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The Lisbon Strategy and the EU's structural productivity problem

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THE LISBON STRATEGY AND THE EU'S STRUCTURAL PRODUCTIVITY PROBLEM

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Executive Overview

The structural nature of the EU's productivity downturn is confirmed by the analysis in this paper, with the bulk of the deterioration emanating from an outdated and inflexible industrial structure which has been slow to adapt to the intensifying pressures of globalisation and rapid technological change. The EU's productivity problems are driven by the combined effect of an excessive focus on low and medium-technology industries (with declining productivity growth rates and a globalisation-induced contraction in investment levels); an inability to seriously challenge the US's dominance in large areas of the ICT industry, as reflected in the relatively small size of its ICT production sector; and finally, its apparent slowness in reaping the productivity enhancing benefits of ICT in a range of ICT-using industries, although measurement issues severely complicate an assessment of the gains from ICT production and diffusion.

The post-1995 differences in EU-US productivity patterns are fundamentally driven by the US's superiority in terms of its capacity to produce and absorb new technologies, most notably in the case of ICT. Healthy knowledge production and absorption processes are mutually supportive elements of any successful long run productivity strategy. Evidence is presented which suggests that the US's overall innovation system is superior to that of the EU's, both in terms of the quality and funding of its knowledge sector and the more favourable framework conditions prevailing. The repeated ability of the US system to direct resources towards the newer, high technology (and often high productivity growth), industries is a reflection of the quality of the interrelationships between the different actors in its innovation system and of an economic and regulatory framework which has the capacity to transform excellence in knowledge creation into a globally competitive industrial structure.

The systemic inadequacies of the EU's innovation system are highlighted by the experience of the ICT industry, with the history of this industry suggesting that a "national champions" strategy in high technology industries is highly problematic. A wide range of factors are shown to have contributed to the US's global dominance in ICT. These factors include focussed R&D activities; world class research and teaching establishments; defence procurement contracts which nurtured the ICT industry (on the demand side) in its incubation phase in the 1950s and 1960s; and the unique combination of financing mechanisms and a highly competitive domestic marketplace which brought the ICT industry from the knowledge creation phase to the critical diffusion/mass market phase. The history of the ICT industry also suggests that a "national champions" strategy in high technology industries is a recipe for failure, with the study highlighting in particular the large price which Europe has paid for its "national champions" policy in this particular industry back in the 1960s and 1970s, which contrasted sharply with the strategies adopted by Japan and the US.

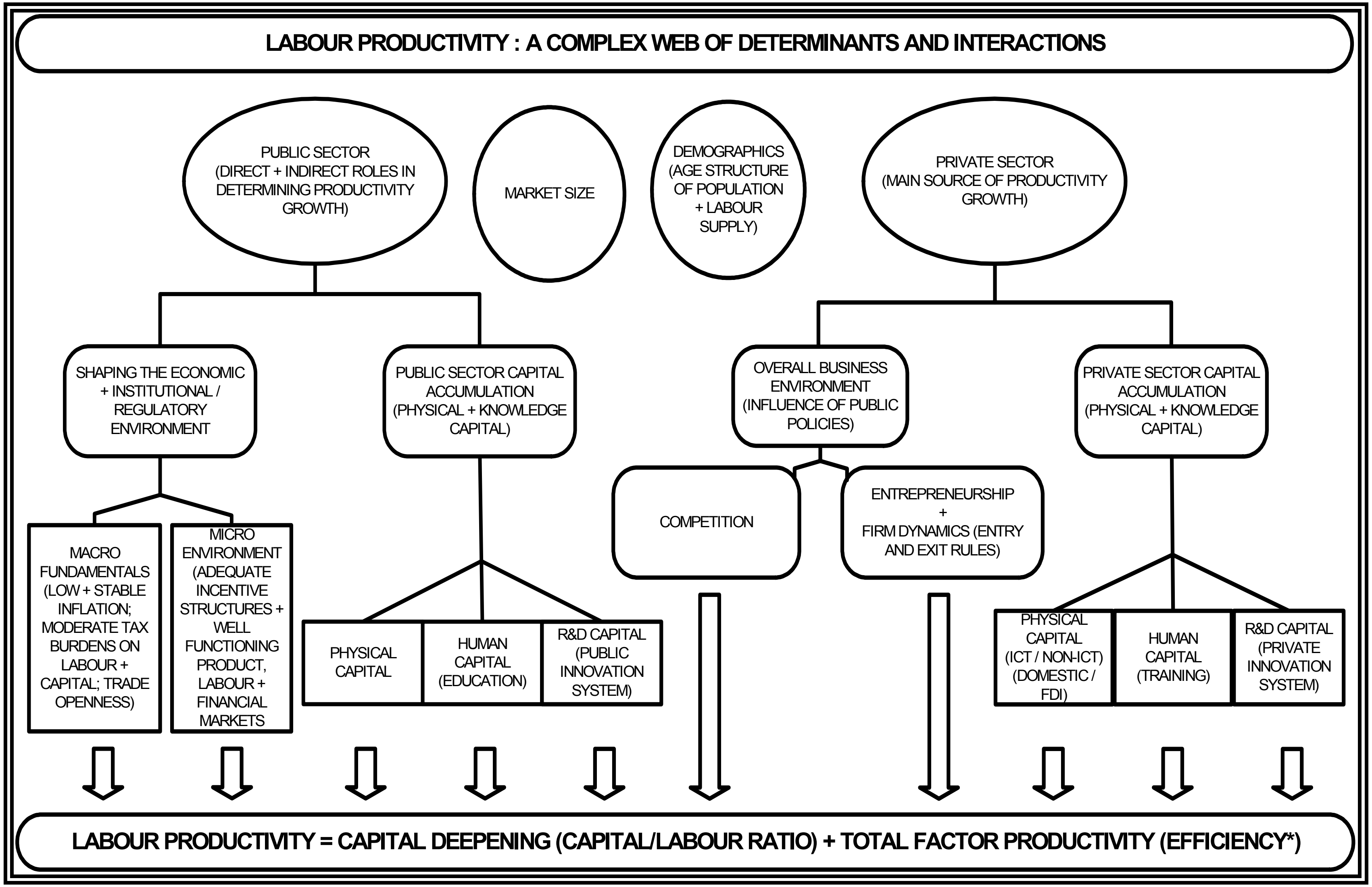
In terms of policy, the study stresses that the EU's innovation system needs to be fundamentally reformed if the EU is to make a decisive shift towards realising the vision of a successful, innovation-based, economic model, the broad features of which have been laid out in the Lisbon 2010 agenda. The success of such a model will be determined not only by an increase in the amount of financial resources devoted to knowledge production (i.e. increased spending on R&D and higher education) but more importantly by an acceptance of the need to improve linkages in the innovation system and to make painful changes in many areas of the EU's economic and regulatory environment. More specifically the present study stresses the following:

- *The systemic nature of the innovation process needs to be fully recognised and the quality of the interrelationships between the different actors in the EU's system needs to be* *dramatically improved. In addressing these issues, some politically sensitive areas will need to be examined at the national and EU levels i.e. the principle of an excellence / meritocratic based system for awarding research funds; greater university autonomy, in financial as well as academic terms; a change of culture towards the commercialisation of research via closer university / business sector links; and the need to develop and nurture centres of excellence and leading edge technology clusters.*

- *The public and private sectors each play important, mutually supportive, roles in determining a country's innovation capacity and each must assume its responsibilities if the EU's knowledge economy objectives are to be realised. Governments have crucial direct and indirect roles to play in the innovation process, directly in the form of financial support for human capital development and for the public innovation system and, more importantly, indirectly in terms of shaping the macroeconomic fundamentals (low and stable inflation; moderate tax burdens on labour and capital; trade openness) and providing adequate framework conditions / regulatory regimes for the private sector to enhance productivity via well functioning product, labour and capital markets.*

- *While competition is a crucial determinant of productivity growth, industry-specific framework conditions need to be carefully assessed by EU policy makers due to the complicated link between competition and innovation. Product market structures (e.g. possibilities for product differentiation) and the characteristics of specific technologies (e.g. is it a radical or incremental innovation; are there network externalities; are there economies of scale in R&D) is what ultimately determines the industry specific relationship between market concentration (i.e. the degree of competition) and R&D intensity.*

- *Appropriate market entry and exit rules, by putting pressure on incumbent firms to innovate and by supporting market experimentation, are fundamental to an effective innovation process in rapidly changing industries. This experimentation role is particularly important in industries where the general purpose technologies being used are changing quickly such as in the production and use of ICT. This latter industry provides a striking example of the need for policy makers to promote entrepreneurship and a healthy process of "creative destruction".*



**** Total factor productivity is affected by factors such as labour quality/skill mix improvements; capital quality (vintage and asset composition); pure technological progress; sectoral reallocation effects; changes in capacity utilisation rates and measurement errors with respect to the contributions from physical capital/labour.***

1. Introduction

Europe's growth performance has been the subject of increasing scrutiny over recent years, most notably in the context of the Lisbon process and its efforts to encourage governments to introduce employment and productivity enhancing reforms. This reform agenda is all the more pressing given that the EU's underlying growth rate has been trending downwards since the second half of the 1990's and since the medium to long term outlook points to a continuation of these trends. While many EU countries are understandably preoccupied with extricating their economies from the relatively prolonged short run downturn, it is widely acknowledged that many of the solutions to this slow growth problem require a longer term policy perspective. A sustainable medium-term recovery process in fact demands action on a Lisbon-inspired structural reform agenda aimed at effectively addressing the EU's fundamental growth challenges, presently posed by the accelerating pace of technological change, globalisation (most recently in terms of the growing tradability of large parts of the service economy) and ageing populations.

Whilst accepting the absolute necessity of encouraging a more labour intensive growth pattern over the medium to long term, the present paper focuses on the productivity part of the Lisbon agenda. It specifically analyses the nature / source of the deterioration in the EU's productivity performance relative to that in the US since the mid-1990's and outlines the approach to be adopted in order to remedy this situation. Given the extensive treatment accorded to the productivity theme in an earlier ECFIN Economic Paper[1], the present paper will build on this latter work by focussing on three specific issues related to the EU's recent productivity performance and of its ambitions to become the most competitive, knowledge based, economy in the world by 2010 :

- Firstly, how does the EU compare with the US in terms of economy-wide productivity trends and how big a role has ICT played in explaining the diverging patterns ? Furthermore, should the post-1995 deterioration in EU productivity be interpreted as a transitory or a structural phenomenon ?

- Secondly, in explaining recent EU-US divergences in productivity trends, to what extent is the EU's relatively poor performance linked with its particular industrial structure and its difficulty in reorientating its economy towards the newer, higher productivity, growth sectors such as ICT ?[2] In terms of the specific role of ICT, the study asks whether the contribution of the ICT-producing industries to overall productivity patterns has been underestimated

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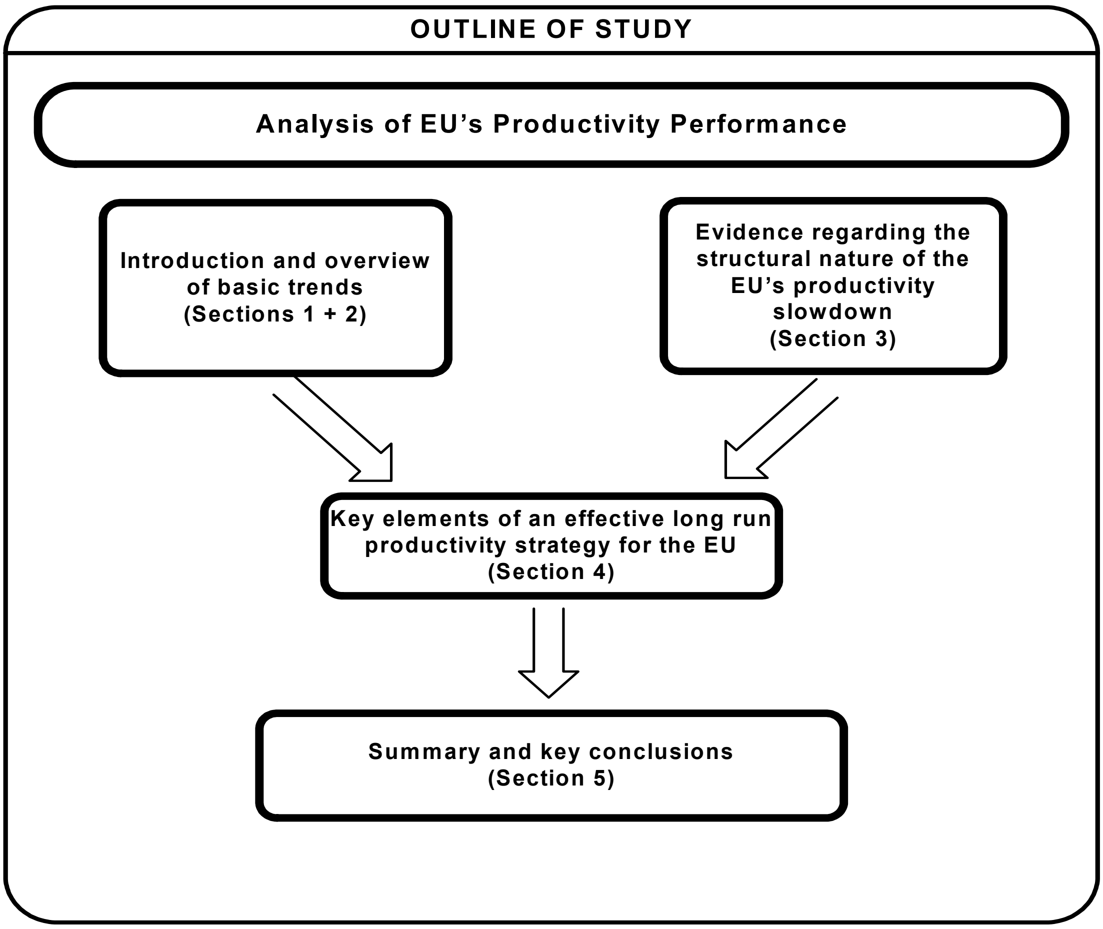
1 Economic Paper No. 208 "An analysis of EU and US productivity developments (a total economy and industry level perspective)", July 2004.

2 In particular, is the failure of the EU's economic system to deliver a satisfactory productivity growth performance linked to its inability to transform its industrial structure from one based on imitation of US technological advances (which worked well in the post World War II, catching-up, phase) to one founded on an innovation-based model (which is necessary when one is close to the technology frontier).

in favour of ICT diffusion / absorption explanations which stress the crucial role of a small number of intensive ICT-using industries such as wholesale and retail trade.

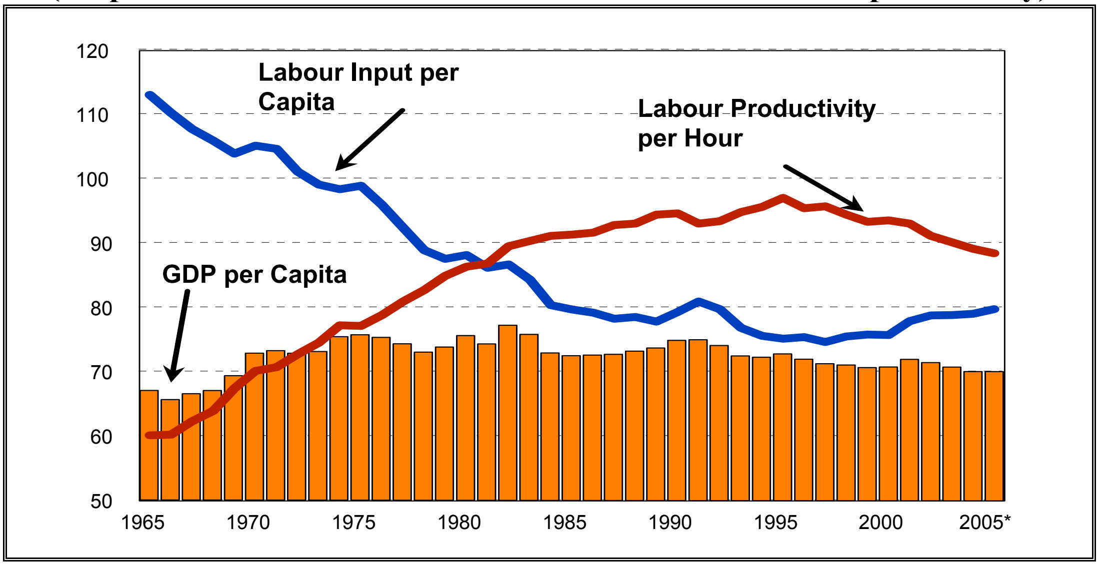
- Finally, in the context of delivering on the EU's longer term ambitions of progressively moving towards a more knowledge-based economy, the study focuses on the specific role to be played by the production and absorption of new technologies in any overall strategy. While the present paper fully accepts that the absorption of innovation from other industries / countries will remain a fundamental element in determining the EU's future productivity performance, it nevertheless argues strongly in favour of a greater recognition amongst EU policy makers of the importance of a globally competitive knowledge production system to the realisation of the Lisbon goals. Creating a system capable of delivering on both aspects of the innovation process is not simply an issue of more spending on R&D and 3rd level education. More importantly it is a question of better linkages between the different players in the innovation system and a recognition of the need for a dynamic, competitive, business environment in accelerating the move from the knowledge creation / absorption phase to the critical commercial phase.



2. EU productivity Trends at the Economy Wide Level : A Comparison with the US

2.1 : Overview of Main Trends : At the moment, EU living standards (GDP per capita) are at roughly 70% of US levels, with about 1/3 of the gap due to labour productivity differences, with the remaining 2/3 due to differences in the utilisation of labour (i.e. differences in hours worked per worker and the employment rate)[3]. The EU has also experienced some important changes over the course of the 1990's with, on the positive side, the previously downward movement in the EU's labour input[4] relative to the US coming to an end and, on the negative side, the post World War II convergence to US productivity levels going into reverse (graph 1). In fact, after having peaked in the mid-1990's at around 97% of US levels, EU labour productivity per hour is projected to deteriorate to around 88% in 2005, which is close to its relative level in the early 1980s. This post 1995 deterioration in relative productivity levels reflects a sharp decline in EU productivity growth rates relative to those of the US over the period in question.

Graph 1 : GDP per capita levels accounting - EU15 relative to the US (US=100) (Proportion of income differences due to labour utilisation / productivity)[5]



Source : EU Commission, AMECO database

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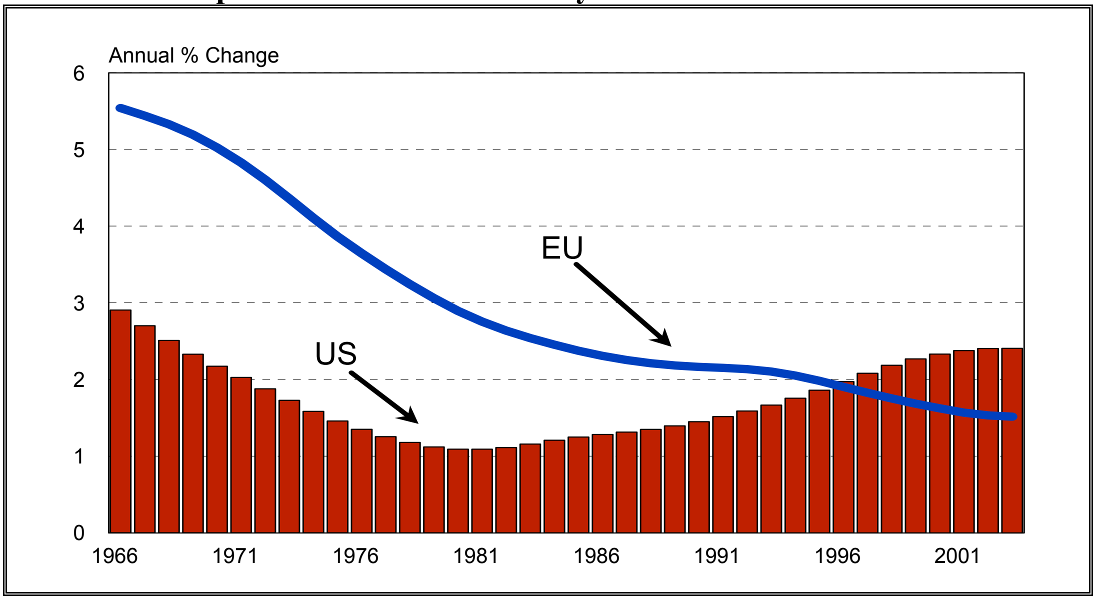
[3] See Annex 1 for an overview of the ongoing discussion on measurement issues.

[4] This is driven by the increase in the EU's employment rate relative to the US (from 87%–92% of US levels), with hours worked per worker stabilising at 87%-88% of US levels.

[5] Labour input per capita = hours worked per employee * employment rate (of the 2/3 difference between the EU and the US, 50% is due to differences in the number of hours worked per employee (EU workers on average work roughly 10% fewer hours) and 50% is due to differences in the employment rate. In overall terms therefore the 30% income gap between the EU and the US can be split into 3 equal parts – 1/3 due to productivity, 1/3 due to working fewer hours and 1/3 due to the fact that the EU has a lower overall employment rate. It should be noted however that, on the basis of present trends, an increasing proportion of the EU's income gap with the US is emanating from productivity differences.

Graph 2 shows labour productivity per hour trend developments in the US and the EU since the mid-1960's. Over most of that time, and indeed for most of the post World War II period up until the mid-1990's, the EU has enjoyed productivity growth rates well in excess of those prevailing in the US. Given relatively low employment rates, the EU was able to use its superior productivity performance to broadly maintain its living standards relative to the US. This is why policy makers need to be seriously concerned with the fact that the EU is now, for the first time in decades, on a trend productivity growth path which is lower than that of the US, with the cross-over point occurring in the mid-1990's[6]. This recent EU performance marks a serious downgrading relative to the situation in the early 1990s when annual EU labour productivity growth was averaging 2 ½ per cent, compared with 1 ½ per cent for the US. Since that time there has been a dramatic reversal in fortunes, with the EU's labour productivity growth rate declining by a full 1% point to 1½ per cent, compared with an acceleration of a roughly similar amount in the US to 2 ½ per cent.

Graph 2 : Labour Productivity Per Hour Growth Trends



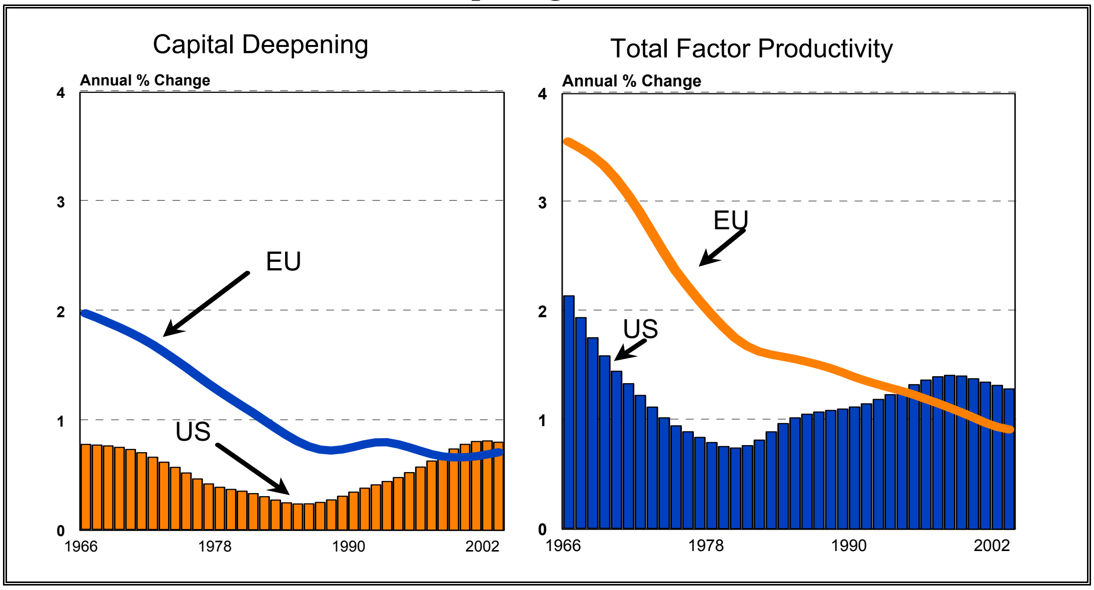
Source : EU Commission, AMECO database

[6] While overall EU productivity trends have clearly deteriorated over recent years, it is important to underline the wide range of performances at the individual EU Member State level, with large numbers of countries comparing favourably with international trends. With regard to the performance of the existing Member States in terms of labour productivity per person employed, there is a clear divergence for the Euro Area and non-Euro Area countries. The non-Euro Area Member States have been able to arrest the decline in their 1980's productivity growth rate and stablise it in the 1½ -2% range over the 1990's. Over the same period the Euro Area countries as a group have experienced a decline in their productivity growth rate from close to 2% to well under 1%. This Euro Area pattern is totally dictated by developments in the big four area countries, namely Germany, France, Italy and Spain. The remaining 8 Euro Area countries have managed to achieve an acceleration in their productivity growth rates between the first and second half of the 1990's similar to that which occurred in the US. The problem of course is that with the big four countries accounting for nearly 80% of overall Euro Area output, the poor performances from all four of these countries ensures that the "Area" as a whole has a clear productivity problem and as graph 1 indicates if one includes the latest Spring 2004 Commission services forecasts for 2004-2005, the EU as a whole is expected to continue to lag behind the performance of the US over these forecast years (see Annex 3).

From a purely growth accounting perspective, the 1 percentage point decline in EU labour productivity emanates from 2 sources :

- Firstly, 50% can be attributed to a reduction in the contribution from capital deepening i.e. lower investment[7].
- Secondly, the remaining 50% appears to emanate from a deterioration in total factor productivity i.e. a decline in the overall efficiency of the production process.

Graph 3 : Breakdown of Trend Labour Productivity into Capital Deepening and TFP



Source : EU Commission, own calculations

[7] This lower rate of capital deepening (i.e. a reduction in the growth rate of investment per worker) reflects broadly positive factors such as the impact of labour market reforms (i.e. an unwinding of the unfavourable capital-for-labour substitution of earlier periods, with investment growth being lower than employment growth in the 1990's) but also more worrying structural factors such as locational investment considerations and adverse demographic trends. In addition, as the rest of this paper will emphasise, the solution is not simply an increase in capital deepening since the problem for the EU seems to lie more in terms of the productivity of capital rather than with the overall investment rate, which still compares favourably with that of the US. The fact that labour productivity growth rates continue to decline in the EU, despite having relatively high investment rates, suggests that the marginal productivity of capital may be declining. This could be linked to overinvestment in certain traditional sectors, with any additional investments in these areas yielding less and less returns, and to underinvestment in a range of the newer, high productivity growth, industries. Consequently, while Europe undoubtedly needs more investment, the more pressing need is for structural reforms in order to ensure that any additional resources liberated from, for example, fiscal consolidation will be directed to those sectors with the highest growth potential.

TABLE 1 : DECOMPOSITION OF US AND EU15 HOURLY LABOUR PRODUCTIVITY GROWTH RATES INTO CAPITAL DEEPENING AND TFP (PERIOD AVERAGES)

	1966-1970	1971-1980	1981-1990	1991-1995	1996-2000	1996-2003
US						
LABOUR PRODUCTIVITY (HOURLY)	**2.2**	**1.6**	**1.3**	**1.5**	**2.4**	**2.4**
(TFP)	***(1.4)***	***(1.1)***	***(1.0)***	***(1.0)***	***(1.7)***	***(1.5)***
(CAPITAL DEEPENING)	***(0.8)***	***(0.5)***	***(0.3)***	***(0.5)***	***(0.7)***	***(0.9)***
EU15						
LABOUR PRODUCTIVITY (HOURLY)	**5.4**	**3.7**	**2.3**	**2.5**	**1.8**	**1.5**
(TFP)	***(3.6)***	***(2.3)***	***(1.5)***	***(1.4)***	***(1.3)***	***(0.9)***
(CAPITAL DEEPENING)	***(1.8)***	***(1.4)***	***(0.8)***	***(1.1)***	***(0.5)***	***(0.6)***

Source : EU Commission, own calculations.

2.2 : ICT as an explanatory factor at the total economy level : One of the most popular explanations for the diverging productivity fortunes of the EU and the US has been the relative exposure of both areas to ICT. Last year's Economic Paper[8] showed that ICT has indeed been an important part of the story, especially in terms of explaining the turnaround in the productivity trend of the US. The overall contribution to labour productivity growth from ICT investments (i.e. purchases of software, computing and communications equipment) and from technical progress in the production of ICT goods and services (e.g. the semiconductor and telecommunications industries) accounted for about 60 per cent of US labour productivity growth over the second half of the 1990s, compared with 40 per cent in the four EU countries for which such a breakdown exists (i.e. France, Germany, the UK, and the Netherlands). This translates over the second half of the 1990s into an ICT contribution to labour productivity growth of around 1 ½ percentage points in the US and ¾ of a percentage point in the case of the EU4.

In terms of the trend acceleration in US labour productivity growth over the two halves of the 1990's, about half of the 1 percentage point acceleration can be directly attributed to ICT. In the case of the EU4 group of countries, the effects of ICT on both capital deepening and TFP over the same period was positive, although significantly less positive than in the US (Graphs 4 and 5). Consequently, given that ICT was not responsible for the deteriorating EU productivity trend, the role of non-ICT determinants such as labour market reforms or the EU's outdated industrial structure needs to be assessed. Section 2.3 looks at the role of labour market reforms, with section 3 asking whether an excessive focus on traditional, low productivity growth, industries could be responsible for the deteriorating EU trend.

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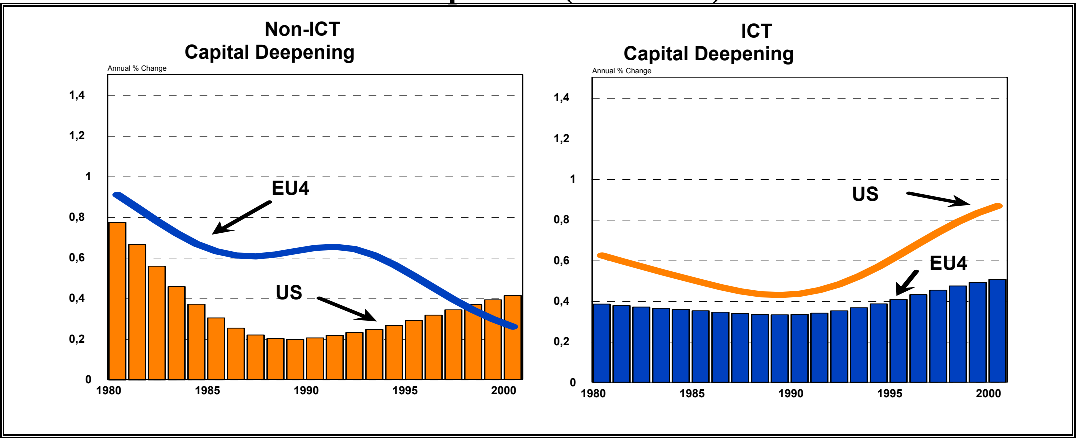
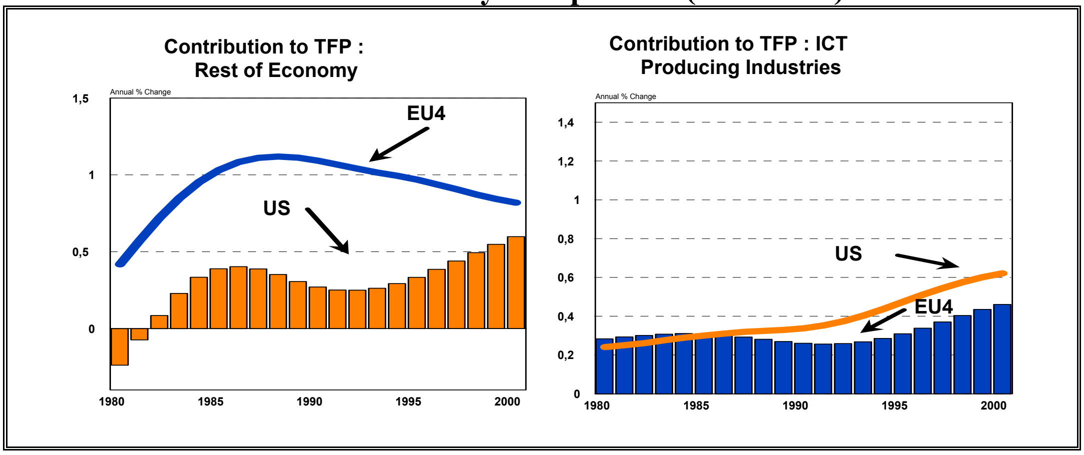
[8] No. 208, op.cit.

Graph 4 : Breakdown of Trend Capital Deepening into ICT and Non-ICT Components (1981-2000)



Source : DG Enterprise / GGDC and own calculations

Graph 5 : Breakdown of Trend TFP into ICT and Rest of Economy Components (1981-2000)



Source : DG Enterprise / GGDC and own calculations

2.3 : Are low EU productivity growth rates likely to be a permanent phenomenon or a temporary blip linked to labour market reforms ? : To help answer these questions, it is helpful to review the basic growth patterns (employment and productivity) between the EU and the US in the 1990s :

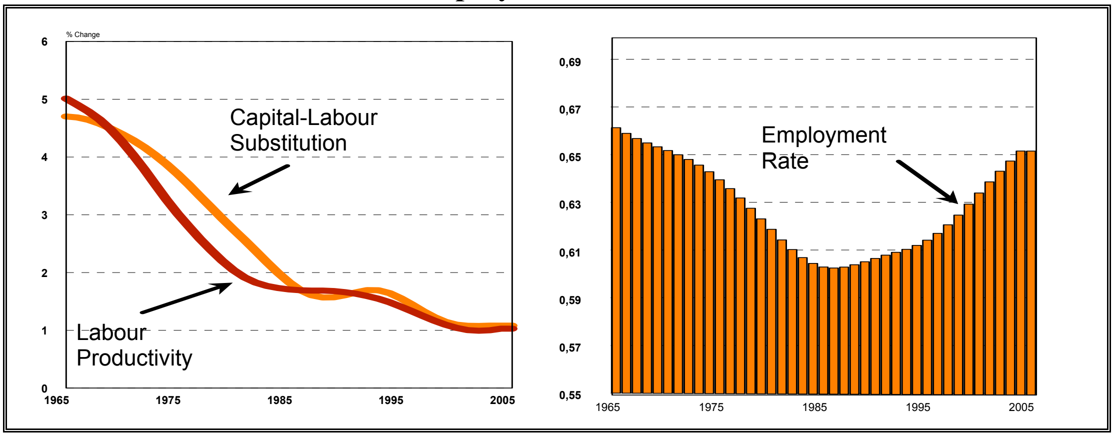
- The EU's trend productivity growth rate, as shown earlier, continued to decline throughout the 1990's and fell below the equivalent, and rapidly increasing, US productivity growth rate around the middle of the decade.

- Regarding employment, the decline in employment rates in the EU came to an end in the early 1990's and started to trend upwards. In the US a positive trend continued but at a slower pace.

- Closely associated with the movement in labour productivity growth, fairly parallel trend developments for capital-labour substitution were observed, i.e. a further decline in Europe and an increase in the US.

