

# Evaluating and Comparing the innovation performance of the United States and the European Union

Expert report prepared for the *TrendChart* Policy Workshop 2005 \*

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June 29, 2005

## 1 Introduction

The present report aims at evaluating and comparing the innovation performance of the United States and the European Union. In particular, bearing in mind the subtleties entailed by innovation measurements, we discuss the European comparative performance in terms of scientific output, proxies for technological innovation, and actual production and export in those lines of business which draw more directly on scientific advances. The general message of our analysis can be summarized as follows. Certainly one observes significant differences across scientific and technological fields, but it happens that Europe has structural lags in top level science and innovative performance *vis-à-vis* the US, together with some points of strength in physical sciences and engineering. At the same time, one also finds

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\*We wish to thank Anthony Arundel and Franck Dupont for reading previous versions of the present report and providing insightful comments and suggestions. The usual disclaimers apply. The present work partially draws upon a recent working paper by the same authors to which the reader is referred for more detailed discussion (Dosi et al., 2005).

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ample evidence of a widespread European corporate weakness, notwithstanding major success stories.

One wants to recognize that knowledge, the basic ingredient of the innovative process, is often difficult to measure in a straightforward vein. In order to coherently interpret distinct proxies and indicators, Section 2 of this report makes explicit where we stand in the long-lasting controversy on the nature and properties of scientific and technological knowledge and on the institutions supporting its generation.

Notwithstanding the limitations of the simplistic representation which links science to technology in a deterministic vein, scientific knowledge may be considered (and it is increasingly so!) as one of the main determinants of technological and innovation performance. Section 3, therefore, discusses the *scientific Impact of Nations* exploiting bibliometric data.

Section 4 distinguishes between input and output indicators of technology performance, trying to put forward extremely clearly what they mean for evaluating EU and US technological capabilities. Indeed, we believe that distinct and detailed measurements might be a better guidance for policy makers than not so much informative indexes which aggregate inhomogeneous indicators.<sup>1</sup> In this section, we also highlight some of the distinctive features of higher systems of educations in the US and Europe.

Section 5 links the limits and weaknesses that European business enterprises display in innovating and competing in the world economy with the previous analysis.

Finally, Section 6 concludes putting forwards some far reaching normative im-

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<sup>1</sup>For a general discussion on such indexes see Archibugi and Coco (2005).

plications. We suggest that effective European catching up would require much less emphasis on various types of "networking", "interactions with the local environment", "attention to user need" — current obsessions of European and national policy makers — and, conversely, much more on policy measures aimed to both strengthen "frontier" research and, at the opposite end, strengthen European corporate actors.

## **2 Science and technology: some interpretative yardsticks**

In order to interpret the pieces of evidence collected in the present work, one needs to lay down the broad interpretative framework concerning the nature and properties of scientific and technological knowledge. With this goal in mind, in this section we presents what one could call the *Stanford-Yale-Sussex* (SYS) *synthesis*, as a shorthand for the confluence between works on the economics of information (including Arrow (1962); Nelson (1959); David (1993, 2004)) and works focussing on the specific features of technological knowledge (including Freeman (1982, 1994); Freeman and Soete (1997); Nelson and Winter (1982); Nelson (1959); Pavitt (1987, 1999); Rosenberg (1976, 1982); Winter (1982, 1987); and also Dosi (1982, 1988)). In such a *synthesis*, first, one fully acknowledges some common features of information and knowledge — in general, and with reference to scientific and technological knowledge, in particular. Moreover, second, one distinguishes the specific features of technological knowledge and the ways it is generated and exploited in contemporary economies.

As to the former point, both information and knowledge share the following properties:

- Some general features of public goods: (i) non-rival access (i.e. the fact that one holds an idea does not constrain others from holding it too); (ii) low marginal cost of reproduction and distribution, which *in principle* makes it difficult to exclude others from having access to newly generated information (except for legal devices such as copyrights and patents), as compared to high fixed costs of original production [The latter point applies primarily to *information, stricto sensu*].
- A fundamental uncertainty concerning the mapping between whatever one expects from search activities and their outcomes.
- (Relatedly) serendipity in the ultimate economic and social impact of search itself (Nelson, 2004).
- Quite often, very long lags between original discoveries and "useful" applications.

However, scientific and even more so technological knowledge share, to different extent some degrees of *tacitness*. This applies to the pre-existing knowledge leading to any discovery and also to the knowledge required to interpret and apply whatever codified information is generated.

As Pavitt (1987) puts it with regards to technological knowledge

- "*most technology is specific, complex ... cumulative in its development*". "Specificity" applies in two senses: "*It is specific to firms where most technological activity is carried out, and it is specific to products and processes,*

*since most of the expenditures is not on research, but on development and production engineering, after which knowledge is also accumulated through experience in production and use on what has come to be known as 'learning by doing' and 'learning by using'" (Pavitt, 1987) (p.9).*

- Moreover *"the combination of activities reflects the essentially pragmatic nature of most technological knowledge. Although a useful input, theory is rarely sufficiently robust to predict the performance of a technological artefact under operating conditions and with a high enough degree of certainty, to eliminate costly and time-consuming construction and testing of prototype and pilot plant"*(Pavitt, 1987)(p.9).

As far as scientific knowledge is concerned, we share Richard Nelson view in that *"science base largely is the product of publicly funded research and the knowledge produced by that research is largely open and available for potential innovations to use. That is, the market part of the Capitalist Engine [of technological progress] rests on a publicly supported scientific commons"*. (Nelson, 2004)(p.455).

Together, the fundamental vision underlying such a view of publicly supported *open science* throughout a good part of the 20<sup>th</sup> century entailed (i) a sociology of the scientists community largely relying on self-governance and peer evaluation, (ii) a shared culture of scientists emphasizing the importance of motivational factors other than economic ones and (iii) an ethos of disclosure of search results driven by "winner takes all" precedence rules.<sup>2</sup>

Taken for granted the above points, the relations between scientific knowledge,

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<sup>2</sup>On those points following the classic statements in Bush (1945); Polanyi (1962) and Merton (1973), see the more recent appraisals in Dasgupta and David (1994); David (2004); Nelson (2004) and the conflicting views in Geuna et al. (2003).

technological innovation, and their economic benefits are far from being linear, going from the former to the latter. Many scholars have in fact convincingly argued that the relationships go both ways (Freeman, 1982, 1994; Rosenberg, 1982; Kline and Rosenberg, 1986; Pavitt, 1999).

In particular, first, technological innovations sometimes precede science in that practical inventions come about *before* the scientific understanding of why they work (the engine is a good example). Second, it is quite common that scientific advances are made possible by technological ones especially in the fields of instruments (e.g. think of the importance of the microscope). Third, one typically observes complementarities between science and technology, which however "varies considerably amongst sectors of application, in terms of the direct usefulness of academic research results, and of the relative importance attached to such results and to training" (Pavitt, 1987)(p.7).

