication of the material in the first book. Instead future dissemination will be through submitting EPKE working papers to academic journals. In addition to the forthcoming publications listed in VII. 1. , papers have to date also been submitted to The Review of Income and Wealth, The Journal of the European Economic Association and Applied

Economics and are awaiting referees comments. Early in the new year it is planned to submit papers to The Economic Journal, 2005 conference issue and Labor Economics.

Summary of Deliverables

Deliverable title	**Delivery date**	**Nature**	**Dissemination level**
Literature Review	9	Draft	Public
Report on knowledge indicators.	12	Draft	Restricted
Report on taxonomies of industries	15	Draft	Restricted
Report on employment prospects in European industries	19	Final	Public
Dataset on knowledge indicators	19	Draft/Final	Restricted/Public
Reports on results of workpackages WP4-WP8	30	Draft	Restricted
End report on project.	36	Draft	Restricted
Revised end report on project.	38	Final	Public

Notes: Restricted = restricted to a group specified by the consortium (including Commission Services, representatives from OECD, Eurostat and other commentators specified by the partners); Public = general distribution.

VI. REFERENCES AND BIBLIOGRAPHY

References

Acemoglu, D. (2002), "Technical Change, Inequality and the Labour Market", *Journal of Economic Literature*, 40, pp. 7-72.

Aghion, P., N. Bloom, R. Blundell, R. Griffith and P. Howitt (2002), "Competition and Innovation: An Inverted U Relationship", Working Paper WP02/04, The Institute for Fiscal Studies, UK.

Aghion, P., E. Caroli and C. Garcia-Penalosa (1999), "Inequality and Economic Growth: The Perspective of the New Growth Theories", *Journal of Economic Literature*, 37, pp. 1615-1660.

Aghion, P. and P. Howitt (1998). "On the macroeconomic effects of major technological change", in E. Helpman, ed., *General Purpose Technologies and Economic Growth*, MIT Press, Cambridge MA.

Ahn, S. (2002), "Competition, innovation and productivity growth: A review of theory and evidence", OECD Economics Department Working Paper No. 317, OECD, Paris.

Anderson, G. and R. Blundell (1982), "Estimation and Hypothesis Testing in Dynamic Singular Equation Systems", *Econometrica*, 50, pp. 1559-1576.

Atrostic, B. K. and S. Nguyen (2004), "IT and productivity in US manufacturing: Do

computer networks matter?", Centre For Economic Studies, U.S. Bureau of the Census, Washington D.C., Mimeograph.

Autor, D., L. Katz and A. Krueger (1998), "Computing inequality: have computers changed the labour market?", *The Quarterly Journal of Economics*, 113, 4, pp. 1169-213.

Bakker, C. (2000) "Information and Communication Technologies and Electronic Commerce in Canadian Industry", Working Paper 88F006XIB No. 4, Statistics Canada, Science, Innovation and Electronic Information Division.

Bassanini, A. and E. Ernst (2002), "Labour Market Institutions, Product Market Regulations and Innovation: Cross-Country Evidence", OECD Economics Department Working Paper No. 316, OECD, Paris.

Berman, E., J. Bound and Z. Griliches (1994), "Changes in the Demand for Skilled Labour within US Manufacturing Industries", *The Quarterly Journal of Economics*, 109, 2, pp. 367-98.

Bertolila, S. and G. Bertola (1990), "Firing Costs and Labour Demand: How Bad is Eurosclerosis?" *Review of Economic Studies*, 57, pp. 381-402.

Bertschek, I. and U. Kaiser (2004), "Productivity Effects of Organizational Change: Microeconometric Evidence", *Management Science*, 50, pp. 394-404.

Biscourp, P., B. Crépon, T. Heckel and N. Riedinger (2003), "How do firms respond to cheaper computers? Microeconometric evidence for France based on a production function approach", INSEE, CREST Working Papers, No. 2003-05 and EPKE Working Paper No. 22, available at:http://www.niesr.ac.uk/epke/biscourp-22.pdf

Black, S.E. and L.M. Lynch (2001), "How to Compete: The Impact of Workplace Practices and Information Technology on Productivity", *The Review of Economics and Statistics*, 83, 3, pp. 434-445.

Bratti, M. and N. Matteucci (2004) "Is there a skill biased technological change in Italian Manufacturing?: Evidence from Firm Level Data" *Brussels Economic Review*, forthcoming and EPKE Working Paper No. 21, available at http://www.niesr.ac.uk/epke/Bratti-21.pdf

Bresnahan, T. (1999), "Computerization and Wage Dispersion: An Analytical Reinterpretation", *Economic Journal*, 109, 456, pp. 390-415.

Bresnahan, T., E. Brynjolfsson and L. Hitt (2002), "Information Technology, Workplace Organization and the Demand for Skilled Labor: Firm-level Evidence", *The Quarterly Journal of Economics*, 117, 1, pp.339-376.

Bresnahan, T.F. and M. Trajtenberg (1995), "General Purpose Technologies: Engines of growth?" *Journal of Econometrics*, 65, pp. 83-108.

Broersma, L. and B. van Ark (2004), "The impact on regulation on performance: an empirical investigation at the industry level in OECD countries", EPKE Working Paper No. 31.

Brynjolfsson, E. and L.M. Hitt (1995), "Information technology as a factor of production: the role of differences among firms", *Economics of Innovation and Technology*, 3-4, pp. 183-199.

Brynjolfsson, E. and L.M. Hitt (1996), "Paradox Lost? Firm-level Evidence on the Returns to Information Systems", *Management Science*, 42, 4, pp. 541-58.

Brynjolfsson E., and L.M Hitt, (2000), "Beyond computation: Information technology, organisational transformation and business performance", *Journal of Economic Perspectives*, 14, 4, pp. 23-48.

Brynjolfsson, E. and L.M. Hitt (2003), "Computing Productivity: Firm-Level Evidence", *The Review of Economics and Statistics*, 85, 4, pp.793-808.

Brynjolfsson, E. and C. Kemerer (1996), "Network externalities in microcomputer software: an econometric analysis of the spreadsheet market", *Management Science*, 42, 12, pp. 1627-2647.

Caballero, R.J. and R.K. Lyons (1989), "The role of external economies in U.S. manufacturing", NBER Working Paper No 3033.

Caballero R.J. and R.K. Lyons (1990), "Internal versus external economies in European Industry", *European Economic Review*, 34, pp. 805-30.

Capitalia (2002), Indagine sulle imprese manifatturiere. Ottavo rapporto sull'industria italiana e sulla politica industriale. (Survey on manufacturing firms), December, Rome.

Casavola, P., A. Gavosto and P. Sestito (1996) "Technical Progress and Wage Dispersion in Italy: Evidence from Firms' Data", *Annales d'Economie et de Statistique*, 41/42, pp. 387-412.

Caselli F. (1999), "Technological Revolutions", *American Economic Review*, 89, 1, 78-102.

Chun, H. (2003), "Information Technology and the Demand for Educated Workers: Disentangling the Impacts of Adoption Versus Use", *The Review of Economics and Statistics*, 85, 1, pp. 1-8.

Clayton, T. and C. Criscuolo (2002), "Electronic Commerce and Business Change",

Economic Trends, 583, pp 62-69.

Crépon B., T. Heckel and N. Riedinger (2003), "Information Technologies and Productivity: Microeconometric Evidence for France", INSEE mimeo, November and EPKE Working Paper No. 23.

Criscuolo, C. and K. Waldron (2003). "E Commerce and firm productivity", *Economic Trends*, 600, pp. 52-57.

Daveri, F. (2002). "The new economy in Europe, 1992-2001", *Oxford Review of Economic Policy*, 18, 3, pp. 345-362.

David, P. (1990), "The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox", *American Economic Review*, 80, 2, pp. 355-61.

DiNardo, J. and J. Pischke (1997), "The returns to computers revisited: have pencils changed the wage structure too?", *The Quarterly Journal of Economics*, 112, pp. 291-303.

Doms, M., T. Dunne and K. Troske (1997), "Workers, Wages and Technology", *The Quarterly Journal of Economics* 112, 1, pp. 253-289.

Dunne, T., L. Foster, J. Haltiwanger and K. Troske (2000), "Wage and productivity dispersion in U.S. manufacturing: the role of computer investment", NBER Working Paper No. 7465.

Entorf, H., M. Gollac and F. Kramarz (1999), "New technologies, wages and worker selection", *Journal of Labour Economics*, 17, 3, pp. 464-491.

Entorf, H. and F. Kramarz (1997), "Does unmeasured ability explain the higher wages of new technology workers?", *European Economic Review*, 41, 15, pp. 1489-1509.

European Commission, (2002), *Employment in Europe*, web edition (http://europa.eu.int).

Fabricant, S. (1942), Employment in Manufacturing, 1899-1939, An Analysis of its Relation to the Volume of Production, New York, National Bureau of Economic Research.

Falk, M. (2001), "Diffusion of Information Technology, Internet Use and the Demand for Heterogeneous Labour", ZEW Discussion Paper No. 01-48, Mannheim.

Falk, M. (2002), "Endogenous Organizational Change and the Expected Demand for Skilled Workers", Applied Economics Letters, 9, pp. 419-423.

Falk, M. and B.M. Koebel (2002), "Outsourcing, imports and labour demand", *Scandinavian Journal of Economics*, 104, 4, pp. 567-586.

Falk, M. and B.M. Koebel (2004), "The impact of office machinery, and computer capital on the demand for heterogeneous labour", *Labour Economics*, 11, 1, pp. 99-117.

Falk, M. and K. Seim (2001), "The Impact of Information Technology on High-Skilled Labor in Services: Evidence from Firm-Level Panel Data", *Economics of Innovation and New Technology*, 10, 4, pp. 289-324.

Freeman, R. (2002), "The labour market in the new information economy", *Oxford Review of Economic Policy*, 18, 3, pp. 288-305.

Garibaldi, P. and P. Mauro (2002), "Anatomy of employment growth", *Economic Policy*, 1, pp. 67-113

Geroski, P. A. (2000), "Models of Technology Diffusion", *Research Policy*, 29, pp. 603-625.

Gollac M., N. Greenan and S. Hamon-Cholet (2000) "L'informatisation de l'ancienne économie: nouvelles machines, mouvelles organisations et nouveaux travailleurs", *Economie et Statistique*, 339-340, 9/10.

Gordon, R. (2000), "Does the 'New Economy' Measure up to the Great Inventions of the Past?", *Journal of Economic Perspectives*, 14, 4, pp. 49-74.

Goux, D. and E. Maurin (1997), "Le déclin de la demande de travail non qualifié. Une méthode d'analyse empirique et son application au cas de la France", *Revue Économique*, 48, 5, pp. 1091-1114.

Goux, D. and E. Maurin (2000), "The Decline in the Demand for Unskilled Labour: An Empirical Analysis Method and its Application to France", *The Review of Economics and Statistics*, 82, 4, pp. 596-607.

Greenan, N. and J. Mairesse (2000), "Computers and productivity in France: some evidence", *Economics of Information and New Technology*, 9, pp. 275-315.

Griffith, R. Harrison, R. and Van Reenen, J. (2004), 'How special is the special relationship? Using the impact of US R&D spillovers on UK firms as a test of technology sourcing,' paper presented at the EPKE Final Conference, London, 28-29 October 2004, available at http://www.niesr.ac.uk/epke/confppt/Van_Reenen.pdf

Griliches, Z. (1992), "The Search for R&D Spillovers", *Scandinavian Journal of Economics*, 94, pp. S29-S47.

Griliches, Z. (1990), "Patent Statistics as Economic Indicators: A Survey", *Journal of Economic Literature*, 28, 4, pp. 1661-1707.

Griliches, Z. and J. Mairesse (1984), "Comparing Productivity Growth: An Exploration of French and U.S. Industrial Firm Data", *European Economic Review*, 21, pp. 89-119.

Gust, C. and J. Marquez (2004), "International Comparisons of Productivity Growth: the Role of Information Technology and Regulatory Practices", *Labour Economics*, 11, pp. 33-58.

Helpman, E. (1984), "The factor content of foreign trade", *The Economic Journal*, 94, pp. 84-94.

Helpman, E. (1998), *General Purpose Technologies and Economic Growth*, MIT press.

Hempell, T. (2003), "Do Computers Call for Training? Firm-level Evidence on Compelementarities Between ICT and Human Capital Investments", ZEW Discussion Paper 03-20, Mannheim.