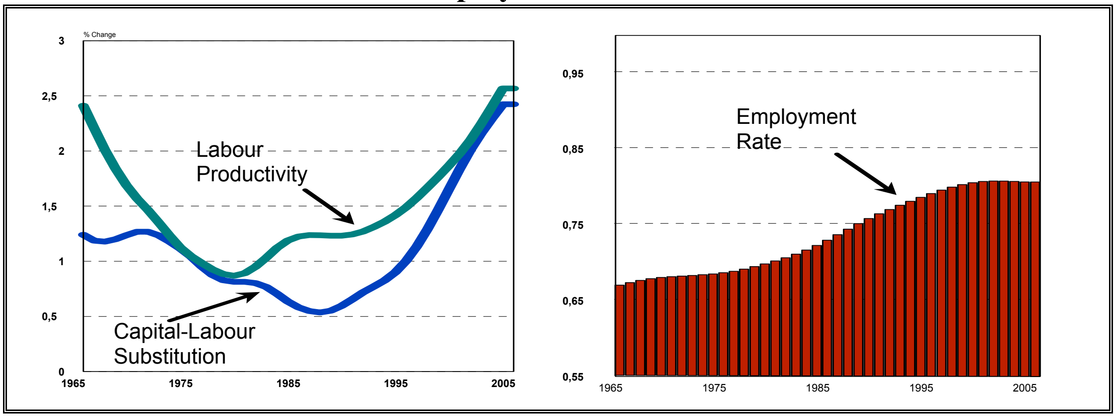
Graph 6 shows the basic movements for the EU for these three variables, with these trends especially striking when contrasted with those of the US over the same period (Graph 7). This comparison shows in a dramatic way the extent to which the EU economy is failing to exploit the technological opportunities which are presently available in the world economy. The US in contrast has experienced a marked trend reversal in its labour productivity performance, with the latter strongly linked to its exploitation of the opportunities presented by the ICT industry.

Graph 6 : EU Labour Productivity, Capital-Labour Substitution and Employment Rate Trends



Source : EU Commission, AMECO database

Graph 7 : US Labour Productivity, Capital-Labour Substitution and Employment Rate Trends



Source : EU Commission, AMECO database

The trends in these graphs can be assessed in alternative ways, with different interpretations having different implications for the long run outlook for productivity and employment, with our main interest here being productivity.

- A popular interpretation explains the recent productivity trends as a response of the economy to a positive labour supply shock. The shock to labour supply/wages could be the result of labour market reforms. It could also reflect an increasing awareness amongst European citizens that pension income will be more uncertain in the future. This negative income effect could have contributed to an increase in labour force participation. Under this interpretation, recent developments could be judged as healthy. Slower wage growth could have led to a temporary decline in capital-labour substitution.

Once full employment is reached, wage and productivity growth could accelerate again and the economy could go back to a higher growth rate of labour productivity at a higher level of employment. The decline in productivity growth and in capital-labour substitution (i.e. capital deepening) could thus be regarded as a temporary phenomenon.

- An alternative view regards the labour market story as incomplete. According to this view, the data can be explained correctly only if one assumes a negative shock to productivity, either in the form of a decline in the growth rate of TFP or in the form of a positive shock to capital productivity, with the latter shock induced by higher required rates of return for investors. At the macro level a trend decline in TFP could be due to a further increase in the size of the service sector; a reduction in the quality of labour as more low skilled workers are brought into the labour force; and / or a trend decline in technological advances in traditional manufacturing industries. Also with globalisation and increased international capital mobility, the higher returns which can be earned outside Europe may exert pressure on capital productivity[9]. Both developments could explain why capital-labour substitution declined[10].

Both of the above interpretations would obviously provide a different diagnosis for Europe. According to the first view, recent productivity trends are a temporary phenomenon and a healthy indication that labour markets in Europe have become more flexible. The second view is more pessimistic. It regards the productivity slowdown as a continuation of the previous adverse productivity trends, with the recent increase in employment simply having an additional temporary, negative, effect on productivity. The productivity picture is further complicated by a third possible explanatory factor, namely aggregate demand, with domestic demand over the most recent period being sluggish, triggering a cyclical impact on measured productivity[11].

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[9] This positive shock to capital productivity must be interpreted in the context of locational investment considerations and from the perspective of changes in the required rates of return expected by international investors / stockmarkets. With improved international communications and reductions in transport costs, international locational choices for investors have increased and investment is undertaken in those regions which offer the most favourable (expected) ratio between capital productivity and capital cost. The US investment boom in the 1990's offers a good example of how investment opportunities in one country can attract substantial foreign direct investment. Falling ICT investment prices and high rates of innovation, as expressed by accelerating productivity and TFP growth rates, created an exceptionally positive investment climate in the US in the 1990's which in turn led to a strong increase in US investment. These international investment trends were unfortunately not without repercussions for domestic EU investment rates.

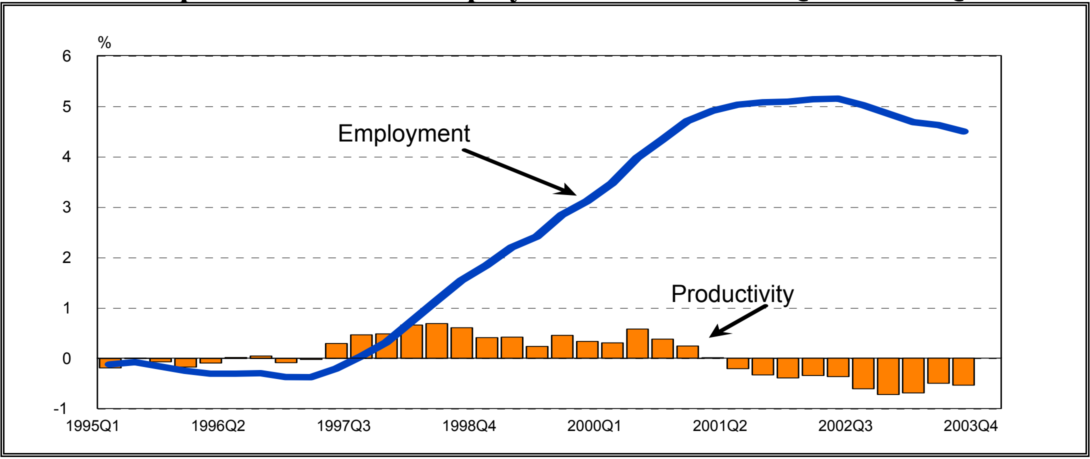
[10] It is also interesting to notice that the negative productivity shock could be consistent with a temporary increase in employment (see Gali -1999). While this is a theoretical possibility, it should not be seen as a credible alternative explanation (to labour market reforms) for the increase in employment which occurred. In fact, as the VAR analysis points out, the link is empirically weak.

[11] Unpublished work done recently by DG ECFIN suggests that very little of the decline in the TFP part of productivity is cyclical in nature. ECFIN has calculated trend TFP using a Kalman Filter approach which removes the cyclical part of TFP by using correlations with a capacity utilisation series. This procedure shows that the Kalman Filter derived trend TFP is very close to ECFIN's stochastic trend TFP estimates and that there are few cyclical influences at play.

To analyse more rigorously whether the productivity pattern is temporary or more structural, we need to be able to identify the nature of the shocks driving productivity. We use a VAR methodology to analyse the various contributions to the productivity slowdown, coming from the three shock variables : employment, productivity and demand. A VAR analysis is particularly suited for this purpose since it allows us to identify the driving forces behind employment and productivity and, in addition, to analyse the temporary versus permanent nature of the effects.

Box 1 contains a technical description of the VAR analysis. This analysis is used firstly to examine to what extent the increase in employment can explain the decline in productivity growth. The VAR analysis identifies a sequence of positive employment shocks in the second half of the 1990s which have increased the level of employment by about 5% in the Euro area. The shock driving employment, however, only had a small effect on productivity (Graph 8). According to the estimate, the 5% increase in employment has reduced the level of productivity by only about 0.75%. This is about 10% of the total reduction in productivity growth experienced since the mid 1990s. Hence, employment shocks can only marginally explain the decline in productivity growth[12].

Graph 8 : Euro Area Employment Shock : 1995 Q1 to 2003 Q4



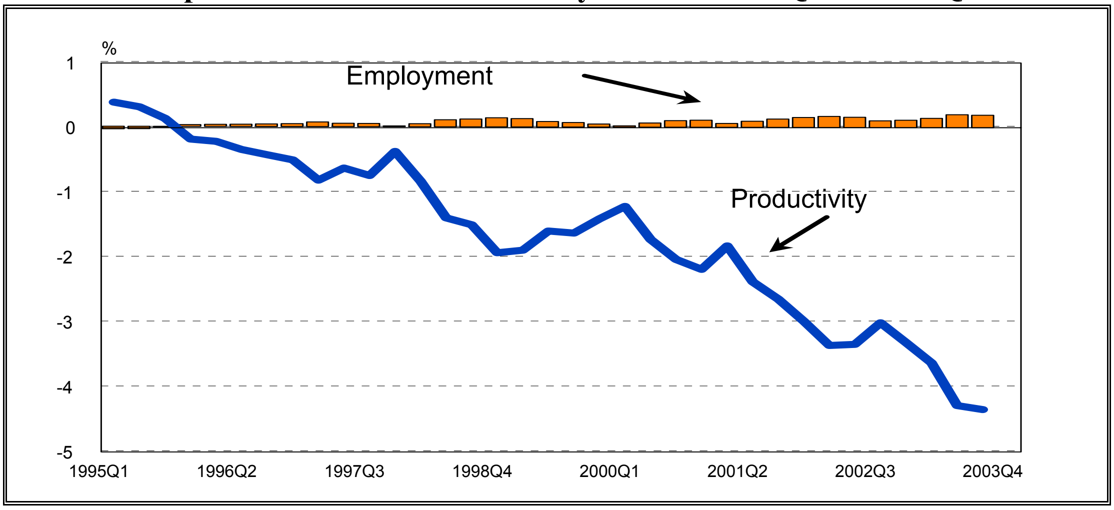
Source : Own calculations

The second contribution of the VAR model relates to the question of the structural versus temporary nature of the effects. Based on the underlying assumptions on the short, medium and long term impact of the various shocks, the VAR model attributes most of the decline in productivity to a structural trend decline in productivity growth. As can be seen from graph 9, the autonomous shock to productivity explains a decline in the level of productivity of 5%, which would translate into an annual average productivity growth rate effect of the order of 0.6%. This is fully consistent with the growth accounting result given earlier of a decline in TFP of the order of ½ a percentage point, with TFP considered to be a reflection of the structural component

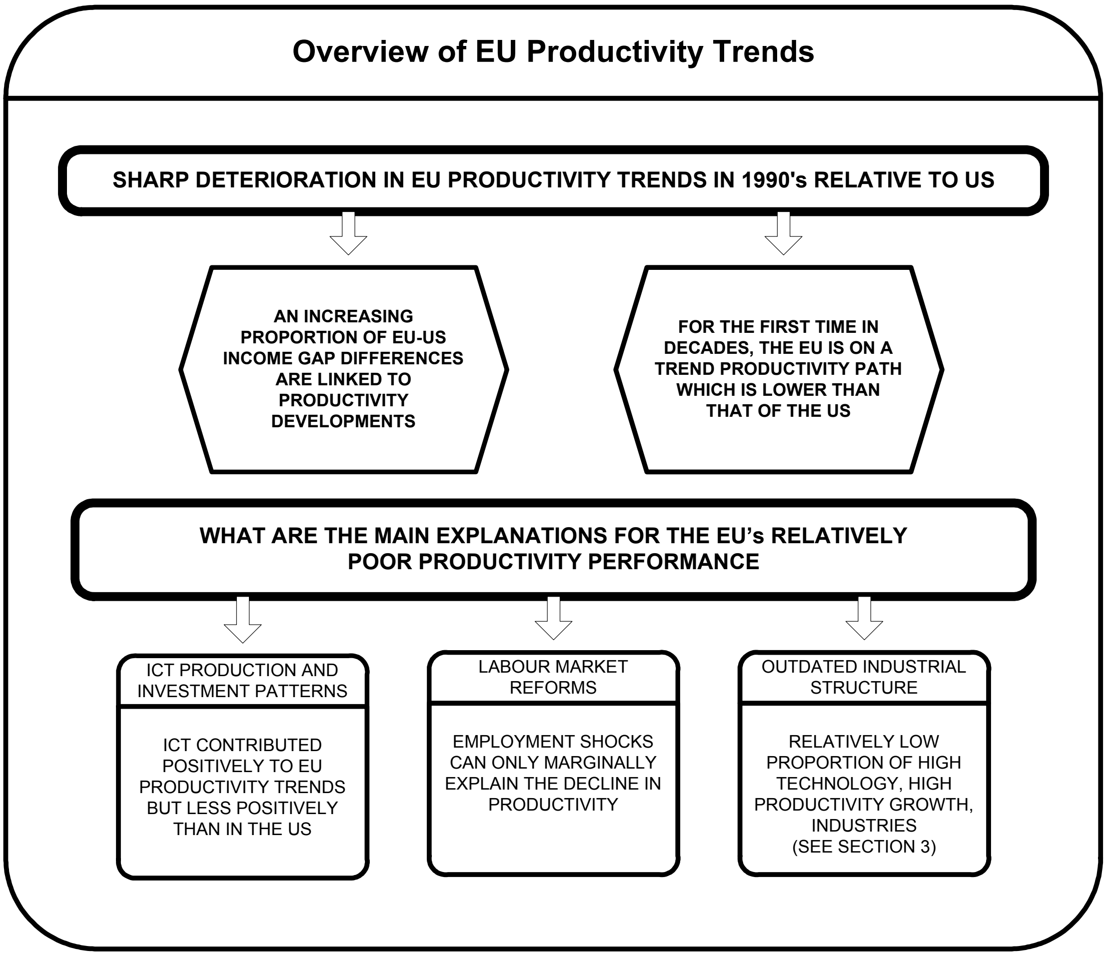
[12] It should be noted that this VAR estimate of 10% is at the lower end of the estimates obtained using a range of estimation methods. For example, results from the Commission's QUEST model suggest that about 30% of the reduction in productivity growth could be explained by the employment shock. Also results from growth regressions suggest that about 25% of the productivity decline is due to the increase in employment.

of the productivity trend. Graph 9 also indicates that the autonomous productivity shock is unable to explain the increase in employment. Therefore, an interpretation of both shocks is necessary in order to give a complete picture of the employment and productivity developments. However, concerning productivity, the overall conclusion from the analysis suggests that the decline in productivity growth is to a large extent structural in nature.

Graph 9 : Euro Area Productivity Shock : 1995 Q1 to 2003 Q4



Source : Own calculations



BOX 1 : IDENTIFYING STRUCTURAL SHOCKS TO EMPLOYMENT, PRODUCTIVITY AND DEMAND WITH A STRUCTURAL VAR MODEL

We use a structural VAR (SVAR) methodology, based on Stock and Watson (1988) and Blanchard and Quah (1990), for the identification of structural shocks. The intuition for shock identification in Blanchard and Quah is based on the idea that demand shocks only have temporary effects while supply shocks have permanent effects. Stock and Watson extend this approach and allow for separate supply contributions from labour and productivity (TFP). In order to identify different supply contributions, namely those coming from employment and those coming from productivity, additional identification criteria must be introduced. Stock and Watson use long run restrictions implied by the neoclassical growth model for that task. The neoclassical growth model appears to be suitable, since there are at least three important features in the long run trends shown in Graphs 8 and 9 which are compatible with this model :

- 1. There is a close trend correlation between the growth of labour productivity and capital intensity.
- 2. Capital intensity and productivity grow at a similar rate in the long run.
- 3. If one looks over long periods of time and across the EU and the US, the employment rate appears to be unrelated with productivity growth.

If one uses the neoclassical growth model then one can impose the following long run structure on the data:

- The labour market shock can have short and long run effects on employment, productivity and inflation.
- The productivity shock can have long run effects on productivity and inflation but only short and medium run effects on employment. (This constraint arises from the assumption that real wages are indexed to productivity in the long run).
- The demand shock can have a long run effect on inflation only but not on employment and productivity. No long run constraint is imposed on inflation.

These three types of restrictions imply a triangular long run structure between the growth rate of employment (Δh), productivity ($\Delta(y-h)$) and inflation (π) on the one hand and the corresponding shocks to employment (v), productivity (e) and demand (d) on the other. If one defines the vector $\Delta x_t = [\Delta h_t, \Delta(y_t - h_t), \Delta\pi_t]$ and the vector $\xi_t = [v_t, e_t, d_t]$, then the moving average representation of this model is given by :

$$\Delta x_t = A(L)\xi_t \qquad \text{with } A(1) = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

where the matrix A(1) shows the long run restrictions. Notice, this particular structure is particularly suited to test for the short, medium and long run effects of an employment shock. Allowing for a non-zero long run productivity effect of an employment shock allows one to test for labour quality effects associated with a permanent change in the employment rate. A similar analysis has been conducted by Gali (1999). He is mainly interested in the employment effects of productivity shocks.

3. The structural nature of the EU's Productivity Problem – A Sectoral / Industry Level Breakdown

The present section extends the analysis from section 2, in particular its suggestion that the EU has a structural productivity problem, by taking a closer look at sectoral / industry level productivity developments. Two specific issues are examined :

- Firstly, an attempt is made in 3.1 / 3.2 to isolate the source of the EU's productivity problems at both the sectoral / industry levels : are those difficulties confined to the manufacturing, private services or rest of the economy sectors or linked to particularly dynamic specific industries within these broad sectors ? In addition, by categorising the different industries on the basis of their ICT content into ICT producing, intensive ICT-using and less-intensive ICT-using industries, the section gives a more detailed insight into the role of ICT in shaping overall EU and US productivity trends. The key question is to what extent Europe's problems reflect an inflexible and outdated industrial structure which has failed to fully exploit the direct and indirect productivity benefits from new, leading edge, technologies such as ICT.

- Secondly, whilst not questioning the overall contribution of ICT to labour productivity trends, section 3.3 adds to the ongoing debate regarding the relative importance of the different channels (i.e. production, investment and spillover effects) via which ICT impacts on the respective economies. It is contended that a large proportion of the recent literature may be underestimating the direct gains from the production of ICT goods and services in favour of the view that most of the gains emanate from the use of ICT. This debate on the respective contributions of the different ICT transmission channels is important to the policy debate in the final section of the paper when we discuss a productivity agenda for the EU and the importance to be attributed to the production and absorption of new technologies.

3.1 : Productivity trends at the sectoral level (1980-2000)[13] : The basis for this sectoral level analysis is an aggregation of a 56 industry breakdown of the EU and US

[13] For the analysis in sections 3.1 and 3.2 we use an internationally comparable dataset from the Groningen Growth and Development Centre (GGDC). This dataset has a 56 industry breakdown for all 15 of the old Member States and for the US and is essentially an expanded version of the OECD's STAN database. An interesting feature of this dataset is that, for all countries, it uses US hedonic deflators for deflating the relevant ICT industries and classifies computer software as investment expenditure (and not as a business expense which is the convention in a large number of EU countries). It therefore provides a more accurate, internationally comparable, estimate of the contribution of ICT to the growth performances of the respective countries. In this way it is possible to assess whether the decline in EU labour productivity growth could be due, as some commentators have suggested, to mismeasurement of the growth impact of ICT. For example, Jorgenson (2003) asserts that ICT has made a much larger contribution to growth in the non-US, G7, countries than that suggested by official statistics. In his recent paper, "Information Technology and the G7 economies", he compares the growth performances of the G7 economies, on the basis of an internationally comparable dataset (similar to the one used in this section) which focusses on the impact of investment in IT equipment and software. See also the "Economist" article "Computing the gains", of 25 October 2003, which summarises the Jorgenson paper.

economies into the three broad sectors of manufacturing, private services and rest of economy (i.e. primary industries + public services). While section 3.2 will analyse the contributions of each of the 56 industries to the acceleration in US labour productivity compared with the EU over the second half of the 1990's, the present section confines itself to an overview of the longer term patterns for the different sectors. This longer term analysis enables us to show the contribution of each of the three sectors to the total economy labour productivity growth of both the EU and the US (i.e. the combined effect of productivity growth in the specific sector and of its share in overall output). To give some idea of the respective weights in overall output, manufacturing presently accounts for roughly 20% of EU and US output, with private services and the "rest of economy" sectors representing 55% and 25% respectively.

The overall trends for the period 1980-2000 are given in Graph 10, with the key points to be retained being the following :

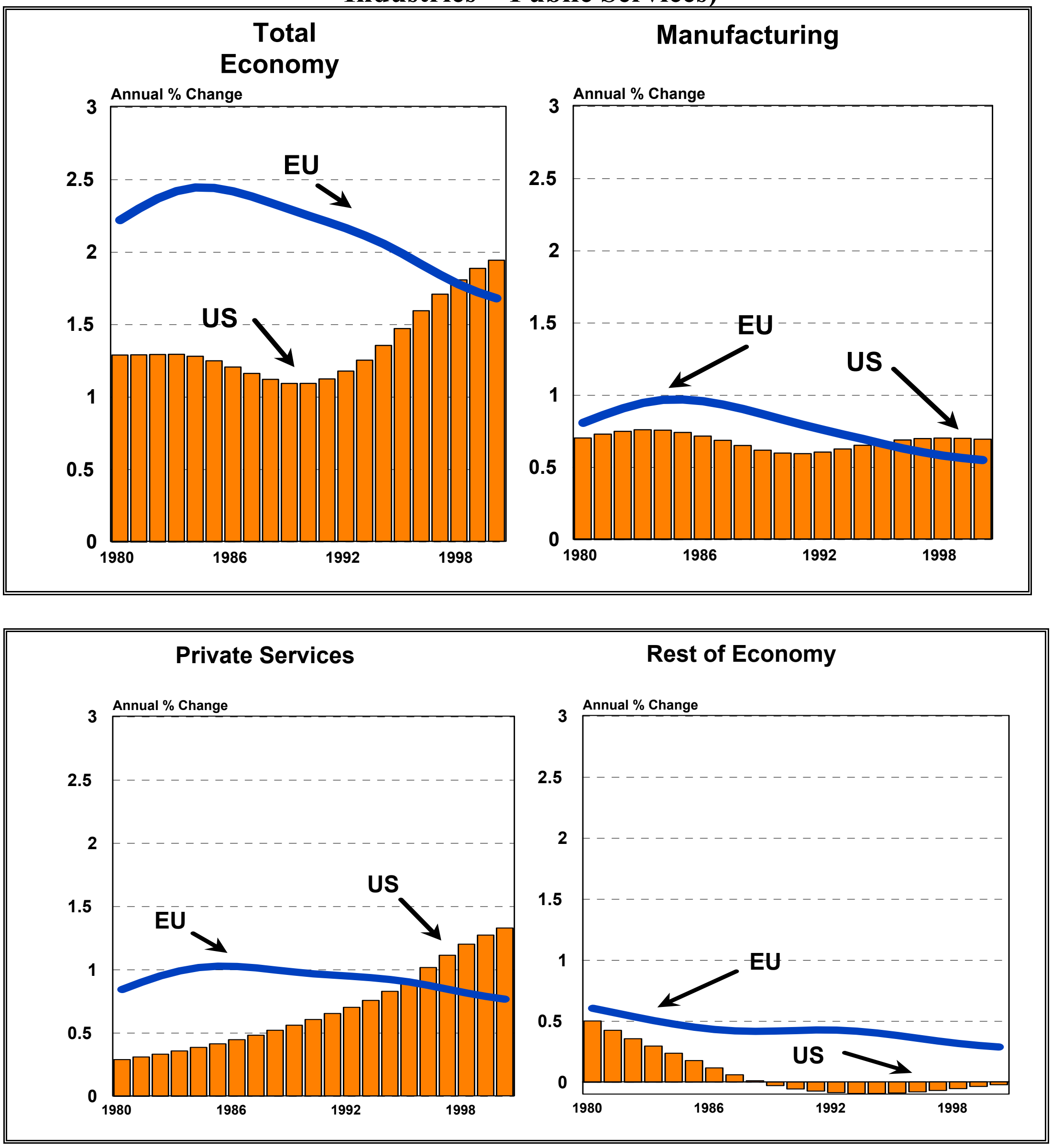
- In terms of overall labour productivity growth rates, the aggregation of the 56 industries confirms the trends established in Section 2 on the basis of the economy-wide data, namely that the EU has experienced a sharp deterioration in its labour productivity growth over the two halves of the 1990s, with the US experiencing a marked acceleration. This is a significant conclusion since the datasets used for the sectoral analysis have been constructed using a very different methodology compared with those employed for the economy wide analysis in Section 2 (see footnote 13).

- For manufacturing, the EU is on a long run downward trend due to its dependence on a range of low to medium technology industries which are increasingly exposed to the competitive pressures of globalisation. The US on the other hand appears to have arrested its 1980's decline and has managed to put itself on a slightly rising trend since the mid-1990's, driven in large part by its global dominance in high technology industries such as semiconductors and office machinery.

- More impressive still has been the US's relative performance in the private services sector. Nearly 2/3 of the US's overall productivity growth rate now emanates from services, compared with as little as 1/6 at the beginning of the 1980's. Over the same period the EU's private services sector has been contributing less and less in absolute terms to overall EU labour productivity growth.

- Finally, the EU is doing better than the US in the "rest of the economy" sector (i.e. primary industries / public services) but even here the trend is downwards and the contribution of the sector to overall productivity growth is small.

Graph 10 : Contributions to the Total Change in Labour Productivity per Hour from Manufacturing, Private Services and the Rest of the Economy (Primary Industries + Public Services)



Note : The graphs show the contribution to the total change in labour productivity per hour i.e. the combined effect of labour productivity growth and the output shares of the respective industries. The graphs have all the same scale and are additive (i.e. manufacturing + services + rest of economy = total economy).

Source : GGDC and own calculations

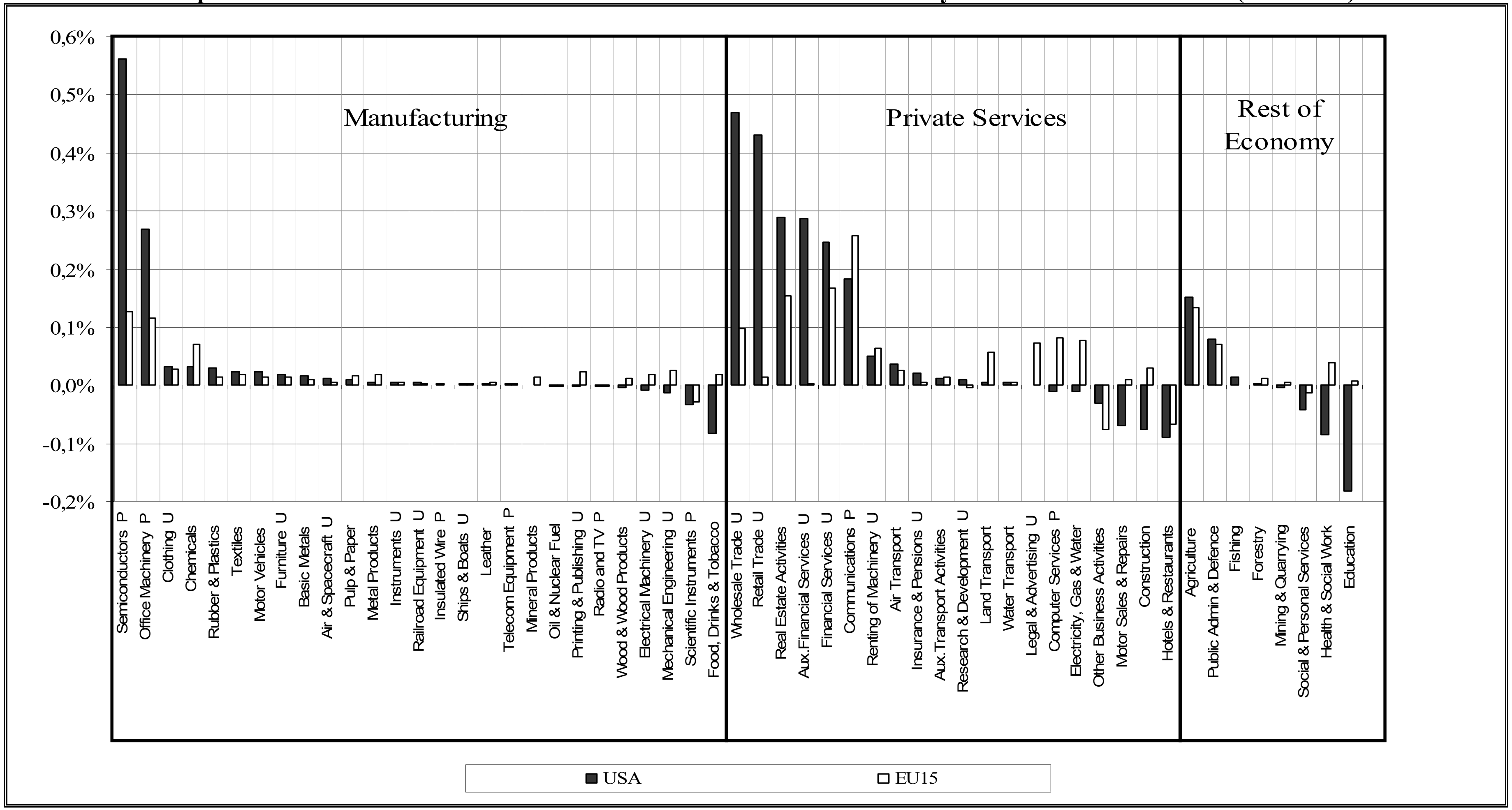
3.2. : Productivity trends at the industry level : A 56 Industry breakdown of labour productivity trends : Where are the EU's problems emanating from ? : Following on from the sectoral level analysis in 3.1, the present section provides a snapshot of each of the 56 industries and their importance for the productivity performance of the EU and US economies over the second half of the 1990's. This breakdown is shown in graph 11 and visualises the productivity dilemma facing the EU by giving a panoramic overview of the contribution of the 56 industries. For ease of exposition the industries are shown as part of the manufacturing, private services and rest of economy sectors which has already been discussed in 3.1.

3.2.1 : Overview of all 56 Industries (1996-2000) : Graph 11 shows that the EU has been doing reasonably well compared with the US in a wide range of manufacturing and service industries over the second half of the 1990's. However, the problem is that most of these industries are not making big contributions to overall productivity growth, with the graph indicating a contribution of much less than 0.1% for most of the industries concerned. For example, while Graph 11 shows that the EU's chemical industry contributed more than twice as much to the EU's overall productivity growth rate as did the equivalent US industry, it nevertheless still contributed only 0.07% points to the EU's overall total. This is only 1/8 of the contribution of the semiconductor industry to overall US productivity growth[14]. This latter industry in fact contributed nearly a quarter of all US productivity growth over the period 1996-2000. This basic story is replicated right across the 56 industries. In the 37, mainly traditional and medium tech, industries where the EU has equalled or outperformed the US over the second half of the 1990's, apart from communications[15], all of the remainder are either low productivity growth industries or do not have a large enough share of EU output to alter the EU's overall productivity performance. In addition, for most of these industries not only are productivity growth rates low but they have been declining over the course of the 1990's.

[14] It should be noted that the US productivity revival is not the result of a massive reallocation of employment to high productivity growth industries but is rather the result of productivity gains in industries where the US has had a strong position from the beginning of the 1990s (like in ICT production). In fact the reallocation effect for aggregate productivity growth is small in both regions (about zero in the EU and -0.1% points in the US). Also the correlation between productivity growth and employment changes across industries is of a similar magnitude in both the EU and the US if one excludes the real estate industry which is difficult to measure.

[15] It should be stressed that within the ICT-producing sector, communications is an industry where the EU has an undoubted advantage over the US, is characterised by high productivity growth and has a relatively large share of EU output.

Graph 11 : Contributions of the 56 Industries to Overall Labour Productivity Growth in the US + EU15 (1996-2000)



Source : GGDC and own calculations (See Annex 5 for the value added shares and productivity growth rates of the respective industries which are combined to produce graph 11)

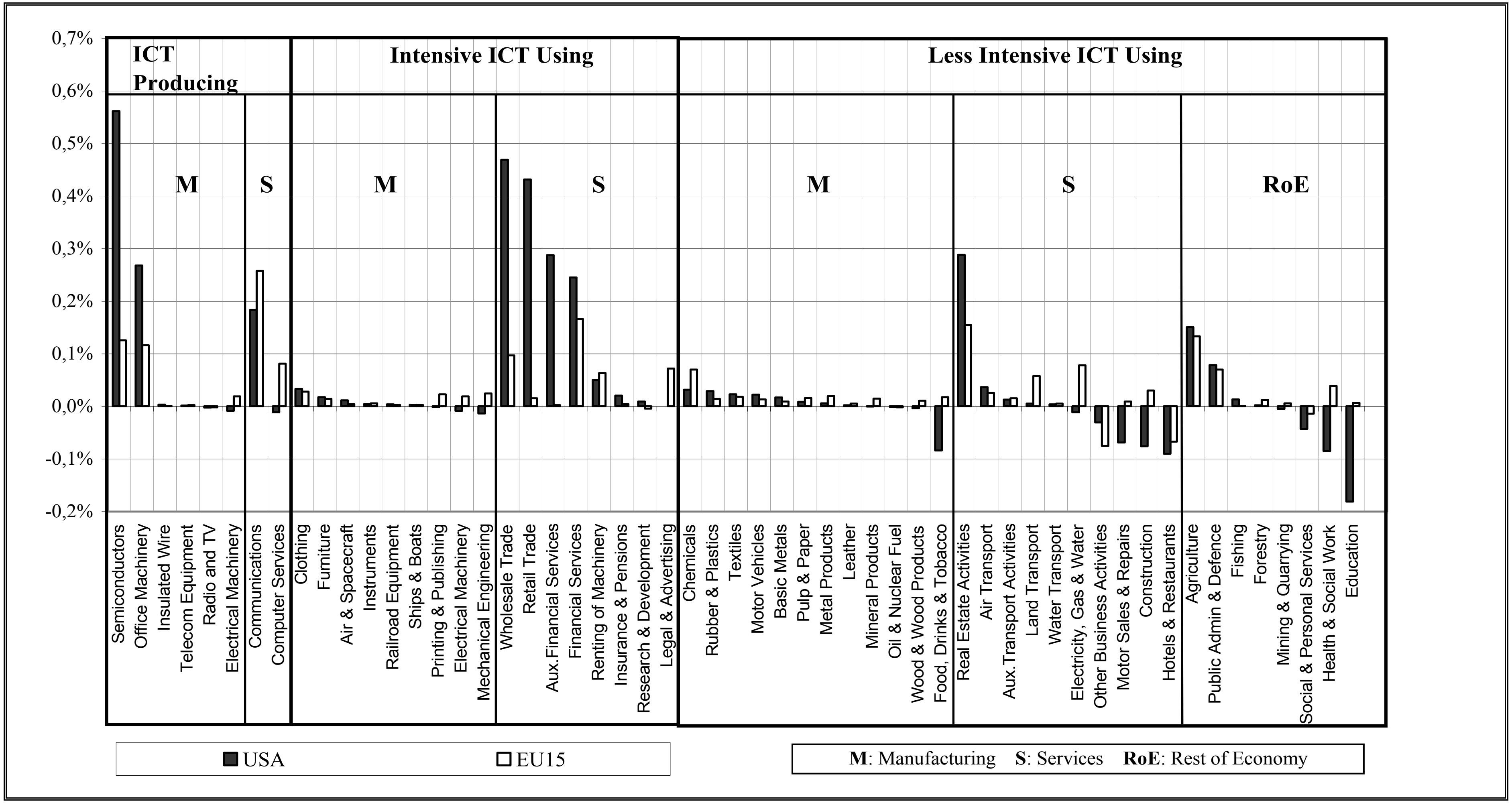
3.2.2 : Breakdown of 56 Industries Based on their ICT content : Another way of highlighting the EU's underlying productivity problem is to classify the 56 industries according to their ICT content into ICT producing, intensive ICT-using and less intensive ICT-using industries. This has the advantage of firstly isolating the importance of ICT in driving overall productivity growth and secondly this three-way ICT breakdown can also be used as a rough proxy for high, medium and low productivity industries in the EU and US as a whole. This breakdown is given in Table 2 which indicates that the ICT producing manufacturing and intensive ICT-using private services categories are driving the 1996-2000 divergences in EU-US productivity growth rates (Graph 13). In fact, these two groups of industries were responsible for virtually all of the acceleration in US productivity over the second half of the 1990's. It is precisely in these two areas of the economy that the EU fares badly relative to the US either in terms of the size of the respective industries (i.e. small shares of overall EU output) or by having relatively low productivity growth rates. In addition, as shown in the 2004 Economic Paper (No.208), in terms of explaining EU-US productivity growth differentials over the second half of the 1990's, it turns out that out of the total of 56 industries, just five (semiconductors; communications; wholesale trade; retail trade; and financial services) dominate the overall labour productivity growth patterns and all five are located in the ICT-producing and ICT-using categories. These 5 specific industries contributed 80 per cent of the US total productivity growth rate over 1996-2000, compared with a contribution of only 40 per cent in the case of the EU.