A not simplistic representation of the multifaceted interaction between science, technology and the economy is extremely useful for the understanding of the sources and procedures of technological innovation. However, on the normative side, the critics of the so-called linear model (i.e. from science to technology to their economic benefits) have probably gone too far in downplaying the relative contribution of science to technology (e.g. Kealy (1996)). Overlooking the importance of science is somewhat odd, given its increasing pervasiveness of the last decades, when the rates of innovation have often been shaped by the strength of the science base from which they draw (Nelson, 1993; Mowery and Nelson, 1999).

### 3 The myth of European Leadership in Science

At the end of the last decade, also inspired by the linear model critics, the European Commission has supported the conjecture that the EU lags in some of the high tech sectors and technological applications (essentially ICT and biotech) stem from its inability in converting its scientific strengths into economic profitable innovation (EC, 1995). The central claim of what thereafter has been dubbed as the "European Paradox" was that the EU plays a leading global role in terms of top-level scientific output from which European firms for a number of reasons do not benefit.<sup>3</sup> To a good extent, the consequences of such conjecture have been an emphasis on policies aimed at university-to-firms technological transfer and a general disregard for the scope of financing more speculative basic research.<sup>4</sup> In this section we aim at showing that the claim of the European excellence in science is largely misplaced.

Measuring the *scientific Impact of Nations* it is not straightforward. In particular, bibliometric analysis offers important insights, but also presents drawbacks and biases. To begin with, the main source of data, the Thomson ISI dataset, is itself a business activity of the Thomson Corporation responding to economic incentives different from measuring science quality. Second, comparing citations across disciplines is likely to be misleading, given different citation intensities (e.g. papers in medical research are much more cited than mathematical ones). Nevertheless, bearing in mind the above limitations, data on publications and citations

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<sup>3</sup>For an overall assessment of the above argument, see Dosi et al. (2005). As a matter of fact, the Commission seems to have re-considered its position concerning European excellence in science in a recent communication paper (EC, 2004).

<sup>4</sup>In this respect, the recent Commission support for the creation of an independent European Research Council is a welcome novelty.

can be revealing. And indeed, as we show below, the picture that emerges is far from pinpointing a European leadership in science, unless one want to take the total number of publications as a meaningful measure of scientific performance (See the first column of Table 1).

In the second column of Table 1 it is shown that, if one adjusts for population, European claimed leadership in publication (see for instance EC (2003)) disappears.<sup>5</sup>

Moreover, in science, together with the number of publications, at least equally important, are the originality and the impact of scientific output upon the relevant research communities. Two among the most used proxies of such an impact are articles' citations<sup>6</sup> and the shares in the top 1% most cited publications.

As shown in Table 1, the US is well ahead with respect to both indicators. In particular, controlling for population, the *outstanding* EU output is still less than half than the US one.

In the third and fourth column of the same table, we decompose numbers of publications, citations, and top 1% publications per population into two components: a measure of scientific productivity of university researchers (i.e. output per university researcher)<sup>7</sup> and a ratio of university researchers to population. The table clearly shows that US leadership is due to scientific productivity rather than to the sheer number of researchers. Similar results are obtained from other measures

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<sup>5</sup>Certainly normalization by population is a very rough proxy which also averages across very different entities, ranging from Sweden, Germany and the UK all the way to Italy, Greece and Portugal (just sticking to EU-15). However also the US average over Massachusetts and California but also Mississippi and Idaho.

<sup>6</sup>Typically, they are very skewed: only a few publications are highly cited, while the overwhelming majority of articles receives zero citations.

<sup>7</sup>Ideally, one would like to control for those non academic researchers who publish in scientific journals.

Table 1: **Publications and Citations weighted by Population and University Researchers**

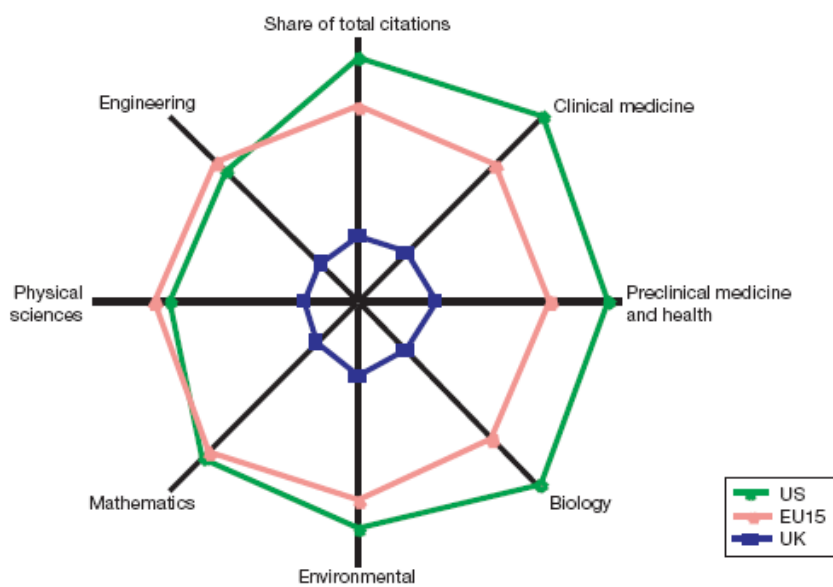
	Publications	$\frac{\text{Publications}}{\text{Population}}$	=	$\frac{\text{Publications}}{\text{Researchers}}$	$\times$	$\frac{\text{Researchers}}{\text{Population}}$
<b>US</b>	1,265,808	<b>4.64</b>		<b>6.80</b>		<b>0.68</b>
<b>EU-15</b>	1,347,985	<b>3.60</b>		<b>4.30</b>		<b>0.84</b>
	Citations	$\frac{\text{Citations}}{\text{Population}}$	=	$\frac{\text{Citations}}{\text{Researchers}}$	$\times$	$\frac{\text{Researchers}}{\text{Population}}$
<b>US</b>	10,850,549	<b>39.75</b>		<b>58.33</b>		<b>0.68</b>
<b>EU-15</b>	8,628,152	<b>23.03</b>		<b>27.52</b>		<b>0.84</b>
	Top 1% publications	$\frac{\text{Top1\%publications}}{\text{Population}}$	=	$\frac{\text{Top1\%publications}}{\text{Researchers}}$	$\times$	$\frac{\text{Researchers}}{\text{Population}}$
<b>US</b>	23,723	<b>0.09</b>		<b>0.13</b>		<b>0.68</b>
<b>EU-15</b>	14,099	<b>0.04</b>		<b>0.04</b>		<b>0.84</b>

*Notes:* Our calculations based on numbers reported by King (2004) and OECD (2004a). Number of publications, citations and top 1% publications refers to 1997-2001. Population (measured in thousands) and number of university researchers (measured in full time equivalent) refer to 1999. Each cited paper is allocated once to every country in which an author is based. The totals for EU15 are adjusted to adjust for duplications, by removing papers with multiple EU national authorship, giving an accurate net total.

of research performance based on different indicators (see Dosi et al. (2005)).