Hempell, T. (2004a), "What's Spurious? What's Real? Measuring the Productivity Impacts of ICT at the Firm Level", *Empirical Economics*, forthcoming.

Hempell, T. (2004b), "Does Experience Matter? Innovations and the Productivity of ICT in German Services", *Economics of Innovation and New Technology*, forthcoming.

Hulten, C.R. (2000), "Total factor productivity: a short biography", NBER Working Paper No. 7471.

Inklaar, R., M. O'Mahony, C. Robinson and M. Timmer (2003), "Productivity and Competitiveness in the EU and the US", in M. O'Mahony and B. van Ark (2003a), eds. *EU Productivity and competitiveness: An industry perspective. Can Europe resume the catching-up process?* European Commission, Enterprise publications.

Inklaar, R., M. O'Mahony and M. Timmer (2003), "ICT and Europe's Productivity Performance. Industry-level growth account comparisons with the United States", Groningen Growth and Development Centre, Research Memorandum GD-68.

Inklaar, R., L. Stokes, E. Stuivenwold, M. Timmer and G. Ypma, (2003), "Data Sources and Methodology", in M. O'Mahony and B. van Ark (2003a), eds. *EU Productivity and competitiveness: An industry perspective. Can Europe resume the catching-up process?* European Commission, Enterprise publications.

Inklaar, R. and M. Timmer (2004), "Job-rich growth in the European Union: Cycles, wages and regulation", paper presented at EPKE Final Conference, 28th and 29th October 2004, London, available at http://www.niesr.ac.uk/epke/confppt/Inklaar.pdf

Jaffe, A.B. (1986), "Technological opportunity and spillovers of R&D: evidence from firms' patents, profits and market value", *American Economic Review*, 76, 5, pp. 984-1001.

Janz, N., G. Ebling, S. Gottschalk and H. Niggemann (2001), "The Mannheim Innovation Panels of the Centre for European Economic Research", *Schmollers Jahrbuch*, 121, pp. 123-129.

Jorgenson, D.W., F.M. Gallop and B. Fraumeni (1987), *Productivity and US Economic Growth*, Harvard University Press, Cambridge MA.

Jorgenson, D.W. and Z. Griliches (1967), "The Explanation of Productivity Change", *Review of Economic Studies*, 34, pp. 249-83.

Jorgenson, D.W. and K. Stiroh (2000), "Raising the Speed Limit: U.S. Economic Growth in the Information Age", *Brookings Papers on Economic Activity*, 1, pp. 125-211.

Jorgenson, D., M. Ho and K. Stiroh (2002), "Growth of U.S. Industries and Investments in Information Technologies and Higher Education", NBER/CRIW Conference on 'Measurement of Capital in the New Economy', April 2002.

Jorgenson, D., M. Ho and K. Stiroh (2003), "Lessons from the U.S. Growth Resurgence", *Journal of Policy Modeling*, 25, 5, pp. 453-470.

Jorgenson, D.W., Ho, M.S. and Stiroh, K.J. (2004), 'Growth of U.S. Industries and Investments in Information Technology and Higher Education', in C. Corrado, J. Haltiwanger and D. Sichel, *Measuring capital in a new economy*, Chicago, University of Chicago Press, forthcoming, available at http://post.economics.harvard.edu/faculty/jorgenson/papers/jhs_revised_criw1.pdf

Kaiser, U., M. Kreuter and H. Niggemann (2000) "The ZEW/Creditreform Business Survey in the Business Related Service Sector: Sampling Frame, Stratification, Expansion and Results", ZEW Discussion Paper 00-22, Mannheim.

Karshenas, M. and P. Stoneman (1995) "Technological Diffusion", in P. Stoneman, ed. *Handbook of the Economics of Innovation and Technological Change*, Blackwell, Oxford.

Kölling, A. (2000), "The IAB Establishment Panel", *Schmollers Jahrbuch*, 120, pp. 201-300.

Kreuger, A. (1993), "How computers have changed the wage structure: evidence from microdata, 1984-1989", *The Quarterly Journal of Economics*, 108, 1, pp. 33-60.

Layard, R., S. Nickell and R. Jackman (1991), *Unemployment: Macroeconomic Performance and the Labour Market*, Oxford University Press, Oxford.

Lehr, B. and F. Lichtenberg (1999), "Information Technology and Its Impact on Productivity: Firm-Level Evidence from Government and Private Data Sources, 1977-1993", *Canadian Journal of Economics*, 32, 2, pp.335-362.

Licht, G. and D. Moch (1999), "Innovation and Information Technology in Services", *Canadian Journal of Economics*, 32, pp. 335-362.

Lichtenberg, F. (1995), "The output contributions of computer equipment and personnel: A firm-level analysis", *Economics of Innovation and New Technology*, 3, pp 201-217.

Lucchetti, R. and A. Sterlacchini (2004), "The Adoption of ICT among SMEs: Evidence from an Italian Survey, *Small Business Economics*, 23, 2, pp. 151-168.

Lucchetti, R., S. Staffolani and A. Sterlacchini, (2005) "Computer, Wages and Working Hours in Italy", *Giornale degli Economisti*, forthcoming, and EPKE Working Paper No. 15, available at http://www.niesr.ac.uk/epke/computer.pdf.

Machin, S. and J. van Reenen (1998), "Technology and Changes in Skill Structure: Evidence from an International Panel of Industries", *The Quarterly Journal of Economics*, 113, 4, pp. 1215-44.

Mairesse, J., N. Greenan and A. Topiol-Bensaid (2001), "Information Technology and Research and Development Impacts on Productivity and Skills: Looking for Correlations on French Firm Level Data", NBER Working Paper, No. 8075.

Mairesse, J. and M. Sassenou (1991), "R&D and productivity: a survey of econometric studies at the firm level", STI Review, 8, pp. 9-43, OECD, Paris.

Mason, G., C. Robinson, J. Forth and M. O'Mahony (2003), "Industry-level estimates of ICT and non-ICT employment, qualifications and wages in the UK and USA, 1979-2000", NIESR: Report to DTI, DfES and HM Treasury.

Matteucci, N. and A. Sterlacchini (2003), "ICT and Employment Growth in Italian Industries", *Quaderni di Dipartimento* WP Series, n. 193, and EPKE Working Paper No. 17, available at http://www.niesr.ac.uk/epke/WP-17.pdf

Matteucci, N. and A. Sterlacchini (2004), "ICT, R&D and productivity growth: evidence from Italian manufacturing firms", EPKE Working Paper No. 28.

McGuckin, R., M. Spiegelman and B. van Ark (2004), "The U.S. Advantage in Retail and Wholesale Trade Performance: How can Europe catch up?", *Perspectives on a Global Economy*, The Conference Board, available at http://www.niesr.ac.uk/epke/confppt/McGuckin.pdf

McGuckin, R.H. and K.J. Stiroh (2001), "Do Computers Make Output Harder to Measure?", *Journal of Technology Transfer*, 26, pp. 295-321.

McGuckin, R.H. and B. van Ark (2003), "Performance 2002: Productivty, Employment and Income in the World's Economies", The Conference Board, Report R-1328-03-RR, March.

McKinsey Global Institute (2002), US Productivity Growth 1995-2000, summary available at http://www.mckinsey.com/

Melka J. and L. Nayman (2003a) "Skills, Technology and Growth: Is ICT the key to Success?", CEPII Working Paper, No. 2003-04, May.

Melka J. and L. Nayman (2003b) "TIC et productivité: où en est la France?", La Lettre du CEPII, No. 220, February.

Melka J. and L. Nayman (2004a) "TIC et productivité: une comparaison internationale", *Economie Internationale*, 98, 2, pp. 35-58.

Melka J. and L. Nayman (2004b) "Qualité du travail, TIC et productivité dans les services en France", in Productivité et emploi dans le tertiaire, rapport du Conseil d'Analyse Economique de P. Cahuc and M. Debonneuil, No. 48.

Melka J. and L. Nayman (2004c) "L'impact des Nouvelles Technologies de l'Information et des Communications sur la croissance française, 1980-01", *L'Actualité Economique*, forthcoming.

Melka J. and L. Nayman (2004d) "Growth accounting and labour quality in France, 1982-01", Contribution to the workshop book *Growth, capital stock and new technologies* held on November 25 and 26, 2002 in Valencia, edited by M. Mas and P. Schreyer.

Melka J. and L. Nayman (2004e) "Labour Quality and Skill Biased Technological Change in France", EPKE Working Paper No. 25, available at http://www.niesr.ac.uk/epke/france_skills_24.pdf

Menger, C. (1871), *Grundsätze der Volkswirtschaftslehre*, 2nd edn, Hölder-Pichler-Tempsky: Vienna, 1871/1923.

Milana, C. and A. Zeli. (2004), "Productivity Slowdown and the Role of ICT in Italy: A Firm-Level Analysis", in OECD (2004), *The Economic Impact of ICT – Measurement, Evidence and Implications*, OECD, Paris, pp. 261-277.

Nickell, S. and R. Layard (1999), "Labour Market Institutions and Economic Performance", in O. Ashenfelter and D. Card, eds. *Handbook of Labor Economics*, Vol. 3, North Holland: Amsterdam.

Nicoletti, G. (2001), "Regulation in Services: OECD Patterns and Economic Implications", OECD Economics Department Working Paper No. 287, OECD, Paris.

Nicoletti, G. and S. Scarpetta (2003), "Regulation, Productivity and Growth: OECD Evidence", *Economic Policy*, 18, 36, pp. 9-72.

OECD (1994), OECD Jobs Study. *Facts, Analysis and Strategies*, OECD, Paris.

OECD (1999), *Employment Outlook*, OECD, Paris.

OECD, (2002), *Employment Outlook*, web edition (www.sourceoecd.org).

Oliner, S. D. and D. E. Sichel (2000), "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?", *Journal of Economic Perspectives*, 14, 4, pp. 3-22.

O'Mahony, M. and B. van Ark (2003a), eds. *EU Productivity and competitiveness: An industry perspective. Can Europe resume the catching-up process?* European Commission, Enterprise publications.

O'Mahony, M and B. van Ark (2003b), "Productivity Performance Overview", in M. O'Mahony and B. van Ark (2003a), eds. *EU Productivity and competitiveness: An industry perspective. Can Europe resume the catching-up process?* European Commission, Enterprise publications.

O'Mahony, M., C. Robinson and M. Vecchi (2004), "The Impact of ICT on the demand for skilled labour: a cross-country comparison", EPKE Working Paper No. 16, available at http://www.niesr.ac.uk/epke/RES%20final.pdf

O'Mahony, M., L. Stokes and E. Stuivenwold (2004), "Employment Generation in the EU", EPKE Working Paper No. 23

O'Mahony, M. and M. Vecchi (2002). "Do Intangible Investments affect Companies' Productivity Performance?", NIESR Discussion Paper No. 201.

O'Mahony, M. and M. Vecchi (2004), "Quantifying the impact of ICT capital on output growth: A heterogeneous dynamic panel approach", *Economica*, forthcoming.

Oulton, N. and Srinivasan, S. (2004), 'Productivity growth in UK industries, 1970-2000: structural change and the role of ICT', paper presented at the EPKE Final Conference, London, 28-29 October 2004, available at http://www.niesr.ac.uk/epke/confppt/Oulton.pdf

Pavitt, K. (1984) "Sectoral Patterns of Technical Change: Toward a Taxonomy and a Theory", *Research Policy*, 13, 6, pp. 343-73.

Peneder, M. (2003a), "Industry Classifications: Aim, Scope and Techniques", *Journal of Industry, Competition and Trade*, 3, 1-2, pp. 109-129 and EPKE Working Paper No. 7, available at http://www.niesr.ac.uk/epke/MPtax.pdf.

Peneder, M. (2003b), "The Employment of IT Personnel", *National Institute Economic Review*, 184, pp. 74-85 and EPKE Working Paper No. 14, available at http://www.niesr.ac.uk/epke/Penerev.pdf.

Peneder, M. (2004a), "A sectoral taxonomy of educational intensity: Statistical cluster analysis and validation", EPKE Working Paper No. 26, available at http://www.niesr.ac.uk/epke/peneder-wp26.pdf

Peneder, M. (2004b), "Tracing empirical trails of Schumpeterian development", EPKE Working Paper No. 24, available at http://www.niesr.ac.uk/epke/peneder-24.pdf

Pesaran, M.H., Y. Shin and R. Smith (1999), "Pooled mean group estimation of dynamic heterogeneous panels", *Journal of the American Statistical Association*, 94, pp. 621-634.