Table 2 : Breakdown of Total Economy into 3 categories – 2 ICT categories (ICT producing + Intensive ICT-Using) and 1 category of Less Intensive ICT using (i.e. more traditional) industries

	Hourly Labour Productivity (Average % Change)		Value Added Share		Contribution to Total Change in Hourly Labour Productivity	
	1991-1995	**1996-2000**	**1991-1995**	**1996-2000**	**1991-1995**	**1996-2000**
Total Economy (1+2+3)						
EU	**2.3**	**1.6**	**1**	**1**	**2.3**	**1.6**
US	**1.1**	**2.3**	**1**	**1**	**1.1**	**2.3**
1. Manufacturing Sector						
EU	**3.7**	**2.6**	**0.23**	**0.21**	**0.9**	**0.5**
US	**3.6**	**4.6**	**0.19**	**0.18**	**0.7**	**0.8**
1(a) ICT-Producing Manufacturing Industries						
EU	(9.6)	(17.1)	0.02	0.01	(0.2)	(0.2)
US	(16.4)	(26.0)	0.03	0.03	(0.4)	(0.7)
1(b) Intensive ICT-Using Manufacturing Industries						
EU	(2.6)	(2.0)	0.07	0.06	(0.2)	(0.1)
US	(-0.6)	(1.4)	0.06	0.05	(0.0)	(0.1)
1(c) Rest of Manufacturing (Less-Intensive ICT using)						
EU	(3.6)	(1.6)	0.14	0.13	(0.5)	(0.2)
US	(2.6)	(0.6)	0.10	0.11	(0.3)	(0.1)
2. Private Services Sector						
EU	**1.9**	**1.4**	**0.52**	**0.54**	**1.0**	**0.7**
US	**1.0**	**2.7**	**0.53**	**0.54**	**0.5**	**1.5**
2(a) ICT-Producing Service Industries						
EU	(4.8)	(6.8)	0.03	0.03	(0.2)	(0.2)
US	(2.4)	(0.8)	0.03	0.04	(0.1)	(0.0)
2(b) Intensive ICT-Using Service Industries						
EU	(1.8)	(2.1)	0.20	0.21	(0.4)	(0.4)
US	(1.6)	(5.3)	0.23	0.25	(0.4)	(1.3)
2(c) Rest of Services (Less-Intensive ICT using)						
EU	(1.7)	(0.2)	0.29	0.30	(0.5)	(0.1)
US	(0.2)	(0.3)	0.27	0.26	(0.1)	(0.1)
3. Rest of Economy (Primary Industries + Public Services) (Less Intensive ICT-Using)						
EU	**2.0**	**1.1**	**0.25**	**0.25**	**0.5**	**0.3**
US	**-0.3**	**-0.1**	**0.28**	**0.27**	**-0.1**	**0.0**

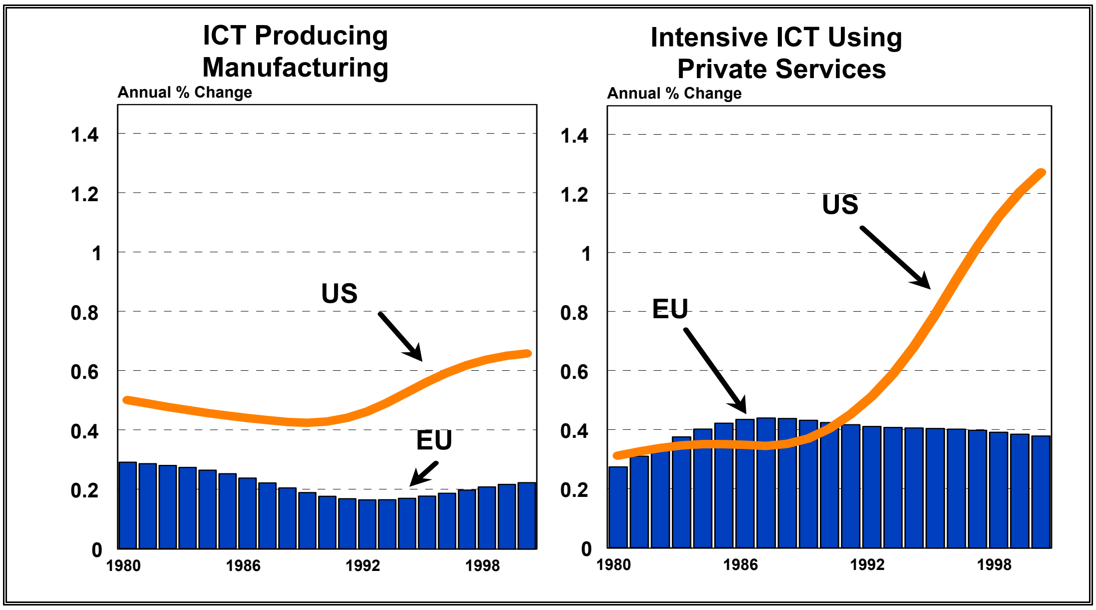
Source : GGDC and own calculations

GRAPH 12 : CONTRIBUTIONS OF THE 56 INDUSTRIES TO OVERALL LABOUR PRODUCTIVITY GROWTH IN THE US + EU15 (1996-2000)
- SPECIFIC FOCUS ON ROLE OF ICT -



Source : GGDC and own calculations

Graph 13 : Contribution to the total change in Trend Labour Productivity per Hour from ICT-Producing Manufacturing and intensive ICT-using Private Services



Source : DG Enterprise / GGDC and own calculations

Regarding the less-intensive ICT-using part of the respective economies, the slowdown in the EU's productivity growth rate in both the "rest of manufacturing", "rest of services" and "rest of economy" categories shown in Table 2 is marked over the most recent period. These more traditional industries collectively still account for over 70 per cent of EU GDP. The US has also experienced a slowdown in productivity growth in their "rest of manufacturing" category, whilst showing only marginal changes in the "rest of services" and the "rest of economy" categories. In the case of the US, however, the globalisation-related downturn in their more traditional manufacturing industries and the relatively poor contribution from a range of its low to medium-tech service industries was offset by strong performances elsewhere in the economy. In particular the US has had good performances in the newer, more knowledge intensive, manufacturing industries such as semiconductors and in a number of its intensive ICT-using service industries. The problem for the EU is that its pattern of declining / expanding industries is very different to that in the US, with the EU's trend productivity growth rate being pushed downwards by :

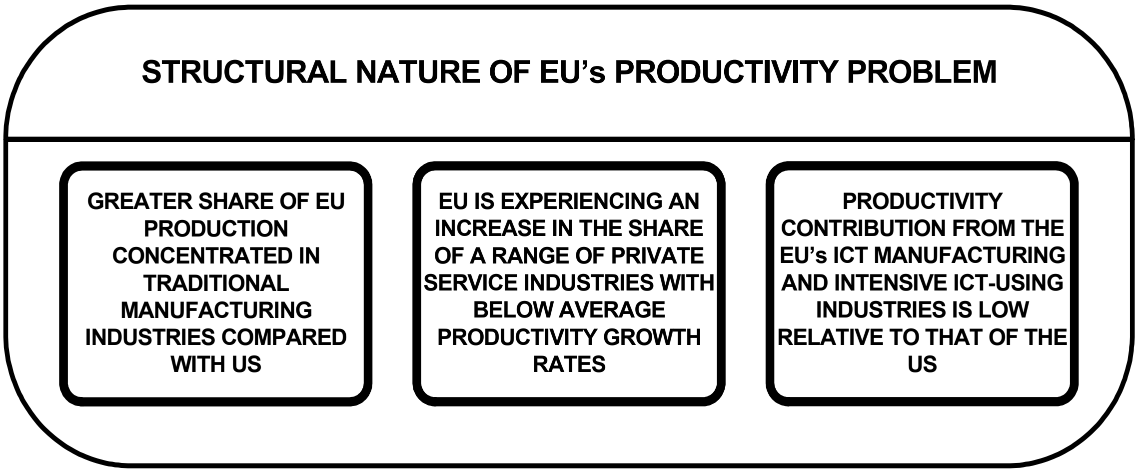
- firstly, having a greater share of its production concentrated in traditional manufacturing industries[16] where the EU has in the past been strong in global terms but where competitive conditions are now becoming more difficult due to globalisation.

- secondly, the EU is experiencing a further increase in its share of private services, with below average growth rates of labour productivity (at least historically), and with an additional downward shift in productivity in these

[16] 14% of EU output is still produced in these traditional industries compared with a share of 10% in the US.

industries over the 1990's due to the labour market reforms discussed earlier. It is in these traditional service industries, such as hotels and restaurants, transport etc, where the productivity reducing effects of these reforms have been felt most.

- thirdly, unlike in the case of the US, the productivity contributions from the EU's ICT manufacturing and intensive ICT-using service industries cannot make up for the losses in its more traditional manufacturing and private services sectors[17].



3.3 Are the ICT Productivity Gains coming from the production of ICT goods and services, from ICT capital deepening or from spillover effects ?

The analysis in section 3.2 showed that it was the superior performance of the US in ICT-producing manufacturing and in ICT-using service industries, such as wholesale and retail trade, which was the source of the diverging EU-US productivity trends since the mid-1990's. While this is the generally accepted view of developments, a number of commentators have been surprised by the fact that the large productivity enhancing effects of ICT have tended to appear in the hard-to-measure service industries and not in other well measured areas of the economy such as manufacturing. While the present analysis is not an attempt to rewrite the conclusions from section 3.2, it nevertheless tries to rebalance the messages coming out from this work in order to impress on policy makers that the EU's productivity problems emanate both from the ICT production side as well as from the ICT adoption / using side. Whilst accepting that these measurement issues in the services sector are

[17] Regarding the demographic challenges facing Europe, ageing could represent an additional factor explaining both the adverse sectoral changes which have occurred in Europe and the limited adaptation of companies to new technology trends. As societies age, there will be increasing demand for the output of a range of relatively low productivity industries such as health and social services, and less demand for the output of higher productivity sectors such as consumer durables. In addition, an ageing labour force may be less willing/able to switch into the latest leading-edge technology fields or have the capacity to generate the type of new innovative ideas needed to stay at the technology frontier.

unlikely to be resolved in the near future, what must be avoided at all costs is that erroneous policy conclusions are drawn given the uncertainties involved.

Productivity Developments and the Difficulties in disentangling the respective contributions from ICT Production and Diffusion (Capital Deepening + Spillovers[18]) : A primary source of the acceleration in US productivity growth in the 1990s has been the increasing share of ICT production in the overall output of the US economy allied to the extraordinary TFP gains in this specific industry. A second channel through which ICT has impacted on productivity has been through capital deepening, with the falling prices for ICT equipment leading to sharp increases in ICT investment rates (i.e. diffusion in the narrow sense of the term). While the economy-wide productivity gains from these two ICT transmission channels are both impressive, what has been missing up until now has been evidence that these large ICT investments have been generating productivity gains in those industries actually using this equipment (i.e. diffusion in the wider sense of the term). Given the "general purpose technology" characteristics of ICT[19], one would expect to be witnessing these productivity "spillover" effects from using the technology, with these TFP gains representing a third channel via which ICT can impact on aggregate productivity.

From the analysis in 3.2 it would appear that the experience of a small number of intensive-ICT using industries in the US has provided some evidence that these elusive "spillover" effects are finally emerging. However, as this section will show, the debate is far from settled with a large degree of controversy still surrounding the size of the productivity contribution coming from these specific ICT using industries, with Gordon[20] remaining sceptical whilst Stiroh / O'Mahony[21] are more optimistic. Attempts to disentangle ICT production, ICT investment and ICT spillover effects on labour productivity growth, using different methodologies, different levels of aggregation and different datasets arrive at rather heterogeneous conclusions. This makes it difficult not only to locate the precise source of the current productivity divergence between the US and Europe but it also complicates projections on future productivity growth and policy recommendations. This section reviews the alternative approaches and tries to trace the source of the productivity gains in specific ICT using service industries, such as wholesale and retail trade, at a higher level of

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[18] Spillover effects are the efficiency gains achieved from using ICT equipment.

[19] The contribution of ICT diffusion to productivity growth makes it a prime example of a General Purpose Technology (GPT). According to Bresnahan & Trajtenberg (1995), a GPT has the following three characteristics : pervasiveness - spreading to most sectors; improvement - constant lowering of costs to users; and innovation spanning - making it easier to invent and produce new products and processes. Jovanovic and Rousseau (2003) illustrate how ICT easily matches these criteria. In addition, they demonstrate for ICT another typical symptom of a GPT : namely that in the initial phase of a GPT, productivity may actually slow down before it peaks. This is due to various adjustment costs, learning delays and the slow introduction of the necessary complementary investments. As such the EU-US gap in ICT contributions may reflect different phases in the GPT cycle. Furthermore, Jovanovic and Rousseau link ICT's arrival as a GPT to higher firm entry and exit rates, with the young, smaller, firms doing better relative to the old incumbent firms, indicating the importance of flexible product markets for the diffusion of new technologies.

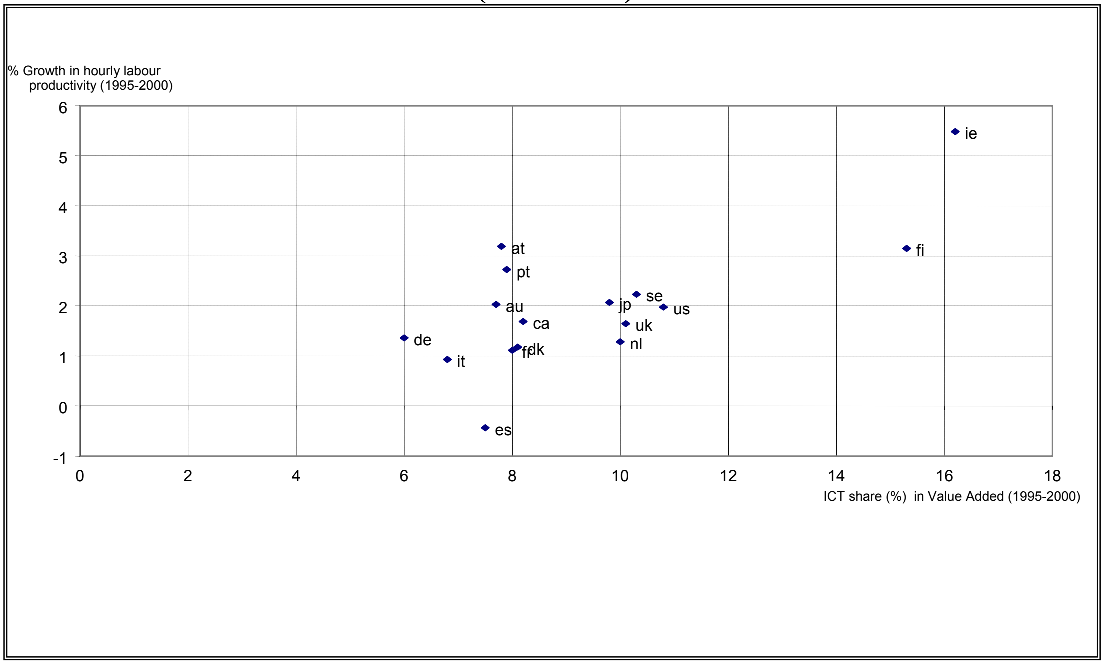
[20] Gordon (2003)

[21] Stiroh (2002) and O'Mahony et al. (2003)

disaggregation. However, it also points to a more fundamental problem, namely how to measure productivity in those service industries which are heavy users of ICT technologies.

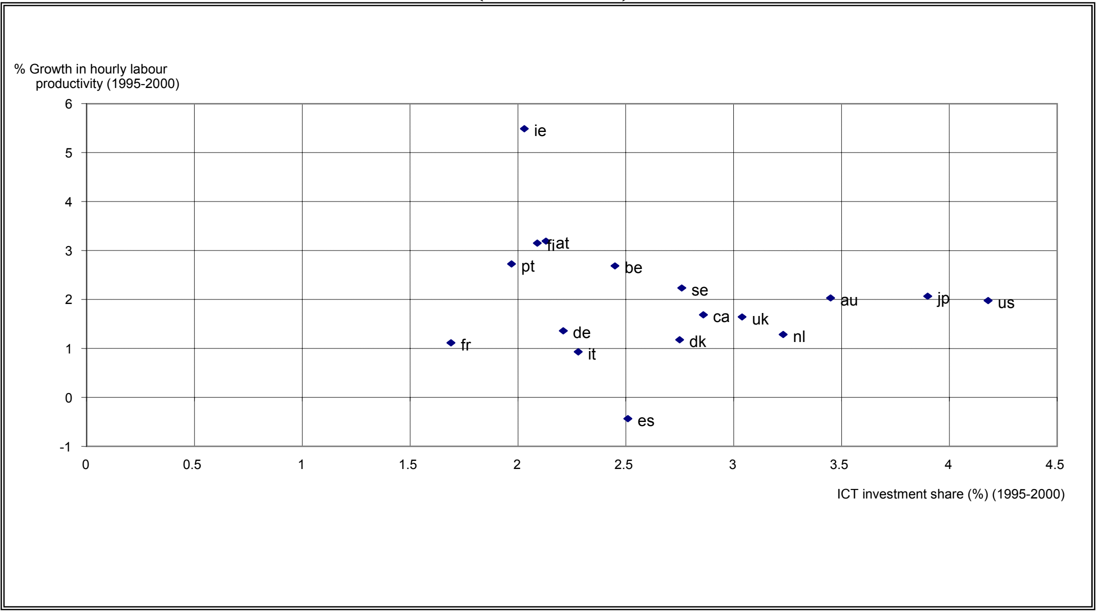
Results from International / Regional Comparison Approach : If one looks at international / regional cross section data, then ICT production rather than ICT-use, appears to be the dominant source of productivity growth. As can be seen from Graphs 14 and 15, there is a correlation between productivity growth and ICT production in the 1990s but there is little correlation between productivity growth and ICT investment. Consistent with the international data, Daveri and Mascotto (2002) present evidence across US states which suggest that the productivity acceleration mostly occurred in those States specialised in the production of IT goods and services. Based on cross-State econometric regressions over the period 1987-2000 they conclude that "… when States where IT production and non IT durable manufacturing which are mostly localized are excluded, the remaining States do not exhibit any significant acceleration in productivity. In particular, the association between productivity gains and IT use is weak".

Graph 14 : Hourly Labour Productivity Growth and the ICT Production Share (1995-2000)



Source : GGDC, Ameco

Graph 15 : Hourly Labour Productivity Growth and the ICT Investment Share (1995-2000)



Source : GGDC, Ameco

Results from the Growth Accounting Approach : Growth accounting exercises, on the other hand, attribute a sizeable fraction (i.e. about half) of the productivity acceleration to the use of ICT. Recent exercises[22] for the US estimate that ICT investment has contributed about 0.5% points to US productivity growth, with ICT production contributing another 0.5% points. Other studies, such as Inklaar et al (2003), suggest a 0.24% point contribution from ICT production and a 0.19% point contribution from ICT investment for an EU4 aggregate (see Table 3)[23], with higher contributions for the US (0.40% points for ICT investment and 0.36% points for ICT production). As the Inklaar results in table 3 show, the absolute difference between the US and the EU in terms of ICT capital deepening is largely due to one specific industry, namely financial services (FS). If one excludes the FS industry, it is striking that the contribution of ICT capital deepening to the change in labour productivity growth (i.e. ICT diffusion in a narrow sense) has been remarkably similar on both sides of the Atlantic. These figures suggest that the EU is catching up with the US in terms of the usage/diffusion of ICT in the narrow sense of the term (i.e. in terms of the actual purchases of ICT investment goods and services by the different industries).

However, what Table 3 also shows is that there are big differences between the EU and the US in terms of the spillover effects from these investments. For example, while the EU and the US wholesale trade (WT) and retail trade (RT) industries have both made similar gains in terms of ICT capital deepening, the US appears to have

[22] Gordon (2003) quoting an unpublished update of Oliner and Sichel (2002)

[23] The countries are France, Germany, the Netherlands and the UK.

reaped substantially more from the use of this capital in the form of much higher TFP gains (i.e. ICT diffusion in the broader sense). It must be emphasised however that these TFP gains occur in a very narrow segment of the services sector where productivity is difficult to measure. In other better measured areas such as ICT using manufacturing[24], Table 3 shows that the relative TFP gains in the US are significantly smaller.

One can argue that the above analysis provides evidence of positive spillover effects in the US, i.e. ICT investment is enabling organisational changes in ICT using industries. The fact that the TFP accelerations in ICT using industries are not observed in the EU could be due either to adjustment costs (EU is in an earlier stage of the transition) or it could be the result of institutional / regulatory constraints in specific industries (e.g. land use regulations / opening hours in WT and RT; less entry of new establishments / insufficient competition etc) which prevents firms from reaping the full benefits of the new technology in EU countries.

Table 3 : Growth Accounting Estimates

	Productivity Growth Differentials (% Points) (1979-1995 versus 1995-2000)	
	US	**EU-4**
Labour productivity (1+2+3+4+5)	**1.25**	**-.27**
Contributions to Labour Productivity Growth Differential		
1. Labour quality	**-.07**	**-.09**
2. Employment Reallocation Effect	**.05**	**-.06**
3. ICT capital deepening : Total Economy	**.40**	**.19**
3a: ICT producing Industries	**.04**	**.03**
3b: ICT using industries	**.29**	**.14**
-ICT using manufacturing	*.01*	*.01*
-Wholesale Trade	*.05*	*.05*
-Retail Trade	*.01*	*.01*
-Financial Services	*.17*	*.02*
-Business services	*.05*	*.05*
3c: Less Intensive ICT using industries	**.07**	**.03**
4. Non ICT capital deepening :Total Economy*	**.08**	**-.45**
5. TFP : Total Economy	**.79**	**.13**
5a: ICT producing Industries	**.36**	**.24**
5b: ICT using industries	**.83**	**.02**
-ICT using manufacturing	*.06*	*.00*
-Wholesale Trade	*.31*	*-.02*
-Retail Trade	*.28*	*-.03*
-Financial Services	*.27*	*.06*
-Business services	*-.10*	*.01*
5c: Less Intensive ICT using industries	**-.40**	**-.13**

* In terms of non-ICT capital deepening in WT and RT, only small differences exist between the US and the EU4

Source : Inklaar et al (2003)

[24] Inklaar et al. classify the paper, printing and publishing, machinery as well as furniture and misc. manufacturing as ICT using industries.

There are also two counter arguments to the US spillover thesis that should be taken into account :

- Gordon (2003), argues that the revival in RT and WT productivity is due to organisational changes unrelated to the use of ICT[25]. Microeconomic evidence provided by Foster et al (2002) shows that productivity growth is strongly linked with new establishments, whilst existing establishments do not experience a productivity gain[26]. This is despite the massive investment in ICT which presumably went into both old and new establishments (e.g. bar code readers have become universal in old and new retail stores). Gordon consequently speculates that productivity gains in the newly built "big box" stores may reflect far more than just the use of computers, such as for example size effects, better unloading systems, improved storage facilities etc.

- A second line of argumentation stresses statistical problems with measuring productivity in WT and RT. Volume measures for WT and RT are calculated using the deflators of the products sold by the WT and RT industries[27]. This practice could imply that countries where the share of ICT goods sold to firms and private households is large and where quality improvements are fully taken into account in the price measures, may have a larger increase in WT and RT productivity simply because prices in the basket of goods sold are falling more strongly[28]. If there has been a genuine productivity acceleration, because of the higher use of ICT in WT and RT, one would expect the productivity gains to be evenly distributed across different WT and RT sub-sectors. If the productivity acceleration can be traced to specific sub-sectors within the RT and WT industries with a relatively large exposure to ICT, there is a higher likelihood that the acceleration could be largely due to measurement issues related to ICT :

    - For WT one observes (Table 4) that the productivity increases are concentrated in the durables sector, and within durables in sub-sectors with a

[25] In the case of financial intermediation it has been argued by Stiroh (2002), for example, that one should be careful in assuming spillover effects since the productivity effects in financial services have probably been strongly influenced by the stock market bubble.

[26] This is consistent with the view that the within-firm productivity differences between the EU and the US are small. The big differences are due to the high productivity growth rates of the new entrants to the US retail market. This is why entry and exit rules / planning laws are often mentioned as possible explanations for EU-US productivity differentials. Other factors linked to globalisation could also be playing a role. For example, there is anecdotal evidence that Wal Mart and the large US supermarket groups are sourcing a much larger proportion of their goods from low-cost production centres such as China, compared with European retailers.

[27] See Ahmad et al (2004) and Triplett and Bosworth (2000).

[28] For example, this means that since the volume of computer sales has increased due to improvements in speed and capacity, a store which sells the same number of computers at the end and at the beginning of the 1990s would record a higher productivity growth rate without any change in the organisation (number of employees and hours worked) of the store. As noted by Triplett and Bosworth, a volume measure for the goods sold by a certain retail sector which combines the increase in quality with the growth in the number of goods, as is the case with hedonically deflated goods, bears little relationship to the actual activities of the store, even though it is the appropriate output measure for that specific good.

high ICT concentration such as commercial equipment and electrical and electronic goods. This disaggregation suggests therefore that the productivity acceleration is closely linked to the evolution of IT prices, with this evidence underlining the need for an extremely careful interpretation of growth accounting studies using data on WT services.

Table 4 : Productivity in the US Wholesale Trade (WT) Industry

	1988-1995			1995-2000			Difference in Contribution (1995-2000 V 1988-1995)
	Productivity Growth Rate (%)	Share of Total Output in WT	Contribution to Prod'y Growth Rate of WT	Productivity Growth Rate (%)	Share of Total Output in WT	Contribution to Prod'y Growth Rate of WT	
TOTAL WHOLESALE	3.04	1.00	3.04	4.03	1.00	4.03	0.99
DURABLES	4.84	0.46	2.24	5.94	0.48	2.86	0.62
NON DURABLES	0.32	0.42	0.13	0.75	0.38	0.29	0.15
ELECTRONIC MARKETS	4.70	0.12	0.57	6.17	0.14	0.84	0.27
DURABLES DECOMPOSITION							
MOTOR VEHICLES	2.21	0.11	0.23	3.92	0.11	0.44	0.21
FURNITURE	3.33	0.02	0.05	1.72	0.02	0.03	-0.03
CONSTRUCTION	-2.11	0.02	-0.05	-0.36	0.02	-0.01	0.04
COMMERCIAL EQUIPMENT	13.08	0.07	0.97	13.78	0.08	1.13	0.15
METALS	-0.31	0.05	-0.02	-0.41	0.04	-0.02	0.00
ELECTRICAL & ELECTRONIC	8.81	0.06	0.50	12.98	0.07	0.93	0.43
HARDWARE	2.70	0.02	0.04	2.50	0.02	0.04	0.00
MACHINERY	2.75	0.08	0.22	2.97	0.08	0.24	0.02
MISCELLANEOUS	2.43	0.04	0.09	3.24	0.04	0.13	0.04

Source: BLS and own calculations. The productivity measure is real output divided by total hours

- In RT (table 5), two sub-sectors, electronics and appliance stores and non-store retailers (with a large share of ICT equipment dealers) show high productivity growth rates. However, compared with WT, the productivity acceleration in RT is more widespread across the sub-sectors. It is difficult nevertheless to assess the extent to which the productivity acceleration in RT can be traced to the use of ICT. A recent paper by Sieling et al. (2001) traces the productivity improvements in various retail sectors to two developments, increased concentration in the industry and ICT investments[29]. In 1987, the 50 largest retail firms accounted for 20% of all sales but by 1997 that proportion had grown to 26%. In the case of department stores, labour productivity

[29] A typical ICT investment in retailing are point of sale systems (POS) which allow retailers to gather information which leads to improved inventory management.

growth partly reflects shifts away from conventional stores to discount or mass merchandising department stores. In 1987 the latter had a market share of 43% which increased significantly to 63% in 1997. With such a shift, productivity gains arise naturally because the latter are to a large extent self-service stores[30].

Table 5 : Productivity in the US Retail Trade (RT) Industry

	1988-1995			1995-2000			Difference in Contribution (1995-2000 V 1988-1995)
	Productivity Growth Rate (%)	Share of Total Output in RT	Contribution to Prod'y Growth Rate of RT	Productivity Growth Rate (%)	Share of Total Output in RT	Contribution to Prod'y Growth Rate of RT	
TOTAL RETAIL	1.91	1.00	1.91	3.79	1.00	3.79	1.88
MOTOR VEHICLES	1.15	0.25	0.28	1.74	0.26	0.46	0.18
FURNITURE	3.06	0.03	0.10	3.84	0.03	0.11	0.01
ELECTRONICS & APPLIANCES	10.81	0.02	0.25	15.46	0.03	0.44	0.19
BUILDING MATERIALS	1.98	0.09	0.18	3.45	0.09	0.30	0.12
FOOD & BEVERAGES	-0.86	0.20	-0.17	1.56	0.17	0.26	0.44
HEALTH / PERSONAL CARE	0.74	0.04	0.03	3.61	0.05	0.16	0.13
PETROL	2.16	0.08	0.17	2.76	0.08	0.22	0.05
CLOTHING	4.21	0.06	0.27	4.62	0.06	0.26	0.00
SPORTS / HOBBIES	2.80	0.02	0.07	5.66	0.03	0.15	0.08
GENERAL MERCHANDISE	3.18	0.12	0.39	4.96	0.13	0.65	0.26
MISC RETAILERS	3.62	0.03	0.10	3.26	0.03	0.11	0.01
NON-STORE RETAILERS	6.52	0.04	0.27	10.26	0.05	0.51	0.24

Source: BLS and own calculations. The productivity measure is real output divided by total hours

Overall Assessment of ICT's Contribution to Productivity Growth : Regarding the international / US regional comparison approach, the results on ICT production / diffusion effects suggest that ICT production rather than ICT-use is the dominant source of productivity growth and that the evidence of extraordinary spillover effects associated with ICT investment is still somewhat questionable[31]. Given the EU's

[30] The composition effect is especially visible with food stores. Grocery stores are by far the largest group within the food stores area. Here superstores and hypermarkets are replacing conventional grocery stores. In 1988 conventional grocery stores accounted for 43% of all consumer expenditures for food at home; by 1998, that proportion had fallen to 13%. The productivity improvements with car dealers can probably be traced to the increased use of computer diagnostic equipment. Productivity growth amongst the non-store retailers (catalogue and mail order houses) was increased by online sales. Based on annual retail trade data by the Census Bureau, E-commerce sales accounted for 0.5% of total retail sales in 1999, with 77% of these sales occurring in the non-store retailer industry group.

[31] In relative terms, these studies suggest that the ICT production / productivity link is more visible or clearcut compared with the ICT investment share / productivity link. In terms of the overall investment

relatively small ICT producing sector, especially on the manufacturing side, this raises important questions as to why the EU has failed to allocate sufficient resources to ICT production.

Regarding the results from growth accounting studies and in particular the gains from ICT diffusion, a closer look at the productivity growth acceleration in the WT and RT industries in the US, which is commonly used as evidence in favour of positive TFP effects, also casts doubt on the robustness of the ICT investment / productivity link. One should bear in mind that the recent growth accounting studies do not attribute the productivity growth acceleration in the US relative to the EU to different speeds of ICT investment (i.e. ICT diffusion in a narrow sense) but to an increase in TFP in these industries (ICT diffusion in a broad sense). In WT, the measurement effect could explain a substantial part of the TFP acceleration in this industry[32]. In RT, while the effects are more dispersed, there are other factors beyond ICT which could account for the TFP acceleration in the US, such as larger store size, the increased share of self service markets and the greater entry of new establishments. It is difficult however to establish a clear causal ordering amongst these latter factors[33].

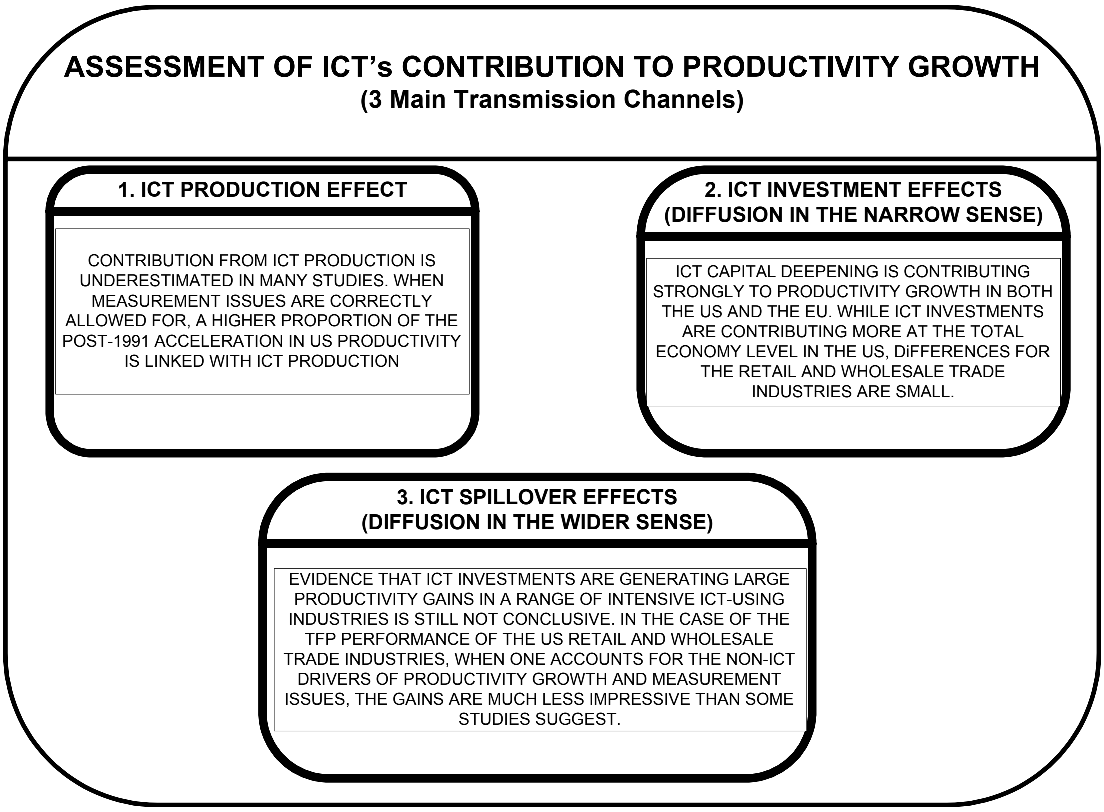
Finally, the above discussion on ICT diffusion effects must not be seen as contradicting the correct belief that ICT spillover effects are making a positive contribution to labour productivity growth, or that these gains may be larger in the US than in the EU because of institutional / regulatory constraints in a number of the EU's Member States. It simply suggests that the US benefits are presently not as high as some commentators estimate when one correctly accounts for non-ICT drivers of productivity change and measurement issues. ICT diffusion in the narrow sense of ICT capital deepening is clearly contributing strongly to productivity growth in both the US and the EU. The evidence for ICT diffusion in the broader sense of large TFP

share (i.e. the investment to GDP ratio), ICT investments are evidently taking a higher proportion of overall investment but the belief that these new ICT investments are significantly more productivity-enhancing compared with the non-ICT investments which they are replacing is simply not evident in the productivity figures of the countries shown earlier in Graph 15. Consequently, while ICT investments are contributing strongly to productivity growth, this reflects their growing share in overall investment not that their relative contribution is spectacular. This differs from the productivity gains being generated in ICT production, where the contribution to economy wide productivity growth is extraordinary relative to the contribution from non-ICT production.