Despite the overall weaknesses, the inter-disciplinary variation in the revealed quality of European research deserves further scrutiny: comparing one discipline across the US and the UE should be easier and more revealing than the overall assessment. Aggregating the 68 disciplinary units used by the UK national research assessment in seven broad categories (i.e. clinical medicine, preclinical medicine and health, biological sciences, environment, mathematics, physical sciences, and engineering), King (2004) finds a clear US superiority in life and medical sciences, while Europe performs slightly better in physical sciences and engineering (see Figure 1). Incidentally, a few important distinctive patterns within the EU also emerge: for example France is strong in math, while Germany and UK do relatively

Figure 1: Strengths in different disciplines



Notes: Plot shows research footprints based on the shares of citations. The distance from the origin is citation share. See King (2004) for sources (ISI Thompson) and details.

well in physical and life sciences respectively.<sup>8</sup>

The general message is therefore far from suggesting any generalized European leadership. On the contrary, one observes a structural lag in top level science *vis-à-vis* the US, together with a few sectoral outliers in physical sciences and engineering. In our view catching up in science productivity *vis-à-vis* the US, which entails both more public funding for basic research and broad reforms of the European higher education systems, is a basic ingredient of a more dynamic innovative performance.

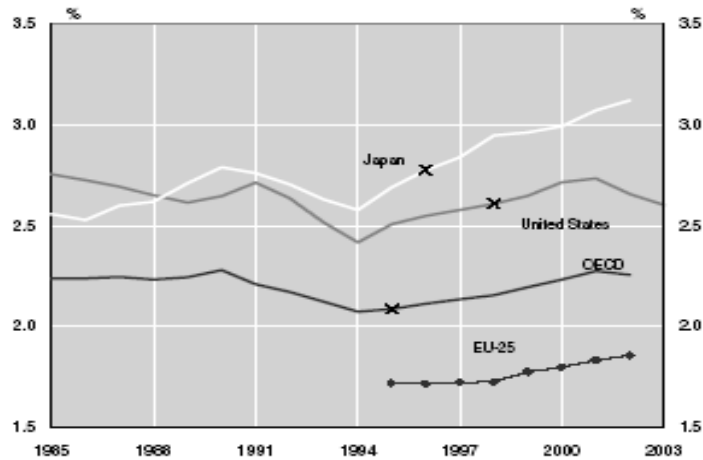
## 4 Poorer Technological Performances

In order to explore in detail the European performance in technology and innovation *vis-à-vis* the US, one needs to distinguish between European investments in science and technology (i.e. inputs typically proxied by education and R&D expenditures) with outputs (typically proxied by patents). The present report does not address explicitly the role played by distinct institutions financing innovation and, more specifically, venture capital. We believe, in fact, that the importance of the latter in the success of US national system of innovation has been largely overstated by both scholars and policy makers. On the contrary, we largely share Anna Lee Saxenian (1996) point of view: studying the importance of distinct financial intermediaries in regional clusters, she stresses that venture capital is likely to be a consequence rather than a prerequisite of high tech agglomeration. Moreover, she convincingly argues that virtually all policies which have tried to foster innovation creation through venture capital have been to a large extent ineffective.

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<sup>8</sup>See King (2004) for further details on this point.

Figure 2: Gross Domestic Expenditures on R&D as (%) of GDP



Source: OECD (2004a)

#### 4.1 Investments in Research and Development

The most cited indicator which pinpoints the European weaknesses in innovative efforts is probably the lower Gross Domestic Expenditure on R&D (GERD) as a percentage of GDP depicted in Figure 2.

In order to both understand the causes of European weaknesses and to guide policy measures aimed at increasing overall R&D expenditures, it might be insightful to highlight those dimensions which respond more promptly to policy shifts. Table 2 depicts Government Financed General Expenditure in R&D as a percentage of GDP for a selected sample of EU countries and the US. Even if French and German governments invest comparable amounts of resources, the aggregate picture for EU-25 is below the US one. The usual claim concerning the higher amount of publicly funded R&D in the EU as compared to the US is simply groundless.<sup>9</sup>

<sup>9</sup>The misunderstanding is usually based on the use of the share of publicly funded R&D on total R&D expenditures, which does not carry much economic sense. The meaningful figures regard normalization with the economic size of the economy.

Table 2: **Government Financed GERD as a Percentage of GDP**

<i>Country</i>	<i>1998</i>	<i>1999</i>	<i>2000</i>	<i>2001</i>
Finland	0.87	0.94	0.89	0.87
France	0.81	0.80	0.84	0.82
Germany	0.81	0.78	0.78	0.79
Italy	0.51	...	...	...
Spain	0.35	0.36	0.36	0.38
Sweden	...	0.89	...	0.90
United Kingdom	0.55	0.55	0.53	0.53
<b>EU-15</b>	<b>0.65</b>	<b>0.65</b>	<b>0.65</b>	<b>0.66</b>
<b>EU-25</b>	<b>0.63</b>	<b>0.63</b>	<b>0.63</b>	<b>0.63</b>
<b>US</b>	<b>0.79</b>	<b>0.76</b>	<b>0.71</b>	<b>0.76</b>

*Notes:* OECD (2004a). Italian percentage refers to 1996

Publicly supported of R&D may be categorized into several components. As showed in Table 3 the US government, compared to the EU ones, spends more both in R&D carried out by firm (business enterprise R&D (BERD)) and in other forms of R&D (i.e. higher education, government, etc.). However, the bulk of the difference is in publicly financed BERD.

As far as the latter is concerned, the well known recognition that the private level of R&D is likely to be too low from a social point of view does not bear clear cut implication in terms of specific policy measures aimed at supporting industrial technology. The central problem is to avoid that governments' funds support R&D investments that would have been carried on even without public subsidies.<sup>10</sup>

Moreover, government financed BERD underestimates the full amount of public support for industrial technology, because it does not include (i) all the financial instruments used by governments for this purposes (e.g. fiscal incentives and loans) and (ii) R&D carried out in other sectors which governments finance with the aim

<sup>10</sup>See the *Research Policy* 2000 special issue (29(4-5)).

Table 3: **Decomposing 2001 Government funded R&D: BERD and non BERD**

<i>Country</i>	<i>Government Financed BERD on GDP(%)</i>	<i>Government Financed nonBERD on GDP(%)</i>
<b>EU-15</b>	9,369 0.10	53,352 0.56
<b>EU-25</b>	9,868 0.09	55,073 0.52
<b>US</b>	18,849 0.19	57,533 0.57

*Notes:* Our calculations on OECD (2004a). Gross expenditures are expressed in million 2000 dollars - constant prices and PPP.