Petit, P. and L. Soete (2001), "Introduction", in P. Petit, P and L. Soete, eds. *Technology and the Future of European Employment*, Edwar Elgar, Cheltenham, UK and Northampton, MA, US.

Pilat, D. (2004), 'Productivity performance in the OECD area: an international perspective', paper presented at the EPKE Final Conference, London, 28-29 October 2004, available at http://www.niesr.ac.uk/epke/confppt/Pilat.pdf

Pilat, D. (2001), "Innovation and Productivity in Services: State of the Art", in *OECD Proceedings of Workshop on Innovation and Productivity in Services* held in Sydney, Australia, November 1-2 2000, Chapter 2, pp.17-54.

Pilat, D. (1997), "Regulation and Performance in the Distribution Sector", OECD Economics Department Working Paper No. 180, OECD, Paris.

Piva, M. and M. Vivarelli (2002a), "The Determinants of the Skill Bias in Italy: Technology, Globalisation or Organisation?", paper presented at the MIUR-ITG Workshop, Università degli Studi di Torino, 13 June 2002.

Piva, M. and M. Vivarelli (2002b) "The Skill Bias: Comparative evidence and an Econometric Test", *International Review of Applied Economics*, 16, 3, pp. 347-57.

Rincon, A., C. Robinson and M. Vecchi (2004), "The productivity impact of e-commerce in the UK, 2001: evidence from microdata", EPKE Working Paper No. 30

Rincon, A. and M. Vecchi (2003), "Productivity performance at the company level", in M. O'Mahony and B. van Ark (2003a), eds. *EU Productivity and competitiveness: An industry perspective. Can Europe resume the catching-up process?* European Commission, Enterprise publications.

Rincon, A. and M. Vecchi (2004), "The dynamic impact of ICT spillovers on companies' productivity performance", NIESR Discussion Paper No. 245.

Robinson, C., L. Stokes, E, Stuivenwold and B. Van Ark (2003), "Industry Structure and Taxonomies", in M. O'Mahony and B. van Ark (2003a), eds. *EU Productivity and competitiveness: An industry perspective. Can Europe resume the catching-up process?* European Commission, Enterprise publications.

Rowlatt, A. (2001), "Measuring E-commerce: Developments in the United Kingdom", *Economic Trends*, 575, pp.30-36.

Sassenou, M. (1988), *Recherche-développement et productivité dans les entreprises japonaises: une étude économétrique sur données de panel*, Doctoral dissertation, Ecole del Hautes Etudes en Sciences Sociales, Paris.

Scarpetta, S., P. Hemmings, T. Tressel and J. Woo (2002), "The Role of Policy and Institutions for Productivity and Firm Dynamics: Evidence from Micro and Industry Data", OECD Economics Department Working Paper No. 329, OECD, Paris.

Schankerman, M. (1981), "The effect of double-counting and expensing on measured returns to R&D", *The Review of Economics and Statistics*, 63, pp. 453-58.

Schultz, T.W. (1960), "Capital Formation by Education", *Journal of Political Economy*, 68, pp. 571-583.

Schumpeter, J.A. (1911), *Theorie der wirtschaftlichen Entwicklung*, 4th edn., Duncker & Humblot, Berlin, 1911/34.

Schumpeter, J.A. (1942), *Capitalism, Socialism and Democracy*, 3rd edn, Harper & Row, New York, 1942/50.

Sena, V. (2004). "The return of the prince of Denmark: A survey on recent developments in the economics of innovation", *Economic Journal*, 114, F312-F332.

Siegel, D. (1997), "The impact of investments in computers on manufacturing productivity growth: a multiple-indicators, multiple-causes approach", *The Review of Economics and Statistics*, 79, 1, pp.68-78.

Snower, D. J. (1999), "The Organizational Revolution and its Labor Market Implications", Keynote address at the European Association of Labor Economists (EALE), Regensburg.

Solow, R. (1957), "Technical change and the aggregate production function", *The Review of Economics and Statistics*, 39, pp. 312-320.

Statistics Canada (1999) Questionnaire on "Information and Communication Technologies and Electronic Commerce", Technical Report downloaded from http://www.statcan.ca.

Stiroh, K. (2002), "Information Technology and the US Productivity Revival: What Do the Industry Data Say", *American Economic Review*, 92, 5, pp. 1559-76.

Timmer, M.P., G. Ypma and B. van Ark (2003), "IT in the European Union: A Driver of Productivity Divergence?", Groningen Growth and Development Centre, mimeographed.

Triplett, J.E. and Bosworth, B.P. (2003), "Productivity Measurement in Service Industries: 'Baumol's Disease' has been Cured", *Federal Reserve Bank of New York Economic Policy Review*, 9(3), 23-33.

van Ark, B., R. Inklaar, and R.H. McGuckin (2002a), " 'Changing Gear' Productivity, ICT and Service Industries: Europe and the United States", GGDC Research Memorandum, No. GD-60, and EPKE Working Paper No. 2, available at http://www.niesr.ac.uk/epke/bart2.pdf

van Ark, B, R. Inklaar, R. McGuckin and M.P. Timmer (2003), "The employment effects of the 'new economy'. A comparison of the European Union and the United States", *National Institute Economic Review*, 184, pp.86-98 and EPKE Working Paper No. 12, available at http://www.niesr.ac.uk/epke/bartrev.pdf van Ark, B., J. Melka, N. Mulder, M.P. Timmer, and G. Ypma (2002b), "ICT Investment and Growth Accounts for the European Union, 1980-2000", Final Report on "ICT and Growth Accounting" for DG Economics and Finance of the European Commission, Brussels; and EPKE Working Paper No. 3, available at http://www.niesr.ac.uk/epke/gd56-2.pdf

Van Leeuwen, G. and H. van der Wiel (2003). "Do ICT spillovers matter: Evidence from Dutch firm-level data", CPB Discussion Paper No 26.

Vecchi, M. (2000), "Increasing Returns versus Externalities: Pro-Cyclical Productivity in US and Japan", *Economica*, 67, pp. 229-244.

Venturini, F. (2004), "How much does IT consumption matter for growth? Evidence from National Accounts", paper presented at EPKE Final Conference, 28th and 29th October 2004, London. EPKE working paper n. 29.

Wolf, E. and T. Zwick (2002), "Reassessing the Impact of High Performance Workplaces", ZEW Discussion Paper 02-07, Mannheim.

Zwick, T. (2002a), "Training and Firm Productivity – Panel Evidence for Germany", ZEW Discussion Paper 02-50, Mannheim.

Zwick, T. (2002b), "Employee resistance against innovations", *International Journal of Manpower*, 23, 6, pp. 542-552.

Zwick, T. (2003), "The Impact of ICT Investment on Establishment Productivity", *National Institute Economic Review*, 184, pp. 99-110 and EPKE Working Paper No. 13, available at http://www.niesr.ac.uk/epke/zwickrev.pdf.

Zwick, T. (2004a), "Employee participation and productivity", *Labour Economics*, 11, forthcoming.

Zwick, T. (2004b), "Weiterbildungsintensität und betriebliche Produktivität", *Zeitschrift für Betriebswirtschaft*, 74, 7, pp. 651-668.

Zwick, T. (2005), "Continuing Vocational Training Forms and Establishment Productivity in Germany", *German Economic Review*, 6, 2, forthcoming.

VII ANNEXES

1. Annex A: Dissemination of research results: Working papers, publications and presentations

EPKE Working Papers

EPKE-WP-01: *Evaluating the Impact of the New Economy on Economic Performance*: A Review, by the EPKE Research Group.

EPKE-WP-02: C*hanging Gear: Productivity, ICT and Service: Europe and the United States*, by Bart van Ark, Robert Inklaar and Robert H. McGuckin.

EPKE-WP-03: *ICT Investment and Growth Accounts for the European Union, 1980-2000*, by Bart van Ark, Johanna Melka, Nanno Mulder, Marcel Timmer and Gerard Ypma.

EPKE-WP-04: *In Search of an ICT Impact on TFP: Evidence from Industry Panel Data*, by Mary O'Mahony and Michela Vecchi.

EPKE-WP-05: *Do intangible assets affect companies' productivity performance*?, by Mary O'Mahony and Michela Vecchi.

EPKE-WP-06*: Factors affecting the adoption of ICTs among SMEs: evidence from an Italian survey*, by Riccardo Lucchetti and Alessandro Sterlacchini.

EPKE-WP-07: *Industry Classifications: Aim, Scope and Techniques*, by Michael Peneder.

EPKE-WP-08: *Industrial Structure and Aggregate Growth*, by Michael Peneder.

EPKE-WP-09: *Do Lower Computer Prices Increase the Demand for IT Workers*? by Martin Falk.

EPKE-WP-10: *Is ICT the Key to Success? An Analysis of ICT Impact on French Economic Growth*, by Johanna Melka, Laurence Nayman, Soledad Zignago and Nanno Mulder.

EPKE-WP-11: *The growth of ICT and industry performance - manufacturing in the US and UK compared*, by Mary O'Mahony and Catherine Robinson.

EPKE-WP-12: *The employment effects of the 'new economy'. A comparison of the European Union and the United States*, by Bart van Ark, Robert Inklaar, Robert H. McGuckin and Marcel P. Timmer.

EPKE-WP-13: *The impact of ICT investment on establishment productivity*, by Thomas Zwick.

EPKE-WP-14: *The employment of IT personnel*, by Michael Peneder.

EPKE-WP-15: *Computers, wages and working hours in Italy*, by Riccardo Lucchetti, Stefano Staffolani and Alessandro Sterlacchini.

EPKE-WP-16: *The impact of ICT on the Demand for Skilled Labour: A cross country comparison, by Mary O'Mahony*, Catherine Robinson and Michela Vecchi

EPKE-WP-17: *ICT and Employment Growth in Italian Industries*, by Nicola Matteucci and Alessandro Sterlacchini.

EPKE-WP-18: *Works councils and the productivity impact of Direct Employee Participation*, by Thomas Zwick.

EPKE-WP-19: *The end of catching up: an industry perspective on European Union and US Productivity growth*, by Robert Inklaar, Mary O’Mahony and Marcel Timmer.

EPKE-WP-20: *Continuous training and firm productivity in Germany*, by Thomas Zwick.

EPKE-WP-21: *Is there Skill-Biased Technological Change in Italian Manufacturing? Evidence from Firm-Level* Data, by Massimiliano Bratti and Nicola Matteucci.

EPKE-WP-22: *How do firms respond to cheaper computers? Microeconometric evidence for France based on a production function approach*, by Pierre Biscourp, Bruno Crepon, Thomas Heckel and Nicholas Riedinger.

EPKE-WP-23: *Employment generation in the EU*, by Mary O’Mahony, Lucy Stokes and Edwin Stuivenwold

EPKE-WP-24: *Tracing empirical trails of Schumpeterian development*, by Michael Peneder.

EPKE-WP-25: *Labour quality and skill biased technological change in France*, by Johanna Melka and Laurence Nayman

EPKE-WP-26*: A sectoral taxonomy of educational intensity*: Statistical cluster analysis and validation, by Michael Peneder.

EPKE-WP-27: *The impact of Computers on Productivity in the Trade Sector: Explorations with Dutch Microdata*, by Lourens Broersma, Robert McGuckin and Marcel Timmer.

EPKE-WP-28: ICT, *R&D and productivity growth: evidence from Italian manufacturing firms*, by Nicola Matteucci and Alessandro Sterlacchini.

EPKE-WP-29*: How much does IT consumption matter for growth? Evidence from National Accounts*, by Francesco Venturini.

EPKE-WP-30: *The productivity impact of e-commerce in the UK, 2001: evidence from microdata*, by Ana Rincon, Catherine Robinson and Michela Vecchi.

EPKE-WP-31: *The impact of regulation on performance: An empirical investigation at the industry level in OECD countries*, Lourens Broersma and Bart van Ark

EPKE Technical notes

EPKE-TN-01: *Measuring Capital Input*, by Marcel Timmer and Mary O'Mahony.