32 It is important to keep in mind that the mis-measurement of productivity in the US WT and RT industries is not translated onto the aggregate level. The combined productivity improvement in ICT production plus ICT diffusion is measured correctly, it is only the distribution of the productivity gains across production and diffusion which is questionable. In this context, the present analysis suggests that the contribution from the ICT production side to the acceleration in US labour productivity growth has been underestimated in a lot of the most recent growth accounting studies. In other words while the size of the EU-US productivity growth gap is still the same, less of this gap is due to the US's performance in ICT-using industries such as WT and RT and more of it is located in semiconductors and other ICT-producing industries.

33 These different TFP effects are especially surprising since the employment changes in the retail and wholesale trade industries in the US and the EU have been very similar over the second half of the 1990's and consequently the TFP gains in the US are not coming from a sharp reduction in the numbers employed in these industries. Such a reduction in employment is often the source of the efficiency gains associated with the introduction of new technology or from the liberalisation of previously state-owned industries.

gains in specific ICT-using industries is still however open to some debate. While it is undeniable that given the pervasiveness of ICT in developed economies that there are TFP gains related to the use of this general purpose technology, the present section has simply questioned the spectacular nature of those gains in a small number of US service industries[34].



[34] There is a final point which casts some additional doubt on the growth accounting studies. The strong productivity contribution of RT and WT is due to an extraordinary productivity acceleration (from 2.3% to 7.2% in WT and from 2.5 to 6.6 in RT) in the US. The data used are from the Bureau of Economic Analysis (BEA). Using a different data source, namely data from the Bureau of Labour Statistics (BLS), which is the source used in the present study, yields dramatically different productivity growth accelerations in the US (from 3% to 4% in WT and from 1.9% to 3.8% in RT).

4 : Enhancing the EU's productivity performance : Focussing on The Production and Absorption of New Technologies is the key to any Effective Long Run Productivity Strategy

The analysis in section 3 on the contribution to overall productivity growth from ICT production / ICT use has indicated a more general theme, namely the importance to the EU's future productivity performance of an ongoing process of structural change aimed at boosting the production and absorption of new, more knowledge intensive, technologies. The relative success of this whole process hinges ultimately on the extent to which the Lisbon Strategy's objective of creating a more knowledge-driven economic model is realised over the coming years and decades and in particular on the ability of governments to create an environment in which the EU's innovation infrastructure (R&D expenditure, research personnel)[35] can generate the new skills, ideas and products needed to compete successfully in the global marketplace. Excellence in the knowledge production sector and the creation of a more effective absorption / diffusion process in the EU will be driven not only by the innovation infrastructure but by a complex range of factors, with macroeconomic fundamentals (low and stable inflation; moderate tax burdens on labour and capital; trade openness); the physical / human capital investment activities of firms, households and the government; firm dynamics[36] and competition[37] all playing important and interlinking roles in shaping the overall productivity environment.

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[35] A country's innovation infrastructure is made up of a network of publicly funded research institutes / 3rd level education establishments allied to the research activities of small and large private sector firms, all of which contribute to an economy's knowledge creation process.

[36] Firm level analyses look at the micro determinants of growth and focus on the reallocation of resources within specific industries, emanating from the expansion of more productive firms, the entry of new players and the exiting of relatively inefficient ones. According to the OECD's firm level analysis, a key finding is that "a large fraction of aggregate labour productivity growth is driven by what happens in each individual firm, whilst shifts in market shares from low to high productivity firms seem to play only a modest role". The OECD's analysis also points to a healthy process of "creative destruction" in OECD countries, with the failure rate of new small entrants being particularly high, suggesting a large degree of market experimentation. This process of creative destruction should be encouraged by easing the regulatory burden on the start-up of new firms and on the development of fast growing firms. These firms contribute to productivity growth in a number of different ways, with new start-ups directly contributing when their degree of efficiency is higher compared with exiting firms. In addition, new and fast growing firms which pose a credible threat to the position of incumbent firms can force the latter to respond by raising their own productivity. Greater experimentation by highly innovative firms is particularly important in periods of rapid technological change, with new ideas and methods of production boosting the innovation process and leading to faster rates of adoption of new productivity enhancing technologies.

[37] Innovation directly results from greater competition and is increasingly being used by firms to drive their competitive strategies. However, there is a complicated non-linear relationship between innovation and competition with the recent research literature suggesting that it takes the form of an inverse U i.e. competition is positive for innovation but only up to a certain point. This research underlines the need to take industry-specific circumstances into account when assessing the precise relationship between competition and productivity. At the private sector level, innovation directly contributes to the productivity of firms and via spillover effects it impacts on the productivity of other firms and even other countries. These spillover effects enable firms to add to their own innovation capacity by absorbing knowledge produced elsewhere, be it domestic or foreign sourced.

In this context, the earlier Economic Paper[38] on productivity described how ECFIN's productivity model could be used to look at the channels via which the more fundamental factors driving growth affected investment and total factor productivity (TFP) and how these factors interacted to generate labour productivity growth. Using this model, the analysis showed that EU-US productivity differentials could in fact be related to some fundamental structural differences at the individual country level. According to this analysis, there are five areas which are both quantitatively important for productivity and relevant in an EU policy making context. These are the regulatory burden; the structure of financial markets (bank based versus more market based financial systems); differences in the degree of product / service market integration (especially in terms of entry and exit rules and overall competition levels); ageing of the labour force; and finally the focus of the present section, the knowledge economy. These are the areas where the EU either compares poorly with the equivalent conditions prevailing in the best performing OECD countries or, in the case of ageing, where the EU is facing a more severe medium to long run challenge. While the present section focuses on the EU's knowledge economy problems, this particular productivity driver cannot be seen in isolation from the other weaknesses highlighted in the 2004 analysis or from the wider economic and regulatory environment in which start-up and established firms must operate in executing their productivity strategies.

4.1 : Why the knowledge Economy must be a central element of any EU productivity agenda ? : Given the EU's knowledge economy ambitions, evidence is presented in the present section which suggests that the US has a superior knowledge creation and absorption system, with particular features of the EU's innovation model needing to be urgently re-assessed. As the text makes clear, it is not just an issue of increasing R&D and tertiary education spending to US levels, its more a matter of the framework conditions / flanking policies needed to provide adequate incentive structures for the private sector to enhance productivity, with well functioning product, labour and capital markets a clear priority in this respect. Given the structural nature of Europe's productivity problem and the fact that the trend is continuing to deteriorate, a key objective for the forthcoming mid-term review of the Lisbon strategy must be to embolden national leaders to the absolute necessity for action in this area. Arresting the present decline in productivity growth rates and realising the EU's stated objective of creating a globally competitive, knowledge-based, economy, will require a number of essential reforms.

Knowledge Investments and their Economic Significance : With the striking impact of ICT, there has been considerable interest in analysing the effects of investments in knowledge and human capital formation. The empirical growth literature emphasises knowledge and the creation of knowledge via the investment activities of firms, households and the government in both R&D and education as

[38] No.208, op.cit.

significant drivers for enhancing the level of technology (total factor productivity). Last years Economic Paper[39] indicated the relative potency of knowledge investments (R&D and education) in determining long run productivity growth rates, with a simulation indicating that a combination of regulatory reform and a substantial increase in EU knowledge production could boost EU potential growth rates by between ½ to ¾ of a percentage point annually over a 5-10 year horizon[40]. Regarding the US, the knowledge based economy would appear to be more fully entrenched, with Graph 16 suggesting that investments in R&D[41] and education can explain nearly 75% of the US productivity growth rate over the period 1950-2003[42] and with the more recent decades accelerating its dependence on more knowledge intensive forms of investment, such as ICT. According to Jones (2002), the US's average labour productivity growth rate of 2-2¼% over this period could only have been generated via a (permanent) shift of resources into knowledge production activities and that without such investments US labour productivity growth would have averaged only 1/3 of a % point over this period. In other words, over the longer run, these knowledge investments are the key drivers of productivity growth in advanced economies and our future standards of living depend crucially on them.

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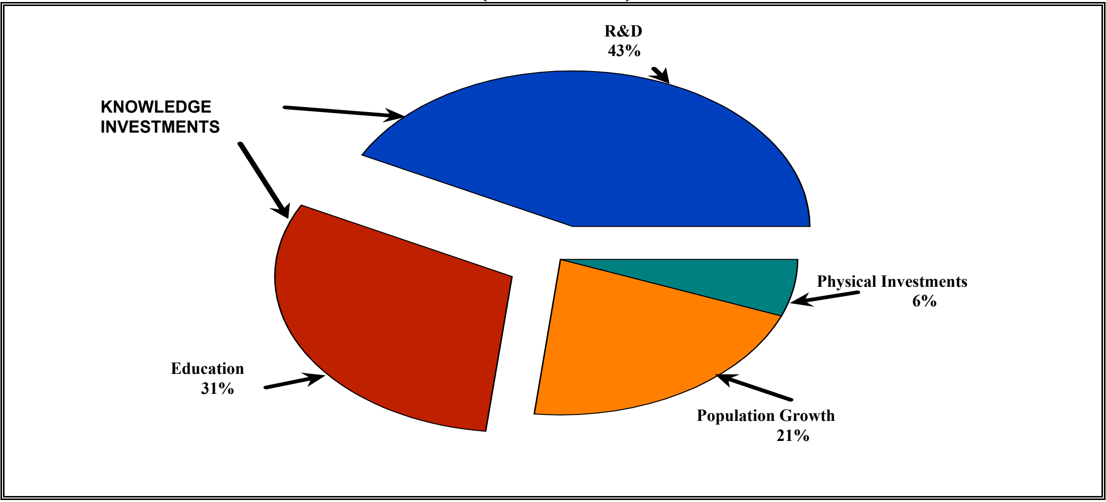
[39] No. 208, op.cit.

[40] While a ½-¾ of a % point would undoubtedly represent a significant turnaround in the EU's present economic fortunes, given the extent of the present gap in performance, this package of reforms would still not be sufficient for the EU to overtake the US in productivity terms over the timescale laid out for the Lisbon agenda. Apart from the time which will need to elapse between the implementation of reforms to the appearance of visible effects, there are two further obstacles to be overcome in reaching the Lisbon-imposed productivity target, firstly the temporary productivity trade-off in attaining the parallel employment target of 70 per cent and secondly the continuous drag on productivity induced by Europe's ageing labour force.

[41] Innovation is one of the main drivers of productivity growth, with Graph 16 indicating that by itself it has been responsible for over 40% of US labour productivity growth over the last half century.

[42] The contributions to productivity growth in the Jones analysis (Graph 16) are calculated by multiplying historical changes (from 1950 to 2003) of R&D, education and capital shares with their respective output elasticities. The relatively small contribution of physical capital to growth is due to the fact that unlike the shares of R&D and educational attainment, the share of physical capital has not changed much over the last 50 years. This is typical of a country (such as the US) at the technology frontier, with steady state physical investment levels and where physical capital accumulation becomes a smaller part of the overall productivity performance. For countries however in the "catching-up" phase of their economic development, the productivity contribution attributed to physical investments would be substantially larger. The contribution of population to productivity growth in the Jones analysis comes from an increasing returns to scale effect in production. The basic point of the graph is that since the EU15 is now close to the technology frontier, with steady state physical investment levels, any additional productivity gains over the coming decades are more likely to be generated from a boost to knowledge investments rather than from changes to our present physical investment to GDP ratio.

Graph 16 : Determinants of US Labour Productivity Growth (1950-2003)



Source : Jones (2002) and own calculations

ICT is a striking example of the importance of knowledge investments : As shown in section 3, individual knowledge intensive sectors such as ICT are now crucial to the overall productivity performances of individual countries. But its role extends well beyond its direct contribution as a high-growth sector. ICT in fact is a very good example of the growth in importance of more knowledge intensive forms of investment, with its share of total investment growing steadily over the last 15-20 years, having now reached 1/3 of overall non-residential gross fixed capital formation in the US. Within the ICT sector, specific industries such as semiconductors now have overall knowledge investment budgets which are equal in size to their spending on physical investments such as plant and machinery and buildings. Furthermore ICT investment itself has not only a larger than average "knowledge" content, in the form of the software and R&D spending needed to generate it, but has an additional knowledge element in that it is also complementary to skilled labour.

Given ICT's status as a high productivity growth industry and at the same time its potential as a "general purpose technology", inciting productivity growth in ICT-using industries, it should be a concern to policy makers that the US has established, and is retaining, a large global advantage in this pivotal industry[43]. How have the Americans achieved such a dominant position and why have other industrialized countries failed so far to catch up to the technology frontier ? With the US continuing to reap enormous gains from its dominance of the global ICT industry, Europe should be looking at those factors which have allowed this industry to flourish in the US. Box 2 explores the mix between knowledge investment, government support and

[43] The link between diffusion and production may actually not be coincidental : being strong in ICT production might also give a nation an advantage in being faster and/or better in adopting the new technology.

market structure that lay behind the US's success in the ICT area and some of the historical reasons why Europe stayed behind.

An important question arising from the analysis in Box 2 is the extent to which the example of ICT will be replicated in future high tech industries. If this is a credible risk then the key issue is whether the EU has specific problems in relation to its innovation infrastructure (i.e. in terms of the resources devoted to innovation) and whether the US has specific features / framework conditions such as the linkages between the various actors in the system etc which make it more likely to be the location of any future breakthroughs in technology. This is a pertinent question if one accepts the contention of Gordon (2004), amongst others, that the US's lead in ICT is not an isolated case. The US holds a comparative or absolute advantage not only in computer hardware, but more broadly in software and in other general purpose technologies, like its initial leadership in the electricity industry and in its exploitation of the internal combustion engine (Gordon 2004). While some comfort can be taken from the EU's ability in the past to catch up with the US in the latter technologies, this did not occur without a large restructuring and refocusing of EU industry. In addition, the wider issue is why is it that the US seems to be systematically better in creating and exploiting new (general purpose) technologies ? This requires broadening the discussion beyond ICT to consider why the US seems to have a better innovation capacity than the EU.

4.2 : Evidence that the US has a superior innovation model in terms of Knowledge Creation and Absorption : While traditional growth theories explain differences in growth across countries by the expansion in inputs, such as capital and labour, and by the catching-up of countries with lower productivity, modern theories emphasize research inputs and human capital as the key drivers for long-run growth. They stress not only the importance of "own" innovation but also the capacity to imitate and to absorb externally available know-how. Institutional factors and framework conditions are seen as an important part of the "innovative system" in which innovative firms operate.

National Innovation Systems and the National Innovation Capacity : Using the macroeconomic insights from neo-classical and endogenous growth theory, as well as the ideas from the literature on "National Innovation Systems", applied economic theorists (e.g. Stern, Furman & Porter 2002) have synthesized what determines an economy's "***national innovation capacity***" defined as the ability of a nation to not only produce new ideas but also to commercialize a flow of innovative technologies over the longer term (see Table 6). From this perspective a range of factors are deemed to be important for an effective innovation effort :

- **1. Overall Innovation Infrastructure** : A sufficiently developed 'supply' side of R&D (as reflected in the amount of R&D carried out or the number of skilled researchers) is a necessary but insufficient condition for successful innovation.

- **2. Essential Framework Conditions / Flanking Policies** : Broader framework conditions are important as well, including a sufficient 'demand' for innovation to reward successful innovators. This requires sophisticated lead users willing to pay for innovations, effective intellectual property rights (IPR) schemes, a favourable macro-economic environment and effective competition in output markets.

- **3. Interconnectedness of the Overall Innovation System** : Perhaps the most critical element in the framework is the interconnectedness of the agents in the system, linking the common innovation infrastructure to specific technology clusters. Through networking amongst firms, researchers and governments, the supply of new ideas diffuses throughout the economy. This requires good industry-science links and well functioning capital and labour markets, such that the human and financial capital inputs get allocated to their most efficient applications.

Table 6 : National Innovation Capacity : An Integrated Framework

1. Common Innovation Infrastructure : Interlinked institutions, resources and policies	1a : Existing Stock of Technological Know-how
	1b : Supporting Basic Research and Higher Education
	1c : Overall Science and Technology Policy
2. Technology / Cluster Specific Conditions	2a : Technology specific know-how : specialized R&D personnel
	2b : Incentives for innovation : lead users, appropriate IPR systems and output market competition : local rivalry, openness
	2c : Presence of related / supporting industries (clusters)
3. Quality of Links between clusters & common factors	3a : Industry-Science relationships
	3b : Efficient labour & capital markets

Source : Based on Stern et al. (2000)

National Innovative Capacity and the Crucial Importance of Market Entry and Exit Rules : As highlighted in Box 2 in relation to the specific example of the ICT industry and strikingly indicated below in Table 7, a country's innovative capacity is strongly linked to market conditions and especially market entry and exit rules. According to Baumol (2004), private sector innovations[44] in the US come from two distinct sources, firstly from the activities of large firms and secondly from the efforts of independent inventors and their entrepreneurial partners. Baumol asserts that the active presence of both groups enhances the overall innovation process since their activities are complementary, with the independent inventors / entrepreneurs specialising in breakthrough innovations and with the R&D departments of the larger firms enhancing these breakthroughs and adding to their overall usefulness. Baumol concludes by saying that "it is fortunate for the US economy that its institutions and arrangements are such as to facilitate and stimulate the profuse formation of small firms and to encourage their more radical innovative contributions". There is increasing evidence to support Baumol's view that more competition may well drive

[44] Due to market failures in the form of abuses of market power or the need to ensure a socially optimal level of human capital and R&D investment (due to the positive externalities associated with these determinants), governments are also big players in the innovation process.

up the rate of technological and organisational innovation. Firms enjoying significant market power do not appear to plough back excess profits into higher rates of R&D and innovation. Rather the lack of competition tends to provide little incentive for firms to pursue technological innovations, slows down its diffusion and impedes a higher variety and quality of goods and services being delivered to consumers[45].

Table 7. Some Important Innovations by U.S. Small Firms in the Twentieth Century

Air Conditioning	Heart Valve	Portable Computer
Air Passenger Service	Heat Sensor	Prestressed Concrete
Airplane	Helicopter	Prefabricated Housing
Articulated Tractor Chassis	High Resolution CAT Scanner	Pressure Sensitive Tape
Artificial Skin	High Resolution Digital X-Ray	Human Growth Hormone
Assembly Line	High Resolution Microscope	Programmable Computer
Audio Tape Recorder	Microscope	Quick-Frozen Food
Biomagnetic Imaging	Hydraulic Brake	Rotary Oil Drilling Bit
Biosynthetic Insulin	Integrated Circuit Board	Safety Razor
Catalytic Petroleum Cracking	Kidney Stone Laser	Six-Axis Robot Arm
Polaroid Camera	Large Computer	Soft Contact Lens
Defibrillator	Microprocessor	Supercomputer
DNA Fingerprinting	Magnetic Resonance Scanner	Two-Armed Mobile Robot
Electronic Spreadsheet	Optical Scanner	Vacuum Tube
Freewing Aircraft	Outboard Engine	Variable Output Transformer
FM Radio	Pacemaker	Vascular Lesion Laser
Front-End Loader	Personal Computer	Xerography
Gyrocompass	Photo Typesetting	X-Ray Telescope

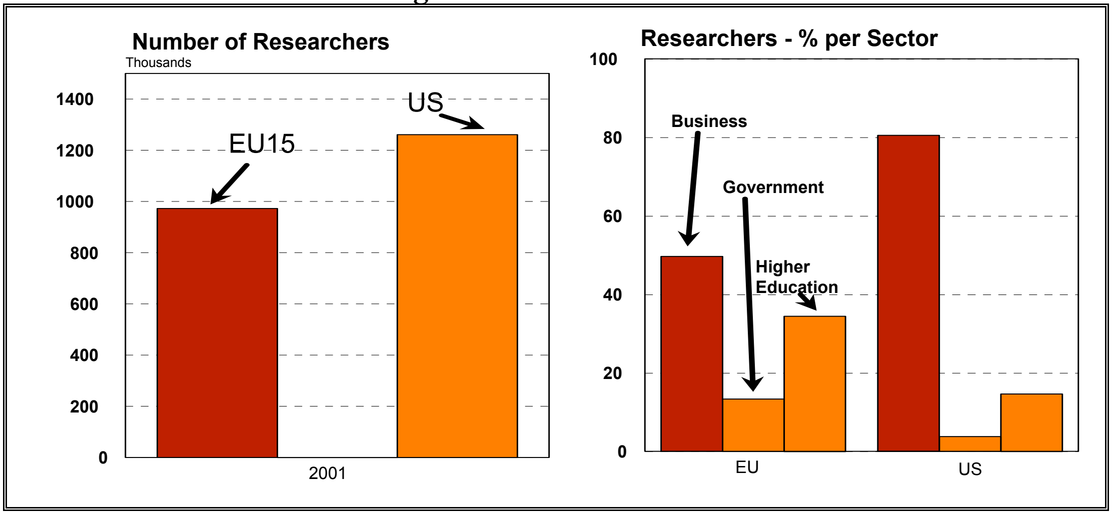
Source : US Small Business Administration (1995) / Baumol (2004)

4.2.1 : Overview of Innovation Infrastructures in the EU and the US : Graphs 17-19 provide a short graphical overview of the basic differences in the overall innovation infrastructures of the EU and the US.

- **Human Resources in R&D :** The US employs nearly 300000 more researchers compared with the EU, with the vast majority of the overall total (over 80%) employed in the business sector, compared with less than 50% in the EU.

[45] In terms of policy, while the general prescription clearly supports the case for greater competition, differences in the interplay between competition, innovation and productivity also suggests that for a number of individual industries, allowance must be made for specific market characteristics. For example, industry-specific framework conditions (i.e. incentive structures) are needed in markets characterised by network externalities or economies of scale where innovation tends to be stifled by cut-throat competition. Increasing dynamic efficiency in these industries may be better promoted via pre-competitive cooperation agreements between firms in the form of research joint ventures. While the results of the OECD's growth project (2004) showed that aggregate labour productivity growth is mainly driven by what happens in existing companies, entry and exit rules still play an important role in boosting productivity.

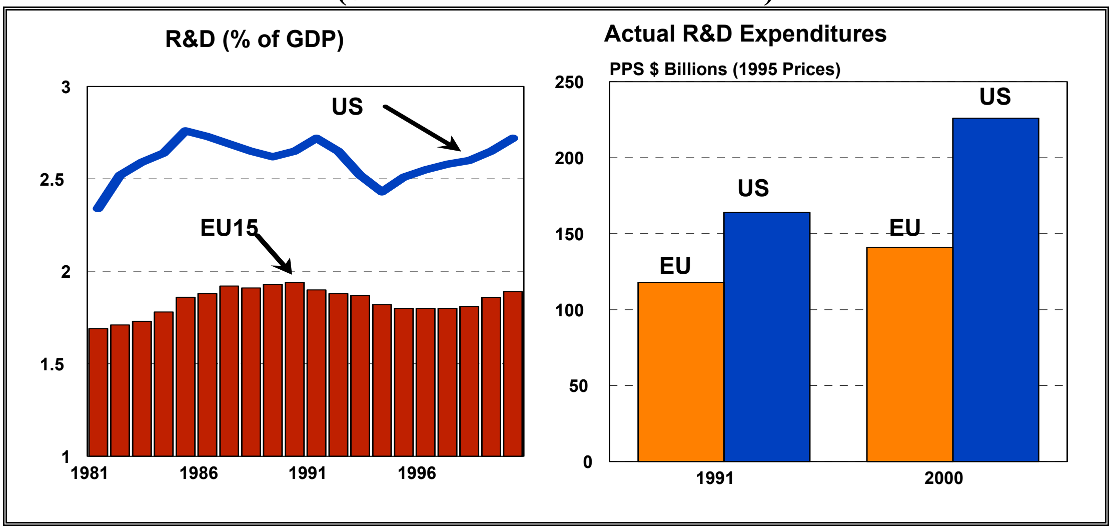
Graph 17 : Number of Researchers : Breakdown into Business, Government and Higher Education Sectors



Source : OECD

- **Basic R&D Expenditure Differences at the Economy-Wide Level :** A persistent and growing differential exists in the amount of resources devoted to R&D in the EU and the US both in terms of the overall research intensity of the respective economies (1.9% versus 2.8% of GDP) and in absolute amounts. To put the respective research efforts into context, the absolute gap in the volume of research is roughly $110 billion. If one widens the definition of the knowledge economy to also include expenditure on the higher education sector, the US is investing well over $200 billion more annually on its knowledge economy compared with the EU.

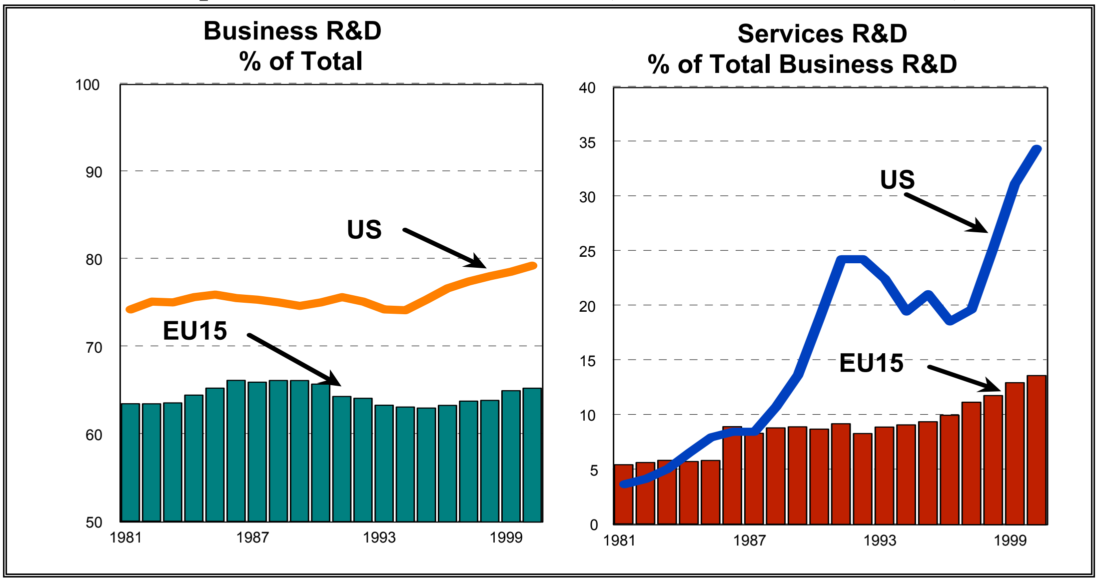
Graph 18 : R&D Intensity of EU and US Economies (% of GDP + Absolute Amount)



Source : OECD

- **Basic R&D Expenditure Differences at the Sectoral Level :** Compared with the EU, a much larger share of US R&D is carried out by the business, as opposed to the government, sector. Within the business sector, the US spends substantially more on services compared with the EU, especially in the "Computer and Related Activities" area. Of the total US R&D effort, roughly 1/3 is devoted to services and 2/3 to manufacturing. Regarding the EU, its research efforts continue to be overwhelmingly focussed on the manufacturing sector which presently accounts for around 85% of its overall business sector R&D spending.

Graph 19 : Business Sector R&D (+Focus on Services R&D)



Source : OECD

Basic R&D Expenditure Differences at the Industry Level (Technology Specific R&D) : Since no reliable comparative figures exist for a breakdown of service sector R&D activities, the industry level comparison is restricted to the manufacturing sector. Of the 27 industries which make up the manufacturing sector in the present study (see Graph 11), only 8 can be regarded as having an above average R&D intensity and therefore classified as high technology industries[46]. The details regarding these 8 industries and their aggregation into the two categories of ICT and non-ICT is given in Tables 8/8a-c below, with some supplementary information given in graph 20.

[46] A high technology industry is defined as one with an above average R&D intensity (i.e. a high share of its output is devoted to R&D activities). Whether an industry is R&D intensive or not is highly technology specific and hence very similar across the EU and the US. Nevertheless it is interesting to note the relative differences across the two regions, which also applies over time, and which reflects the particular national specialisations. For example, while the 6 most knowledge intensive industries in the EU and the US are the same, the relative ranking differs. For the EU the ranking is 1.Telecom, 2.Aircraft and Spacecraft, 3.Office Machinery, 4.Chemicals, 5.Motor Vehicles and 6.Instruments. For the US, in relative terms Office Machinery is the most R&D intensive sector, following by 2.Aircraft and Spacecraft, 3.Instruments, 4.Telecom, 5 Motor Vehicles and 6.Chemicals.

Table 8 : Splitting High-Technology Manufacturing R&D spending into ICT and non-ICT

	EU Actual Expenditure (Current PPP$ Millions)		US Actual Expenditure (Current PPP$ Millions)		Gap in R&D Spending EU-US*	
	1991-95	1996-99	1991-95	1996-99	1991-95	1996-99
Total Economy	76077	91308	122052	163524	0.623	0.558
Total Manufacturing	66612	78048	95413	122718	0.698	0.636
Total High Technology Manufacturing	58398	68425	85148	110210	0.686	0.621
(ICT)	(19765)	(21670)	(35782)	(52721)	(0.552)	(0.411)
(Non- ICT)	(38633)	(46755)	(49366)	(57489)	(0.783)	(0.813)

* This gap is calculated by dividing the EU figure with that of the US
Source : On the basis of OECD (Anberd Databank)

Table 8a : Shares of Some Specific R&D Intensive Manufacturing Industries in total R&D Spending of the Manufacturing Sector (Period Average 1996-1999)

	% Share of total Manufacturing R&D	% Share of total Manufacturing R&D
	EU-15	**US**
1. Chemicals	23.8	16.4
2. Mechanical engineering	9.3	5.0
3. Office machinery	3.2	11.2
4. Electrical Machinery	4.1	3.5
5. Semiconductors / Communications	14.6	16.0
6. Instruments	5.8	12.3
7. Motor vehicles	17.6	13.0
8. Aircraft and spacecraft	9.1	12.5
Total High-Technology Industries	**87.5**	**89.9**
Total Manufacturing	100	100

Source : On the basis of OECD (Anberd Databank)

Table 8b : Shares of Some Member States in total EU-15 R&D Spending of the Manufacturing Sector (Period Averages 1992-1995 and 1996-1999)

	% SHARE OF TOTAL EU-MANUFACTURING R&D	% SHARE OF TOTAL EU-MANUFACTURING R&D
	1992-1995	1996-1999
TOTAL EU-15	100%	100%
EURO AREA-BIG 4	74%	66%
(FRANCE)	(22%)	(20%)
(GERMANY)	(37%)	(36%)
(ITALY)	(8%)	(7%)
(SPAIN)	(7%)	(3%)
U.K.	16%	16%
FINLAND	1%	2%
SWEDEN	5%	6%
NETHERLANDS	4%	4%

Source : On the basis of OECD (Anberd Databank)

Table 8c : Shares of R&D Intensive Manufacturing Industries in total R&D Spending of the Manufacturing Sector for the US and some EU-15 Member States (Period Average 1992-1995 and 1996-1999)

	% SHARE OF TOTAL MANUFACTURING R&D IN HIGH-TECH		% SHARE OF TOTAL MANUFACTURING R&D IN NON-ICT HIGH-TECH		% SHARE OF TOTAL MANUFACTURING R&D IN ICT	
	1992-1995	1996-1999	1992-1995	1996-1999	1992-1995	1996-1999
US	89%	90%	52%	47%	37%	43%
TOTAL EU-15	88%	88%	58%	60%	30%	28%
EURO AREA -BIG 4	91%	88%	61%	62%	30%	27%
(FRANCE)	(93%)	(86%)	(61%)	(56%)	(32%)	(30%)
(GERMANY)	(91%)	(91%)	(62%)	(67%)	(29%)	(24%)
(ITALY)	(89%)	(90%)	(54%)	(56%)	(35%)	(34%)
(SPAIN)	(79%)	(74%)	(52%)	(50%)	(27%)	(24%)
U.K.	89%	89%	66%	68%	23%	21%
FINLAND	72%	82%	30%	22%	42%	60%
SWEDEN	89%	90%	53%	55%	36%	35%
NETHERLANDS	83%	84%	45%	43%	37%	41%

Source : On the basis of OECD (Anberd Databank)

The key points from Tables 8/8a-c and Graph 20 are as follows :

- Firstly, in terms of absolute expenditures, the US retains a sizeable advantage over the EU in terms of overall R&D spending. Furthermore, this gap has increased over the nineties. This gap is somewhat smaller when looking at manufacturing R&D only, since the US is concentrating a higher proportion of its R&D spending on the services sector compared with the EU. Nevertheless, even in manufacturing a serious and expanding gap in R&D spending remains. This gap is particularly high in the ICT sector and is growing over time. In the non-ICT high-tech sectors, the gap is smaller and closing, but there is still a gap.

- Secondly, the EU's R&D expenditures are not focussed on the best industries from a high productivity growth rate perspective. The ideal combination would appear to be industries, such as ICT, which combine both high technology (i.e. above average R&D intensities) and high productivity growth rate characteristics[47]. While one cannot exclude the possibility that there have been other similar "dual" technologies in the past, it is fairly safe to conclude, in terms of the size of the overall growth rate effect, that the ICT manufacturing industry is remarkable and possibly unique. From this perspective, it is disturbing to note from Table 8 and 8a that the US totally dominates the EU in terms of its research efforts in this area, particularly in office equipment, and that this dominance has continued to grow over time. Compared to the US, the EU's R&D expenditures in manufacturing are more concentrated on chemicals and motor vehicles, which are not particularly high-growth areas within the overall high-tech sector.

- Thirdly, given that the productivity enhancing characteristics of ICT were already known in the first half of the 1990's, what is particularly significant from table 8 is the fact that the US's dominance in ICT manufacturing was not seriously challenged over the second half of the 1990's. In fact the US increased its advantage significantly over this period[48], with the EU gap in R&D spending increasing from \$16 billion in the first half of the nineties to \$31 billion in the second half. Over this period, the EU instead extended its specialisation in the relatively low productivity growth, non-ICT, manufacturing industries which contributed only 1/20th of the productivity gains achieved by the US from ICT. This is an important point to bear in mind in the context of the Lisbon strategy's objective of an increase in the EU's R&D intensity from 2% to 3% over the coming years. On the basis of the above analysis, if this target had been set in

[47] This distinction is important for understanding the significance of ICT. For example, the most R&D intensive industry is aerospace (40% of its output is spent on R&D), with ICT in second place (25% of its output is devoted to knowledge production). Since all R&D intensive industries tend to have high levels of labour productivity (linked to the high skill levels of the research personnel employed in these industries), what distinguishes the ICT producing industries is that they are also high productivity growth rate industries, due to the TFP-enhancing effects of Moore's law which is largely exogenous to the labour input. Consequently while specific ICT producing industries may be less knowledge intensive than aerospace, they nevertheless have a much higher productivity growth rate due to this TFP effect. In fact ICT is one of the few large industries in history to combine these two features of having both a very high productivity level (due to its R&D intensity) and a high productivity growth rate.