Table 4: **Main Categories of Government Support for Industrial Technology**

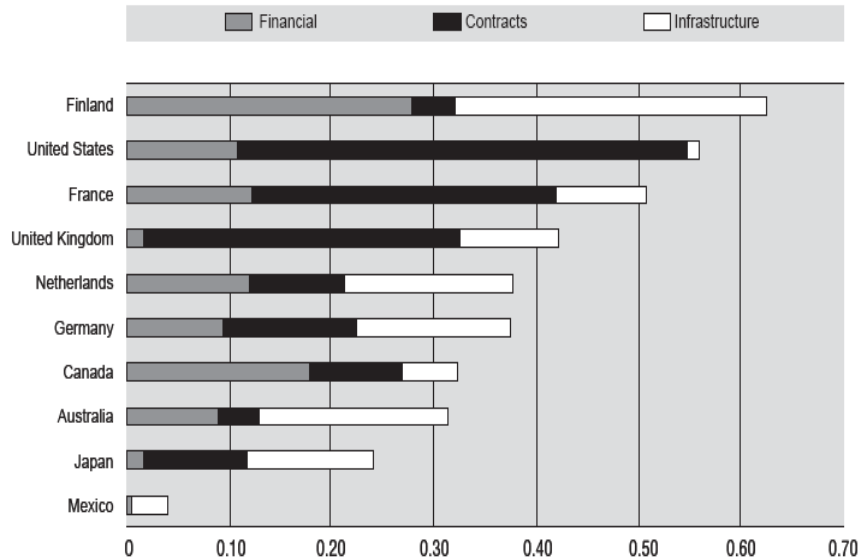
<i>Financial Incentives</i>	<i>Contracts and Procurement</i>	<i>Infrastructures</i>
1. Fiscal incentives	1. Defence	1. Institutes
2. Grants	2. Space	2. Academic
3. Other Incentives	3. Other contracts	3. Diffusion

*Source:* Young (2001).

of supporting industry. More generally, as summarized in Table 4, three broad categories of public support for industrial technology might be identified: first, all programmes designed to encourage industrial firms to carry out R&D by reducing its costs, through grants, loans, and fiscal measures; second, government payments to industrial firms financing R&D as part of procurement programs, notably for defence or space objectives; and third, public support to "research infrastructures" specifically aimed at industrial development not involving however any financial transfer to private firms (e.g. applied research undertaken in public institutes and universities).

Unfortunately international statistics on the above are hardly available, even for industrialized countries. Figure 3 reports the results from a Pilot Study run by OECD which categorize the estimated government support for industrial tech-

Figure 3: **Estimated government support for industrial technology as a percentage of Domestic Product of Industry (DPI)**



*Note:* 1997 or nearest year available  
*Source:* Young (2001)

nology as a percentage of industrial GDP (Young, 2001). Even if results need to be taken with caution, given the preliminary nature of the study, the pattern of support varies considerably across countries. In particular, the US federal support for industrial technology is almost entirely paid to firms (universities do not seem to receive public funds for industrial technology!), with the largest share in the form of mission-oriented contracts and procurement. As far as EU countries are concerned, in France and the United Kingdom mission oriented contracts are also relatively important, while in Germany and the Netherlands funds are distributed evenly across the three categories. Of course, figures for the entire EU-25 group would be extremely helpful.

The EU-US gap is wider in Industry financed gross expenditure on R&D as a percentage of GDP (see Table 5). Moreover, despite diverse countries patterns,

Table 5: **Industry Financed GERD as a Percentage of GDP**

<i>Country</i>	<i>1998</i>	<i>1999</i>	<i>2000</i>	<i>2001</i>
Finland	1.84	2.16	2.39	2.41
France	1.16	1.18	1.14	1.21
Germany	1.44	1.59	1.65	1.65
Italy	0.43	...	...	...
Spain	0.44	0.43	0.47	0.45
Sweden	...	2.47	...	3.07
United Kingdom	0.86	0.91	0.91	0.88
<b>EU-15</b>	<b>0.98</b>	<b>1.04</b>	<b>1.06</b>	<b>1.08</b>
<b>EU-25</b>	<b>0.93</b>	<b>0.98</b>	<b>1.00</b>	<b>1.02</b>
<b>US</b>	<b>1.70</b>	<b>1.77</b>	<b>1.88</b>	<b>1.84</b>

*Notes:* EC (2004). Italian Percentage refers to 1996

there is no sign of catching up. Important factors in explaining the asymmetries in industry financed R&D are the wide and persistent differences in the efforts devoted to knowledge production and absorption across industrial sectors.

A last remark concerning overall R&D investments has to do with the share of higher education R&D (HERD) financed by industry.<sup>11</sup> The latter is one of the few reliable indicators measuring the importance of university-business interaction and the US-EU comparison goes against the conventional wisdom concerning stronger financial university-industry links in the US. As shown in Table 6 the share of private investment in university R&D, while low everywhere, is marginally higher in the EU than in the US. Similar results are obtained if one considers the private sector's annual investment in the public research sector (i.e. the sum of higher education and government R&D) (King, 2004).

Likewise for scientific production, it is very instructive to measure the relative importance of both public and private investments in R&D in different science

<sup>11</sup>Incidentally, investments in HERD as percentage of GDP are very similar between US and EU-25 (0.40 and 0.39 respectively in 2001).

Table 6: **Shares of Higher education Expenditure on R&D (HERD) financed by industry**

<i>Country</i>	<i>1998</i>	<i>1999</i>	<i>2000</i>	<i>2001</i>
Belgium	11.1	10.5	11.8	12.7
France	3.4	3.4	2.7	3.1
Germany	10.5	11.3	11.6	12.2
Spain	7.0	7.7	6.9	8.7
UK	7.3	7.3	7.1	6.2
<b>EU-15</b>	<b>6.4</b>	<b>6.5</b>	<b>6.6</b>	<b>6.8</b>
<b>EU-25</b>	<b>6.4</b>	<b>6.5</b>	<b>6.5</b>	<b>6.7</b>
<b>US</b>	<b>6.1</b>	<b>6.1</b>	<b>6.0</b>	<b>5.5</b>

*Source:* EIS and OECD (2004a).

Table 7: **Shares of HERD by country and S&E field: 1998 or 1999**

<i>Country</i>	<b>NS&amp;E</b>	<i>Natural sci.</i>	<i>Engin.</i>	<i>Medical sci.</i>	<i>Agricultural sci.</i>	<b>Social sci. &amp; Huma.</b>
Germany	<b>78,4</b>	29,2	20,3	24,7	4,2	<b>20,6</b>
Spain	<b>77,9</b>	39,4	18,7	14,2	5,6	<b>22,1</b>
Sweden	<b>76,3</b>	21,0	21,9	27,4	6,1	<b>17,6</b>
US	<b>93,7</b>	41,8	15,5	29,1	7,4	<b>6,3</b>

*Note:* NS&E natural sciences and engineering.  
*Source:* OECD, Science and Technology Statistics database, 2003.

and technology fields and industrial sectors. Even if, as already mentioned, not all academic performed R&D is publicly funded, an interesting exercise is to break down R&D performed by the academic sector according to the field. Table 7 shows that a selected number of EU countries devote a larger proportion of their R&D to engineering, social sciences, and humanities than does the US. Conversely, the US academic R&D effort concentrates on the medical and natural sciences. The latter is consistent with both the scientific evidence presented in the previous section and the emphases in health and biomedical sciences for which the United States is known.