EPKE-TN-02: *Industry-level Estimates of ICT and Non-ICT Employment, Qualifications and Wages in the UK and USA, 1979-2000*, by Geoff Mason, Catherine Robinson, John Forth and Mary O'Mahony

Database

EPKE has also completed the generation of a harmonised European dataset, which has been available on the EPKE website (http://www.niesr.ac.uk/epke/database.html) since late 2003.

The EU industry database contains three databases as outlined in the scientific report above.

The first database (Industry Labour Productivity Database) is an industry database on labour productivity including series on value added and labour input covering 56 industries for all 15 EU member states and the US allowing output and labour productivity growth comparisons.

The second database (Industry Growth Accounting Database) was constructed for four European countries (France, Germany, Netherlands and UK) and the US allowing calculation of the contribution to growth from labour skills, (ICT-)capital and total factor productivity.

The third database (Manufacturing Productivity and Unit Labour Cost Database) contains relative measures of levels of productivity and unit labour cost in manufacturing, with relative levels being derived on the basis of unit value ratios (UVRs).

Publications

National Institute Economic Review, Special Issue - The role of information and communications technology inputs

O'Mahony, M. and C. Robinson (2003) The growth of ICT and industry performance – manufacturing in the US and UK compared, *National Institute Economic Review*, No. 184, April, pp.60-73.

Peneder, M. (2003) 'The Employment of IT personnel', *National Institute Economic Review*, No. 184, April, pp.74-85.

van Ark, B., R. Inklarr, R. H. McGuckin and M. P. Timmer (2003) 'The employment effects fo the 'new economy'. A comparison of the European Union and the United States', *National Institute Economic Review*, No. 184, April, pp.86-98.

Zwick, T. (2003), 'The impact of ICT investment on establishment productivity', *National Institute Economic Review*, No. 184, April, pp.99-110.

Books

O'Mahony, M. and B. van Ark (2003a), *eds. EU Productivity and competitiveness: An industry perspective. Can Europe resume the catching-up process*? European Commission, Enterprise publications.

This publication by researchers at NIESR, University of Groningen and the Conference Board, summarised much of the research at the industry level, together with research using company accounts data. It gives an overview of productivity trends in the EU relative to the US, detailed analyses and policy conclusions. The chapters in the book were as follows.

Chapter I "Productivity Performance Overview", Mary O'Mahony and Bart Van Ark

Chapter II "Industry Structure and Taxonomies", Catherine Robinson, Lucy Stokes, Edwin Stuivenwold and Bart Van Ark

Chapter III "Productivity and Competitiveness in the EU and the US", Robert Inklaar, Mary O'Mahony, Catherine Robinson and Marcel Timmer

Chapter IV "Structural and Cyclical Performance", Robert Inklaar and Robert McGuckin

Chapter V "Productivity performance at the company level", Ana Rincon and Michela Vecchi

Chapter VI "The Policy Framework: Does the EU need a Productivity Agenda", Geoff Mason, Mary O'Mahony and Bart Van Ark

Chapter VII "Data Sources and Methods", Robert Inklaar, Lucy Stokes, Edwin Stuivenwold, Marcel Timmer and Gerard Ypma

Sterlacchini, A. (2005), ed. ICT, *Mercato del lavoro, Produttività (ICT, Labour Market and Productivity)* forthcoming, Carocci, Rome.

This book contains contributions by the members of the EPKE research group at Marche Polytechnic University (previously the University of Ancona). It analyses new empirical evidence on production and adoption of ICT, addressing its productivity and labour market consequences. It focuses on Italy and elaborates on works done at the industry and micro (firm and individual) level; it also provides an overview of the broader macro-trends of ICT in the country, combining the main conclusions of previous literature. Finally, the chapters discuss the main implications for a policy aimed at raising the technological level of the country, including ICT production and adoption. The chapters in the book are as follows.

Chapter I – "Sintesi del volume" (Book overview), Alessandro Sterlacchini.

Chapter II – "Produzione e diffusione di ICT in Italia" (Production and diffusion of ICT in Italy), Alessandro Sterlacchini.

Chapter III – "Determinanti dell'adozione di ICT nelle piccole e medie imprese" (Determinants of ICT adoption in small and medium-sized firms), Riccardo Lucchetti and Alessandro Sterlacchini.

Chapter IV – "Adozione di ICT e implicazioni strategiche per le imprese" (ICT adoption and strategic implications for firms), Marco Cucculelli.

Chapter V – "ICT ed occupazione in Italia: un'analisi settoriale" (ICT and employment in Italy: an industry-level analysis", Nicola Matteucci and Alessandro Sterlacchini.

Chapter VI – "R&S, ICT e lavoro qualificato nelle imprese manifatturiere italiane" (R&D, ICT and skilled-labour in Italian manufacturing firms), Massimiliano Bratti and Nicola Matteucci.

Chapter VII – "Uso del Computer e Differenziali Salari in Italia" (Computer use and wage differentials in Italy), Riccardo Lucchetti, Stefano Staffolani and Alessandro Sterlacchini.

Chapter VIII – "Capitale ICT, crescita e produttività: analisi macro e settoriali" (ICT capital, growth and productivity: macro and industry analyses), Francesco Venturini.

Chapter IX – "R&S, ICT e crescita della produttività: un'analisi con dati di impresa" (R&D, ICT and productivity growth: a firm-level analysis) Nicola Matteucci and Alessandro Sterlacchini.

Journal articles

Ark, B van (2002), "Measuring the New Economy: An International Comparative Perspective", *The Review of Income and Wealth*, 48, 1, pp. 1-14.

Ark, B. van (2002), "Mitkä toimialat johtavat globaalia tuottavuuskilpailua? EU, Suomi ja USA" (Which Industries Lead the Global Productivity Race? The European Union, Finland and the United States), *Talous & Yhteiskunta* (Economy and Society), no. 3, pp. 9-14, Labour Institute for Economic Research.

Ark, B. van, R. Inklaar and R.H. McGuckin (2003), "ICT and productivity in Europe and the United States. Where do the differences come from?", *CESifo Economic Studies*, Vol. 49, 3/2003, pp. 295–318.

Bratti, M. and N. Matteucci (2005) Is there Skill-Biased Technological Change in Italian Manufacturing? Evidence from Firm-Level Data, *Brussels Economic Review*, forthcoming.

Broersma, L., R.H. McGuckin and M.P. Timmer (2003), "The impact of Computers on Productivity in the Trade Sector: Explorations with Dutch Microdata", *De Economist*, 151, 1, pp. 53-79

Falk, M. (2002), "Endogenous Organizational Change and the Expected Demand for Skilled Workers", *Applied Economics Letters*, 9, pp. 419-423.

Falk, M. and B.M. Koebel (2002), "Outsourcing, imports and labour demand", *Scandinavian Journal of Economics*, 104, 4, pp. 567-586.

Falk, M. and B.M. Koebel (2004), "The impact of office machinery, and computer capital on the demand for heterogeneous labour", *Labour Economics*, 11, 1, pp. 99-117.

Hertog, den P., L. Broersma and B. van Ark (2003) 'On the soft side of innovation. Services innovation and its policy implications', *De Economist*, 151, 4, pp. 433-452.

Inklaar, R., J. Sleifer and B. van Ark (2002), "Innovatie en Productiviteit" (Innovation and Productivity", *Economische en Statistische Berichten, Dossier: Duitsland*, 5 December, pp. D14-D16.

Lucchetti, R. and A. Sterlacchini (2004) The adoption of ICT among SMEs: evidence from an Italian survey, *Small Business Economics*, 23, 2, pp. 151-168.

Lucchetti, R., S. Staffolani and A. Sterlacchini, (2005) "Computer, Wages and Working Hours in Italy", *Giornale degli Economisti*, forthcoming.

Matteucci, N., M. O'Mahony, C. Robinson and T. Zwick, (2004), Productivity, workplace performance and ICT: Industry and firm level evidence for Europe and the US, *Scottish Journal of Political Economy*, forthcoming

Melka J. and L. Nayman (2004) "TIC et productivité: une comparaison internationale", *Economie Internationale*, 98, 2, pp. 35-58.

Melka J. and L. Nayman (2004) "L'impact des Nouvelles Technologies de l'Information et des Communications sur la croissance française, 1980-01", *L'Actualité Economique*, forthcoming.

O'Mahony, M. (2002), 'Productivity and Convergence in the EU' *National Institute Economic Review*, April 2002.

O'Mahony, M. and M. Vecchi (2004) 'Quantifying the impact of ICT capital on output growth: A heterogeneous dynamic panel approach' *Economica*, forthcoming

O'Mahony, M. and B. van Ark (2005), 'Assessing the Productivity of the UK Retail Trade Sector – The Role of ICT', *International Review of Retail, Distribution and Consumer Research*, forthcoming

Peneder, M. (2003), 'Industrial structure and aggregate growth', *Structural Change and Economic Dynamics*, 14, 4, pp.427-448.

Peneder, M. (2003), 'Industrial classifications. Aims, scope and techniques', *Journal of Industry, Competition and Trade*, 3, 1-2, pp.109-129.

Peneder, M., S. Kaniovski and B. Dachs, (2003) 'What follows tertiarisation? Structural change and the role of knowledge based services' *The Service Industries Journal*, 23, 2, pp. 47-66.

Pilat, D., F. Lee and B. van Ark (2002), "Production and Use of ICT: A Sectoral Perspective on Productivity Growth in the OECD Area", *OECD Economic Studies*, vol. 35, no. 2, pp. 47-78.

Zwick, T. (2002b), "Employee resistance against innovations", *International Journal of Manpower*, 23, 6, pp. 542-552.

Zwick, T. (2004a), "Employee participation and productivity", *Labour Economics*, 11, forthcoming.

Zwick, T. (2004b), "Weiterbildungsintensität und betriebliche Produktivität", *Zeitschrift für Betriebswirtschaft*, 74, 7, pp. 651-668.

Zwick, T. (2005), "Continuing Vocational Training Forms and Establishment Productivity in Germany", *German Economic Review*, 6, 2, forthcoming.

Chapters in books

Ark, B. van (2002), "Understanding Productivity and Income Differentials Among OECD Countries: A Survey," in A. Sharpe, F. St-Hilaire and K. Banting, eds., *The Review of Economic Performance and Social Progress. Towards a Social Understanding of Productivity*, CSLS/IRPP, pp. 69-92.

Ark, B. van, R. Inklaar and R.H. McGuckin (2003), " "Changing Gear: Productivity, ICT and Service Industries in Europe and the United States", in J.F. Christensen and P. Maskell, eds., *The Industrial Dynamics of the New Digital Economy*, Edward Elgar, pp. 56-99.

Ark, B. van (2004), "The Measurement of Productivity: What do the Numbers Mean?", in G. Gelauff, L. Klomp, S. Raes and Th. Roelandt, eds., *Fostering Productivity. Patterns, Determinants and Policy Implications*, Elsevier, pp. 28-61.

Melka J. and L. Nayman (2005) "Labour quality and skill-biased technological change in France, 1982-2001", in "Divergences in Productivity between Europe and the United States", CESIFO ed. (papers edited from the conference held in Royaumont, March 2004).

Colecchia A., J. Melka and L. Nayman (2004) 'La qualité du travail, une comparaison internationale', in Productivité et croissance, rapport du Conseil d'Analyse Economique de P. Artus and G. Cette, n°48.

Melka J. and L. Nayman (2004) "Qualité du travail, TIC et productivité dans les services en France", in Productivité et emploi dans le tertiaire, rapport du Conseil d'Analyse Economique de P. Cahuc and M. Debonneuil, No. 48.

Melka J. and L. Nayman (2004) "Growth accounting and labour quality in France, 1982-01", Contribution to the workshop book *Growth, capital stock and new technologies* held on November 25 and 26, 2002 in Valencia, edited by M. Mas and P. Schreyer.

Peneder, M. (2003), 'Intangible investment and human resources, in Metcalfe, J. S. and Cantner, U. (eds.), *Change, transformation and development,* Physica Verlad, Heidelberg, pp. 229-256. (reprinted from *the Journal of Evolutionary Economics*, 2002, 12, 1-2).

Other publications

Broersma, L., P. den Hertog and B. van Ark (2003), ICT, Organisational Innovation and Productivity Growth in Services, University of Groningen and Dialogic, mimeographed.

Colecchia A., J. Melka and L. Nayman (2004) 'La qualité du travail, une comparaison internationale', in Productivité et croissance, rapport du Conseil d'Analyse Economique de P. Artus and G. Cette, n°48.