[48] The US's absolute increase in its ICT R&D investments was roughly nine times greater than the equivalent increase for the EU.

1990 for attainment in 2000, without any specific sectoral focus, and if the EU continued to invest heavily in the more traditional high technology industries such as cars and chemicals (which it actually did do), it would have gained relatively little in terms of closing the productivity gap with the US. A sizeable productivity effect from the additional expenditure would have necessitated a shift in focus to the newer, high technology, industries such as ICT.

- Fourthly, Graph 20 confirms the broad trends from tables 8/8a, indicating on the basis of the R&D expenditures of the top 300 international firms in each individual sector that while the EU may be dominant in low productivity growth, high technology, industries such as cars and chemicals, the US is dominant in the high productivity / high technology areas of IT hardware and electronics. This US dominance is already worryingly been extended to software and computer services. Graph 20 further allows one to single out pharmaceuticals and biotechnology from the rest of the chemicals sector. It is again a source of concern to see in the pharma/biotech part that the US is leading in terms of R&D expenditures. Within the chemicals sector, an area of traditional strength for the EU, pharma/biotech is arguably the key productivity growth component for the future.

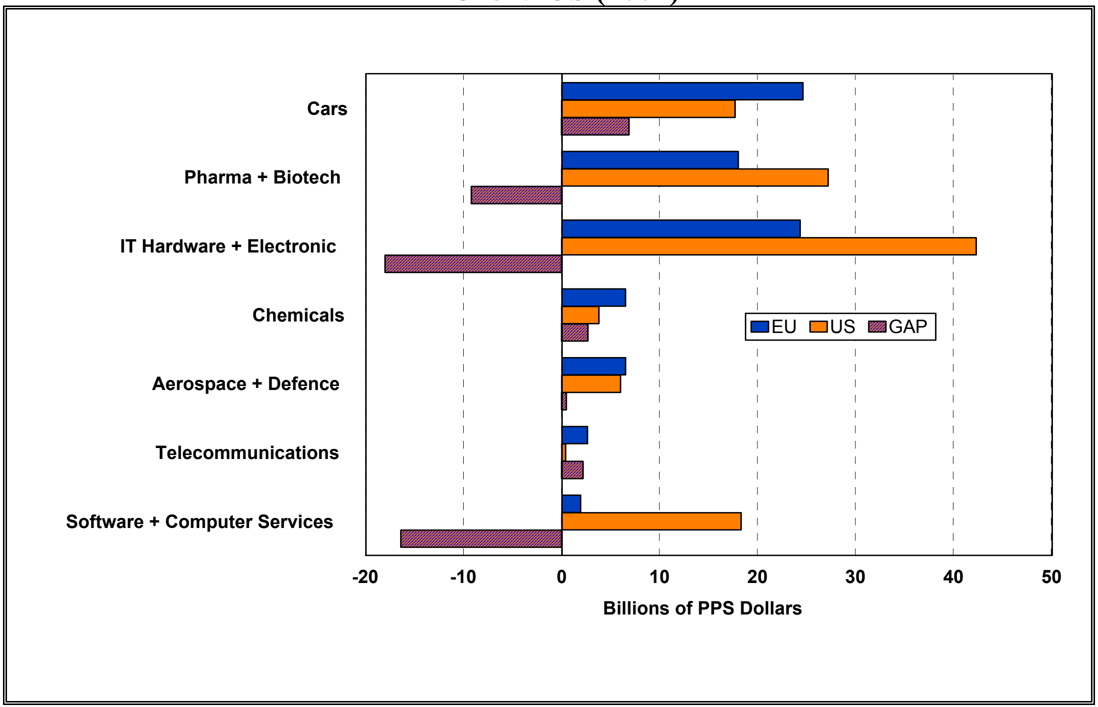
- Finally, as tables 8b-c show, the picture for the EU-15 is strongly determined by the big countries: France, Italy, Germany, and the UK. For these countries, the share of total manufacturing R&D in the high growth ICT sectors is much smaller than in the US and decreasing over time. France and Italy have a share in ICT, which is above the EU average, but still considerably below the US share. All these countries show a stronger concentration of their manufacturing R&D in the non-ICT high-tech sectors. For Germany, this concentration is in the motor vehicles sector (with 27% of total manufacturing R&D in the second half of the 1990s versus only 13% in the US). For the UK, this concentration is in the pharmaceuticals sector, which is one of the other high growth opportunity sectors in the high-tech area (27% of total manufacturing R&D in the second half of the 1990s versus only 9.5% in the US). The comparison over time shows little change, even strengthening the specialisation away from ICT in the big countries. Amongst the smaller Member States, the Netherlands and especially Finland have shares of high-growth ICT sectors which are above the EU-average share and which are close to, or even above, that of the US[49]. Both of these countries have increased their specialization in R&D spending over time into the high-growth ICT sectors. Unfortunately the share of these smaller countries in the total R&D expenditures of the EU as a whole is too small to influence the average EU pattern.

Assessment : The most significant issue posed by the above analysis is not so much the differences in the amounts of resources devoted to the knowledge production sector, but the EU's systemic failure (especially in the larger Member States) to refocus its R&D activities over the 1990's, firstly on <u>established</u> high productivity growth industries such as ICT; and secondly on <u>potentially</u> high productivity growth industries in the pharma/biotech area and perhaps also in a number of service

[49] Ireland, which is not reported because of its very small share of total EU manufacturing R&D (0.7%), also has a high concentration in ICT (>50%).

industries (software and computer related services). A host of factors could be explaining the superior US performance e.g. closer links between the main actors in the US innovation system; better framework conditions; healthier "creative destruction" and market experimentation processes in the US which have proved vital to the development of a range of new, high tech, industries in the ICT producing and ICT using areas. While all of these factors are potentially playing a role, it is unfortunately not possible to assess the contribution of the US's superior innovation capacity to differences in EU-US productivity trends at the total economy level. However, a tentative assessment can be made for the manufacturing sector on the basis of the earlier analysis of R&D spending in this sector. Since this analysis underlined the dominance of the US's innovation model, it constitutes a prime candidate for explaining EU-US differences in the productivity growth performances of their respective manufacturing industries. This is what is attempted in 4.2.2.

Graph 20 : R&D Expenditures by the Top 300 international firms by Industry : EU15 V US (2002)



Source : DG Research

4.2.2. : Can the Superiority of the US's Innovation Infrastructure Explain EU-US Productivity Growth Differentials in the Manufacturing Sector : To what extent can differences in EU-US productivity growth rates be linked to differences in the innovation capacities of both areas. Beyond the higher expenditures on manufacturing R&D, particularly in the high productivity growth ICT industries, various links can be made at the industry level which can contribute towards explaining the productivity gap through R&D expenditures. In this context, two key issues are :

- Firstly, has the US economy specialized more in specific high technology industries which are also the high-productivity growth areas – in other words are the EU-US productivity growth differentials linked to industry specialisation in high-tech industries ?

- Secondly, within each industry, beyond the effect of differences in spending levels, is the US getting a higher rate of productivity growth from its R&D spending i.e. a better leverage out of its R&D into productivity growth which can roughly be equated with a higher rate of return on its R&D expenditures.

While our analysis of these two issues, and of their role in explaining the link between R&D spending and EU-US productivity growth differentials, is still in its infancy, a number of interesting conclusions are already emerging :

- Firstly, as shown earlier in section 3, there are large EU-US differences in terms of specialisation (i.e. differences in the size of specific industries as a share of total output)**.** Within the overall high technology sector, it is clear from Table 9a that the US is especially concentrated/specialized in ICT manufacturing, with nearly 15% of total US manufacturing output coming from these ICT industries compared with only 6% for the EU. In the non-ICT area, there are no differences between the EU and the US, with the high technology industries representing around 34% of the overall manufacturing output of both areas.

Table 9a : Percentage Shares of High Technology Industries in the total output of the Manufacturing Sector (Current Prices)

	EU		US		Specialisation Gap Indicator *	
	1991-1995	1996-2000	1991-1995	1996-2000	EU-US (1991-95)	EU-US (1996-00)
TOTAL HIGH TECHNOLOGY MANUFACTURING SECTOR	39.3	40.3	47.6	48.8	0.825	0.826
(ICT)	(6.2)	(6.3)	(13.8)	(14.9)	(0.448)	(0.419)
(NON-ICT)	(33.1)	(34.0)	(33.8)	(33.8)	(0.979)	(1.005)

*Calculated by dividing the EU figure by the US figure for the respective periods, with a value of less than 1 indicating that the US is relatively more specialised in a particular sector or industry, with a value in excess of 1 showing the same for the EU. A value of around 1 suggests broad balance.
Source : Own calculations

- Secondly, since amongst the high technology industries as a whole, it is ICT which has been shown to have the highest opportunity for productivity growth, it is not surprising to find in Table 9b that the US's specialization in these industries, and their realization of a high productivity performance, is a key factor in explaining overall EU-US productivity growth differences. In fact the ICT industry totally explains the better performance of the US's manufacturing sector over the 1990's compared with that of the EU's and it contributes nearly four times more to the US's, economy-wide, productivity growth rate compared with the equivalent sector in the EU. Not only is the productivity gap substantial, there is no evidence of significant catching-up after 1995[50].

[50] Regarding the non-ICT, high-technology, sector the picture looks different, with the EU getting a higher contribution to productivity growth from these industries as compared to the US, especially in the second part of the 1990's. Unfortunately, these industries represent much smaller opportunities for productivity growth as compared to the ICT sectors.

Table 9b : Contribution to growth in productivity from High Technology Manufacturing Industries (% Points)*

	EU		US		EU-US Gap in Productivity Growth Rates*	
	1991-1995	1996-2000	1991-1995	1996-2000	EU-US (1991-95)	EU-US (1996-00)
TOTAL HIGH TECHNOLOGY MANUFACTURING SECTOR	0.399	0.352	0.830	0.849	0.48	0.41
ICT	0.137	0.219	0.603	0.802	0.23	0.27
NON-ICT	0.262	0.132	0.227	0.047	1.15	2.81

*Calculated by dividing the EU figure by the US figure for the respective periods, with a value of less than 1 indicating that the US is relatively more specialised in a particular sector or industry, with a value in excess of 1 showing the same for the EU. A value of around 1 suggests broad balance.
Source : Own calculations

- Thirdly, Table 9c presents evidence of EU-US differences regarding "rates of return" from R&D investments**.** For specific high-tech manufacturing industries, the gap in productivity growth is considerably higher than the gap in R&D spending, implying a lower rate of return from R&D spending in high-tech industries in the EU compared with the US. This is entirely due to the ICT high-technology industries[51].

Table 9c : Comparison of EU-US Differences in R&D Rates of Return

	EU-US Gap in R&D Spending		EU-US Gap in Productivity Growth Rates	
	1991-1995	1996-2000	1991-1995	1996-2000
TOTAL HIGH TECHNOLOGY MANUFACTURING SECTOR*	0.68	0.62	0.48	0.41
(ICT)	0.55	0.41	0.23	0.27
(NON-ICT)	0.78	0.81	1.15	2.81

Source : Own calculations

Overall Assessment of the EU's Innovation Infrastructure in the High Technology Manufacturing Sector : Taking all the caveats in mind of the basic analysis presented, the evidence for the manufacturing sector supports the importance of differences in the innovation system in explaining diverging EU-US productivity growth rates. Within high-technology industries, the specific role of ICT cannot be ignored. ICT producing industries have the highest productivity growth rates in all of manufacturing (in fact in the total economy). The US is more specialized in these ICT industries as compared to other high-tech sectors; it has a higher productivity growth in these sectors; spends more in total on R&D; and gets a higher rate of return out of its R&D investments. For the non-ICT high-tech industries, the picture is less devastating for the EU, particularly in the second part of the nineties. There is no difference in specialization in these industries, nor a productivity disadvantage. The

[51] The reverse appears to hold for the non-ICT sectors.

gap in total expenditures on R&D is also minimal. Unfortunately, however, these industries have far less scope for productivity growth than ICT.

4.3. Reforming the EU's Innovation Capacity : Action is needed in terms of resources, framework conditions and linkages **:** In terms of policy prescriptions, what do the results in 4.2 suggest for the innovation capacity of the EU relative to the US. While differences in the amount of resources committed are large, it is abundantly clear that in addition to much larger investments in R&D both by the public and the private sector (i.e. the basic innovation infrastructure), there are also other characteristics of the US innovation system which explain its ability to focus on the high productivity growth areas and to gain a higher rate of return from its knowledge investments. It is these latter features which determine its superior overall innovation capacity and which need to be taken into account in assessing the relative effectiveness of both systems. These features relate, as mentioned earlier, to the US's established capacity to link its common innovation infrastructure to technology specific know-how and the generally more favourable environment for innovation in the US compared to the EU. Gordon (2004) identifies a better connectedness of science and industry with an openly competitive system of private and public universities and government subsidies to universities through peer-reviewed research grants, which result in a higher quality of the research base. Other important framework conditions present in the US are the advantage of a large, unified market unencumbered by differences in language, customs and standards; a clearer and stronger US Intellectual Property Rights system; more flexible financial markets, making available venture capital finance to innovating firms; and more flexible labour markets, affecting both internal migration and the international immigration of highly skilled people.

The importance of the above features to an effective innovation process may help in explaining a number of specific worrying trends which have emerged in the EU over the 1990's which are suggestive of the need for a radical overhaul of its knowledge creation system. These include the failure, as stressed earlier, to re-orientate its R&D activities towards the new, high technology, ICT industries; the increasing proportion of R&D by EU firms which is being done outside the EU (over 40%); the large and growing brain drain from the EU to the US on the research side (at present, twice as many EU researchers move to work in the US compared with the opposite inward flows and, in stock terms, DG Research estimates that roughly 40% of US R&D is carried out by EU-trained scientists); and finally the US's rapidly expanding share of internationally mobile R&D expenditures (table 10). This latter point is an important new risk factor given the evidence[52] that such flows are increasing rapidly and that the relative quality of third level education systems is a key locational determinant for such mobile R&D flows. In overall terms, without EU reforms to its innovation system, the present haemorrhaging of R&D spending and of research talent will continue and with it a large proportion of the EU's future productivity potential.

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[52] Mobile R&D expenditures have been growing globally since the mid 1990's at between 10-15 percent on an annual average basis.

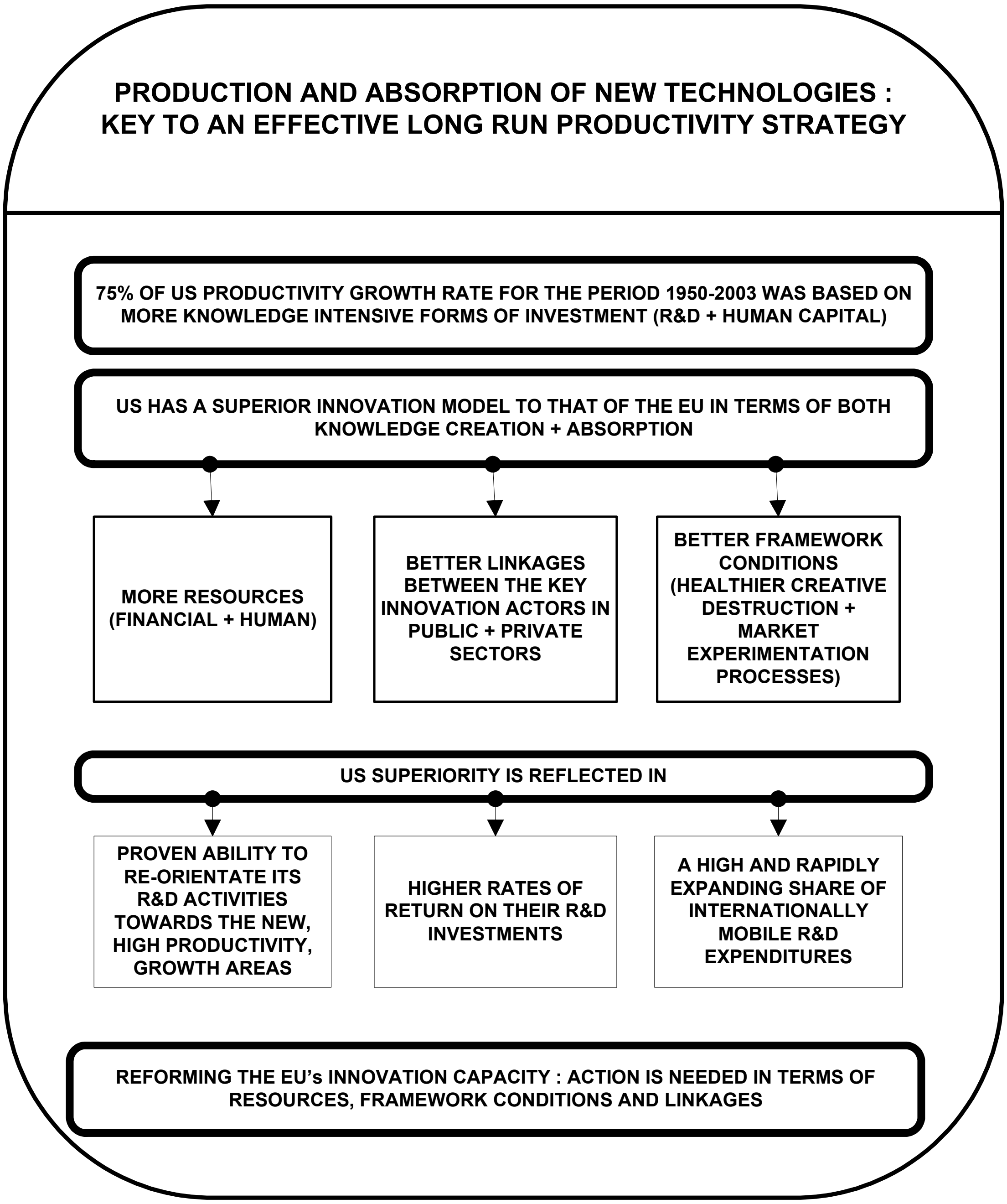
Table 10 : Shares of Mobile World Research Expenditures

	1987	1995	1997	1999
FRANCE	**4**	**6**	**5**	**4**
GERMANY	**10**	**10**	**8**	**7**
UK	**7**	**5**	**4**	**4**
JAPAN	**32**	**34**	**27**	**21**
US	**47**	**45**	**56**	**64**
TOTAL	**100**	**100**	**100**	**100**
GROWTH RATES IN GLOBAL R&D EXPENDITURES				
		1987-1995	**1995-1997**	**1997-1999**
COMPOUND ANNUAL GROWTH RATE		**2%**	**16%**	**12%**

Source : Conference Board, OECD Science and Technology Database.

Given the above worrying EU trends; the fact that the US's comparative advantage in this area of knowledge production appears to be becoming more entrenched; and that the new knowledge industries are increasingly driving economy-wide productivity trends, the calls for reform at the EU level are becoming more urgent. What can policy makers do to address the EU's innovation weaknesses ? The most important point to stress is that R&D spending is only one of the key elements of a country's knowledge production system – the present analysis has underlined that it is the overall package of elements which matters. Reforms are particularly needed in terms of entry and exit rules (to allow, for example, new innovative firms to come through the system and challenge the incumbents) and in the overall business environment (to improve the "rates of return" of any additional R&D investments which may be linked to the Lisbon 3% target). This will require getting the framework conditions right; improving the overall interconnectedness of the innovation system; and ensuring that the common innovation inputs are better aligned on specific technology clusters, where the EU's production structure displays a specialisation. Such a technology-specific policy however requires more detailed analysis of the data at the sectoral level, even at the technology and firm levels. Furthermore, since innovation systems are typically "national", or even "regional", data at these levels of aggregation should also be brought into the analysis.

Finally, regarding the specific example of the ICT industry, while the current analysis has shown the substantial differences between the EU and the US in terms of the overall volume of R&D expenditures on ICT, Box 2 also raises more fundamental issues regarding the mix of features in the US's innovation system which have conspired to create an industry which has grown in a comparatively short period of time to represent 15% of the overall manufacturing output of the US. The failure of the EU's knowledge production sector to seriously challenge the US's dominance in ICT over the second half of the 1990's, despite all the evidence in the late 1980's suggesting that this was a potentially key driver of productivity growth, is a striking example of the EU's extremely slow pace of structural change. This absence of any serious industrial restructuring shows the extent of the challenge facing EU policy makers in realizing their Lisbon-imposed, knowledge economy, targets. While bridging the EU-US gap in terms of the basic innovation "infrastructure" (i.e. spending levels on R&D and third level education) is specifically targeted by policy makers, the more difficult task will be to create the innovation "capacity" necessary to compete globally in the new high tech industries of the future. A globally competitive innovation capacity will require action on issues such as the EU's market signalling process, its product market reforms and its overall framework conditions which, without change, will seriously restrict the EU's ambitions to become the most knowledge intensive economy in the world.



BOX 2 : HISTORY OF ICT

The invention of the point contact transistor at AT&T's Bell Laboratories in the US in 1947 marked the beginning of a new technology, semiconductors, which has paved the way for the information age. An important feature of this technology is the speed with which microprocessors become more powerful, leading to a widening in the number of ICT applications. Semiconductors were initially used for hearing aids and in mainframe computers. In the 1950s computers largely replaced mechanical calculators. They were seen as being good in performing complicated and lengthy sets of arithmetical operations. The first leading edge applications were military. The Korean War won IBM the first contract to deliver a computer. In the late 1950s and early 1960s computers began to be used for simple calculations in civilian government agencies (e.g. the Census Bureau) and by the human resource departments of large corporations. The next generation of computers was used for storing and releasing data in real time. This was important for airline reservation processing, insurance companies and for inventory control. The computer surpassed the stage where it was only used as a calculator and became an organizing device. In a further step, the invention of the spreadsheet computerized white collar work in the 1980s. But the domain of computer usage has been widening further. Robots in manufacturing and scanner based retailing are transforming production and distribution processes. The internet, which connects computers all over the world, further transforms the way business is conducted.

In terms of pure numbers, nominal spending on ICT in the US rose from about 1% of GDP in the 1960s to about 2% in 1980. The share increased further to 3% in 1990 and has reached about 5% to 6% of GDP in the year 2000. Given the other distinguishing feature of this technology, namely the rapid speed of technical progress in the production of semiconductors, this sector now shows up in the aggregate productivity statistics of those countries which have managed to have a sizeable ICT production sector.

The semiconductor and computer industry has been a US dominated industry since the end of the second World War and the US has not given away the lead to other countries though they have faced severe challenges, especially from Japan. The ICT industry has some special features which poses specific challenges for government-industry interactions. The most important characteristics are :

- The semiconductor/computer industry is the high tech industry par excellence. It undertakes large amounts of knowledge investments, with R&D shares exceeding hugely the average shares of most other manufacturing industries.
- The sunk cost nature of R&D requires careful thinking about competition and industrial policy regarding the best strategy of combining large R&D efforts with a competitive environment.
- The industry also relies on a stream of well educated scientists and engineers as well as on the basic research undertaken in national research labs and universities.
- Since ICT has become a general purpose technology (GPT), with the ability to influence the productivity growth rates of ICT-using industries[53], it is also therefore of strategic interest since the products sold by this industry shape process innovations in other manufacturing and service sectors.

How have the Americans achieved such a dominant position and why have other industrialized countries failed to catch up to the technology frontier ? What was the mix between knowledge investment, government support and market structure that created the success in the US and what were the reasons why Europe stayed behind. The history of ICT in the US, Japan and Europe (see table on next page) will at least provide some tentative answers to these questions. In the US, early computer technology had a distinctly military focus (Brock, 2003). Japan and Europe in contrast tried to reduce the substantial lead of US companies in commercial markets. However both regions pursued rather different strategies. Japanese technology policy was based on a system of cooperation and competition amongst diverse groups of firms. In Europe, all bets were usually placed on a single 'national champion', the beneficiary of a steady diet of financial subsidies and preferential procurement policies' (Flamm, 1987).

An important factor in the development of the ICT industry has been the level of knowledge investments. The size of R&D spending and government funding of IT shows marked differences between countries. In the early 1970s, total R&D spending in the US's computer industry was about 5 to 6 times larger than the combined efforts in Japan, France and the UK (Flamm, 1987). In the 1960s and early 1970s about 1/3 of all R&D spending in the US was publicly financed, while the French and UK share ranged between 10% to 15%. The Japanese share of public funding was in between. Thus in contrast to the popular view which saw the US as the least interventionist amongst the major industrial countries, it must be acknowledged that the US was strongly supporting industrial investment in technology directly in the formative years of the ICT industry.

53 ICT is an innovating technology, i.e. it facilitates productivity improvements in ICT-using industries.

	US	Japan	EU
R&D (Knowledge Investments)	It is undeniable that in the 1950s, when commercial applications of the new technology were hardly imaginable, that the US government was supporting all major computer technology projects. Military projects (such as Whirlwind and SAGE) filled assembly lines and helped to train electronic engineers. Purchases of the US government (not all was military, the Census Bureau also ordered computers) amounted to more than 50% of total sales in the 1950s. If one includes defence contractors, about 70% of the computer bill was paid directly or indirectly by the taxpayer. Due to the strong increase in the use of computers for administrative purposes in large corporations, the government's share fell rapidly in the 1960s. However, government purchases remained the largest single factor in sales of new, leading-edge, machines (about 40% until the mid 1980s). The US government's share of funding for computer related R&D was 75% in the 1950s, 50% in the mid 1960s, and 15% in the late 1970s. With the military build up in the 1980s the share increased again to more than 20%. The US spends vastly more on ICT research than any other country in the world and it started much earlier. In the 1950s, many of the American computers built were government financed machines later adapted to the commercial market. The Airforce's SAGE project alone accounted for billions of dollars in development funds compared to only the tens of millions spent by governments in other countries.	There were four major players in Japan : 1) Ministry of trade and industry (MITI) plus its technical arm, the Electrotechnical Laboratory (ETL); 2) Nippon Telephone and Telegraph (NTT); 3) Ministry of Education (national universities); 4) Industry. The division of labour between these four players and how it has changed over time can briefly be described as follows : **-1950s**: Research is carried out in 1) to 3). Industry adopted the designs which had been developed in the various laboratories. **-1960s**: Erection of trade barriers and the price for foreign admission was access to important technology. The first research cooperation amongst Japanese manufacturers (NEC, Hitachi, Fujitsu) was started and a period of joint government–industry cooperation during all phases of research and early development began. **-1970s**: Dual crisis: 1) IBM system 370 forces other US companies (which were cooperating with Japanese companies) to exit the market. 2) Commitment to open Japanese computer market. MITI prescriptions : 1) Increase research funding : + 60% in 1973. 2) Consolidate research amongst private firms and promote the survival of the largest and technologically fittest firms. **-1980s**: Steep increase in private R&D funding : Like in the US in the 1960s, with the large expansion in the commercial sales of Japanese computers, the role of private R&D increased (while public funding stayed at a constant nominal level).	The European countries responded to the increasing commercial success of US computer companies in the 1960s (mainly IBM) with the creation and support of national champions. Small firms were encouraged to merge in order to exploit scale economies in research and production. The national champions in the 1960s were ICL in the UK, CII in France and Siemens in Germany. Research subsidies started relatively late in the 1960s and were not very generous. Especially striking is the UK example. In 1950, the UK's computer technology matched or even surpassed that of the US. However, within a decade the lack of financial and technical resources led to a decline. The government tried to stop this decline by creating ICL via mergers of smaller producers. In the 1980s larger efforts were undertaken to coordinate research at a European level. The Esprit program amounted to about 1.5 Bio $ over a five year period starting in 1984 (50% was paid for by the European Community and the remainder was paid by participating firms). Numerous European firms were cooperating in what was labelled pre-competitive research. A similar program in telecom research was RACE.
Procurement Policies (Government Support)	In the 1950s purchases of computers by the US government and defence contractors amounted to about 70% of total sales. In the 1970s the government's share declined to only about 5%.	In the 1970s, nearly 100% of all the computer purchases of the government were Japanese.	Like in other countries, government procurement was used to provide markets for national champions. However the share of national producers never reached the same levels as in the US and Japan. This is likely to have been the result of dismal technical performance and not of policy.
Market Structure	Vigorous antitrust suits instituted during the 1950s played some role in the rapid diffusion of semiconductor and computer technology from Bell Telephone Laboratories and IBM. Entry and exit into the market played a big role in adapting technologies for commercial use. In the early 1970s, the top 5 companies were IBM, Texas Instruments, Motorola, Western Electric and Fairchild. None of them was a leader in the 1950s. Top ranked companies in the 1990s such as Microsoft and Intel were not around in the 1970s. However, the US government has also responded to foreign competition by allowing for more cooperation amongst US companies in R&D. In 1984 the Joint research and Development Act was passed by Congress, which encouraged firms to undertake cooperative research (this was likely to have been provoked by Japan's 5th Generation Computer Research Program in 1981). Furthermore, in response to a loss in the US's market share in the semiconductor industry (the Japanese market share exceeded that of the US for the first time in 1986), SEMATECH, a joint research effort of the semiconductor industry, was initiated and supported by the US government. The defence department contributed about 100 Mio $ per year, about 50% of the total budget (the project was expected to end in 1997). Reflecting concerns about the national security implications of dependence on foreign sources for the supply of semiconductors, its goal was mainly to improve US semiconductor production technology. That the US government regarded SEMATECH as a national project can also be seen by the total entry restrictions for the US affiliates of foreign companies. The US also emphasizes industry-university research centres. They have been initiated by the government but also by private companies (Flamm 1987).	Joint research (in order to avoid duplication and increase productivity) but competition in downstream applications and commercialization e.g. in the 1970s the three groups of Japanese computer producers (Fujitsu-Hitachi, Mitsubishi-Oki and NEC-Toshiba) shared development costs but remained in direct competition. MITI coordinated the research cooperation. The government also carefully controlled access to the Japanese market, with MITI attempting to induce US producers to transfer computer technology to Japanese manufacturers.	Because the national champions model was adopted early on, antitrust was not an important issue in the computer industry.

5. Summary of Key Findings and Policy Conclusions

This study has analysed productivity trends in the EU over recent years and assessed those trends in the context of the Lisbon target of making Europe the most competitive, knowledge based, economy in the world by 2010. It is a continuation of the work done for an earlier Economic Paper[54] which laid out the main aggregate / sectoral level productivity trends in the EU and the US as well as identifying the key productivity determinants which are relevant in an EU context (i.e. the level of regulation; the structure of financial markets; product market integration; ageing; and the policy focus of the present paper namely the knowledge sector).

Summary of Key Findings

1. Structural Nature of the EU's Productivity Downturn is Confirmed

- The overriding conclusion from the analysis in this paper is that the former EU15 group of countries have a structural productivity problem, with this problem mainly located in the four large Euro Area member states which presently account for close to 80% of the Euro Area's overall output (2/3 of EU15). Unless policies are set in place which lead to a restructuring of the EU's economy towards more knowledge intensive, high productivity growth, industries the present EU-US productivity growth differentials will persist.

- This interpretation of recent productivity trends differs from that of respected commentators such as Olivier Blanchard and the IMF which suggest that the present productivity downturn is temporary, linked to the substantial labour market reforms enacted in many of the EU's Member States throughout the 1990's. In our view these reforms can only explain a small proportion of the deterioration in EU productivity since 1995, with the bulk of the decline due to the EU's outdated and inflexible industrial structure which has proved slow to adapt to the intensifying pressures of globalisation and rapid technological change.

- The EU's productivity problems reflect the combined effect of an excessive focus on low and medium-technology industries (with declining productivity growth rates and a globalisation-induced contraction in investment levels); an inability to seriously challenge the US's dominance in large areas of the ICT industry, as reflected in the relatively small size of its ICT production industry; and finally, its apparent slowness in reaping the productivity enhancing benefits of ICT in a range of ICT-using industries, although measurement issues severely complicate an assessment of the gains from ICT production and diffusion[55].

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[54] No.208, op.cit.

[55] The paper stresses the need for a critical assessment of the respective roles of ICT production and ICT diffusion in explaining EU-US productivity growth differentials. It suggests that, due to measurement issues, a higher proportion of the post-1995 acceleration in US productivity should be linked with the production of ICT than is commonly assumed. In terms of diffusion, it stresses that ICT capital deepening (diffusion in the narrow sense) is contributing strongly to US productivity growth but that the evidence for large TFP gains in specific ICT-using industries (diffusion in the

- The paper also points to the worrying evidence that the US is extending its dominance in ICT production to a range of new, high technology, areas in pharmaceuticals, biotechnology and computer-related services.

- An ongoing and excessive focus on low productivity growth industries is particularly problematic for the EU going forward, given that ageing populations, globalisation pressures and the ongoing shift to the relatively less productive services sector (possibly accelerated and reinforced by the emerging demographic trends) will all be working to dampen EU productivity growth rates over the medium to long run.

2. The Post-1995 Differences in EU-US Productivity Patterns are fundamentally driven by the US's superiority in terms of its capacity to produce and absorb new technologies, most notably in the case of ICT

- The contrasting productivity experiences of the EU and the US over the post 1995 period have their origin in the knowledge production sectors of the EU and US economies and in a complex range of institutional factors and framework conditions which determine a country's overall innovation system and ultimately its success in producing and absorbing the latest, leading edge, technologies.

- The paper argues strongly that healthy knowledge production and absorption processes are mutually supportive elements of any successful long run productivity strategy.

- Evidence is presented which suggests that the US's overall innovation system is superior to that of the EU's, both in terms of the quality and funding of its knowledge generating sector and the more favourable framework conditions prevailing. This system has facilitated a substantial re-structuring of the US economy since the early 1990's towards a range of knowledge intensive, high productivity, growth industries which have compensated for the relatively poor productivity performance of its more traditional industries.

- The inadequacies of the EU's overall innovation system have, in contrast, been cruelly exposed over the same period. Despite the growing evidence of the importance of high productivity growth industries such as ICT, the EU continued to focus its R&D investments throughout the 1990's on relatively low productivity growth areas such as cars and chemicals.

- The repeated ability of the US innovation system to direct resources towards the newer, high technology (and often high productivity growth), industries is a reflection of the quality of the interrelationships between the different actors in its innovation system and of an economic and regulatory framework which

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broader sense), such as wholesale and retail trade, was still questionable. These latter gains are perhaps more modest when proper account is taken of measurement issues and of the role of a number of important non-ICT productivity drivers in these specific industries.

has the capacity to transform US excellence in the knowledge creation part of its innovation system into a globally competitive industrial structure.

- These strengths of the US system need to be replicated here in Europe if the Lisbon-imposed target of increasing R&D expenditure to 3% of GDP is to generate the hoped-for economic benefits. As the EU's experience of the 1990's demonstrates, a policy of continuing to focus R&D spending on traditional industries or of spreading it uniformly across all industries will do little to bridge the EU-US productivity gap when the real issue is one of specialising in the new high technology / high productivity growth industries of the future.

- Given the importance of knowledge spillovers at the international level, policies aimed at absorption / convergence will continue to play a vitally important role for Europe over the coming years and decades. In addition, the present analysis argues in favour of a greater recognition of the knowledge creation part of the EU's overall policy framework and of the role it has played in the US's productivity revival over the 1990's.

- This heightened awareness of the importance of both knowledge absorption / production is already reflected in the Lisbon 2010 objectives and is justified given the evidence of the extent to which specific, knowledge-intensive, industries such as ICT have the potential to transform productivity patterns. As with most of the big productivity success stories over the last 10-15 years, the ICT industry is part of a generalised trend towards more knowledge intensive forms of investment, with for example individual segments of the ICT sector, such as semiconductors, already spending as much on R&D as on physical investments.