Table 8: **Distinct components of GBAORD (%)**

	<i>Defence Budget R&amp;D</i>	<i>Civil Budget R&amp;D</i>		
		<i>Econ. Development</i>	<i>Health &amp; Environ.</i>	<i>Space Progra.</i>
EU-15	15.2	17	14	5
EU-25	14.9	17	13	5
US	55.1	5	26	8

*Note:* Numbers refer to 2004 for the US and to 2001 for EU-15 and EU-25.  
*Source:* OECD (2004a).

Together with publicly financed BERD, a complementary indicator which measures the public support for industrial R&D is the government budget appropriations or outlays for R&D (GBAORD). The basic difference is that while the former is computed from data provided by firms actually performing publicly funded R&D, the latter is calculated using data derived from national budgets. Even if GBAORD figures are probably less accurate, given distinct and often heterogeneous national accounting criteria in categorizing R&D,<sup>12</sup> they have the advantage of being linkable to specific goals and objectives. For our purposes it is instructive to see major EU-US differences.

Table 8 decomposes GBOARD in Defence and a selected number of Civil R&D headings. The US devotes a much higher proportion of its budget to Defence Budget R&D. This is probably also at the roots of the importance that Contracts and Procurement have in Figure 3.

If one breaks down business enterprise R&D, even high-tech industries differ a lot. This in turn is partly due to inter-sectoral differences in technological opportunities and partly in the way the latter are tapped — which in some industries involves formal R&D activities and in others more informal processes

<sup>12</sup>See Young (2001) for a discussion.

of learning-by-doing, learning-by-using and learning-by-interacting with suppliers and customers.<sup>13</sup> It happens that Europe is largely penalized in aggregate BERD by a composition effect, in that it is relatively strong in technologies (such as mechanical engineering) wherein a good deal of search is not recorded under the "R&D" heading. However, even after controlling for intersectoral differences, the European gap does not entirely disappear.<sup>14</sup>

Together with financial investments in R&D, educated and skilled human resources represent an important input of the innovative process. People, however, both produce and convey knowledge and therefore a few authors have stressed that well trained scientists and researchers are one of the most important output of public support for basic research and universities (see for instance Pavitt (2001) and Florida (1999)).

Consistently with R&D evidence, with a few exceptions, one observes dismal EU performance both in overall human capital formation, measured as shares of graduates on the relevant class of population, and the shares of researchers over the employed labor force. Of course, the two classes of indicators are related, but while the former is mostly the result of individual choices and educational institutions, the latter depends more broadly on the coordination mechanisms between educational systems and the productive structure of the economy. Table 9 shows that the EU has comparable numbers of new S&E graduates in the relevant class of population, while lags behind in both the share of population with tertiary education and the number of total researchers per thousand of employed workers.

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<sup>13</sup>Within an enormous literature, on these points see Dosi (1988); Klevorick et al. (1995); Malerba (2004).

<sup>14</sup>See EC (2003) on page 116 for data and discussions.

Table 9: **Population with Tertiary Education (% of 25-64 years age class), New Science & Engineering graduates (per 1000 population aged 20-29), and Total Researchers (per Thousand of Total Employment)**

<i>Country</i>	<i>Tertiary Education</i>			<i>S&amp;E graduates</i>			<i>Researchers</i>		
	<i>1999</i>	<i>2001</i>	<i>2003</i>	<i>1999</i>	<i>2001</i>	<i>2003</i>	<i>1999</i>	<i>2001</i>	<i>2002</i>
France	20.9	22.6	23.1	19.0	20.2	22.2	6.8	7.2	7.5
Germany	23.0	23.5	24.3	8.6	8.0	8.4	6.7	6.8	6.9
Italy	9.5	10.0	10.8	5.5	6.1	7.4	2.9	2.8	...
Spain	21.1	23.6	25.2	9.6	11.3	12.6	4.0	5.0	5.1
Sweden	28.5	25.5	27.2	9.7	12.4	13.9	9.6	10.6	...
UK	27.5	28.7	30.6	15.6	19.5	21.0	5.5	...	...
<b>EU-15</b>	<b>20.5</b>	<b>21.5</b>	<b>22.5</b>	<b>10.2</b>	<b>11.9</b>	...	<b>5.6</b>	<b>5.9</b>	...
<b>EU-25</b>	<b>19.4</b>	<b>20.1</b>	<b>21.2</b>	<b>9.4</b>	<b>11.0</b>	...	<b>5.3</b>	<b>5.6</b>	<b>5.8</b>
<b>US</b>	<b>35.8</b>	<b>37.3</b>	<b>38.1</b>	<b>9.3</b>	<b>9.9</b>	<b>10.9</b>	<b>8.6</b>	...	...

*Note:* US indicator for tertiary education in 2003 refers to 2002. Italian number for S&E graduates in 2003 refers to 2002, EU-25 to 2000. UK number of researchers refer to 1998.  
*Source:* EIS 2005 indicators and OECD (2004a).

## 4.2 Higher Education Systems

At this juncture, it is worthwhile to address the distinctive characteristics of the natural candidate for explaining both the US leadership in scientific productivity and higher enrolment in tertiary schooling: its higher education institutions. Comparing US system of higher education with the European one is however a difficult exercise for at least two reasons. First, EU countries, notwithstanding their recent attempts of converging towards a common model, have rather different and idiosyncratic academic institutions. Second, data allowing international comparisons concerning the structure of the higher educational systems are surprisingly scarce, even for industrial economies. Nevertheless, important insights for cross-national comparison are offered by the huge secondary literature and by a few indicators mainly based on student enrolment and higher education expenditures in R&D (Mowery and Sampat, 2005).

First, historically research universities emerged for the first time in the mid

19<sup>th</sup> century Prussia, with what has been known as the Humbolt model, today universities seem to occupy a more significant position as basic research performers within the United States than in any other industrialized country (Mowery and Rosenberg, 1993). In fact, for instance, in France public institutes such the CNRS (National Center for Scientific Research), the INSERM (National Institute for Health and Medical Research), and the Institute Pasteur play a central role as basic research performers. Similarly, German basic research is mainly concentrated in the Max Plank institutes. On the contrary, after the Second World War, in tune with the influential Vannevar Bush (1945) report, US universities have been considered as the most appropriate institutional locus for basic research. This difference may be important, given the strong complementarities between basic research and teaching activities.