Falk, M. (2001), "Diffusion of Information Technology, Internet Use and the Demand for Heterogeneous Labour", ZEW Discussion Paper No. 01-48, Mannheim.

Inklaar, R., M. O'Mahony and M. Timmer (2003), "ICT and Europe's Productivity Performance. Industry-level growth account comparisons with the United States", Groningen Growth and Development Centre, Research Memorandum GD-68.

Inklaar, R. and M. Timmer (2004), "Job-rich growth in the European Union: Cycles, wages and regulation", paper presented at EPKE Final Conference, 28th and 29th October 2004, London, available at http://www.niesr.ac.uk/epke/confppt/Inklaar.pdf

Matteucci, N. and A. Sterlacchini (2003), "ICT and Employment Growth in Italian Industries", *Quaderni di Dipartimento WP Series*, n.193.

Matteucci, N. and A. Sterlacchini (2004), "ICT, R&D and Productivity Growth: Evidence from Italian Manufacturing Firms", paper presented at EPKE Final Conference, 28th and 29th October 2004, London, available at http://www.niesr.ac.uk/Epke/confppt/Matteucci.pdf

McGuckin, R., M. Spiegelman and B. van Ark (2004), "The U.S. Advantage in Retail and Wholesale Trade Performance: How can Europe catch up?", *Perspectives on a Global Economy*, The Conference Board, available at http://www.niesr.ac.uk/epke/confppt/McGuckin.pdf

Melka J. and L. Nayman (2003) "TIC et productivité: où en est la France?", *La Lettre du CEPII*, February.

Melka J., N. Mulder, L. Nayman and S. Zignago (2003) 'Skills, Technology and Growth: is ICT the key to Success? Part I: an Analysis of ICT impact on French growth', *CEPII working paper* n°2003-04.

Melka J. and L. Nayman (2004) "Contribution des TIC à la croissance de la productivité du travail: une comparaison internationale", Final report, Caisse des Dépôts et Consignations, Décembre

Rincon, A. and M. Vecchi (2004), "The dynamic impact of ICT spillovers on companies' productivity performance", NIESR Discussion Paper No. 245.

Timmer, M.P., G. Ypma and B. van Ark (2003), "IT in the European Union: Driving Productivity Divergence?", *Research Memorandum GD-67*, Groningen Growth and Development Centre, October (downloadable from http://www.eco.rug.nl/ggdc/pub/)

Venturini, F. (2004), "How much does IT consumption matter for growth? Evidence from National Accounts", mimeograph, Department of Economics, Marche Polytechnic University.

Venturini, F. (2004) "Learning-by-Doing, Hi-tech Consumption and Productivity Resurgence", mimeograph, Department of Economics, Marche Polytechnic University.

Wolf, E. and T. Zwick (2002), "Reassessing the Impact of High Performance Workplaces", ZEW Discussion Paper 02-07, Mannheim.

Zwick, T. (2002a), "Training and Firm Productivity – Panel Evidence for Germany", ZEW Discussion Paper 02-50, Mannheim.

Conference and other presentations

Bart van Ark: Productivity, Income and Investment in the OECD Area: Are Intangibles the Missing Link?, Workshop on "Productivity and Social Progress", Centre for the Study of Living Standards, 25-26 January, Ottawa.

Bart van Ark, Robert Inklaar and Robert H. McGuckin: "CHANGING GEAR: Productivity, ICT and Service Industries: Europe and the United States", Brookings workshop on Services Productivity, 17 May 2002, Washingotn D.C..

Mary O'Mahony and Michela Vecchi: *The Impact of Intangible Investments on Company Performance*, University of Stirling Departmental Seminar, 20 March 2002; Network of Industrial Economists, annual meeting, London, 4-5 April 2002; European Economic Association, Venice, 22-24 August 2002; EARIE, Madrid, 5-8 September 2002.

Riccardo Lucchetti and Alessandro Sterlacchini: *Factors affecting the adoption of ICTs among SMEs: evidence from an Italian survey*, 2nd ZEW Conference on the Economics of Information and Communication Technologies, Mannheim, Germany, 24-25 June 2002.

Bart van Ark, Robert Inklaar and Robert H. McGuckin: *Changing Gear: Productivity, ICT and Service: Europe and the United States*, ZEW Conference 24 June, Mannheim; Brookings Workshop on Services Productivity, 17 May 2002; Druid Conference Copenhagen, 6-8 June and NY Federal Reserve, 9 July 2002.

Mary O'Mahony: *Productivity Performance in the EU*, Conference on Economic Prospects in Europe, 11 Downing Street, September 2002.

Mary O'Mahony and Catherine Robinson: *Manufacturing in the New Economy*, Centre for Economic Performance Conference on the Future of Manufacturing, London School of Economics, November 1 2002.

Martin Falk: *Do Lower Computer Prices Increase the Demand for IT Workers?*, 2nd ZEW Conference on the Economics of Information and Communication Technologies, Mannheim, Germany, 24-25 June 2002.

Martin Falk: *The Impact of Office Machinery and Computer Capital on the Demand for Heterogeneous Labor*, European Economic Association, Venice, 19-22 September 2002; German Economic Association, Innsbruck, 17-20 September 2002; EALE Paris.

Michael Peneder: *Industrial Structure and Aggregate Growth*, 9th biannual conference of the International Schumpeter Society (ISS), March 27-31 2002, University of Florida, Gainesville.

Michael Peneder: *Structural Change and Growth: Country Patterns and Policy Conclusions*, conference 'On the Future Agenda of Economic Policy', 23-26 October, 2002, Institute for International Studies (IIS), University of Stanford, California.

Michel Fouquin, Johanna Melka & Laurence Nayman: *The impact of ICT on French growth, 1980-2000*, 42nd Congress of the Canadian Society of Economic Sciences, Aylmer, Canada, 15-16 May 2002; Workshop/Conference at the Caisse des Dépôts et Consignations "New Technologies and subsidisation policy of innovation", 3 July 2002.

Michel Fouquin, Johanna Melka & Laurence Nayman: *ICT and the quality of labour in France, 1980-1999*, XVIIIèmes Journées de l'Association Tiers-Monde, Tunis, 30-31 May 2002.

Michel Fouquin, Johanna Melka & Laurence Nayman: Bi-yearly workshop at CEPII, Paris (with OECD Paul Schreyer, Banque de France Gilbert Cette,…Direction de la Prévision, OFCE, INSEE,..) on over-accumulation of capital, 2 July 2002.

Michel Fouquin, Johanna Melka & Laurence Nayman: *ICT, skills and growth: evidence from France at the sectoral level 1982-00*, 25 & 26 November 2002 at the Seminar/workshop organised by IVIE and the BBVA Foundation, Valencia, Spain; bi-yearly workshop at CEPII, Paris, 3 December 2002; Club du CEPII, Paris, 10 December 2002. (Le Club du CEPII organises meetings for economists from French firms and the French Administration).

Bart van Ark: *ICT Investment and Growth Accounts for the European Union, 1980-2000* (paper with Johanna Melka, Nanno Mulder, Marcel Timmer and Gerard Ypma), 25 & 26 November 2002 at the Seminar/workshop organised by IVIE and the BBVA Foundation, Valencia, Spain

Bart van Ark and Robert Inklaar: "ICT Production and Use in Germany, Japan and the United States: A Comparison of Manufacturing and Services", Conference on "Perspectives of Core Industries in Japan and Germany", DIW (Berlin), FRI (Tokyo) and the Japanese-German Center Berlin (JDZB), 28-29 November, Berlin

Bart van Ark: *ICT and Productivity*, briefing at the high-level expert group on Information Society at DG Information Society, March 19 2003

Bart van Ark: *Is there a Productivity Puzzle? A Comparison of the EU and the U.S.*, speech for 4th Brussels Economic Forum, DG ECFIN, April 10-11 2003.

Mary O'Mahony and Michela Vecchi: *ICT and TFP*, seminar to the Economics Department, University of Sussex, January 2003.

Mary O'Mahony and Michela Vecchi: *In search of an ICT impact on TFP: evidence from industry panel data*, Royal Economic Society Annual Conference, University of Warwick, 7-9 April 2003.

Nicola Matteucci and Alessandro Sterlacchini: presented a paper in Rome on 2nd April, 2003 at the Scientific Committee of the Capitalia Group, which is responsible for carrying out the periodic survey on Manufacturing in Italy.

Bart van Ark: *The Measurement of Growth: What do the Numbers Mean?*, Joint ECFIN-OECD Workshop on "The Policy Agenda for Growth - EU Perspectives", Brussels,

Riccardo Lucchetti, Stefano Staffolani and Alessandro Sterlacchini: *Computers, wages and working hours in Italy*, International Workshop on Innovation in Europe: Empirical Studies on Innovation Surveys and Economic Performance', Rome, January, 2003; XVIII Annual Conference of Italian Labour Economists, Messina, September, 2003; Workshop on "Innovation, Employment, and Economic Growth" held at University of Bologna, Faculty of Statistics and Department of Economics, 28-29 November 2003.

Mary O'Mahony, Catherine Robinson and Michela Vecchi: *The impact of ICT capital and labour quality on labour productivity*, The European Association of Research in Industrial Economics (EARIE) 30th Annual Conference in Helsinki, August 2003.

Michael Peneder: *What follows tertiarisation? Structural change and the role of knowledge based services*, (co-authored with S. Kaniovski and B. Dachs) The European Association of Research in Industrial Economics (EARIE) 30th Annual Conference in Helsinki, August 2003.

Thomas Zwick: *The impact of ICT on Establishment Productivity* 3rd ZEW Conference on Economics of Information and Communications technologies, Manheim, 4-5 July 2003.

Thomas Zwick: *Works councils and the productivity impact of Direct Employee Participation*, European Association of Labour Economists, Seville, September 2003

Laurence Nayman: *ICT, qualifications and growth: sectoral results for France, 1980-00*, Caisse des Dépôts et Consignations, 9 January 2003.

Laurence Nayman: *Quality and employment in Services in France*, Commissariat Général du Plan, 17 November 2003.

Laurence Nayman: *Contribution des TIC à la croissance de la productivité du travail: une comparaison internationale*, presentation of intermediate report, Caisse des Dépôts et Consignations,20 November 2003.

Bart van Ark: *Trends in European Competitiveness: How to avoid the Productivity - Participation Trade Off?*, Conference on Challenges to European Competitiveness: Industrial Performance and Policy Responses, DG Enterprise, Brussels, 9 December 2003

Mary O'Mahony, Catherine Robinson and Michela Vecchi: *The impact of ICT on the demand for skilled labour: a cross-country comparison*, Royal Economic Society Annual Conference 2004, University of Wales, Swansea, 5-7 April 2004.

Nicola Matteucci and Alessandro Sterlacchini: *ICT and Employment Growth in Italian Industries*, International Workshop on "Empirical Studies on Innovation in Europe", held at University of Urbino, Faculty of Economics, 1-2 December 2003.

Nicola Matteucci and Massimiliano Bratti: *Is there skill-biased technological change in Italian manufacturing? Evidence from firm-Level data"*, presented at: Workshop on "La misurazione delle performance economiche: teorie, metodologie, applicazioni", Dipartimento di Scienze Economiche, University of Verona, 27/02/2004; EALE (European Association of Labour Economists) Conference 2004, Lisbon, 9–12 September 2004; XIX AIEL Annual Conference (Italian Association of Labour Economists), 23-24/09, Università degli Studi di Modena e Reggio Emilia, Modena; 87 AEA (Applied Econometrics Association) Conference, 7-8/10, University of Mons-Hainault, Belgium.

Johanna Melka & Laurence Nayman: *Qualité du travail et changement technologique biaisé*, CEPII, 11 March 2004.

Johanna Melka & Laurence Nayman: *Labour quality and skill-biased technological change in France, 1982-2001*, Conference organised by CEPII and Banque de France: "Divergences in Productivity between Europe and the United States", Royaumont Abbay, 21-23 March 2004.

Bart van Ark: *Can Europe Compete?*, Dinner speech at Netherlands Embassy in London for "Young Apeldoorn Conference 2004", 18 March London.

Bruno Crépon: *How do firms respond to cheaper computers? Microeconometric evidence for France based on a production function approach*, NIESR meeting, London, June 2004.

Michael Peneder: *A Sectoral Taxonomy of Educational Intensity*, 10th biannual conference of the International Schumpeter Society (ISS), Milan, June 2004.