- Given globalisation patterns and in particular the increasing international mobility of capital and highly skilled researchers, the conclusion is clear, if Europe wishes to avoid a globalisation induced "race to the bottom" in low to medium-tech industries, it must increasingly focus on knowledge creation / absorption and on reforming its innovation system[56]. This means not only devoting an increasing share of its resources to education and R&D but more

[56] This view is also shared by the Sapir report (2003) which suggests that the EU economic system's failure to deliver a satisfactory growth performance is due to outdated economic institutions (which were supportive of growth in the past but have now become an obstacle to growth) and the failure of the EU to transform its industrial structure to achieve an innovation-based economy. The report concludes that the European model is not sustainable. High growth in the post-WWII era was driven by industrial production, economies of scale and imitation of the US technological advances. As the EU approached the technological frontier, growth became increasingly dependent on innovation. Economies based on innovation are for Sapir the key to higher employment and growth. The necessary new organisational forms, less vertically-integrated firms, greater mobility and flexibility in the labour market, larger reliance on market finance, and the high demand for both R&D and higher education – all necessary conditions to shift from imitative economies to innovative economies – have not yet occurred on a large scale in Europe. The report stresses that innovation will stem from entrepreneurial activities but that these activities can only develop if we focus on higher and better education, higher levels of better targeted R&D, better regulation to facilitate entry and exit of firms, instead of focussing on competition between existing players, more adequate infrastructure to facilitate free movement of people, goods and ideas, increased financial means and instruments (i.e. tax incentives) to finance innovation, and more labour market flexibility, notably through a lower tax burden on labour.

importantly managing this paradigm shift in an effective manner via reforms aimed at a fundamental overhaul of its knowledge production / absorption system. The objective is to create the framework conditions necessary to convert a reformed EU knowledge creation / innovation system into a globally competitive industrial structure[57].

3. The systemic inadequacies of the EU's innovation system are highlighted by the experience of the ICT industry, with the history of this industry suggesting that a "national champions" strategy in high technology industries is highly problematic

- The systemic nature of the EU's productivity problems is highlighted by an analysis of the ICT industry, where a wide range of factors are shown to have contributed to the US's global dominance.

- In terms of explaining EU-US productivity growth rate differentials, our analysis suggests that part of the answer lies in industry specialisation, with the US continuing to reap enormous gains from its dominance of the global ICT industry[58].

- If this thesis is correct then Europe should clearly be looking at those factors which have allowed the ICT industry to flourish in the US. These factors include focussed R&D activities; world class research and teaching establishments; defence procurement contracts which nurtured the ICT industry (on the demand side) in its incubation phase in the 1950's and 1960's; and the unique combination of financing mechanisms (venture capitalists / deep and diversified equity markets) and a highly competitive domestic marketplace which brought the ICT industry from the knowledge creation phase to the critical diffusion / mass market phase.

- The history of the ICT industry also suggests that a "national champions" strategy in high technology industries is doomed to failure, with a number of interesting questions emerging from the analysis as to the type of optimal competition policy which should be pursued for high technology industries.

- The paper highlights in particular the large price which Europe has paid for its "national champions" policy in the ICT industry back in the 1960's and 1970's, which contrasted sharply with the strategies adopted by Japan and the US. In addition, if one looks to the future, and given the changes which have occurred over recent decades, it is safe to conclude that the case for such a

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[57] In this context, an acceptance by policy makers that the structure of an economy largely shapes the share of national resources devoted to R&D, inevitably means an acceptance by them of the need to restructure EU industry towards more knowledge intensive industries. While this may be true, the crucial point to be focussed on in the context of Lisbon is that such a restructuring process will to a large extent occur naturally over time as long as policy makers are successful in ensuring an integrated innovation infrastructure combined with the framework conditions / flanking policies highlighted in the text.

[58] This dominance has if anything become more entrenched over the second half of the 1990's.

"national champions" policy is becoming more and more tenuous as the new industries of the future will increasingly need to draw on an EU, or even a global, knowledge/talent pool.

4. Without Reform, the US's Dominance in ICT will be repeated in other Knowledge Intensive Industries

- Given the strategic importance of ICT as a general purpose technology, the failure of the EU to mount a serious challenge to the US's ongoing dominance of this industry over the 1990's epitomises the inadequacies of its innovation system. More recent developments suggest that the EU has yet to learn the basic lessons from its problems in the ICT area, with the US already opening up a sizeable R&D advantage in emerging specialities in the pharmaceuticals and biotechnology areas and also in important service industries such as software and computer related services.

- While EU policy makers may recognise the importance of dynamic knowledge production and absorption processes in redressing these imbalances, their concrete actions to date have been less than encouraging. Implementation of reforms aimed at a fundamental overhaul of the EU's innovation infrastructure, allied to action on the associated "framework" conditions will be the litmus test of whether the Lisbon targets are to be taken seriously or not.

- More specifically, without an acceptance of the need for excellence in education and research, more appropriate market conditions aimed at delivering a more dynamic and competitive business environment, and the ambition to be world leaders in specific high-tech industries, a Lisbon-induced shift of resources into knowledge production activities will have little impact on bridging the present EU-US productivity gap.

Policy Conclusions

In terms of policy, the paper stresses that the EU's innovation system needs to be fundamentally reformed if the EU is to make a decisive shift towards realising the vision of a successful, innovation-based, economic model, the broad features of which have been laid out in the Lisbon 2010 agenda. Lisbon is in effect a recognition of the importance of such a model to the EU's long run economic prospects and of the key role which it must play in responding to the challenges of globalisation and ageing. Creating a successful knowledge-based economy involves both enhancing the EU's capacity to produce and commercialize a flow of world class innovative technologies and creating an environment conducive to the imitation and absorption of externally available know-how. The success of such a model will be determined not so much by a massive increase in the amount of financial resources devoted to knowledge production (i.e. increased spending on R&D and higher education) but by an acceptance of the need to improve linkages in the innovation system and to make painful changes in many areas of the EU's economic and regulatory environment. More specifically the present study stresses the following :

- **1. The systemic nature of the innovation process needs to be recognised and the quality of the interrelationships between the different actors in the system needs to be dramatically improved :** Firstly, policy makers need to recognise that the different players in the innovation system, public research institutes; third level education establishments; SME's and large firms are not isolated players but are part of a complex system, with its overall strength driven by the relative efficiency of its different components and their interconnectedness. While a large number of specific problems can be highlighted in relation to the specific players, the most serious issue is the poor quality of the linkages within the overall system. In addressing this issue of linkages and of the wider problem of an underperforming EU research sector, some politically sensitive areas will need to be examined at the national and EU levels i.e. the principle of an excellence / meritocratic based system for awarding research funds; greater university autonomy, in financial as well as academic terms; a change of culture towards the commercialisation of research via closer university / business sector links; and the need to develop and nurture centres of excellence and leading edge technology clusters[59].

- **2. The public and private sectors each play important, mutually supportive, roles in determining a country's innovation capacity and each must assume its responsibilities :** Governments have crucial direct and indirect roles to play in the innovation process, directly in the form of financial support for human capital development and for the public innovation system and, more importantly, indirectly in terms of shaping the macroeconomic fundamentals (low and stable inflation; moderate tax burdens on labour and capital; trade openness) and providing adequate incentive structures (i.e. framework conditions / regulatory regimes) for the private sector to enhance productivity via well functioning product, labour and capital markets[60]. The private sector for its part is the ultimate source of productivity growth in an economy, with its overall performance determined by the success

[59] In this context, it is no accident that the top US regions in terms of knowledge production owe much of their success to the presence of world class educational establishments such as San Francisco's Stanford / Berkeley and Boston's Harvard / MIT. These latter universities have been the key driving forces which have propelled the San Francisco and Boston metropolitan areas respectively into the top two positions in most global knowledge competitiveness, benchmarking, exercises (see Annex 7).

[60] In terms of framework conditions, specific attention needs to be devoted to the interaction effects between R&D and regulation, especially in the area of entry and exit rules; public-private sector partnerships; entrepreneurship and the vibrancy of the SME sector. While public sector research subsidies will continue to have an important role to play in basic research, the main returns from such investments, in terms of commercial applications, will inevitably of course be realised in the private sector. Consequently, inappropriate restrictions on market entry; state interventions to protect specific companies; or a reluctance on behalf of governments to accept a high degree of company failures, in the initial experimental phases at least, are all policies which are likely to be prejudical to an efficient and successful innovation system. Finally, it should be noted that the "European Research Area" launched in 2000 and the "Investing in Research Action Plan (2003)" address some of the wider framework conditions which impact on private R&D investment, e.g. intellectual property rights; science and technology human resources; access to venture capital markets; product market regulations; "technological platforms"; with a view to both initiating a process of structural change towards high tech sectors, and supporting the internal specialization of traditional industries towards higher R&D intensity and higher quality products. These measures all aim at influencing the specialization of European industries towards high tech sectors and products.

of the public sector's policies in creating a competitive, dynamic, business environment and by its own ability to use its labour and capital resources to create an industrial structure capable of competing successfully in both the domestic and global marketplaces. In addition, public / private sector research links are becoming increasingly important in many countries. Due to growing competitive pressures over the 1990's, technological complexity and the high risk of failure attached to long run fundamental research, companies have increasingly restricted themselves to their core activities in market / process oriented research (i.e. the "D" part of R&D). This leaves such companies dependent on collaborative links with public research institutes and universities for access to long run basic research (i.e. the "R" part of R&D).

- **3. Industry-specific framework conditions need to be taken into account due to the complicated relationship between competition and innovation :** While competition is a crucial determinant of productivity growth, acting as a powerful incentive for firms to continuously enhance their underlying performance via process or product innovations (thereby differentiating themselves from their competitors), there is nevertheless a need to recognise the complicated non-linear relationship between innovation and competition. This relationship may in fact favour oligopolistic competition between a few large firms in some industries or stronger competition among many small players in others, as the optimal market structure for boosting the innovation process in the respective industries. Due to this non-linear relationship, it is incumbent on policy makers to take industry-specific circumstances into account when assessing the precise link between competition and productivity. Product market conditions (e.g. possibilities for product differentiation) and the characteristics of specific technologies (e.g. is it a radical or incremental innovation; are there network externalities; are there economies of scale in R&D) is what ultimately determines the industry specific relationship between market concentration (i.e. the degree of competition) and R&D intensity.

- **4. Market entry and exit rules are crucial to an effective innovation process in rapidly changing industries :** The example of the ICT industry highlights the need for policy makers to promote entrepreneurship and a healthy process of "creative destruction". Entry and exit rules play an important role in boosting productivity by putting pressure on incumbent firms to innovate and by supporting market experimentation. This experimentation role is particularly important in industries where the general purpose technologies being used are changing rapidly such as in the production and use of ICT. In these industries the evidence is clear that product market regulations that facilitate the easy entry and exit of firms have contributed enormously to the diffusion of innovations in these industries[61].

[61] According to the OECD's firm level analysis (2004), "strict regulations on entrepreneurial activity, as well as high costs of adjusting the workforce, negatively affect the entry of new firms. Thus in the US, low administrative costs of start-ups and not unduly strict regulations on labour adjustments are likely to stimulate potential entrepreneurs to start on a small scale, test the market and, if successful with their business plan, expand rapidly to reach the minimum efficient scale. In contrast, higher entry and adjustment costs in Europe may stimulate a pre-market selection of business plans with less market experimentation. In addition, the more market-based financial system may lead to a lower risk

Concluding Remarks

The present analysis has highlighted the need for the EU to shift the emphasis in its present economic model more towards innovation. This shift in our view is necessitated by the increasing competitive pressures of globalisation, by the future challenges of ageing populations and by the fact that many of the EU's member states are close to the technology frontier. Of these factors, the one of most immediate concern to productivity patterns is undoubtedly globalisation, with the growing interconnectedness of the world's economy already driving up the pace of technological progress, intensifying competitive pressures and magnifying the gains from excellence, with the gains being reaped by the US's global dominance in the ICT industry being a good example of the latter. While world trade volumes have been rising steadily since the 1950's, what has changed recently is the nature and scale of the globalisation phenomenon, with an increasing focus on trade in services and on capital movements in the form of FDI, with for example the stock of FDI as a % of world GDP tripling since the mid-1980's.

This dramatic intensification of the globalisation process is already transforming the economic structures of the developed and developing worlds, with India emerging as a global power in services, China consolidating its position in manufacturing and with the developed world as a whole searching for an appropriate response. Many countries in the developed world have recognised the seismic nature of the change and are responding positively by embracing an open-economy, innovation-based, model which emphasises the importance of world class educational establishments; higher levels of, excellence driven and better targeted, R&D; more market based financing systems; and more flexible regulatory and institutional frameworks delivering a more dynamic and competitive business environment. Others are responding in an inappropriate manner by attempting to cling to the belief that our present economic problems are temporary and that the magnitude of the changes wrought by globalisation will avoid the need for fundamental reforms. In this context, the collective challenge for EU governments is to embrace the reality of a rapidly changing global marketplace and of the structural changes which it inevitably provokes. While Lisbon is a manifestation of this collective desire for change, implementation of the needed reforms will be the litmus test of whether the future will bring a substantial improvement in the EU's productivity fortunes or will confirm the EU's ongoing decline as a global economic power.

aversion to project financing in the US, with greater financing possibilities for entrepreneurs with small or innovative projects, often characterised by limited cash flows and lack of collateral". In addition, while new firms in the US may start on a smaller scale and be less productive than equivalent start-ups here in the EU, if successful in testing the market, these US firms tend to grow more rapidly compared with EU start-ups. This experience suggests that the EU must focus not only on reducing the regulatory burden on start-up companies but also on the factors inhibiting growth in the post start-up phase.

10 KEY POINTS FROM STUDY

1. EU15 HAS A STRUCTURAL PRODUCTIVITY PROBLEM WHICH IS MAINLY LOCATED IN THE FOUR LARGE EURO AREA MEMBER STATES (GERMANY, FRANCE, ITALY AND SPAIN)

2. EU's PRODUCTIVITY PROBLEMS REFLECT THE COMBINED EFFECT OF AN EXCESSIVE FOCUS ON LOW AND MEDIUM TECHNOLOGY INDUSTRIES; AN INABILITY TO SERIOUSLY CHALLENGE THE US's DOMINANCE IN LARGE AREAS OF THE ICT INDUSTRY; AND AN APPARENT SLOWNESS IN REAPING THE PRODUCTIVITY ENHANCING BENEFITS OF ICT IN A RANGE OF ICT-USING INDUSTRIES

3. THE KEY UNDERLYING FACTORS DRIVING EU-US PRODUCTIVITY DIFFERENTIALS ARE A. THE LEVEL OF REGULATION; B. THE STRUCTURE OF FINANCIAL MARKETS; C. PRODUCT MARKET INTEGRATION; D. AGEING; and E.THE POLICY FOCUS OF THE PRESENT PAPER, THE KNOWLEDGE SECTOR

4. KNOWLEDGE PRODUCTION AND ABSORPTION ARE MUTUALLY SUPPORTIVE ELEMENTS OF ANY SUCCESSFUL LONG RUN PRODUCTIVITY STRATEGY

5. US's INNOVATION SYSTEM IS SUPERIOR TO THAT OF THE EU's, BOTH IN TERMS OF THE QUALITY AND FUNDING OF ITS KNOWLEDGE SECTOR AND THE MORE FAVOURABLE FRAMEWORK CONDITIONS PREVAILING (i.e. an economic and regulatory framework which effectively promotes entrepreneurship and healthy creative destruction + market experimentation processes)

6. PAPER HIGHLIGHTS THE LARGE PRICE WHICH EUROPE HAS PAID FOR ITS "NATIONAL CHAMPIONS" POLICY IN THE ICT INDUSTRY BACK IN THE 1960's AND 1970's, WHICH CONTRASTED SHARPLY WITH THE STRATEGIES ADOPTED BY JAPAN AND THE US. A NUMBER OF KEY FACTORS ALLOWED THE ICT INDUSTRY TO FLOURISH IN THE US. THESE FACTORS INCLUDED FOCUSSED R&D ACTIVITIES; WORLD CLASS RESEARCH AND TEACHING ESTABLISHMENTS; DEFENSE PROCUREMENT CONTRACTS WHICH NURTURED THE INDUSTRY IN ITS INCUBATION PHASE IN THE 1950's AND 1960's; AND THE UNIQUE COMBINATION OF FINANCING MECHANISMS AND A HIGHLY COMPETITIVE DOMESTIC MARKETPLACE WHICH BROUGHT THE ICT INDUSTRY FROM THE KNOWLEDGE CREATION PHASE TO THE CRITICAL DIFFUSION / MASS MARKET PHASE

7. WITHOUT AN ACCEPTANCE OF THE NEED FOR EXCELLENCE IN EDUCATION AND RESEARCH; MORE APPROPRIATE MARKET CONDITIONS AIMED AT DELIVERING A MORE DYNAMIC AND COMPETITIVE BUSINESS ENVIRONMENT; AND THE AMBITION TO BE WORLD LEADERS IN SPECIFIC HIGH-TECH INDUSTRIES; A LISBON-INDUCED SHIFT OF RESOURCES INTO KNOWLEDGE PRODUCTION ACTIVITIES WILL HAVE LITTLE IMPACT ON BRIDGING THE PRESENT EU-US PRODUCTIVITY GAP

8. CREATING A SUCCESSFUL, KNOWLEDGE-BASED, ECONOMY INVOLVES BOTH ENHANCING THE EU's CAPACITY TO PRODUCE AND COMMERCIALIZE A FLOW OF WORLD CLASS INNOVATIVE TECHNOLOGIES AND CREATING AN ENVIRONMENT CONDUCIVE TO THE IMITATION AND ABSORPTION OF EXTERNALLY AVAILABLE KNOWHOW

9. THE SUCCESS OF SUCH A MODEL WILL BE DETERMINED NOT ONLY BY A LARGE INCREASE IN THE AMOUNT OF FINANCIAL RESOURCES DEVOTED TO KNOWLEDGE PRODUCTION BUT MORE IMPORTANTLY BY AN ACCEPTANCE OF THE NEED TO RADICALLY IMPROVE LINKAGES IN THE INNOVATION SYSTEM AND TO MAKE PAINFUL CHANGES IN MANY AREAS OF THE EU's ECONOMIC AND REGULATORY ENVIRONMENT

10. WHILE LISBON IS A MANIFESTATION OF A COLLECTIVE EU DESIRE FOR CHANGE, IMPLEMENTATION OF THE NEEDED REFORMS WILL BE THE LITMUS TEST OF WHETHER THE FUTURE WILL BRING A SUBSTANTIAL IMPROVEMENT IN THE EU's PRODUCTIVITY FORTUNES OR WILL CONFIRM THE EU'S ONGOING DECLINE AS A GLOBAL ECONOMIC POWER

LIST OF ANNEXES

1. SOURCES OF WEALTH DIFFERENTIALS BETWEEN THE EU AND THE US AND THE ONGOING CONTROVERSY OVER MEASUREMENT ISSUES

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ANNEX 1 : SOURCES OF WEALTH DIFFERENTIALS BETWEEN THE EU AND THE US AND THE ONGOING CONTROVERSY OVER MEASUREMENT ISSUES

1. Overview of Sources of Wealth Differentials

EU-US wealth differentials[62] can be explained, as indicated in Graph 1 of the main text, by differences in the use of labour (number of hours worked / employment levels) and by differences in productivity. In fact, in rough terms about 1/3 of the differentials are productivity related, with 2/3 due to labour utilisation. What is worrying regarding the productivity side is that since 1995 the EU's relative position vis-à-vis the US has deteriorated significantly, with EU productivity growth rates substantially lower than those of the US over this period. Regarding hours worked, the EU has experienced an important positive change over the course of the 1990's with the previously downward movement in total hours worked relative to the US coming to an end. Given the challenges posed by ageing populations, and the fact that the EU's relative labour input is substantially lower than that of other developed economies, it is accepted that much more action will be needed in terms of labour market reforms over the coming years. This analysis of wealth differentials manifestly underlines the need for a dual policy mandate focussed on improving both the EU's productivity and labour utilisation performances. The problem however for policy makers is that the debate has become confused over recent years, with different international organisations producing different estimates for the respective contributions to the EU's wealth differentials from productivity and employment. Section 2 goes on to look at these measurement issues and tries to draw pragmatic conclusions to guide policy makers given the uncertainties involved.

2. Ongoing Controversy over Measurement Issues

The IMF in its recently released Article IV report on Euro Area policies maintained that the Euro Area did not have a productivity problem since, according to their estimates, hourly productivity was higher than in the US and all of the differences in per capita incomes were due solely to the lower number of hours worked by Euro Area workers. The IMF estimates referred to the business sector in the Euro Area. While ECFIN, in principle, supports the use of the business sector as an indicator, this approach suffers from large data availability and timing problems. In the case of the IMF's productivity level estimates, for example, data is only available for 9 of the 12 Euro Area countries, with the data generally only appearing with a considerable time lag. In addition, the future provision of the required data inputs, most notably public sector employment figures, is not assured since the ESA95 transmission programme, as yet, does not envisage the provision of such data.

On the basis of Eurostat's structural indicators, a different picture to that of the IMF emerges, with Eurostat's productivity measure suggesting that 45% of the gap in living standards between the Euro Area and the US is due to lower labour productivity per hour, with the remaining 55% an hours worked issue. To complicate matters even more, the equivalent OECD estimates suggest a position which roughly

[62] Wealth differentials are measured by GDP per capita which is the most widely accepted indicator of living standards.

lies between that of Eurostat and the IMF, namely that the EU has a productivity problem but that it is not as severe as suggested by Eurostat. The OECD figures roughly coincide with those of ECFIN's own analysis presented below. This ongoing issue of conflicting measurements of the EU-US productivity gap (or the lack of it) is fundamental to the present policy debate and the relative emphasis to be placed on the employment or productivity aspects of the Lisbon strategy.

Overview of Current Situation and the Extent of the Problems : Graph 1 and Table 1 show the extent of the problems to be resolved on the basis of the Eurostat and OECD estimates (comparable IMF data is not available). While there are some differences in terms of GDP per capita and the per person employed productivity measures, it is very clear that the real source of the differences lies in the hours worked calculations and the associated hourly labour productivity figures.

Graph 1 : Comparison of GDP per capita, employment rates, hours worked per worker and labour productivity : Eurostat versus OECD

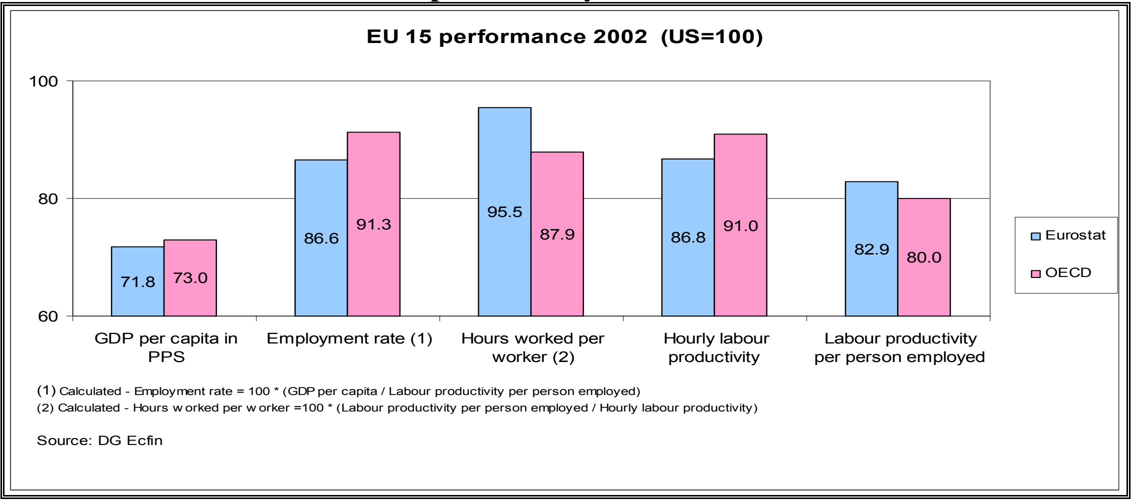


Table 1 : Year 2002 Estimates

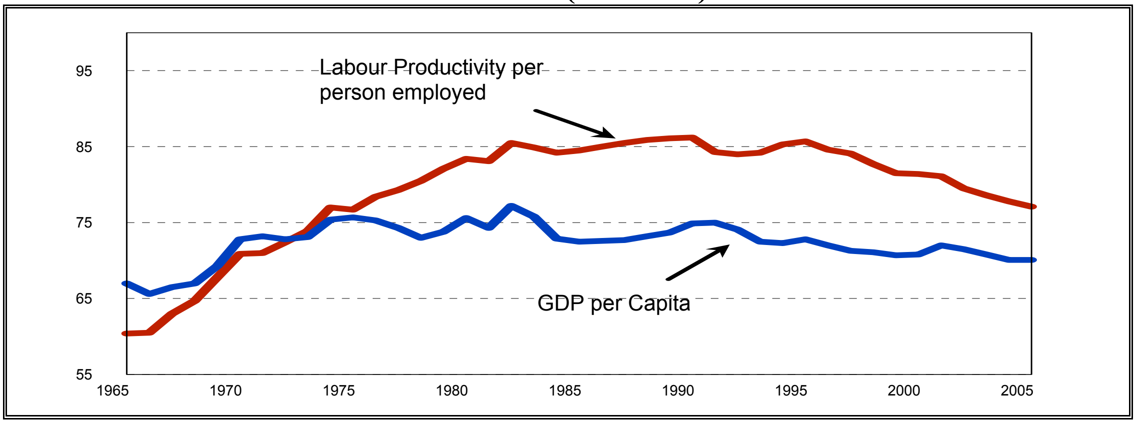
	EUROSTAT	OECD
GDP PER CAPITA IN PPS	71.8	73.0
EMPLOYMENT RATE	86.6	91.3
HOURS WORKED PER WORKER	95.5	87.9
HOURLY LABOUR PRODUCTIVITY	86.8	91.0
LABOUR PRODUCTIVITY – GDP IN PPS PER PERSON EMPLOYED	82.9	80.0

3. Short and Long Run Solutions

There seems to be only one long term durable solution to these ongoing productivity measurement problems and that is for all of the interested parties, most notably Eurostat, the OECD and the IMF, to discuss the different methodologies which they employ for calculating the various input series. This in fact is what is happening at the moment, with Eurostat and the OECD actively discussing these issues. It is hoped that a final long run resolution to these problems can be forthcoming in the coming months.

Regarding possible short run solutions, ECFIN decided that given the uncertainties involved, it was very important to have its own internally produced productivity series for analytical purposes. Following an assessment of the strengths and weaknesses of the various statistical sources, the most internally consistent source was deemed to be the OECD's labour force statistics databank, which has internationally comparable figures for hours worked and employment for both the EU's Member States as well as for the US (see Graphs 2 and 3)[63]. Once convergence has been reached in the discussions between Eurostat and the OECD regarding the best input series to be utilised, ECFIN will adjust its own methodology to make it fully consistent. According to the ECFIN staff who are participating as observers to the Eurostat / OECD discussions, it appears that the final solution will not differ dramatically from the estimates shown in Graphs 2 and 3[64]. In fact, in terms of productivity levels, the EU15 estimate is likely to lie between the present OECD and Eurostat estimates. If this is what turns out to be the basis of a final consensus, the IMF's viewpoint that the EU15 does not have a productivity problem (and consequently that it should focus its Lisbon agenda solely on the employment front) will not be supported by the underlying data. This IMF position, it should be stressed, only applies to productivity levels, with the IMF also accepting that there has been a significant deterioration in the EU's relative position over recent years due to much lower EU productivity growth rates compared with those of the US.

Graph 2 : EU15 – GDP per Capita + Labour Productivity per person employed - 1965-2005* (US = 100)



** 2003-2005 : Estimates based on ECFIN's Spring 2004 short-term forecasts and using an assumption of unchanged hours worked.*
Source : OECD, ECFIN calculations

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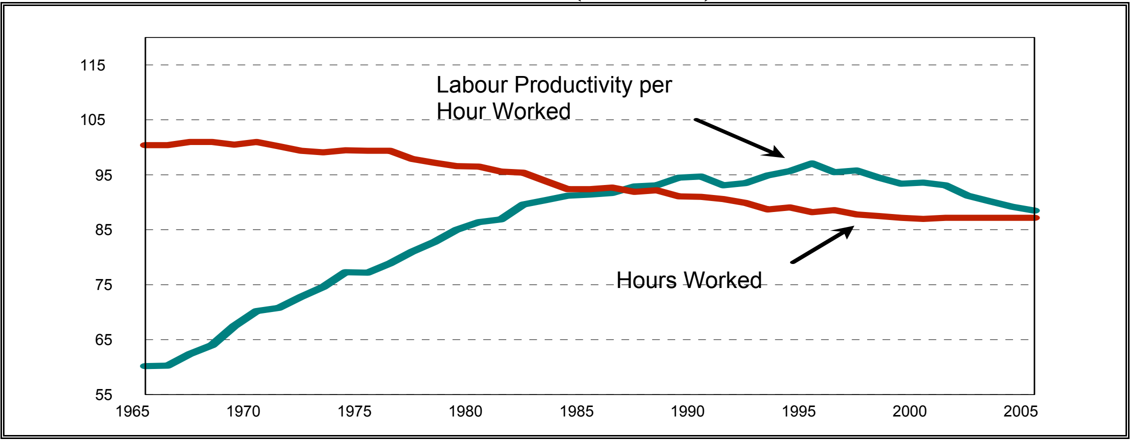
63 The hours worked and productivity calculations are based on the OECD's labour force statistics. These calculations mirror the OECD's own methodology for calculating productivity levels, with ECFIN deriving the productivity growth rates from the levels. One should note that the OECD use a combination of labour force and national accounts data sources for their productivity growth rate calculations.

64 It has been tentatively agreed that the OECD, for the purpose of productivity measurement, will move from the labour force framework to the national accounts. Eurostat will align their basic numbers for the US with those from the OECD, with the OECD in turn converging towards Eurostat's figures for the individual EU Member States.

Graph 3 : EU15 – Hours Worked + Labour Productivity per Hour -1965-2005* (US = 100)



** 2003-2005 : Estimates based on ECFIN's Spring 2004 short-term forecasts and using an assumption of unchanged hours worked.*

Source : OECD, ECFIN calculations

4. Concluding Remarks

While it is accepted that there is still an ongoing controversy regarding the relative levels of productivity between the EU and the US, the most important point to stress is that there is no dispute between Eurostat, the OECD and the IMF regarding the fact that the EU's labour productivity performance has deteriorated significantly in the post 1995 period relative to that of the US. Given this analysis, and the accepted need for action on the employment front, it is incumbent on policy makers to adopt a dual policy focus over the medium to long run. The experience of a number of the EU's Member States and the US suggests that there is no justification for an exclusive focus on either employment growth or on productivity growth, with GDP per capita depending on both. From a policy perspective, the key objective must be to raise productivity levels using all the available instruments to stimulate the growth of total factor productivity, whilst at the same time encouraging the labour-intensive growth pattern that is needed to move towards full employment.

ANNEX 2 : LITERATURE REVIEW ON INNOVATION, PRODUCTIVITY AND GROWTH

It is now widely recognized in the economic literature that R&D and innovation are major drivers of economic growth. An economy's ability to exploit novel technologies and to adapt to a rapidly changing technological environment is seen as essential to its prospects for improving standards of living and prosperity.

1. THEORIES OF ECONOMIC GROWTH : Macroeconomic theories of economic growth, both the neoclassical and the endogenous growth models, reflect the role of "technical progress" in economic development.

Neoclassical models emphasize the accumulation of physical and human capital which are subject to diminishing returns (Solow (1956), Swan (1956)). Hence capital accumulation drives productivity growth in the short-run but eventually capital is subject to diminishing returns. Consequently, long-run steady state growth can only be accounted for through exogenous technological change. Despite its vital importance to growth, technological progress is left unexplained. This does not mean that technology plays no role in this framework. On the contrary, in its steady state, technical progress is the only reason why there is growth. It is however treated as exogenous, i.e. left unexplained.

The continued appeal of the neoclassical growth model lies in the straightforward growth accounting methodology it delivers for measuring the rate of technological progress. Under the usual neoclassical assumptions (perfect competition, input exhaustion, absence of spillovers, Hicks-neutral technical progress) the rate of technical progress equals the Solow residual or "Total Factor Productivity" growth. Being constructed as a "residual" it represents a "measure of our ignorance" (Abramovitz (1956)). In Solow's pioneering study, growth in per-capita income was almost entirely attributed to technological progress. Subsequent refinements (see e.g. Stiroh (2001)), improving the measurement of inputs and expanding the definition of investment beyond tangible assets, have squeezed down the residual. Mankiw, Romer & Weil (1992) further extended the neo-classical growth model by augmenting the production function with human capital, proxied by education, improving the performance of the Solow model in cross-country studies.

Endogenous growth models generate long-term growth without relying on exogenous technical progress. A first approach taken by the so-called "AK" models is to remove the diminishing-returns-to-capital property of the neoclassical approach, by supposing that output is a linear function of capital. In this setting, productivity growth can continue without bound. Another route is taken by the "R&D-based" endogenous growth or "idea" models. A firm's production function is defined by firm-specific variables (capital, labour and R&D inputs) plus a shift term, which is a function of the general stock of knowledge available to all firms. This reflects the public good characteristics of knowledge generating activities such as R&D (Romer (1986)). Alternatively, it could also reflect a "learning by doing" process, where investment in physical capital is a source of spillovers as the aggregate capital stock increases. The shift factor is in this case determined by past gross investment (Arrow (1962)). Lucas (1998) considered the shift factor to be a function of the stock of human capital.

Endogenous growth models "endogenize" the generation of ideas. Ideas are generated by R&D performed by profit maximizing R&D firms and lead to new processes and products which are used as inputs in the production of final goods. As input goods of superior quality or as more specialized intermediate or capital goods, these "products" raised productivity (Romer (1990), Grossman & Helpman (1991) and Aghion & Howitt (1992)). The ideas generating process is characterized by the presence of very large fixed costs and zero marginal costs. Since with increasing returns to scale, average costs is always larger than marginal costs, producing new ideas at profit requires a move away from perfect competition in the research sector.

Ideas are at least partly public goods. New knowledge generated by the R&D activities of one agent can stimulate the development of new knowledge by others, thus giving rise to positive externalities or "knowledge" spillovers. However, spillovers are not "manna from heaven" and require investment in "absorptive capacities" to be successfully implemented (Cohen & Levinthal (1989)). Endogenous growth theory provides a suitable analytical framework to assess the economic impact of international knowledge flows. The seminal Grossman & Helpman (1991) model leads to the prediction that the international diffusion of knowledge, through international trade in intermediate goods, increases the growth rates of output and productivity. These models lead to the prediction that the growth of TFP in countries increases with the degree of openness and the absorptive capacities of the countries.

Both neoclassical and endogenous growth models are criticized for not being able to fully account for the complex relationship between R&D and economic growth. Only recently economic theory has tried to zero in on the micro processes through which R&D influences growth. Aghion and various co-authors[65] examine the microeconomic foundations of growth theory, developing models of the interplay between growth, industrial organization, and contracts and institutions. Their work provides a framework for analysing the effect of product market competition on the relationship between innovation and growth. While on the one hand, post-innovation competition may compete away the rents from innovation and hence stifle the incentives for firms to innovate, these models stress that at the same time, more pre-innovation competition may lead to more innovation as a way for firms to escape competition. Whether the "escape competition" effect dominates the "rent dissipation" effect will depend on how close the firms/industries/countries are to the technology frontier. Competition has a more positive effect on growth for those firms and industries that are closer to the frontier.