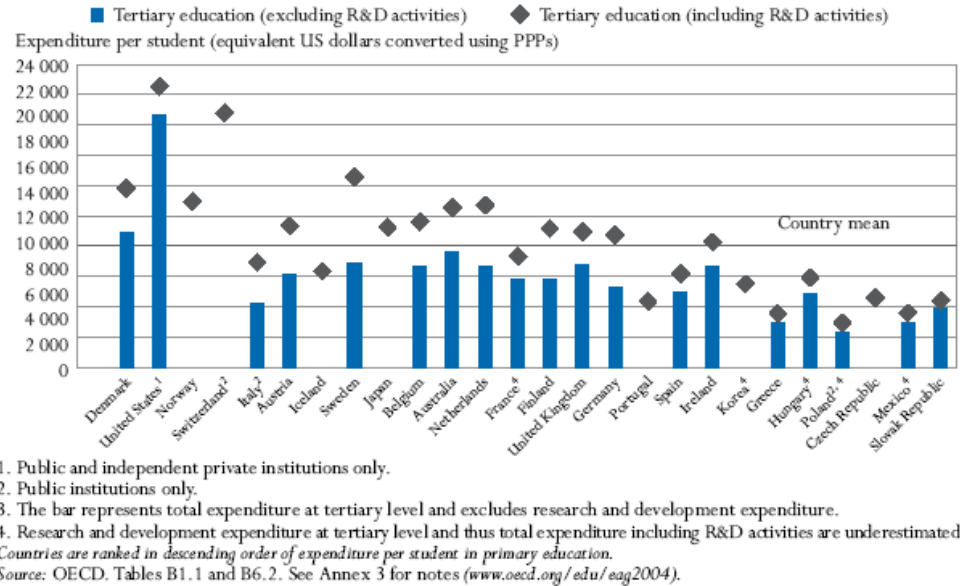
Second, the available data reveal that higher US enrolment is not a new phenomenon: since the beginning of the twentieth century, US higher education institutions have constantly enrolled larger shares of the relevant cohort of population than European ones (Mowery and Sampat, 2005).<sup>15</sup> This has been probably due to a US sharp distinction between research-cum-graduate teaching universities, undergraduate teaching institutions, and technical colleges. On the other hand, Europe (especially Continental Europe) often offers in most universities a confused mix of the three. Anecdotal evidence suggests that this is neither good for research nor for mass-level training.

Moreover, third, if one looks at tertiary education expenditures per student enrolled (Figure 4), the US clearly outperforms EU countries.

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<sup>15</sup>One wants to acknowledge, however, that differences in tertiary education enrolments across countries may stem from diverse programs' length.

Figure 4: Expenditure per student in tertiary education



Fourth, in the last years many scholars have emphasized the role of universities in the innovation process, in sharp contrast with their role in conducting basic research. At the same time, policy makers, pinpointing at the US experience, have increasingly considered higher education institutions as strategic assets, which need to be mobilized through more effective transfer of academic research to industry. Such attitudes have been largely motivated by selected episodes of success of high technology regional clusters in the United States, notably Silicon Valley and Route 128. However, first, little evidence supports the argument that the presence of universities *per se* causes regional high tech agglomerations and no evidence at all shows that deliberate public policies are effective in creating such agglomerations. Rather, second, detailed descriptive accounts of the Silicon Valley success have convincingly stressed the importance of massive increase in federal

defence spending after 1945, with leading universities being a necessary, but not sufficient condition (Saxenian, 1988). As rightly stated by Mowery and Sampat (2005) (p.19):

*” The U.S. experience suggests that the emergence of such agglomerations is a matter of contingency, path-dependence, and (most importantly) the presence of other supporting policies (intentional or otherwise) that may have little to do with university research or the encouragement of university-industry linkages.”*

Last but not least, detailed survey based studies have shown that, with the possible exception of pharmaceuticals, US industrial firms report to benefit more from ”public research” stemming from conferences and publications than from university prototypes, patents and licences (Cohen et al., 2002; Arundel and Geuna, 2004).

Finally, at a complementary level, the evidence that university-industry links are stronger in the U.S. than in Europe is at least mixed: if, on the one hand, qualitative data on labor mobility support to some extent the common wisdom, on the other, data concerning industry support to higher education R&D displayed above point to the opposite direction.

### **4.3 Technology output**

Complementary to proxies for the intensities of innovative search efforts and for the skills of the workforce involved, patent-based indicators are generally used to shed light on the *technological Output of Nations*. Patent-based indicators are probably the most frequently used measure of technology output; however, there is no standard method of calculating such indicators, with the result that the policy lessons that can be drawn from patent statistics are often widely divergent (Dernis and Guellec, 2001). Moreover, one wants to bear in mind a few drawbacks: first,

institutional differences, distinct corporate appropriability strategies, and different propensity to patent across sectors may bias the international comparisons. Second, the value distribution of patents is very skewed, with many patents having no industrial application. Huge heterogeneity implies that if one does not differentiate across patents with different values, one might obtain not very informative indicators. Third, changes in patent laws make it difficult to analyze long run time trends. In particular, the protection granted to patentees has increased worldwide since the early 1980s (but especially in the US)<sup>16</sup> and the list of patentable technologies has grown considerably. Last but not least, patent indicators are generally constructed on the basis of applications issued by national patent offices having an "home advantage" bias.

Given the above limitations, in the following we compare shares of world patents which have been filed in distinct patent offices according to the residence of the applicant and priority date:<sup>17</sup> the OECD has developed "patent families" (i.e. patent filed in different countries to protect the same invention) that try to mitigate the "home advantage" bias and generally capture patents of relatively high economic value. The downside is that triadic patents are usually owned by big corporations and therefore small firms innovation activity is likely to be underestimated.<sup>18</sup>

In Table 10 we report EU-25 and US shares in "triadic" patent families (i.e. inventions filed with the European Patent Office (EPO), the Japanese Patent Office

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<sup>16</sup>See Jaffe and Lerner (2004) for an insightful descriptions of the shortcomings of the US patent system which too often European policy makers consider as a model.

<sup>17</sup>The applicant is the patentee at the date of the application. This classification concentrates on ownership and reflect the innovative performance of a given country firm regardless of where research facilities are located. Priority date is the first application in any country worldwide and it is the closest (compared to application and grant dates) to the date of invention.

<sup>18</sup>See Dernis and Khan (2004) for a discussion.

(JPO), and the US Patent and Trademark Office (USPTO)). Total shares are relatively stable with a slight European decline.

However, EU performance varies significantly in distinct technology fields. The lower part of Table 10 depicts the shares of US and EU patents in nine main fields. Aerospace, mechanical engineering, chemistry, and materials are classified according to the International Patent Classification, while Biotech, ICT and its three subsets are classified grouping together distinct technological subfields according to the methodology suggested by OECD.<sup>19</sup> It is shown that the EU has relative strengths in Mechanical Engineering and Materials (even if in the last years there has been a sharp decline) and major weaknesses in Biotechnology. Aerospace and Chemistry are more in line with the "all fields" shares. It is rather interesting to decompose the ICT shares in three distinct subgroups. Some clear catching up is evident in Consumer Electronics, especially due to Scandinavian countries performance,<sup>20</sup> while EU countries still lag behind in Computers and office machinery and Telecommunication.

Even if part of the EU-US gap may stem from different organizations (i.e. firms and university) propensities to patent, also driven by distinct patent systems, divergent trends and differences in distinct subfield (which in turn mostly reflect different R&D efforts) pinpoint to real European innovation weaknesses.

A last note concerns the importance of patents not only as proxies of innovative output but also as economic institutions aimed at generating innovation and welfare. According to standard economic theory an optimal patent design mechanism should tradeoff static losses due to temporary monopoly rents with

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<sup>19</sup>Details on the methodology used can be found at <http://www1.oecd.org/scripts/cde/members/patentFamiliesAuthenticate.asp>.

<sup>20</sup>Disaggregated figures are available by the authors upon request.