Bart van Ark: *What Do We Know About Services Productivity in Europe?*, CPB Workshop on Services Productivity, The Hague, 7 June 2004

Thomas Zwick: *Productivity Effects of Training Intensity*, presented at EALE Conference, Lisbon, 9-10 September.2004

Mann C. L.: *Global sourcing: economic gains and policy challenges*, Conference organised by CEPII and GROUPAMA: "The challenges and economic outlook of the American elections", Paris, 21 October 2004.

Francesco Venturini: *Learning-by-Doing, Hi-tech Consumption and Productivity Resurgence*: Doctoral Workshop, Marche Polytechnic University, Ancona, 23/01/2004; NIESR lunch seminar, London, 8/06/2004; 4th Conference on Information and Communication Technologies, ZEW, Mannheim, 03/07/2004; 10th Conference on Computing in Economics and Finance, SCE, Amsterdam, 08/07/2004.

Bart van Ark: *What Do We Know About Services Productivity in Europe?*, Keynote Speech at RESER (Réseau Européen Services et Espace) Conference, Toulouse, 23 September 2004

Francesco Venturini: *How much does IT consumption matter for growth? Evidence from National Accounts*, Doctoral Workshop, Marche Polytechnic University, Ancona, 01/10/2004.

EPKE 18-month conference, 16th May 2003, Paris

During the second year of EPKE-funded research, the most notable avenue for disseminating results was the 18 month conference, with title 'Employment, Productivity and Skills in the Knowledge Economy' held on Friday 16th May, 2003 at Carre des Sciences, Paris. This one-day conference was attended by around 50 participants, from universities, research centres and government departments. Invited guest speakers were Professor Karin Wagner (Fachhochschule für Technik und Wirtschaft, Berlin); Nathalie Greenan (Centre d'Etudes de l'Emploi, Paris), and Thomas Coutrot (DARES, Ministère de l'emploi, Paris). Papers were presented by EPKE members in the morning, these are available from the EPKE website.

Keynote papers were presented in the afternoon. The first keynote paper presented was Karin Wagner (FTW, Berlin), who presented a case study comparison of UK and German skill supply strategies in banking, retail, motor vehicles and software. Initially, Wagner outlined the differences between the UK and German training systems for ICT personnel in particular. She reveals that in terms of formal education, though the rate of entrants for German computer science degrees has increased sharply in the latter half of the 1990s, the number of graduates (i.e. passing exams) has remained relatively constant throughout the 1980s and 1990s (only 4 per cent growth 1998-2001). The UK has seen a growth rate of over 20 per cent in first degree graduates, 1998-2001, by comparison. Turning to less formal education, those entering onto apprenticeships schemes in Germany, ICT occupations seem to be attracting many more since 1996, particularly amongst the newer ICT occupations. The UK apprenticeships schemes are generally less easy to characterise and attract a much smaller number of workers. The case study approach reveals the different requirements and preferences in each industry; the motor vehicle industry preferring engineering graduates to ICT graduates, so that they better understand the production process; retailing favours in-company promotion and has generally lower wage levels; the software industry prefers to appoint graduates and the banking sector invests heavily in top graduates. These trends are consistent across the two countries.

In the second keynote paper, Thomas Coutrot (DARES, Paris) presented a paper which discussed the evolution of increased precariousness of French workers. Using a Tobit model, corrected for selection bias on firm level data for 1998-99, Coutrot demonstrates that ICT has been associated with the more intensive use of casual labour (consistent with trends observed by Wagner in the previous paper). This, Coutrot argued, has led to the development of a dual personnel management system, with substantial parts of firms' workforce existing as temporary workers.

Nathalie Greenan (CEE, Paris) presented a paper that looked at the holistic impact that ICT has made, in terms of altering organisational behaviour of firms and the behaviour of workers, who are now more independent but also subject to greater monitoring. Using a number of surveys on organisational change and computerisation, Greenan employs a multiple correspondence analysis to analyse computer use and firm characteristics with which it is associated. She concludes that ICT is more than a new technology, that it provides the 'impetus for new forms of economic organisation' and that it allows for 'certain forms of social organisation' which are 'strongly influenced by traditional divisions based on culture and skills'.

The final session was a roundtable, with Bart van Ark (Groningen), Helene Boudchon (OFCE), Diane Eyben (European Commission) and Dirk Pilat from OECD.

Overall, the conference provided a wide range of papers that discussed the impact that ICT has been having in various countries, not purely in terms of productivity differences, but also in terms of its demand for and use of skilled labour, firms preferences for less secure workers and also the impact that ICT is having on organisational changes within the firm and amongst workers. It also enabled the EPKE project team to disseminate their findings so far and also to receive useful comments on how to develop further their work. The full programme and papers are available at http://www.cepii.fr/anglaisgraph/meetings/2003/160503.htm

Conference Board Workshop on "Benchmarking Reforms in a Renovating Economy", 4 April 2004, London

The aim of this small workshop was to have an open exchange between 12-15 participants coming from academia, government and business on the state of our knowledge and experience with structural reforms on markets in the light of recent surge in technological progress and diffusion. There were three main sessions, on 1) macro-relation between ICT and structural reform; 2) technological opportunities and organizational change in retailing; 3) business and policy experiences with structural reforms in retailing. Presentations were given by Robert McGuckin (Conference Board), Bart van Ark (University of Groningen), Lourens Broersma (University of Groningen), Pim den Hertog (Dialogic), Frank den Butter (Free University Amsterdam), Patrick Burrows (Tesco) and Andrew Bacchus (Assistant Director, Consumer Services, Dept. of Trade and Industry, UK). This workshop has led to subsequent research on the relation between structural reform and productivity, and the work on productivity and reforms in retailing.

"The challenges and economic outlook of the American elections"

Conference organised by CEPII and Banque de France, 21 October 2004 with Catherine Mann

The presentation by Catherine L. Mann dealt with global sourcing: economic gains and policy challenges. Although technological change is the most important driver of IT price declines, globalisation and international trade made IT hardware some 10 to 30% less expensive. Globalization of IT hardware led to 0.3% point to real GDP growth per year from 1995 to 2002.

While IT hardware prices have declined, the importance of IT services and software has increased from 58 to 69% of IT spending in 1993 and 2001 respectively. Software and services are now more and more produced globally and this globalisation will promote a further diffusion of IT in the US economy. This, in turn, points to an even greater demand for workers with IT skills and proficiency. In the nineties, investment in IT propelled job growth for workers with IT skills to twice the rate of job growth in the overall economy. Over the next decade, the BLS projects that job growth to 2010 in occupation requiring IT skills will be more than 3 times the rate of job growth in the overall economy.

The skills related to IT jobs that will be saved in the US are to be found in the highest wage range and are linked to domain-specific demand. The loss in computer programmers jobs pertaining to this category (-18%) is more than counterbalanced by by the increase in computer software engineers, IT analysts and IT administrators (+26%). On the contrary, low-wage IT-related jobs suffer most from outsourcing as these low-wage occupations (data key entry, computer operators, telemarketers) experienced a loss by 25% over the 1999-2003 period.

As outsourcing looms to be a threat to jobs, workers are recommended to train along their whole active life and businesses are urged to foster workplace practices and worker education, develop innovation and new products.

EPKE Final Conference, 28th and 29th October 2004, London

The final EPKE conference, 'Information Technology, Productivity and Growth,' took place in London on the 28th and 29th October 2004. Investigating the impact of information technology use on productivity, employment and growth, the papers presented at this conference provided empirical evidence at both the firm and industry level for both Europe and the US.

The conference brought together a variety of interested parties, providing an excellent forum for discussion. In addition to members of the six collaborating economic institutes and universities involved in EPKE, conference participants also included representatives from a variety of other organisations, including the OECD and government departments, as well as other research institutes and universities in both Europe and the US.

The opening session of the conference began with a presentation by Dale Jorgenson (Harvard) of the paper, 'Growth of US Industries and Investments in Information Technology and Higher Education', (Jorgenson, Ho and Stiroh, 2004). This provided insights into the situation in the US economy, providing a useful base for comparison with Europe. This paper set out to quantify the sources of economic growth in the US, using detailed industry level data, for the period 1977 to 2000. At the industry level, as well as for the whole economy, investments in information technology and higher education were found to be the most important contributors to economic growth. These factors played particularly significant roles in the post-1995 resurgence of the US economy. Total factor productivity growth was also important, although to a lesser extent.

An international perspective was then provided by Dirk Pilat (OECD), who presented work on productivity performance in OECD countries (Pilat, 2004). This discussed empirical evidence on productivity and economic growth, considering the main sources of growth and productivity at aggregate, industry and firm level. Measurement issues remain a significant problem in international productivity comparisons. Particular emphasis was placed on finding explanations for differences across OECD regions and one reason identified for the strong growth performance of the US and other countries during the late 1990s was regulatory reform, particularly in the case of some service industries. ICT investment was also highlighted as a significant factor, although the resulting impact on growth is likely to be influenced by a number of other factors, such as whether economic and social institutions allow the benefits from such increased investment to be maximised.

In the second session, Nick Oulton (CEP, NIESR) presented the paper, 'Productivity growth in UK industries, 1970-2000: structural change and the role of ICT', (Oulton and Srinivasan, 2004). Using new industry level data, Oulton and Srinivasan set out to ascertain the impact of structural change and ICT on productivity growth over the period 1970-2000 for the UK market economy. Investment in ICT is found to have been an increasingly important source of productivity growth in the UK throughout the 1990s. Using a growth accounting approach, ICT capital deepening is shown to account for 28% and 46% of labour productivity growth in the 1990s and 1995-2000 period respectively. Their findings are not disputed by econometric analysis of the data. They also note that while TFP growth appeared to decline in 1995-2000 in comparison with the 1990-1995 period, a possible explanation for this apparent fall may be that the sizeable complementary investment that has accompanied ICT investment has not been appropriately accounted for.

Robert Inklaar (University of Groningen), then presented the paper, 'Job-rich growth in the European Union: Cycles, Wages and Regulation', (Inklaar and Timmer, 2004). In this paper, Inklaar and Timmer consider the increase in European employment growth during the late 1990s, and examine how much of this can be attributed to business cycles, wage moderation and labour market regulation. Using an industry-panel data set, wage moderation is found to have had only a limited impact. Cyclical factors are found to have played some role in the rise in employment. In particular, the authors find evidence to suggest that the decline in employment protection may have led to greater volatility in employment, and hence cyclical factors may have played a more significant role in increasing employment than previous studies have indicated. Structural reforms are found to be of less importance in explaining employment growth. If gains in employment during the 1990s are predominantly due to cyclical rather than structural factors, this may have less favourable consequences for employment growth in a future downturn.

In the third session, Thomas Zwick (ZEW) discussed evidence for Germany on the relationship between technology use, organisational flexibility and innovation. Firstly, the determinants of flexibility were explored. Using two different datasets, ICT was found to be an important determinant of flexibility in both cases. Secondly, the determinants of innovative behaviour were investigated, with explanatory variables including both numerical and functional flexibility as well as an ICT dummy. Both numerical and functional flexibility were found to have a significant effect on product and service innovation using both the IAB and ZEW datasets. Using the IAB data, ICT was found to be positively correlated only with innovation improvement and incremental innovation, not radical innovation. Other factors which impacted positively on innovative behaviour include training, modern technical equipment and exports. From the ZEW data, the share of IT specialists was also found to exert a positive impact. Zwick also finds that an increase in the intensity of training has a positive and significant effect on establishment productivity.

Nicola Matteuci (Marche Polytechnic University, Ancona), then turned the focus to Italy, with the paper, 'ICT, R&D and productivity growth: evidence from Italian manufacturing firms.' Here, Matteucci and Sterlacchini (2004) consider the impact of technological capital on the productivity of Italian manufacturing firms. Both R&D and ICT intensity are employed as measures of technological capital – and both are found to have a positive effect on TFP growth. However, as the ICT intensity is found only to have a significant effect when lagged, this is supportive of the 'delay hypothesis' – that in order to achieve the maximum gains from ICT investment, accompanying complementary investment is necessary. The findings of this study lead the authors to suggest that policies to increase the technological capital of Italian firms are likely to be beneficial.