While macro-economic models of technological progress emphasize the importance of public and private investment in knowledge infrastructure by public and private agents, the literature on "***National Innovation Systems***" (Freeman 1987; Lundvall 1992; Nelson 1993) stresses the character and intensity of the interactions between the elements of the system. In this view, innovation and technological development depend increasingly on the ability to utilise new knowledge produced elsewhere and to combine this with knowledge already available in the economy. The capacity to absorb new knowledge, to transfer and diffuse knowledge, and the ability to learn by interaction are crucial success factors in innovation (e.g. Cohen and Levinthal 1989). New and commercially useful knowledge is not only the result of the conscious

[65] For example Acemoglu, Aghion & Zilibotti (2002) and Agion, Bloom, Blundell, Griffith & Howitt (2003)).

action of creative individuals but also of the interaction and learning processes among various actors in innovation systems, i.e. producers, users, suppliers, public authorities and scientific institutions, which David & Foray (1995) term the "knowledge distribution power" of the innovation system. These interactions incite the process through which knowledge spillovers will influence economic growth, as detailed in the endogenous growth theory literature.

From the National Innovation System perspective, country differences with respect to innovation and growth might reflect not just different endowments in terms of labour, capital and the stock of knowledge, but also the varying degrees of the "knowledge distribution power" or the efficiency of the innovation system. The problem with this approach, however, is to approximate empirically the institutional framework and the "knowledge distribution power" of nations. What is available at present are only pieces of evidence showing the importance of interactions, such as cooperative R&D agreements among firms, between firms and universities or the availability of venture-backed financing (see for example, Stern et al. (2000)). In addition, there are the first attempts to link economy-wide growth to policy and institutional variables (OECD (2004)).

2. EMPIRICAL EVIDENCE ON INNOVATION AND PRODUCTIVITY : The effects of innovation on productivity have been analysed in many empirical studies at different levels of aggregation (country, industry or firm level). Comparing these studies is difficult because of various levels of aggregation, definitions of productivity (TFP vs. labour productivity), definitions of innovation (R&D expenditures vs. patents vs. innovations) and various methodological approaches (case studies, growth accounting, econometric analysis of cost functions vs. production functions vs. productivity studies [66]). Furthermore these studies are plagued by many problems, such as the construction of the R&D capital stock, requiring growth and depreciation rate assumptions; the issue of double counting of the expenditures on labour and capital in R&D; the use of price deflators for measuring output; the measurement of the quality of traditional inputs; the measurement of spillovers.

Despite the various approaches and problems, the evidence clearly points at R&D and innovation as a main driver of productivity growth. Following the pioneering work of Griliches (1988), a large number of empirical studies at the country, firm and sectoral level have confirmed a positive impact of R&D activity on productivity growth (for a review of the literature see e.g. Mairesse & Sassenou 1991, Mohnen 2001, WIFO 2001, Mairesse & Mohnen 2002; OECD 2004).

We summarize the major findings below:

- In the long term there is a significant effect of R&D intensity on TFP growth for OECD *countries* (OECD, 2004, Bassanini et al 2001). In some countries, the average rate of return on R&D investment is more than twice the rate of return on investment in capital equipment.

[66] In the production and cost function approach, R&D capital is used, whereas productivity studies use R&D intensity. In the production function approach the estimated elasticities of R&D are constant across units, whereas in the productivity approach it is assumed that the rate of return to R&D is constant across units.

- Regressions including separate variables for public and private R&D suggest that it is the private R&D that drives the positive association between R&D intensity and output growth (Guellec and van Pottelsberghe 2001).

- A country's own R&D and human capital contributes positively to the speed of catching-up (Griffith et al 2000).

- Empirical studies attempting to assess the importance of knowledge spillovers have identified the international transfer of technology as an important driver of growth (e.g. Griliches 1992; Geroski 1996; Mohnen & Mairesse 1999) with foreign innovative activity having a major impact on domestic productivity, especially for smaller, open countries (Eaton and Kortum 1997). A major issue in this literature is the identification of the channels through which knowledge is transferred internationally. Most extensively studied has been the role of international trade, in particular imports (e.g. Coe and Helpman 1995). Recently studies have begun to examine the role of foreign direct investment by multinational firms (Lichtenberg and van Pottelsberghe de la Potterie 2001; Branstetter 2000).

- The results from *micro* level studies confirm a strong relationship between R&D and productivity growth, with the reported private rates of return, if significant, in a range of 7% to 69% and the elasticities in the range of .02 to .38 (WIFO 2001). Not correcting for double counting considerably biases the estimated coefficients downwards (Schankerman (1981), Mairesse & Hall (1996)).

- The social rates of return are even higher, as knowledge spillovers between firms can double the rate of private returns. Griliches (1992) concludes that "'spillovers are present, their magnitude may be quite large and social rates of return remain significantly above private rates". However, the results vary considerably between studies and industries. Furthermore, it is not clear whether intra- or inter-industry spillovers are more important. Branstetter (1996) and Cincera (1998) suggest that spillover effects are more national than international in scope.

- Whether returns to R&D vary across sectors and countries is hard to assess. Most studies indicate significant differences in the rates of return of specific sectors but there is little consensus as to which industries have higher rates of return. Comparing returns across countries also leave an inconclusive result, although US firms generally come out stronger than the EU.

ANNEX 3 : HOW DOES THE EU COMPARE AT THE GLOBAL LEVEL IN TERMS OF PRODUCTIVITY TRENDS

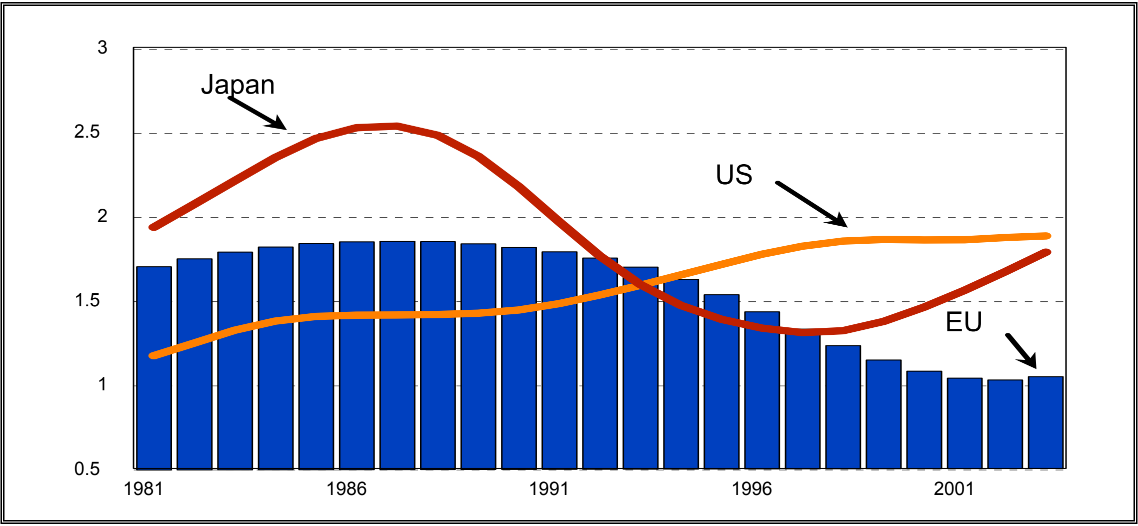
Table 1 gives the period averages for productivity growth rates for the 1980's, the first and second halves of the 1990's and 2001-2003. The HP filtered trend performance for the period 1981-2003 for a selected number of countries and regions is given in Graphs 1 to 6. Compared with the world aggregate, EU15 productivity growth rates have been consistently lower over the last two decades, with the world total being influenced to a considerable extent over that period by a large number of newly emerging global powers; most notably the strong convergence related performances from China and India[67]. Compared with the relatively more developed areas of the world, the EU was holding its own up until the mid 1990's but, as Graph 1 indicates, over the subsequent period to 2003 trends have deteriorated considerably, especially with regard to the US but more recently also with Japan.

TABLE 1 : LABOUR PRODUCTIVITY (PERIOD AVERAGES -PER PERSON EMPLOYED)

	1981-1990	1991-1995	1996-2000	2001-2003
WORLD	5.0	3.3	3.1	1.0
CHINA	10.1	13.0	8.0	7.3
INDIA	7.6	5.4	4.4	3.8
JAPAN	2.7	0.8	1.4	1.5
US	1.3	1.4	2.2	1.3
EU25	NA	**NA**	1.5	0.9
FURTHER BREAKDOWN OF EU25				
NEW MEMBER STATES (EU10)	NA	**NA**	3.6	3.8
EXISTING MEMBER STATES (EU15)	1.8	2.0	1.2	0.4
NON- EURO AREA	1.8	2.4	1.7	1.1
EURO AREA	1.8	1.8	1.0	0.3
FURTHER BREAKDOWN OF EURO AREA				
BIG FOUR	1.9	2.0	0.8	0.2
SMALL EIGHT	1.4	1.3	2.0	0.7

[67] It is important to put the high labour productivity growth rates for China and India into perspective – overall productivity levels in these countries are still less than 10% of those in the US whereas the EU is at around 90% of US levels.

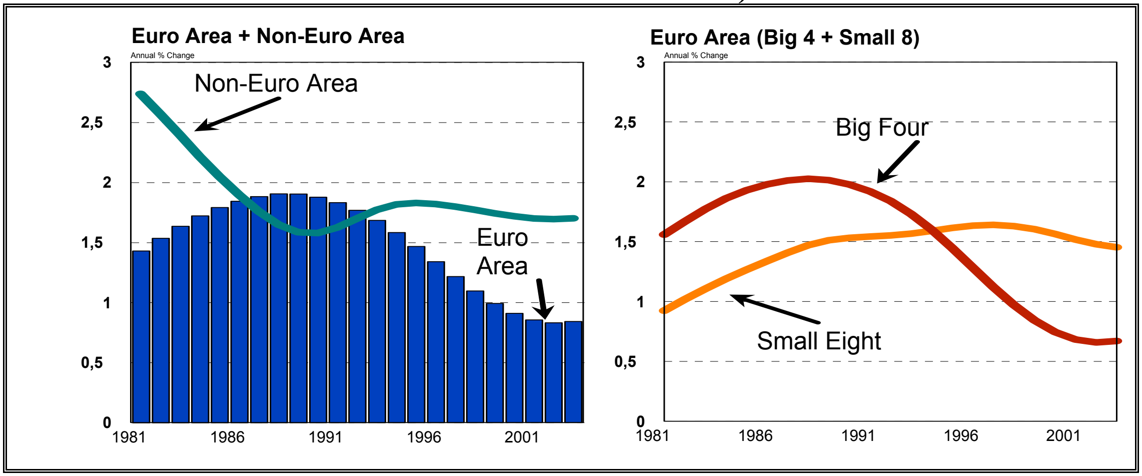
GRAPH 1 : EU15 LABOUR PRODUCTIVITY TRENDS VIS-À-VIS THE US AND JAPAN



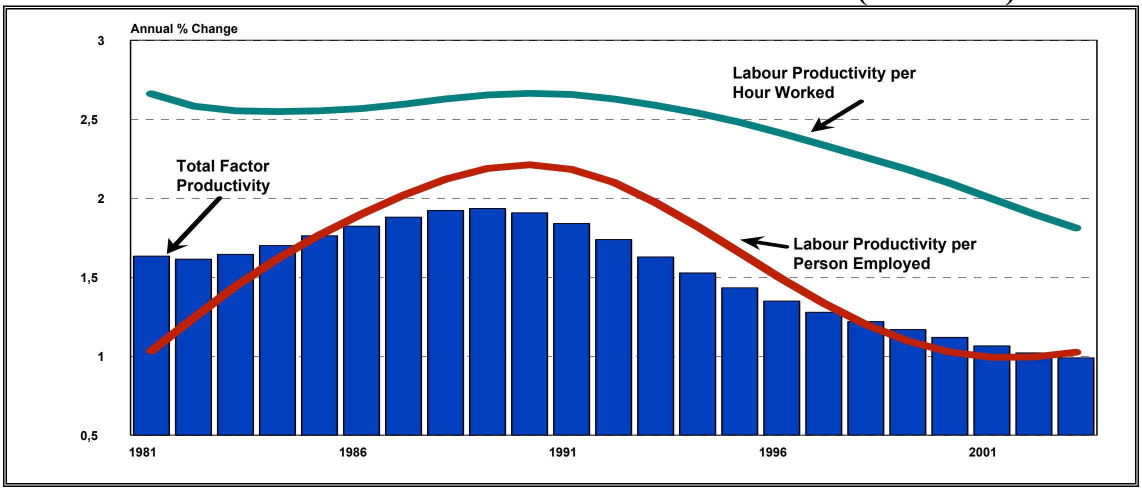
While overall EU productivity trends have clearly deteriorated over recent years, it is important to underline the wide range of performances at the individual EU Member State level, with large numbers of countries comparing favourably with international trends. For example, for the EU's 10 new Member States, the post-1995 pattern has been very positive in terms of productivity, with the group easily outperforming the world total over the period as a whole and most notably continuing to produce solid gains over the 2001-2003 period when most areas of the world were hit with a sizeable slowdown. However, as with India and China, a large part of the productivity growth in this part of the EU was undoubtedly a catching-up phenomenon, aided and fuelled by the prospect of full EU membership.

With regard to the performance of the existing Member States, there is also a clear divergence between the Euro Area and non-Euro Area countries. Graph 2 indicates clearly that the non-Euro Area countries have been able to arrest the decline in their 1980's productivity growth rate and stabilise it in the 1 ½ -2% range over the 1990's. Over the same period the Euro Area countries have experienced a decline in their productivity growth rate from close to 2% to well under 1%. Graph 2 also indicates that this Euro Area pattern is dictated by developments in the big four area countries, namely Germany, France, Italy and Spain (see also graphs 3-6). The remaining 8 Euro Area countries have managed to achieve an acceleration in their productivity growth rates between the first and second halves of the 1990's. The problem of course is that with the big four countries accounting for nearly 80% of overall Euro Area output, the poor performances from all four of these countries ensures that the EU as a whole has a clear productivity problem.

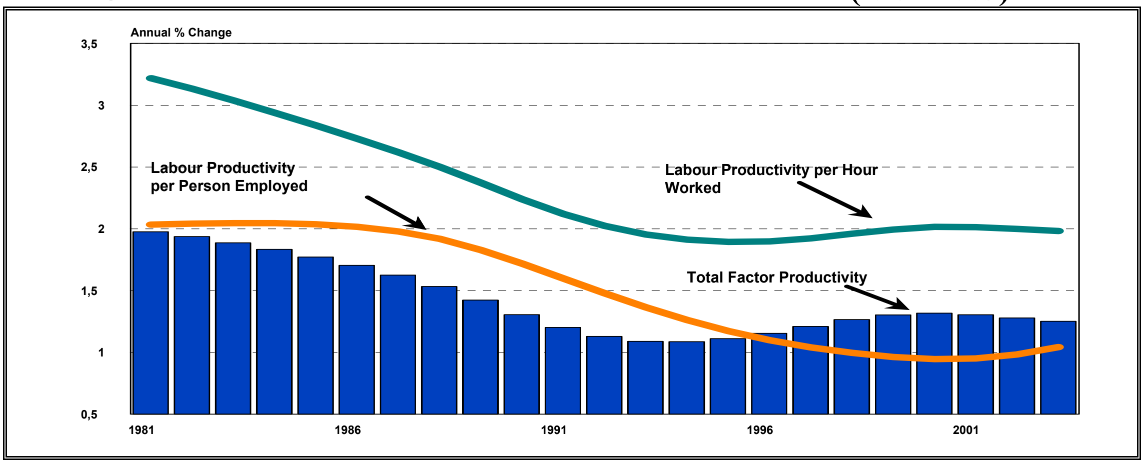
GRAPH 2 : EU15 LABOUR PRODUCTIVITY PER PERSON EMPLOYED TRENDS (EURO AREA AND NON-EURO AREA)



GRAPH 3 : GERMANY : TREND PRODUCTIVITY MEASURES (1981-2003)

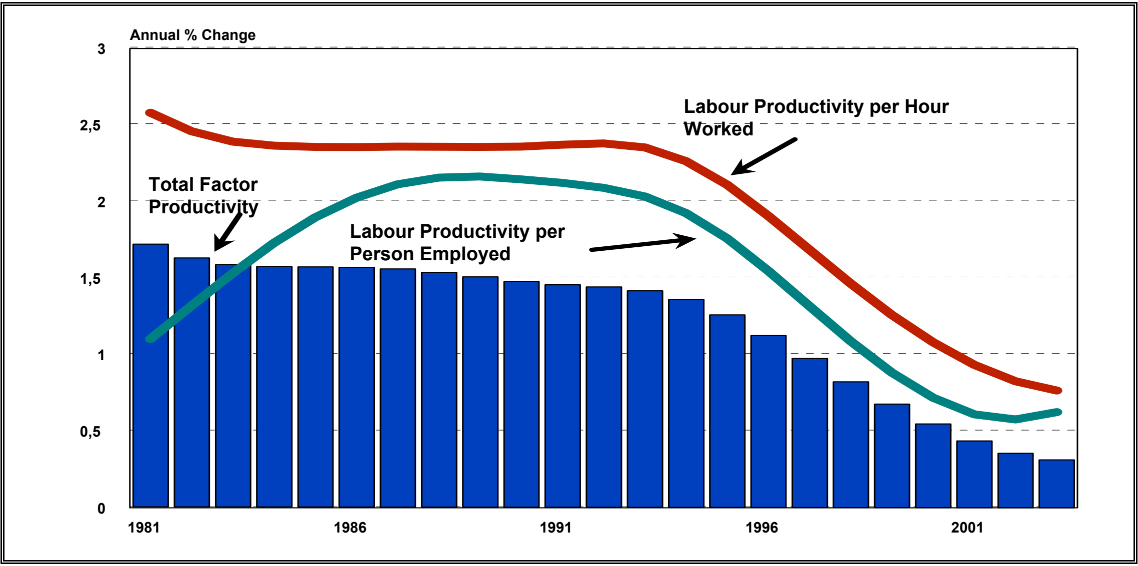


GRAPH 4 : FRANCE* : TREND PRODUCTIVITY MEASURES (1981-2003)

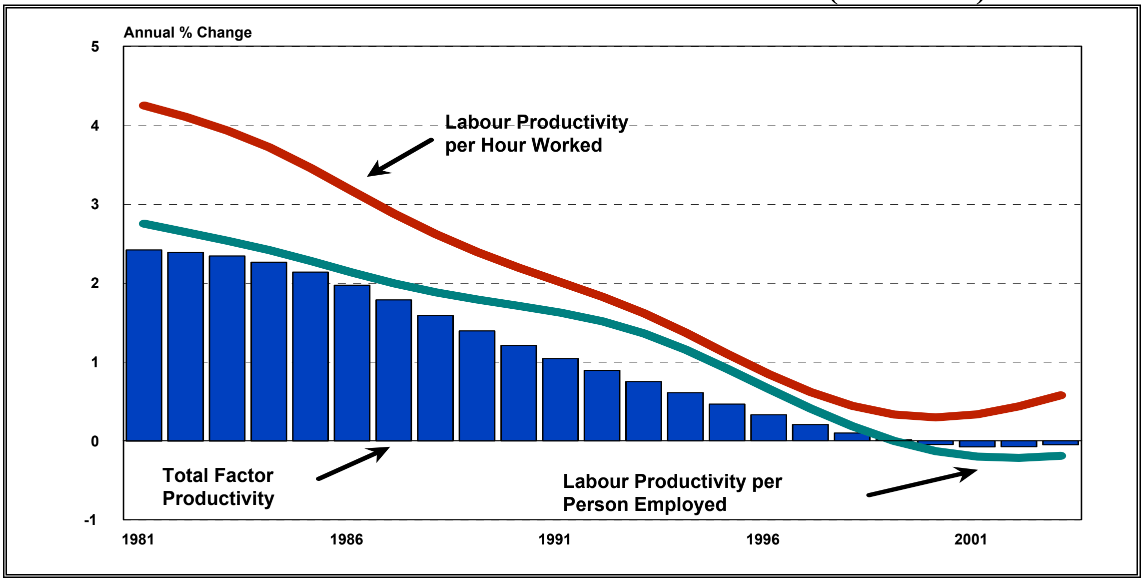


*While productivity trends in France had been declining significantly over the 1980's and the early part of the 1990's, the more recent trends appear to suggest a stabilisation. However, interpretation of these more recent trends is complicated by the introduction of a statutory 35-hour week via the "Aubry laws" of 1998 and 2000 which resulted in large changes in terms of working time. More time will be needed to fully assess the implications of these changes for long run productivity developments.

Graph 5 : Italy : Trend Productivity Measures (1981-2003)



Graph 6 : Spain : Trend Productivity Measures (1981-2003)



ANNEX 4 : THE EU'S SLOW GROWTH PROBLEM

Data Analysis : Table 1 below sets the background for the growing interest in productivity issues. The table shows period averages for 5 key variables (employment, productivity, GDP, population and GDP per capita) for the US, EU15, EU4 (the 4 large Euro Area countries – Germany, France, Italy and Spain) and for EU11 (the remaining 11 of the EU15 aggregate). Data problems precluded extending this analysis to the new Member States.

Table 1 : Employment, Productivity, GDP, Population and GDP per capita developments in Germany, France, Spain, Italy, US and EU aggregates

	Germany	France	Spain	Italy	EU4	EU11	EU15	US
1961-1980								
Employment	0,2	0,6	0	0,1	0,3	0,4	0,3	2,1
Productivity	***3,4***	***3,8***	***5,4***	***4,6***	***3,9***	***3,1***	***3,6***	***1,7***
GDP	3,6	4,4	5,4	4,7	4,2	3,4	3,9	3,7
Population	0,5	0,8	1,1	0,7	0,7	0,5	0,6	1,2
GDP per capita	3,1	3,6	4,3	4	3,5	2,9	3,3	2,5
1981-1990								
Employment	1	0,3	1,1	0,6	0,7	0,6	0,7	1,8
Productivity	***1,3***	***2,2***	***1,8***	***1,7***	***1,7***	***1,8***	***1,7***	***1,3***
GDP	2,3	2,5	2,9	2,3	2,4	2,4	2,4	3,1
Population	0,3	0,6	0,3	0,1	0,3	0,3	0,3	0,9
GDP per capita	2	1,9	2,6	2,2	2,1	2,1	2,1	2,2
1991-1995								
Employment	0	-0,1	-0,3	-0,6	-0,2	-0,6	-0,4	1,1
Productivity	***2***	***1,2***	***1,8***	***1,9***	***1,9***	***2,3***	***2,1***	***1,3***
GDP	2	1,1	1,5	1,3	1,6	1,6	1,6	2,5
Population	1,3	0,5	0,2	0,2	0,4	0,4	0,5	1
GDP per capita	0,7	0,6	1,3	1,1	1,2	1,2	1,1	1,5
1996-2000								
Employment	0,7	1,4	3	1	1,3	1,6	1,4	2
Productivity	***1,1***	***1,3***	***0,8***	***0,9***	***1,1***	***1,8***	***1,3***	***2***
GDP	1,8	2,7	3,8	1,9	2,3	3,5	2,7	4,1
Population	0,1	0,4	0,3	0,1	0,3	0,3	0,3	0,9
GDP per capita	1,7	2,3	3,5	1,8	2	3,2	2,4	3,2
2001-2005								
Employment	-0,1	0,7	2	1,2	0,7	0,5	0,6	0,1
Productivity	***0,9***	***0,9***	***0,7***	***-0,1***	***0,7***	***1,5***	***1***	***2,5***
GDP	0,8	1,6	2,7	1,1	1,3	2	1,5	2,6
Population	0,1	0,5	0,7	0,1	0,3	0,3	0,3	1,5
GDP per capita	0,7	1,1	2	1	1	1,6	1,2	1,1

While a large number of key points are highlighted by the table, we will concentrate on the productivity and GDP per capita (i.e. living standards) trends for the EU aggregates :

- For the periods 1961-1980, 1981-1990 and 1991-1995, the productivity and GDP per capita patterns were very similar for the EU aggregates shown in the Table. For the US, while per capita income growth did not diverge dramatically from that of the EU over these periods, there were big differences in the components, with the US pattern characterised by lower productivity and higher employment compared with the EU.

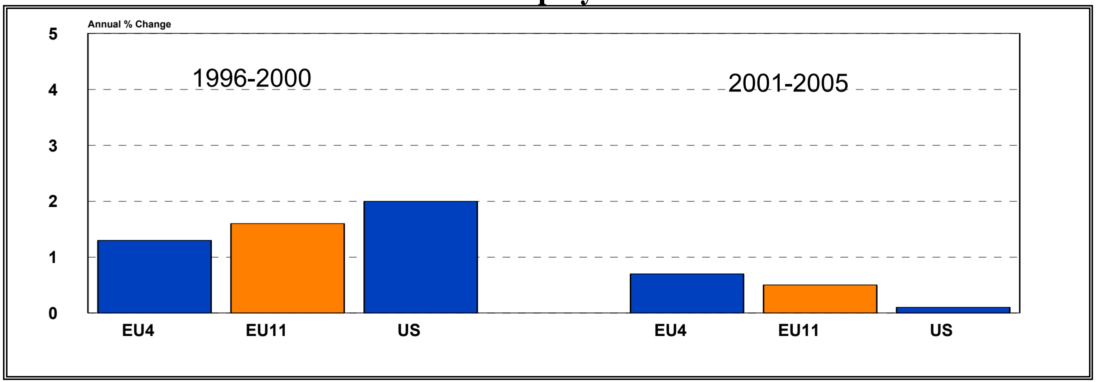
- The table indicates a large structural break after 1995, with the US pulling significantly ahead of the big four Euro Area economies but not relative to the rest of the EU15 countries.

- In terms of the source of differences in per capita growth rates, it is clear that the big divergence in the post 1995 period has been in terms of productivity growth trends, not employment trends. The graphs below reinforce the points made regarding the structural break from the mid-1990's onwards.

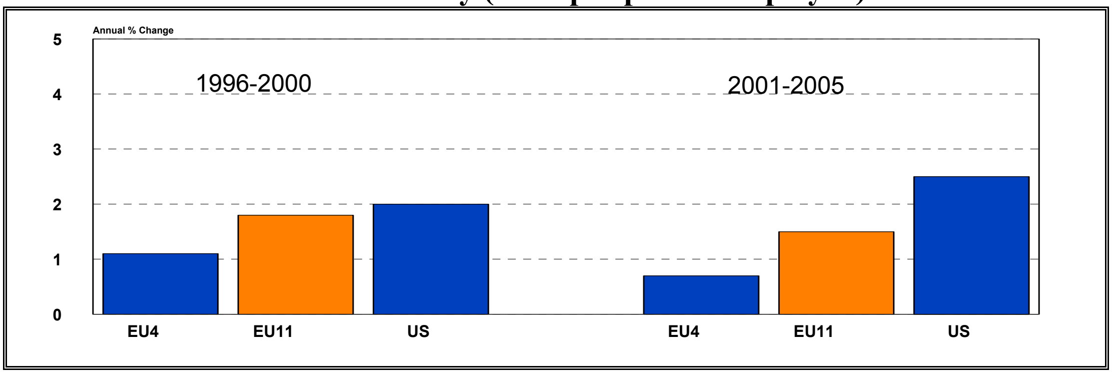
Graphical Analysis : The graphs concentrate on the post 1995 period and show that the US has consistently outperformed the EU4 group in GDP growth rate terms, with this growth advantage increasingly emanating from the productivity side. They show that the gap in performance is much less for the EU11 group on virtually all fronts. In fact, in terms of the growth rate of GDP per capita, the EU11 group has equalled or outperformed the US since the mid-1990's. In terms of productivity, which is the focus of the present paper, it is clear that it is the EU4 group of countries where the problems lie (this is also supported by the evidence presented in Annex 3). Since these 4 large Euro Area economies as a whole represent nearly 2/3 of overall EU15 output, this ensures that the EU as a whole compares badly in comparisons with the US.

Graph 1 : Comparison of EU4, EU11 and US performances over the periods 1996-2000 and 2001-2005

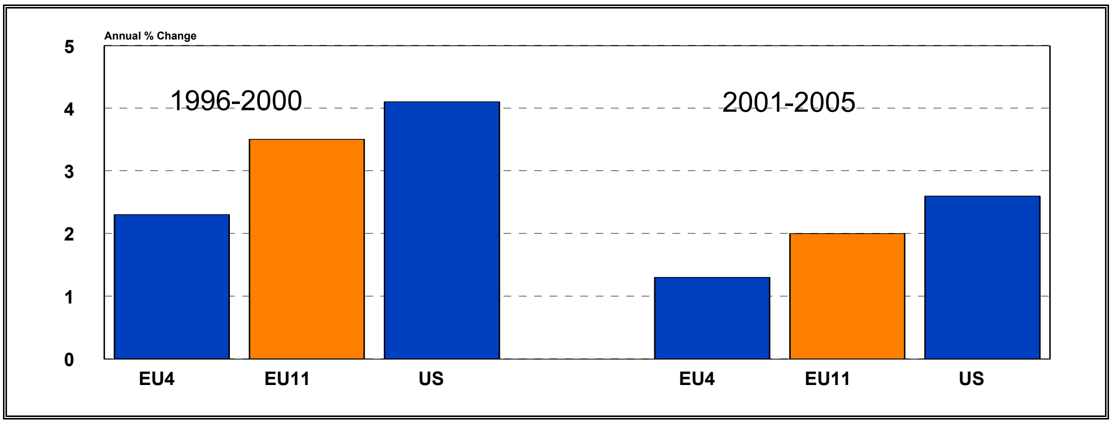
1a : Employment



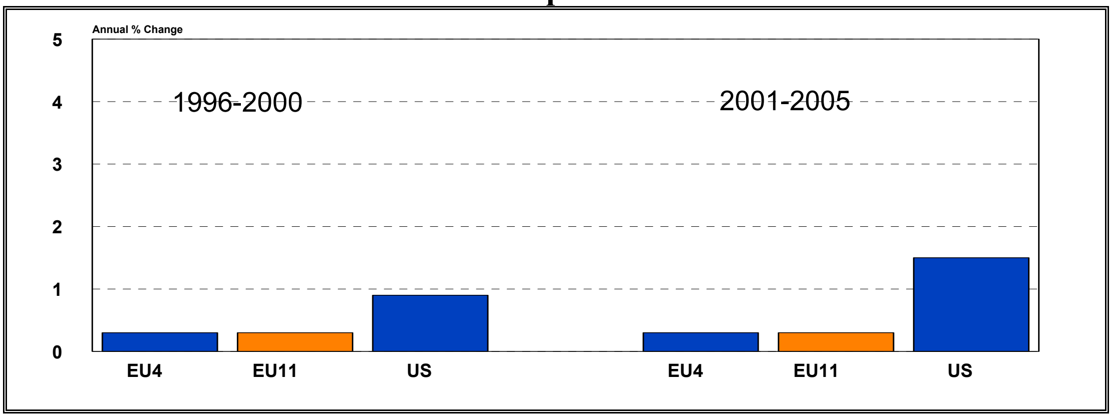
1b : Productivity (GDP per person employed)