Table 10: Shares in "triadic" patent families

	1990	1992	1994	1996	1998	2000
	<i>Total Shares</i>					
<b>EU-25</b>	0.27	0.28	0.29	0.29	0.30	0.23
<b>US</b>	0.39	0.40	0.40	0.38	0.36	0.38
	<i>Aerospace</i>					
<b>EU-25</b>	0.17	0.18	0.21	0.21	0.23	0.20
<b>US</b>	0.40	0.43	0.44	0.41	0.39	0.39
	<i>Mechanical Engineering</i>					
<b>EU-25</b>	0.41	0.39	0.39	0.40	0.41	0.30
<b>US</b>	0.30	0.34	0.27	0.23	0.23	0.26
	<i>Chemistry</i>					
<b>EU-25</b>	0.33	0.36	0.36	0.34	0.34	0.28
<b>US</b>	0.42	0.40	0.39	0.41	0.40	0.45
	<i>Materials</i>					
<b>EU-25</b>	0.29	0.33	0.31	0.31	0.32	0.21
<b>US</b>	0.37	0.35	0.34	0.33	0.33	0.38
	<i>Biotechnology</i>					
<b>EU-25</b>	0.29	0.30	0.29	0.26	0.26	0.19
<b>US</b>	0.50	0.47	0.50	0.53	0.55	0.62
	<i>ICT sector</i>					
<b>EU-25</b>	0.17	0.18	0.21	0.21	0.23	0.20
<b>US</b>	0.40	0.43	0.44	0.41	0.39	0.39
	<i>Telecommunications</i>					
<b>EU-25</b>	0.22	0.26	0.28	0.27	0.30	0.21
<b>US</b>	0.42	0.46	0.45	0.43	0.39	0.47
	<i>Consumer Electronics</i>					
<b>EU-25</b>	0.10	0.11	0.11	0.14	0.15	0.22
<b>US</b>	0.30	0.34	0.41	0.35	0.35	0.26
	<i>Computers, office machinery</i>					
<b>EU-25</b>	0.11	0.13	0.16	0.15	0.18	0.17
<b>US</b>	0.45	0.46	0.46	0.43	0.42	0.39

*Note:* "Triadic" patent families are inventions filed with the European Patent Office (EPO), the Japanese Patent Office (JPO), and the US Patent and Trademark Office (USPTO). See Dernis and Khan (2004) for methodological details.  
*Source:* OECD on line database

dynamic social gains stemming from greater innovative effort. However, the pieces of evidence concerning the latter effect are surprisingly scarce.<sup>21</sup> Conversely, even in pharmaceuticals, the industrial sector where patents are indeed a fundamental instrument for protecting innovation from imitators, the absence of product patent protection has often spurred innovation diffusion and also, less intuitively, trade of knowledge, contributing to the formation of an early market for technology (Dosi et al., 2005).

To sum up, R&D expenditures and patent based indicators identify a *European lag in terms of both lower search investments and lower innovative output*. Moreover, this is largely the effect of the weaknesses in technological fields that are considered as the engine of the contemporary "knowledge economy". On the other hand, data show a few points of strength related to mechanical technologies and new materials.

## **5 Structural weaknesses of European economy and corporations**

In this section we explore the limits and weaknesses that European business enterprises display in innovating and competing in the world economy. The evidence, in our view, suggests that a fundamental factor underlying the worsening performance of European firms is their lower commitments to research and international patenting and, in several sectors, their relatively weak participation to the core international oligopolies. Conversely, as we have shown above, we did not find any

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<sup>21</sup>See for example Sakakibara and Branstatter (2001).

evidence<sup>22</sup> concerning the often mentioned weaknesses in the European industry-university links compared to the US ones (see for instance Figure 3 and Table 6).

Let us focus in particular on those industries where the consequences of European lags in science and technological innovation are likely to be more severe.

Figure 5 shows the production shares in several ICT sectors. If the overall rankings of EU-15 and US have remained more or less stable, variations in individual shares shows that the EU, consistently with patent performance figures, lost the lead even in the telecommunications industry, where in the nineties it had a big advantage. Europe has also declined relative to the United States in office equipment. On the other hand, in radio communications and radar equipment the United States has somewhat lessened its lead relative to Europe (in turn, this has probably been the outcome of the formation of a few European companies especially in the military sector with sizes and capabilities at least comparable with their American counterparts).

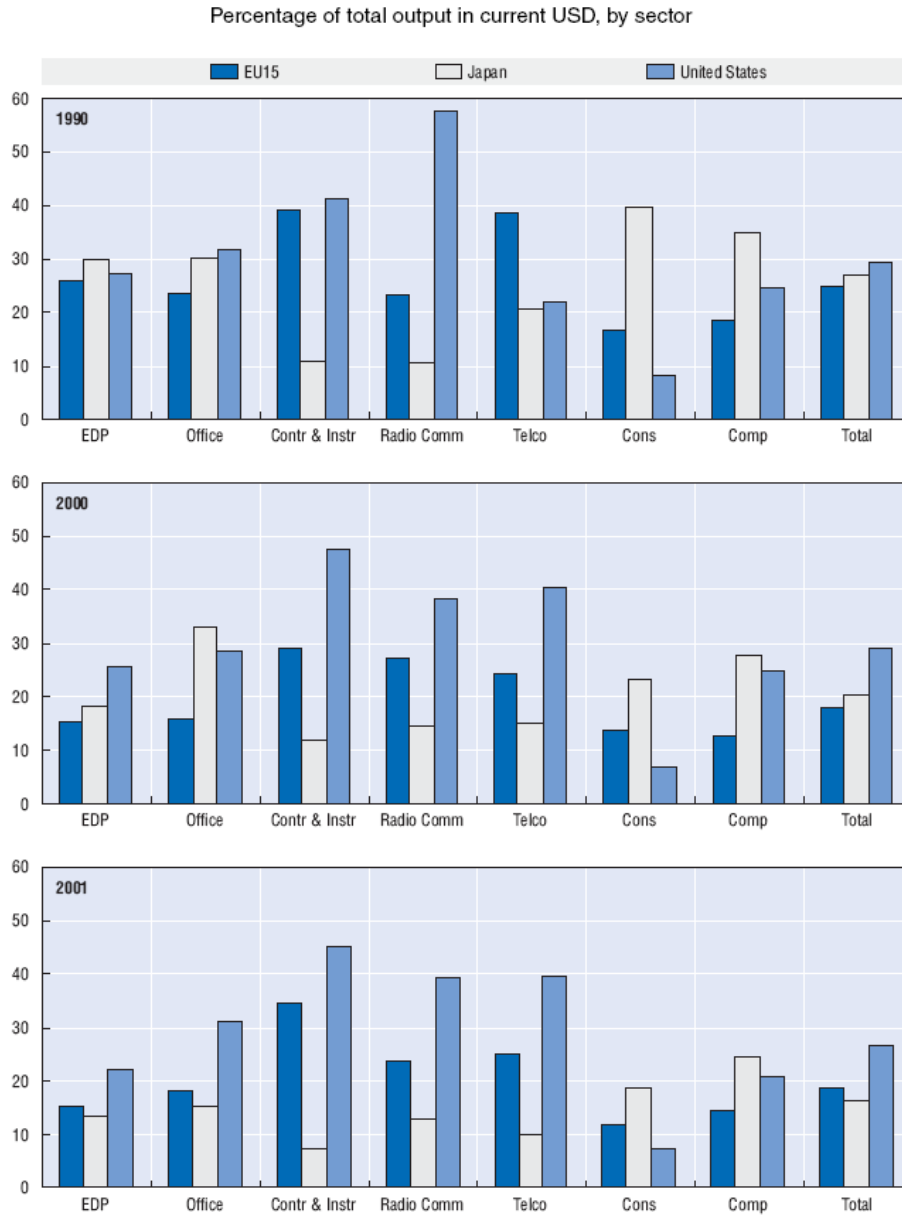
Similar insights are obtained comparing ICT expenditures (i.e. office machine, data processing equipment, data communication equipment, and telecommunication equipment, plus related software and telecom services) as percentages of GDP. As showed in Table 11, with the notable exceptions of Sweden and UK, all European countries under invest with respect to the US.