In the final session of day one, Eric Bartelsman (Free University Amsterdam), presented ongoing work with Stefano Scarpetta on whether there is a role for policy and institutions in encouraging experimentation both within and between firms. In this work, Bartelsman and Scarpetta are interested in ascertaining whether differences in the pace of innovation across countries can partly be explained by variations in firm dynamics across countries. Experimentation by firms is necessary where advances in technology involve uncertainty as to how the market will respond. Evidence was presented that administrative regulations on entrepreneurial activities have a negative effect on entry rates, especially for small and medium-sized firms. Stringent product market regulations and tight hiring and firing regulations also have negative effects on entry. Therefore, policy does seem to have a role to play in determining experimentation by firms.

This was followed by a presentation by John Van Reenen (LSE), who discussed the paper 'How special is the special relationship? Using the impact of US R&D spillovers on UK firms as a test of technology sourcing.' In this paper, Griffith, Harrison and Van Reenen (2004) set out to determine whether the 'technology sourcing' hypothesis holds. Specifically, they explore whether, for UK firms, locating R&D laboratories and inventors in the US allows the UK firm to benefit from US R&D spillovers and enhance productivity. Their results show that those UK firms with a strong inventor presence in the US by 1990 did benefit considerably from the growth in the US R&D stock over the period 1990-2000 – with estimates suggesting that on average TFP was at least 5% higher than it would otherwise have been. These gains were greatest for those industries where a larger TFP gap with the US was apparent. However, the relationship does not seem to operate in reverse – US firms do not appear to benefit hugely from having a UK R&D presence. As locating R&D laboratories in the US seems to generate beneficial gains for UK, the authors suggest that any policies which encourage the relocation of R&D activities away from the US may therefore be partly detrimental, in that firms may have a reduced capacity to benefit from US R&D spillovers.

The first session of the second day of the conference focused on the distributive trades sectors, where particularly strong performance in the US has not been matched in the EU. Focusing first on the retail sector, Marcel Timmer (University of Groningen), presented work with Robert Inklaar and Bart van Ark on, 'Productivity Differentials in US and EU Retailing: Statistical myth or reality?' This study considers the measurement issues in calculating output volume in the retail sector, and sets out to ascertain the impact of any biases in measurement towards either the US or EU. In doing so, the aim is to find an explanation as to why retail trade has made a much greater contribution to productivity growth in the US than has been the case for the EU. Using a double deflation method, experimental estimates of retail output volume were formed, however the results suggest that there is not a bias in the measurement of retail margin volume towards the US. Together with the fact that they find the impact of ICT to be too small to provide a full explanation, they conclude that the differences between the EU and the US are robust. However, they do find evidence that part of the considerable growth in value added in the US retail sector since 1995 is due to savings in terms of intermediate inputs.

Robert McGuckin (The Conference Board) then presented the paper, 'The U.S. Advantage in Retail and Wholesale Trade Performance: How can Europe catch up?', (McGuckin, Spiegelman and van Ark, 2004). This paper explores the contribution of both the retail and wholesale sectors to the productivity gap between the EU and US. The findings suggest that improvements in technology and organisational change are the key reasons why the US has experienced enhanced productivity growth. While considerable improvements and changes have also taken place in Europe, they have not occurred so rapidly. Several reasons for this are identified, including greater regulatory barriers in Europe, less rapid complementary change and more difficulties in increasing scale by expanding across country borders. However, Europe is identified as possessing significant potential to catch-up with the US, for example, as regulations are eased and incentives for investment increase. Europe will also benefit from being able to learn from US mistakes, and so the transformation of the European retail sector may in comparison occur relatively quickly.

The next session presented evidence on the impact of information technology using micro-data for both the UK and France. First, Michela Vecchi (NIESR) presented the paper, 'The productivity impact of e-commerce in the UK, 2001: evidence from microdata', (Rincon, Robinson and Vecchi, 2004). Using the UK e-commerce survey, this paper explores the impact of e-commerce on productivity at the establishment level. Using OLS estimation, e-commerce is not found to have a significant impact on productivity, but once selectivity bias is corrected for, a strong positive effect is revealed. Results from using a treatment effect estimator indicate that there are indeed positive and significant productivity gains from both e-buying and e-selling. For establishments in the service sector, e-selling has been particularly important.

Thomas Heckel (CREST/INSEE) then presented work using firm level evidence for France. Crépon, Heckel and Riedinger found a positive relationship between MFP growth and adoption of the internet, but not for other forms of information technology. This relationship between implementation of the internet and the growth of MFP is found not to be dependent on new work practices. However, the adoption of the internet does not affect the efficiency of all inputs to the same extent – it has a greater impact on both skilled and female labour.

In the closing session of the conference, Michael Peneder (WIFO) presented the paper, 'Tracing empirical trails of Schumpeterian development', (Peneder, 2004b). Schumpeterian development is, "characterised by the simultaneous interplay of growth and qualitative transformations of the economic system". These transformations are reflected in changes in the sectoral composition of production. Using data for 28 OECD countries, econometric analysis provides support for the Schumpeterian development view. The key finding emerging from this work is that aggregate income and growth during the 1990s have been significantly affected by variations in industrial structure.

The final presentation, 'How much does IT consumption matter for growth? Evidence from National Accounts.' was given by Francesco Venturini (Marche Polytechnic University, Ancona). This study aims to assess the contribution of IT consumption to output growth in both the EU and the US. For example, the possession of a computer at home may increase the owner's IT skills. These skills may then prove beneficial in the workplace and hence lead to productivity gains. The results indicate that while IT consumption has made a greater contribution to output growth in the US, it has also played a significant part in the EU. Indeed, these results conceal considerable diversity within the EU, with, for example, the UK and Denmark much closer to the US position.

This brought the final EPKE conference to a close. The collection of papers presented at this conference provided a wide variety of insights into the relationship between information technology use, productivity, employment and growth, providing an extremely fitting end to the EPKE research network. All presentations and papers (where currently available) from the EPKE final conference are available to download from the EPKE website, http://www.niesr.ac.uk/epke/finalconf.html

2. Annex B

Table 11. Industries included in the labour productivity dataset

	Industry Name	ISIC rev 3
	TOTAL ALL INDUSTRIES	**01-99**
1	Agriculture	01
2	Forestry	02
3	Fishing	05
4	Mining and quarrying	10-14
5	Food, drink & tobacco	15-16
6	Textiles	17
7	Clothing	18
8	Leather and footwear	19
9	Wood & products of wood and cork	20
10	Pulp, paper & paper products	21
11	Printing & publishing	22
12	Mineral oil refining, coke & nuclear fuel	23
13	Chemicals	24
14	Rubber & plastics	25
15	Non-metallic mineral products	26
16	Basic metals	27
17	Fabricated metal products	28
18	Mechanical engineering	29
19	Office machinery	30
20	*Insulated wire*	*313*
21	*Other electrical machinery and aparatus nec*	*31-313*
22	*Electronic valves and tubes*	*321*
23	*Telecommunication equipment*	*322*
24	*Radio and television receivers*	*323*
25	*Scientific instruments*	*331*
26	*Other instruments*	*33-331*
27	Motor vehicles	34
28	*Building and repairing of ships and boats*	*351*
29	*Aircraft and spacecraft*	*353*
30	*Railroad equipment and transport equipment nec*	*352+359*
31	Furniture, miscellaneous manufacturing; recycling	36-37
32	Electricity, gas and water supply	40-41
33	Construction	45
34	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	50
35	Wholesale trade and commission trade, except of motor vehicles and motorcycles	51
36	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	52
37	Hotels & catering	55
38	Inland transport	60
39	Water transport	61
40	Air transport	62
41	Supporting and auxiliary transport activities; activities of travel agencies	63
42	Communications	64
43	Financial intermediation, except insurance and pension funding	65
44	Insurance and pension funding, except compulsory social security	66
45	Activities auxiliary to financial intermediation	67
46	Real estate activities	70
47	Renting of machinery and equipment	71
48	Computer and related activities	72
49	Research and development	73
50	*Legal, technical and advertising*	*741-3*
51	*Other business activities, nec*	*749*
52	Public administration and defence; compulsory social security	75
53	Education	80
54	Health and social work	85
55	Other community, social and personal services	90-93
56	Private households with employed persons	95

Table 12. Industries included in the growth accounting dataset

	Industry Name	ISIC rev 3
1	Agriculture, Forestry and Fishing	01-05
2	Mining and Quarrying	10-14
3	Food, Drink & Tobacco	15-16
4	Textiles, Leather, Footwear & Clothing	17-19
5	Wood & Products of Wood and Cork	20
6	Pulp, Paper & Paper Products; Printing & Publishing	21-22
7	Mineral Oil Refining, Coke & Nuclear Fuel	23
8	Chemicals	24
9	Rubber & Plastics	25
10	Non-Metallic Mineral Products	26
11	Basic Metals & Fabricated Metal Products	27-28
12	Mechanical Engineering	29
13	Electrical and Electronic Equipment; Instruments	30-33
14	Transport Equipment	34-35
15	Furniture, Miscellaneous Manufacturing; recycling	36-37
16	Electricity, Gas and Water Supply	40-41
17	Construction	45
18	Repairs and wholesale trade	50-51
19	Retail trade	52
20	Hotels & Catering	55
21	Transport	60-63
22	Communications	64
23	Financial Intermediation	65-67
24	Real Estate Activities and Business Services	70-74
25	Other Services	90-99
26	Non-Market Services	75-85

Table13. Skills categories employed to measure labour quality

France
1. Bachelor degrees and above
2. Baccalaureate plus 2 years college
3. Baccalaureate
4. Vocational (CAP, BEP ou autre de ce niveau)
5. General Education (BEPC)
6. No formal qualifications (Aucun diplôme ou CEP)
US
1. Bachelor degrees and above
2. Associate degrees
3. Some college, no degree
4. High school graduate
5. Did not complete high school
Germany
1. Higher education (16-17 years education or above)
2. Vocational degree
3. No degree
Netherlands
1. Master degree and above
2. HBO
3. HAVO/VWO
4. MAVO
5. MBO
6. LBO/VBO
7. Primary education or below
UK
1. First degrees and above
2. Other NVQ4

3. NVQ3
4. NVQ2 and NVQ1
5. No formal qualifications

Table 14. The IT labour industry classification

(NACE industry codes in brackets)

1. *IT producer – services* (ITP/serv.): Computer and related activities (72)

2. *IT producer – manufa*cturing (ITP/manuf.): Computers and office machinery (30).

3. *Dynamic IT user with a high and growing IT-labour intensity* (ITU/high): Mining and quarrying (10-14); Mineral oil refining, coke and nuclear fuel (23); Chemicals (24); Electrical machinery and apparatus (31); Radio, television and communication (32); Instrument engineering (33); Motor vehicles (34), Other transport equipment (35), Electricity, gas and water supply (40-41), Air transport (62); Telecommunications (642); Financial intermediation (65, 67), Insurance and pension funding (66), Research and development (73); Other business services (71, 74), Public administration and defence, incl. compulsory social security (75); Education (80).

4. *Other IT user industries* (ITU/other): Agriculture, forestry and fishing (01-05), Food, drink and tobacco (15-16), Textiles, leather, footwear and clothing (17-19), Wood, products of wood and cork; Pulp, paper and paper products, printing and publishing (20-22), Rubber and plastics (25), Non-metallic mineral products, furniture, miscellaneous manufacturing (26, 36-37), Basic metals and fabricated metal products (27-28), Mechanical engineering (29), Construction (45), Sale, maintenance and repair of motor vehicles and motor cycles (50), Wholesale trade (51), Retail trade (52), Hotels and catering (55), Railways (601), Other inland transport, Water transport (602-603, 61), Supporting and auxiliary transport activities, activities of travel agencies (63), Post and courier activities (641), Real estate (70), Health and social work (85), Other community, social and personal services (90-93).