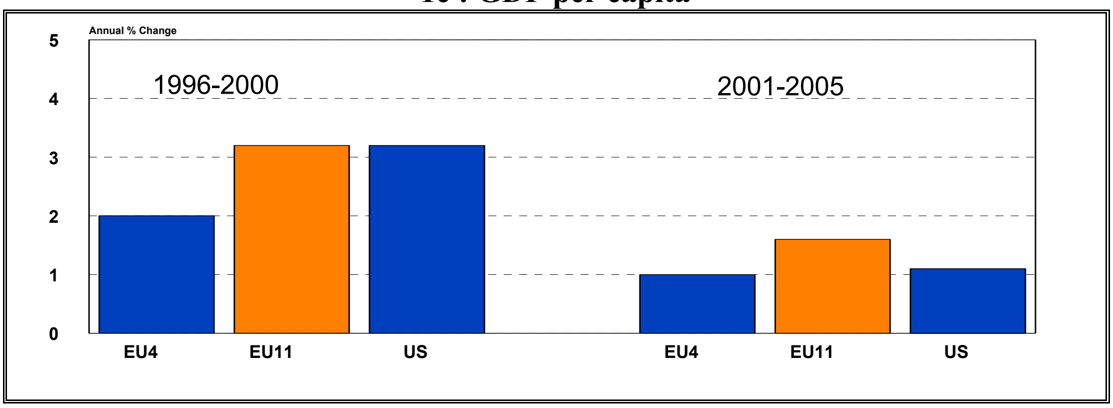
1c : GDP



1d : Population

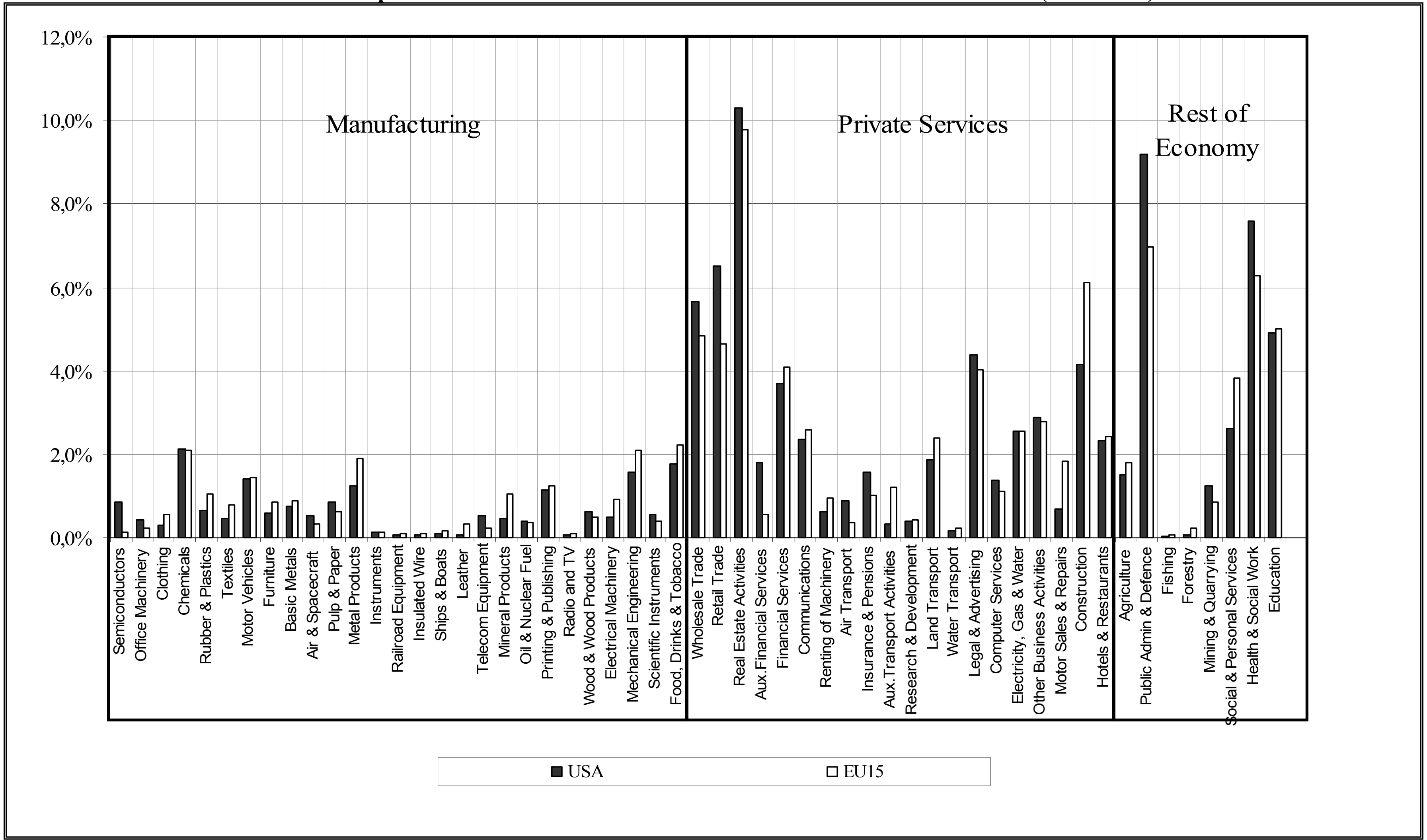


1e : GDP per capita

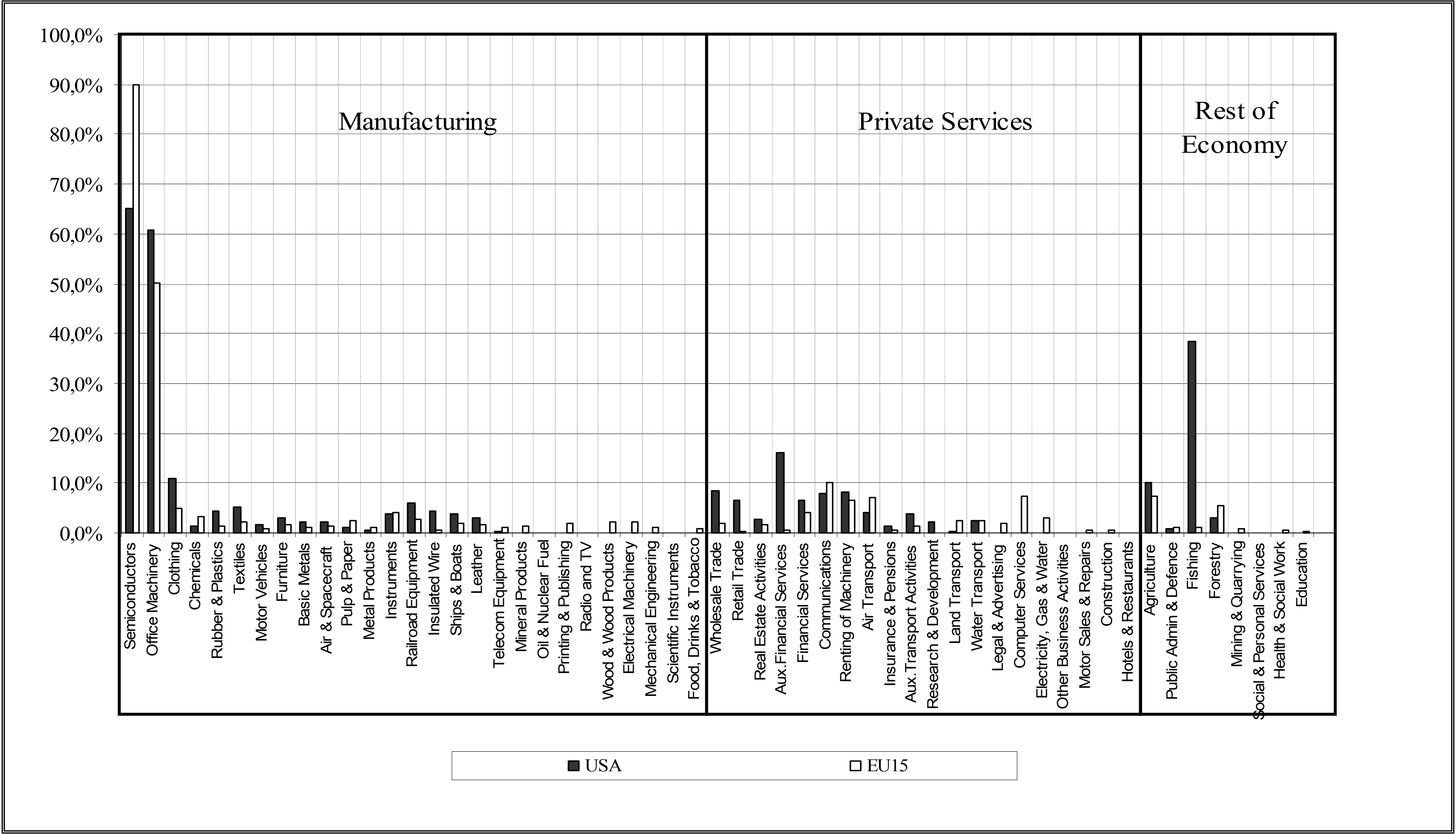


ANNEX 5 : VALUE ADDED SHARES AND PRODUCTIVITY GROWTH RATES OF THE 56 INDUSTRIES

Graph 1 : Value Added Shares of the 56 Industries in the US + EU15 (1996-2000)

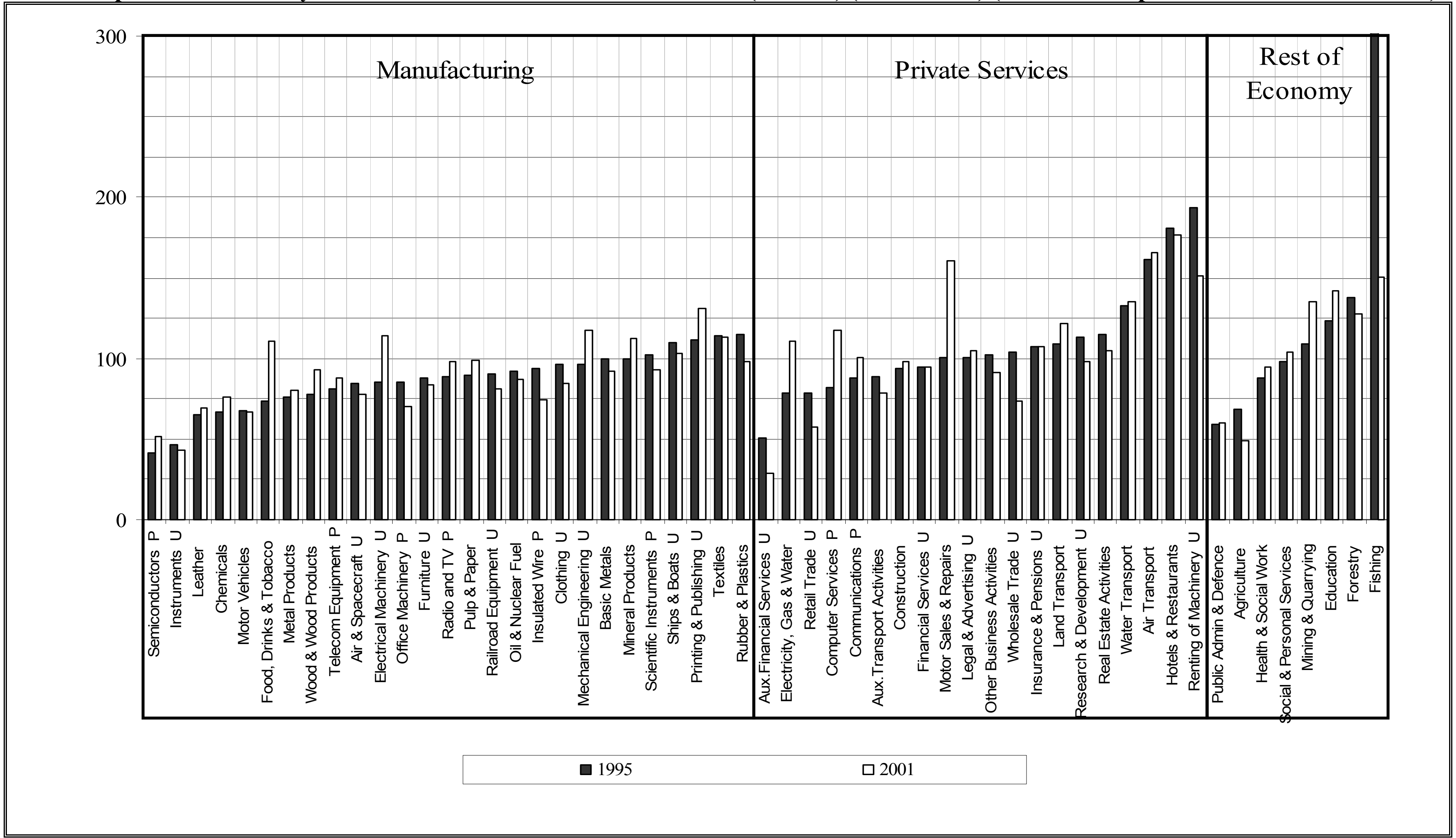


Graph 2 : Productivity growth rates of the 56 Industries in the US + EU15 (1996-2000)



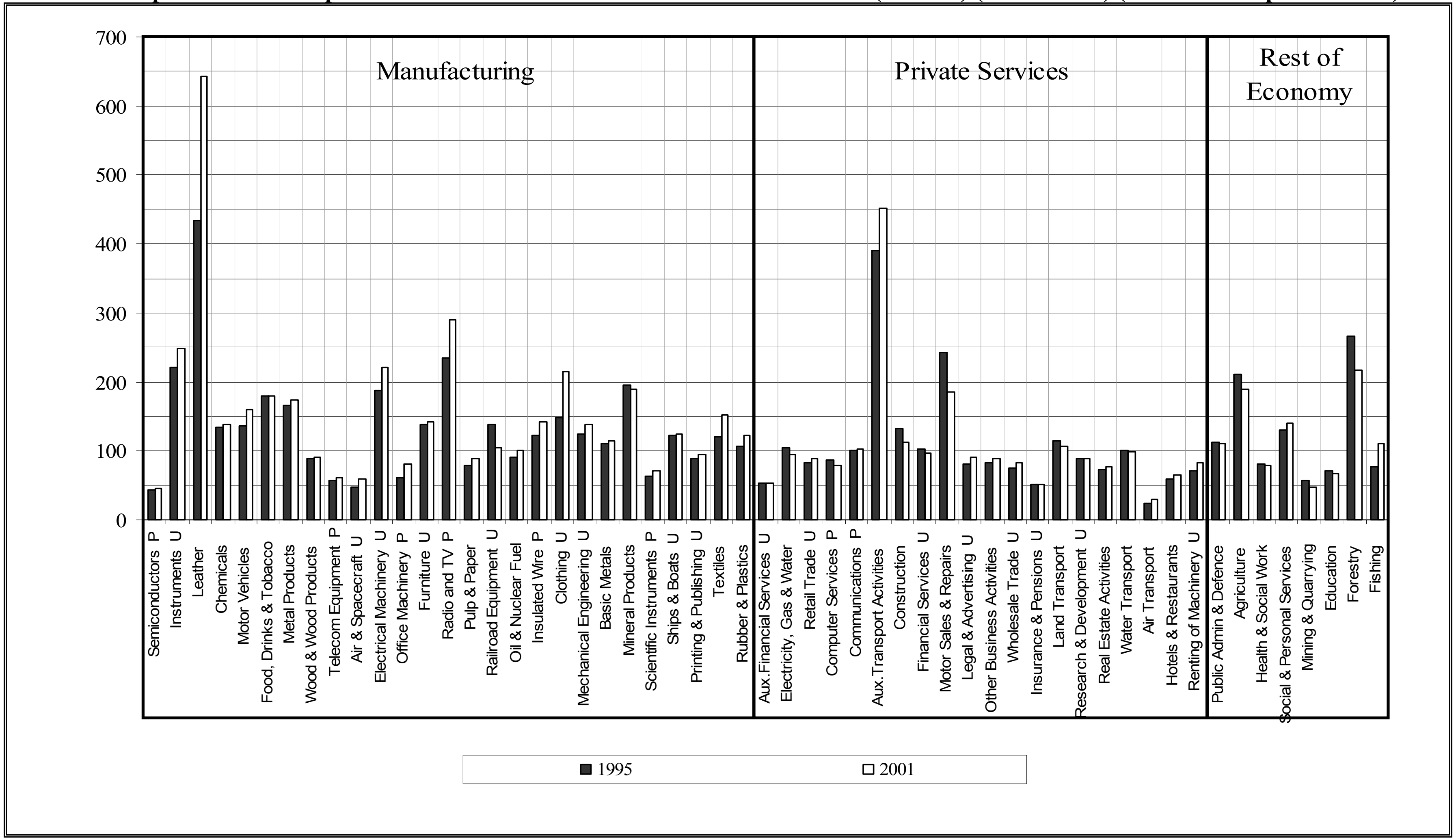
ANNEX 6 : LEVELS ANALYSIS FOR THE 56 INDUSTRIES (EU15 VALUE ADDED, PRODUCTIVITY AND EMPLOYMENT LEVELS RELATIVE TO US)

Graph 1 : Productivity levels in PPS / Hour - EU15 relative to US (US=100) (1995 + 2001) (Relative Competitiveness of EU Industries)*



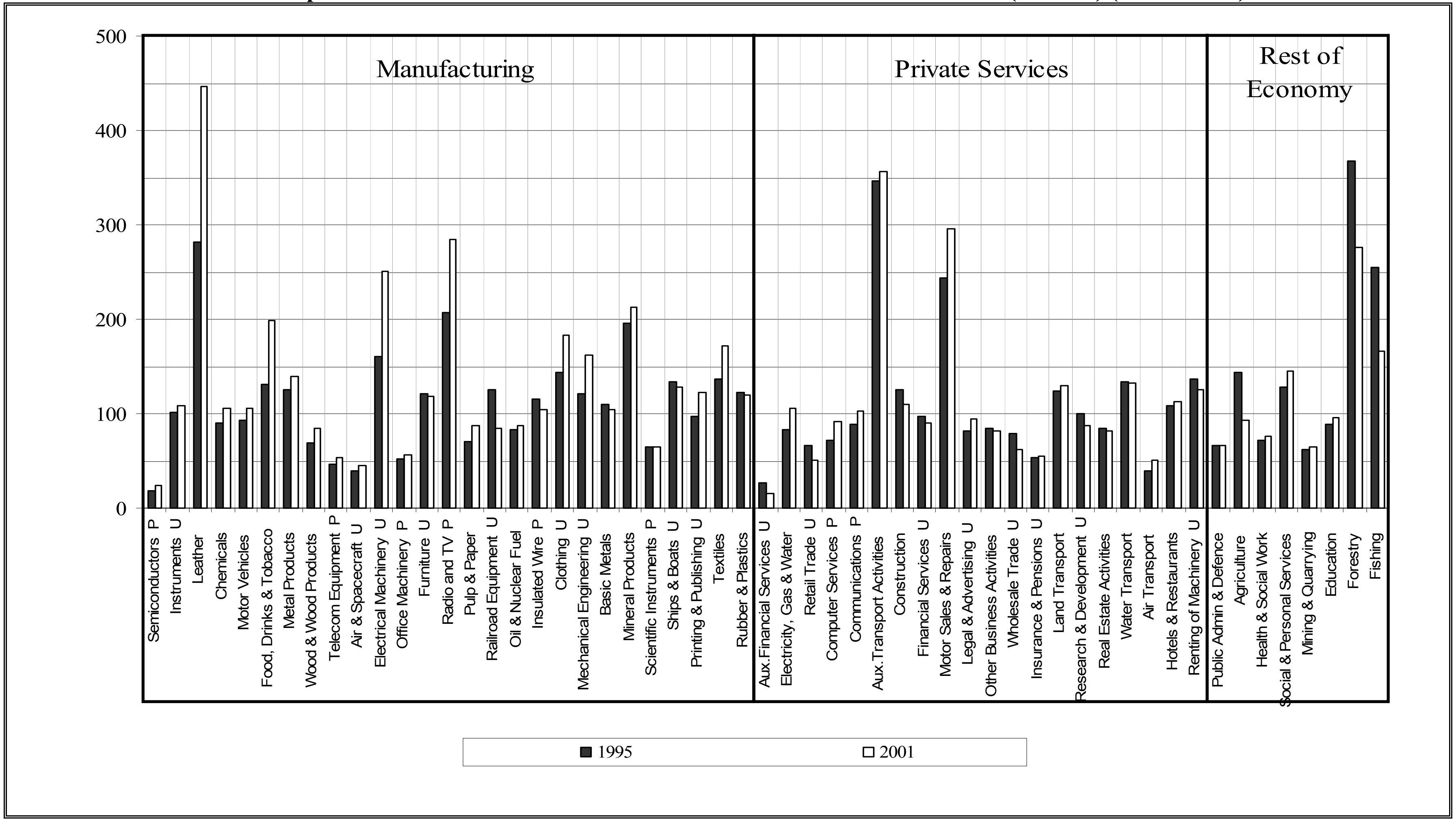
* Economy-wide PPP's are used. EU15 values have been aggregated from the Member States data using economy-wide PPP's.

Graph 2 : Labour input levels for the 56 Industries in EU15 relative to US (US=100) (1995 + 2001) (Indicator of Specialisation)*



* Labour input (employment * hours worked per employee) – Share of overall economy wide labour input allocated to the different industries.

Graph 3 : Value added levels of the 56 Industries in EU15 relative to US (US=100) (1995 + 2001)*



* Economy-wide PPP's are used. EU15 values have been aggregated from Member States data using economy-wide PPP's. The relative value added levels have been corrected for the differences in the respective size of the two economies using the labour input figures. The values in Graph 3 are the product of the values in Graphs 1 and 2.

ANNEX 7 : ADDITIONAL TABLES AND GRAPHS

TABLE 1 : WORLD'S TOP 50 MOST KNOWLEDGE COMPETITIVE REGIONS : 2004
(BASED ON KNOWLEDGE COMPETITIVENESS + KNOWLEDGE INTENSITY)

World Knowledge Competitiveness Index		Knowledge Intensity Ratio*	
Region	**Country**	**Region**	**Country**
1.San Francisco	US	1.San Francisco	US
2. Boston	US	2. Detroit	US
3. Grand Rapids	US	3. Grand Rapids	US
4. Seattle	US	4. San Diego	US
5. Hartford	US	5. Austin	US
6. San Diego	US	6. Shiga	Japan
7. Rochester	US	**7. Stockholm**	**Sweden**
8. Sacramento	US	8. Los Angeles	US
9. Austin	US	9. Rochester	US
10. Minneapolis	US	10. Seattle	US
11. Los Angeles	US	**11. West Sweden**	**Sweden**
12.Detroit	US	12.Cincinnati	US
13. New York	US	13. Sacramento	US
14. Denver	US	**14. Uusimaa (Helsinki)**	**Finland**
15. Stockholm	**Sweden**	**15. South East UK**	**UK**
16. Philadelphia	US	16. Minneapolis	US
17. Chicago	US	**17. South Sweden**	**Sweden**
18. Cincinnati	US	18. Shizuoka	Japan
19. Uusimaa (Helsinki)	**Finland**	19. Portland	US
20. Portland	US	20. Philadelphia	US
21. Dallas	US	**21. Eastern UK**	**UK**
22. Raleigh-Durham	US	22. Tochigi	Japan
23. Washington	US	23. Chicago	US
24. Salt Lake City	US	24. Raleigh	US
25. Houston	US	25. Denver	US
26. Indianapolis	US	26. Milwaukee	US
27. Milwaukee	US	27. Indianapolis	US
28. Buffalo	US	28. Toyama	Japan
29. Columbus	US	29. Cleveland	US
30. Phoenix	US	30. Salt Lake City	US
31. Atlanta	US	31. Pittsburgh	US
32. Kansas	US	32. Switzerland	**Switzerland**
33. Cleveland	US	33. Boston	US
34. Ile De France	**France**	34. Singapore	Singapore
35. Pittsburgh	US	35. Phoenix	US
36. Charlotte-Gastonia	US	*36. New York*	US
37. Richmond	US	**37. South Netherlands**	**Netherlands**
38. Tokyo	Japan	38. Kanagawa	Japan
39. Shiga	Japan	39. Kansas	US
40. South East UK	**UK**	*40. Ontario*	Canada
41. Greensboro	US	41. Columbus	US
42. St. Louis	US	42. Aichi	Japan
43. San Antonio	US	43. Houston	US
44. West Sweden	**Sweden**	*44. Hartford*	US
45. Switzerland	**Switzerland**	45. Dallas	US
46. London	**UK**	**46. Baden Wurtemberg**	**Germany**
47. Nashville	US	**47. Ile de France**	**France**
48. Norfolk	US	*48. Washington*	US
49. Louisville	US	49. St. Louis	US
50. Eastern UK	**UK**	**50. Denmark**	**Denmark**

Countries in which the Top 50 Regions are Located

1. KNOWLEDGE COMPETITIVENESS		2. KNOWLEDGE INTENSITY	
NORTH AMERICA	**40**	**NORTH AMERICA**	**32**
EUROPE	**8**	**EUROPE**	**11**
ASIA / PACIFIC	**2**	**ASIA / PACIFIC**	**7**

*** "The regional ratio of knowledge intensity is calculated on the basis of each region's World Knowledge Competitiveness Index score relative to its index of GDP per capita. Such a measure is the best available derivative of the relative importance of knowledge and knowledge-based activities to the overall economic performance and structure of each region.**

Source : World Knowledge Competitiveness Index 2004, Robert Huggins Associates

TABLE 2A : EUROPEAN REGIONAL COMPETITIVENESS INDEX

TOP 20 REGIONS			BOTTOM 20 REGIONS		
RANK	REGION	INDEX	RANK	REGION	INDEX
1	Uusimaa, Finland	261.8	72	Région Wallonne, Belgium	55.3
2	Stockholm, Sweden	252.3	73	Sachsen-Anhalt, Germany	52.1
3	Brussels, Belgium	248.1	74	Border, Midlands & Western, Ireland	50.1
4	Ile de France, France	230.0	75	Mecklenburg-Vorpommern, Germany	49.1
5	Switzerland	224.7	76	Abruzzo-Molise, Italy	48.8
6	Luxembourg	222.0	77	Portugal (Continent)	40.6
7	Hamburg, Germany	211.5	78	Attiki, Greece	38.9
8	London, UK	186.4	79	Canarias, Spain	38.4
9	Norway	184.6	80	Sardegna, Italy	26.3
10	Bremen, Germany	178.9	81	Nisia Aigaiou, Kriti, Greece	22.4
11	Baden-Württemberg, Germany	175.9	82	Madeira, Portugal	22.1
12	South East, UK	171.7	83	Azores, Portugal	21.9
13	Hessen, Germany	170.7	84	Campania, Italy	19.5
14	West-Nederland, Netherlands	168.2	85	Noroeste, Spain	18.5
15	Bayern, Germany	160.1	86	Sicilia, Italy	15.6
16	Berlin, Germany	154.9	87	Sud, Italy	13.9
17	Eastern, UK	152.7	88	Centro, Spain	13.6
18	Denmark	142.6	89	Vareia Ellada, Greece	11.5
19	Vestsverige, Sweden	135.6	90	Sur, Spain	7.3
20	Zuid-Nederland, Netherlands	135.0	91	Kentriki Ellada, Greece	2.4

Source : European Competitiveness Index 2004, Robert Huggins Associates

TABLE 2B : EUROPEAN REGIONAL COMPETITIVENESS INDEX : BREAKDOWN OF COMPOSITE INDEX AT REGIONAL LEVEL

REGION	OVERALL COMPOSITE INDEX	3 SUB-COMPOSITE INDICES		
		CREATIVE / KNOWLEDGE ECONOMY	ECONOMIC PERFORMANCE	INFRASTRUCTURE & ACCESSIBILITY
Uusimaa, Finland	1	1	8	50
Stockholm, Sweden	2	6	4	60
Brussels, Belgium	3	22	3	12
Ile de France, France	4	2	9	47
Switzerland	5	23	1	16
Luxembourg	6	42	5	1
Hamburg, Germany	7	7	7	4
London, UK	8	19	10	65
Norway	9	12	2	52
Bremen, Germany	10	5	26	2
Baden-Württemberg, Germany	11	11	17	38
South East, UK	12	8	11	53
Hessen, Germany	13	34	21	9
West-Nederland, Netherlands	14	9	12	8
Bayern, Germany	15	18	16	21
Berlin, Germany	16	3	60	32
Eastern, UK	17	15	14	71
Denmark	18	17	13	44
Vestsverige, Sweden	19	89	19	58
Zuid-Nederland, Netherlands	20	84	22	5

Source : European Competitiveness Index 2004, Robert Huggins Associates

TABLE 3 : WORLD'S TOP 20 UNIVERSITIES

WORLD RANKING	UNIVERSITY	COUNTRY
1	Harvard	US
2	Stanford (California)	US
3	Cambridge	UK
4	University of California – Berkeley	US
5	MIT	US
6	California Institute of Technology	US
7	Princeton	US
8	Oxford	UK
9	Columbia	US
10	Chicago	US
11	Yale	US
12	Cornell	US
13	University of California – San Diego	US
14	Tokyo	Japan
15	Pennsylvania	US
16	University of California – Los Angeles	US
17	University of California – San Francisco	US
18	Wisconsin – Madison	US
19	Michigan – Ann Arbor	US
20	Washington – Seattle	US

Source : Academic Ranking of World Universities, 2004

Ranking Criteria and Weights

Criteria	Indicator	Weight
Quality of Education	Alumni of an institution winning Nobel Prizes and Field Medals	10%
Quality of Faculty	Staff of an institution winning Nobel Prizes and Field Medals	20%
	Highly cited researchers in 21 broad subject categories	20%
Research Output	Articles published in Nature and Science	20%
	Articles in Science Citation Index-expanded and Social Science Citation Index	20%
Size of Institution	Academic performance with respect to the size of an institution	10%
Total		100%

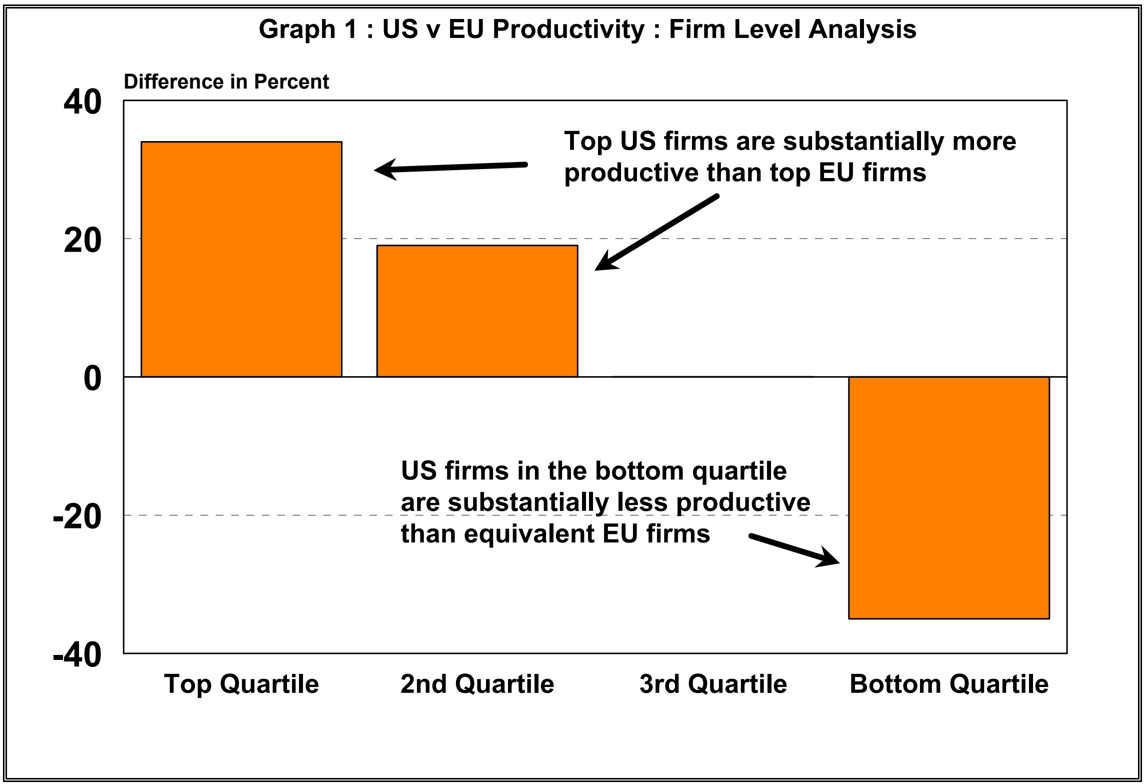
Source : Academic Ranking of World Universities, 2004

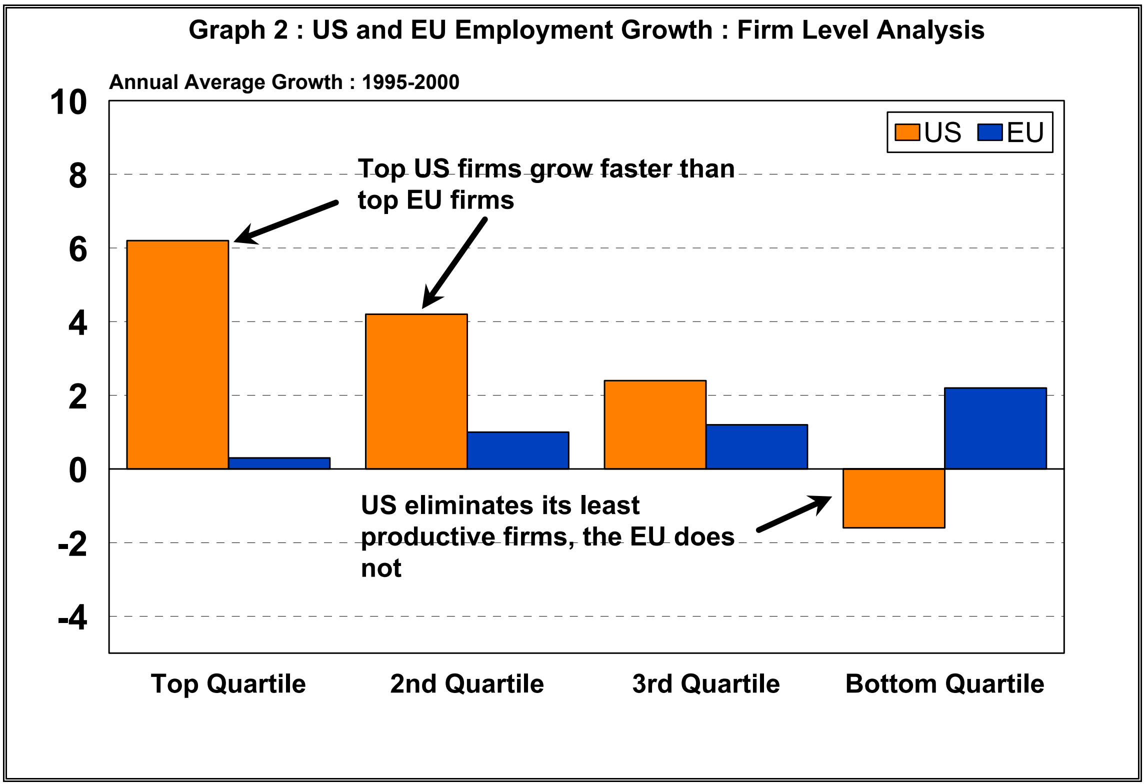
TABLE 4 : OBSERVED AND "STRUCTURAL" HOURLY PRODUCTIVITY IN 2002 (% OF US)

Country	Observed Hourly Productivity (% of US)	Effect of the gap with the US in hours worked + employment rate		Structural Hourly Productivity (% of US)
		Hours Worked	Employment Rate	
United States	100	0.0	0.0	100
European Union	88.2	4.4	5.3	78.5
Japan	67.5	0.1	2.6	64.8
Individual EU Member States				
France	106.6	5.2	7.5	93.9
Germany	91.7	7.2	4.6	80.0
Belgium	106.3	4.9	8.5	92.8
Spain	73.6	0.2	8.6	64.9
Greece	64.2	-2.3	10.4	56.1
Ireland	103.6	2.8	4.8	96.0
Italy	91.8	3.8	11.3	76.7
Netherlands	100.2	9.2	-0.9	91.9
Portugal	52.6	1.9	2.6	48.2
UK	78.6	2.1	-0.6	77.0

Source : G. Cette (Banque de France)

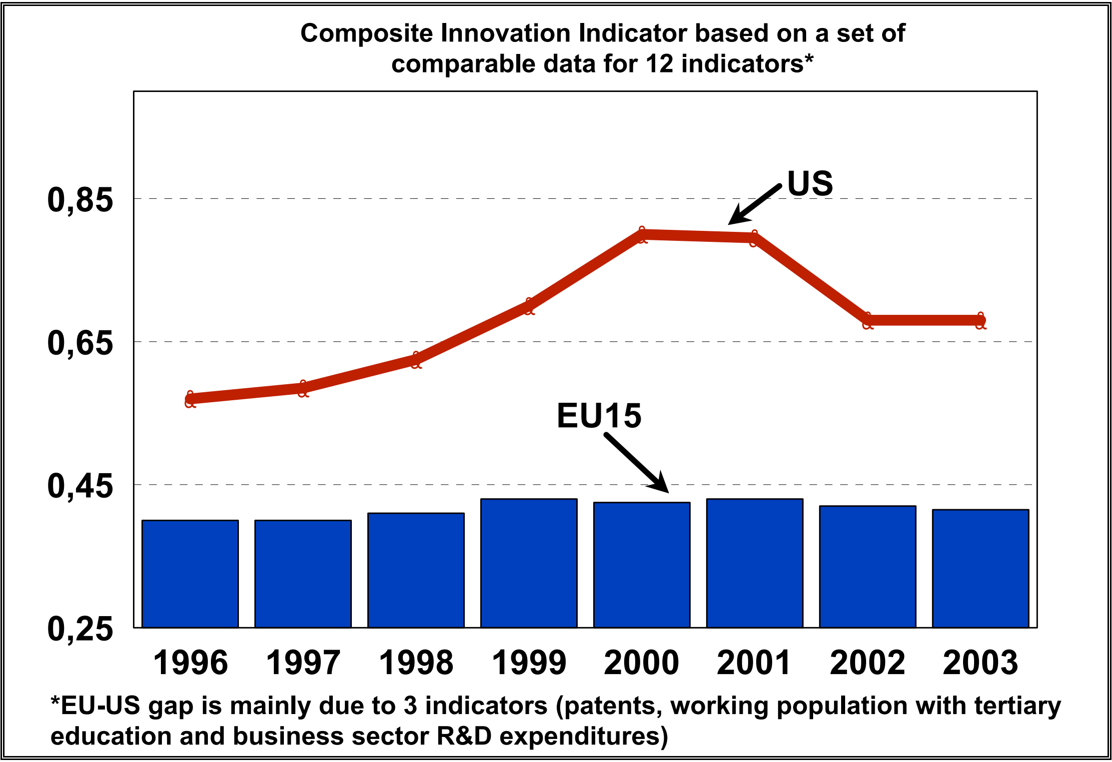
GRAPHS 1 + 2 : FIRM LEVEL ANALYSIS OF EU AND US PRODUCTIVITY AND EMPLOYMENT PATTERNS





Source : Fostering excellence : Challenges for productivity growth in Europe, Draft discussion paper for the Informal Competitiveness Council, 1-3 July 2004 (Netherlands' Ministry of Economic Affairs) based on work by Prof. E. Bartelsman, Economic and Social Institute, Free University of Amsterdam.

GRAPH 3 : MEASURING THE INNOVATION GAP BETWEEN THE EU AND THE US



SOURCE : EUROPEAN INNOVATION SCOREBOARD

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