Table 15. The sectoral taxonomies of educational intensity

ISIC rev. 3	Industry Name	National Taxonomies					International Classification		Notes
		USA	UK D	FRA	GER	AUT			
01-05	Agriculture, forestry, fishing	7	6	-	7	7	**7**	very low	
10-14	Mining and quarrying	4	3	6	4	4	**4**	interm.	
15-16	Food, drink & tobacco	5	5	6	6	6	**6**	low	
17-19	Textiles, leather, footwear & clothing	7	7	7	7	7	**7**	very low	
17	Textiles	(7)	(7)	(7)	7	7	**7**	very low	
18-19	Leather, footwear & clothing	(7)	(7)	(7)	7	7	**7**	very low	
20	Wood & products of wood and cork	(5)	(5)	(6)	7	(6)	**7**	very low	*R2
21-22	Pulp, paper products; printing, publishing	4	4	5	3	(6)	**4**	interm.	
21	Pulp, paper & paper products	(4)	(4)	(5)	(3)	(6)	**(4)**	interm.	
22	Printing & publishing	(4)	(4)	(5)	(3)	4	**4**	interm.	
23	Mineral oil refining, coke & nuclear fuel	3	3	3	4	(4)	**3**	med-high	
24	Chemicals	3	2	3	2	(4)	**3**	med-high	
25	Rubber & plastics	5	5	5	7	6	**5**	med-low	*R1
26	Non-metallic mineral products	(5)	(5)	(6)	6	6	**6**	low	
27-28	Basic metals & fabricated metal products	5	6	6	6	5	**6**	low	
27	Basic metals	(5)	(6)	(6)	6	5	**6**	low	*R3
28	Fabricated metal products	(5)	(6)	(6)	6	5	**6**	low	*R3
29	Mechanical engineering	4	4	6	4	4	**4**	interm.	
30	Computers, office machinery	1	2	1	2	3	**2**	high	
31	Electrical machinery & apparatus, nec	3	4	5	4	4	**4**	interm.	
32	Audiovisual apparatus	2	3	5	4	3	**3**	med-high	
33	Instrument engineering	3	3	3	3	4	**3**	med-high	
34	Motor vehicles	4	4	5	3	4	**4**	interm.	

35	Other transport equipment	3	3	3	4	4	**3**	med-high	
36-37	Furniture, miscellaneous manuf.; recycling	5	5	6	6	5	**5**	med-low	
40-41	Electricity, gas & water supply	4	3	3	4	4	**4**	interm.	
40	Electricity & gas	(4)	(3)	(3)	(4)	4	**4**	interm.	
41	Water supply	(4)	(3)	(3)	(4)	4	**4**	interm.	
45	Construction	6	6	6	5	6	**6**	low	
50	Sale & repair of motor vehicles; retail of fuel	6	6	6	5	5	**6**	low	
51	Wholesale trade and commission trade	4	5	3	4	4	**4**	interm.	
52	Retail trade; repair (exc. 50)	4	5	5	5	5	**5**	med-low	
55	Hotels & catering	7	5	6	7	7	**7**	very low	*R1
60	Railways & other inland transport	5	5	(6)	5	5	**5**	med-low	
61	Water transport	5	5	(6)	4	6	**5**	med-low	
62	Air transport	3	4	(6)	3	2	**3**	med-high	*R1
63	Auxiliary transport activities; travel agencies	3	5	(6)	3	4	**4**	interm.	*R3
64	Communications	-	-	2	4	4	**4**	interm.	*R1
641	Post and courier activities	4	5	(2)	(4)	(4)	**4**	interm.	*R3
642	Telecommunications	3	3	(2)	(4)	(4)	**3**	med-high	
65	Financial intermediation (except 66)	2	3	2	3	2	**2**	high	
66	Insurance and pension funding	2	3	2	3	4	**3**	med-high	
67	Activities auxiliary to financial intermediation	(2)	3	(2)	(3)	3	**3**	med-high	
70	Real estate activities	3	2	5	4	7	**4**	interm.	
71-74	Business services	-	-	-	2	-	**2**	high	
71	Renting of machinery & equipment	-	5	-	(2)	3	**4**	interm.	*R2
72	Computer and related activities	1	1	1	(2)	2	**1**	very high	
73	Research & development	1	1	1	(2)	1	**1**	very high	

74	Other business activities	2	1	2	(2)	2	**2**	high	
75	Public admin., defence; social security	2	3	3	3	4	**3**	med-high	
80	Education	1	1	1	1	1	**1**	very high	
85	Health, social work	3	2	2	3	3	**3**	med-high	
90-99	Other Services	4	3	5	-	-	**4**	interm.	
90-93	Other community, social or personal services	(4)	(3)	(5)	2	3	**3**	med-high	*R3
95	Private households with employed persons	(4)	(3)	(5)	-	7	**7**	very low	*R2
99	Extra-territorial organizations and bodies	(4)	(3)	(5)	-	1	**1**	very high	*R2

Note: 1 = very high; 2 = high; 3 = med-high; 4 = intermediate; 5 = med-low; 6 = low; 7 = very low; numbers in italics are derived from the more aggregate data; * decision Rule R1: median overrules mean; R2: unambiguous identification without overrules those including derived values; R3: if identification without derived values is ambiguous, take next integer towards outcome with derived values.

Table 16. ICT Taxonomy

1. *ICT Producing - Manufacturing* (ICTPM): Office machinery (30); Insulated wire (313); Electronic valves and tubes (321); Telecommunication equipment (322); Radio and television receivers (323); Scientific instruments (331).
2. *ICT Producing – Services* (ICTPS): Communications (64); Computer & related activities (72).
3. *ICT Using – Manufacturing* (ICTUM): Clothing (18); Printing & publishing (22); Mechanical engineering (29); Other electrical machinery & apparatus (31-313); Other instruments (33-331); Building and repairing of ships and boats (351); Aircraft and spacecraft (353); Railroad equipment and transport equipment nec (352+359);Furniture, miscellaneous manufacturing; recycling (36-37).
4. *ICT Using – Services* (ICTUS): Wholesale trade and commission trade, except of motor vehicles and motorcycles (51); Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (52); Financial intermediation, except insurance and pension funding (65); Insurance and pension funding, except compulsory social security (66); Activities auxiliary to financial intermediation (67); Renting of machinery & equipment (71); Research & development (73); Legal, technical & advertising (741-3).
5. *Non-ICT Manufacturing* (NICTM): Food, drink & tobacco (15-16); Textiles (17); Leather and footwear (19); Wood & products of wood and cork (20); Pulp, paper & paper products (21); Mineral oil refining, coke & nuclear fuel (23); Chemicals (24); Rubber & plastics (25); Non-metallic mineral products (26); Basic metals (27); Fabricated metal products (28); Motor vehicles (34).
6. *Non-ICT Services* (NICTS): Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel (50); Hotels & catering (55); Inland transport (60); Water transport (61); Air transport (62); Supporting and auxiliary transport activities; activities of travel agencies (63); Real estate activities (70);

Other business activities, nec (749); Public administration and defence; compulsory social security (75); Education (80); Health and social work (85); Other community, social and personal services (90-93); Private households with employed persons (95); Extra-territorial organizations and bodies (99).

7. *Non-ICT Other* (NICTO): Agriculture (01); Forestry (02); Fishing (05); Mining and quarrying (10-14); Electricity, gas and water supply (40-41); Construction (45)

Table 17. Labour productivity growth, 1979-2001, US and EU-15 – average % per annum

	US			EU-15		
	1979-90	1990-95	1995-01	1979-90	1990-95	1995-01
Agriculture	6.7	2.2	9.0	5.3	5.1	3.5
Forestry	10.9	-9.7	3.7	4.6	3.3	2.4
Fishing	0.8	-11.3	13.5	3.1	1.4	0.3
Mining and quarrying	4.4	5.1	-0.2	2.9	13.1	3.5
Food, drink & tobacco	1.2	3.6	-6.0	2.6	2.7	0.8
Textiles	3.4	2.9	2.1	2.7	3.0	2.1
Clothing	3.0	2.7	5.4	2.6	5.1	3.3
Leather and footwear	4.2	4.5	0.1	2.6	3.5	1.2
Wood & wood products	2.6	-3.0	-0.8	2.3	2.9	2.2
Pulp, paper & paper products	1.4	-0.1	1.2	3.6	3.2	2.9
Printing & publishing	-1.4	-2.9	-0.5	2.3	2.0	1.9
Mineral oil refining, coke & nuclear fuel	7.0	5.5	0.6	-5.3	6.0	-1.0
Chemicals	3.4	3.0	1.9	4.7	6.5	3.8
Rubber & plastics	4.2	4.3	4.1	2.3	2.7	1.3
Non-metallic mineral products	1.9	2.3	-0.5	3.2	3.1	1.5
Basic metals	0.8	3.6	2.7	4.7	6.2	1.3
Fabricated metal products	2.1	2.9	0.2	2.2	2.5	1.1
Mechanical engineering	-0.7	0.3	-2.0	2.0	2.8	1.2
Office machinery	27.1	28.5	48.1	24.0	26.2	44.6
Insulated wire	5.2	2.4	3.8	4.5	6.1	0.2
Other electrical machinery	0.7	1.1	-3.2	1.1	0.3	1.9

Electronic valves and tubes	22.9	38.2	51.8	20.2	34.4	56.8
Telecommunication equipment	21.4	4.8	-1.2	19.4	3.8	0.3
Radio and television receivers	10.4	-5.3	-8.0	10.1	-2.9	-7.0
Scientific instruments	3.0	-4.7	-6.2	1.0	-4.0	-7.8
Other instruments	2.8	2.3	4.5	2.2	5.9	3.5
Motor vehicles	-0.7	3.8	1.3	4.0	3.3	0.5
Building and repairing of ships and boats	3.4	-4.4	3.3	6.1	1.3	0.8
Aircraft and spacecraft	1.3	-1.1	2.3	4.7	2.8	0.5
Railroad and other transport equipment	3.0	-2.4	4.3	3.8	4.1	1.0
Furniture & miscellaneous manufacturing	2.9	1.1	2.6	1.6	1.4	1.6
Electricity, gas and water supply	1.1	1.8	0.1	2.7	3.6	5.7
Construction	-0.8	0.4	-0.3	1.6	0.8	0.7
Sales and repair of motor vehicles[1]	0.6	-2.4	-6.9	1.4	2.3	0.8
Wholesale trade and commission trade[2]	2.6	2.9	7.5	1.8	3.4	1.7
Retail trade[2] and repairs[3]	2.8	2.0	6.6	1.7	1.8	1.2
Hotels & catering	-1.1	-1.0	-0.2	-1.0	-0.8	-0.9
Inland transport	1.7	1.0	0.6	2.6	3.0	2.4
Water transport	0.5	0.7	2.2	3.1	5.7	2.6
Air transport	1.0	2.0	3.5	3.4	9.5	3.6
Supporting transport activities	-0.9	-0.8	3.6	3.2	3.7	1.5
Communications	1.4	2.4	6.9	5.2	6.2	8.9
Financial intermediation	0.1	1.0	4.4	2.3	1.2	4.2
Insurance and pension funding	-5.1	2.5	0.6	2.7	1.2	0.1
Auxiliary financial services	1.3	3.1	10.0	1.1	0.4	0.4
Real estate activities	0.3	1.6	0.9	-0.7	0.0	-0.6
Renting of machinery and equipment	-1.5	8.2	5.8	2.1	3.2	1.6

Computer and related activities	6.3	2.4	-4.4	1.5	1.4	1.6
Research and development	3.6	0.0	1.9	3.3	-0.5	-1.1
Legal, technical and advertising	-1.4	-0.9	-0.1	0.6	0.5	0.7
Other business activities	0.3	-0.7	0.8	-0.2	0.8	-1.1
Public administration[4]	0.8	0.2	0.8	1.1	1.3	1.0
Education	-0.3	0.3	-2.1	0.2	1.0	0.3
Health and social work	-1.5	-1.8	-0.3	0.4	1.2	1.0
Other services[5]	0.7	0.6	-0.7	0.3	0.7	0.4
Private households with employed persons	2.0	2.3	-1.0	-4.5	-0.5	0.1

Notes: 1. Includes motorcycles and retail sale of automotive fuel; 2. except of motor vehicles and motorcycles; 3. repair of personal and household goods; 4. Including compulsory social security; 5. Other community, social and personal services.

European Commission

EUR 23134 — EU RESEARCH ON SOCIAL SCIENCES AND HUMANITIES — Employment Prospects in the Knowledge Economy - EPKE

Luxembourg: Office for Official Publications of the European Communities

2007 — 168 pp. — 21,0 x 29,7 cm

ISBN 978-92-79-07583-4

How to obtain EU publications

Our priced publications are available from EU Bookshop (http://bookshop.europa.eu/), where you can place an order with the sales agent of your choice.

The Publications Office has a worldwide network of sales agents. You can obtain their contact details by sending a fax to (352) 29 29-42758.

KI-NA-23134-EN-N

Publications Office
Publications.europa.eu

ISBN 978-92-79-07583-4