A somewhat similar picture comes from the data measuring trade performances in major high tech sectors. Table 12 depicts export market shares of selected EU countries not considering intra EU trade. While in aerospace the US has lost some ground and the EU has grown, the opposite has happened in Instruments and

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<sup>22</sup>With the possible exception of the European corporation low propensity of recruiting well trained researchers.

Figure 5: Share of World ICT Production



*Note:* Abbreviated sectors stand for: Electronic data processing, Office equipment, Control and instrumentation, Radio communications (including mobiles) and radar, Telecommunications, Consumer audio and video, Components, and Total ICT. Note: The shares are calculated in current USD, and relative exchange rates (strong USD in 2000-01) will have a large short-term influence on calculations of relative shares of ICT production. No data were available for Greece, Luxembourg and Portugal in 1990. Luxembourg is also not available for the other years.  
*Source:* Reed Electronics Research, various years. Reproduced in OECD (2004b).

Table 11: **ICT Expenditures as shares of GDP**

<i>Country</i>	<i>2001</i>	<i>2002</i>	<i>2003</i>	<i>2004</i>
Finland	6.6	7.1	7.0	7.1
France	6.1	6.2	5.9	6.0
Germany	6.3	6.1	6.0	6.2
Italy	5.2	5.4	5.3	5.3
Spain	5.2	5.6	5.4	5.2
Sweden	8.5	9.2	8.8	8.7
United Kingdom	7.4	8.6	8.0	7.9
<b>EU-15</b>	<b>6.3</b>	<b>6.6</b>	<b>6.4</b>	<b>6.3</b>
<b>EU-25</b>	<b>5.6</b>	<b>...</b>	<b>...</b>	<b>6.4</b>
<b>US</b>	<b>8.6</b>	<b>8.1</b>	<b>7.9</b>	<b>7.8</b>

*Notes:* EIS (2005)

Pharmaceuticals.

Combining different sources, the 2004 OECD Information Technology Outlook explores the performance of the top 250 ICT firms and the top 10 ones in four subsectors (communication equipment and systems, electronics and components, IT equipment and systems, IT services, software and telecommunications) (OECD, 2004b). It turns out that 139 of the top 250 firms (56%) are based in the United States and only 33 (13%) in the EU, confirming an overall weak EU amongst the world industrial leaders, notwithstanding subsectoral exceptions. So, six EU firms appear in the top 10 of telecommunication services firms, three in the top 10 of communications equipment and systems firms, two in the top 10 of electronics and components firms, and only one in the top 10 of software ones. Finally, there are no European firms among the 10 larger firms in IT equipment and systems.

On the other hand, if one focuses on a more mature industries like Machine Tool, one finds enduring leadership of a selected subset of European countries. As depicted in Table 13, both Germany and Italy outperform the US in total volumes

Table 12: Trade in High Tech Industries: Export Market Shares relative to OECD total export (excluded intra EU)

	1996	1997	1998	1999	2000	2001
	<i>Aerospace</i>					
France	0.12	0.09	0.10	0.12	0.12	0.11
Germany	0.06	0.06	0.06	0.06	0.07	0.10
Italy	0.02	0.02	0.02	0.02	0.02	0.02
UK	0.05	0.11	0.10	0.10	0.10	0.10
US	0.54	0.52	0.52	0.52	0.48	0.45
	<i>Electronic</i>					
France	0.02	0.02	0.02	0.02	0.02	0.02
Germany	0.04	0.04	0.04	0.04	0.04	0.05
Italy	0.01	0.01	0.01	0.01	0.01	0.01
UK	0.03	0.03	0.03	0.03	0.03	0.03
US	0.30	0.31	0.36	0.36	0.36	0.36
	<i>Office Machinery and Computers</i>					
France	0.01	0.02	0.01	0.01	0.01	0.01
Germany	0.03	0.03	0.04	0.04	0.03	0.03
Italy	0.01	0.01	0.01	0.01	0.01	0.01
UK	0.06	0.05	0.05	0.04	0.04	0.05
US	0.36	0.35	0.38	0.37	0.37	0.38
	<i>Pharmaceutical</i>					
France	0.05	0.05	0.04	0.05	0.05	0.06
Germany	0.13	0.15	0.16	0.15	0.13	0.13
Italy	0.05	0.04	0.04	0.04	0.05	0.04
UK	0.08	0.08	0.07	0.07	0.08	0.07
US	0.21	0.22	0.21	0.21	0.24	0.24
	<i>Instruments</i>					
France	0.03	0.03	0.03	0.03	0.02	0.03
Germany	0.10	0.10	0.10	0.09	0.08	0.09
Italy	0.02	0.02	0.02	0.02	0.02	0.02
UK	0.05	0.05	0.05	0.05	0.05	0.05
US	0.35	0.37	0.38	0.38	0.39	0.39

*Notes:* Our calculations based on STAN database. OECD countries excluding Czech Republic, Hungary, Korea. ISIC revision 3: Aerospace industry (353); Electronic industry ISIC (32); Office machinery and computer industry (30); pharmaceutical industry (2423); medical, precision and optical instruments, watches and clocks (instruments) industry (33).

Table 13: **Production in Machine Tool Industry (million of current euros)**

	1995	1996	1997	1998	1999	2000	2001	2002	2003
Germany	5,556	5,956	5,986	6,686	7,157	7,538	8,629	7,427	6,660
Italy	2,541	2,966	3,041	3,258	3,519	4,163	4,240	4,007	3,678
US	3,416	3,563	4,325	4,216	3,460	3,836	3,185	2,440	1,954
Spain	506	632	719	844	910	929	990	911	836
France	738	652	642	703	742	912	908	746	673

*Source:* UCIMU (Italian Machine Tools, Robots and Automation Manufacturers Association) elaboration on American Machinist Association data.

of production of such industry.

Moreover, as shown in Table 14, their leaderships stem from higher shares in world exports. We suggest that the above results are consistent with the points of strength that European countries have in science and technology fields which are more related with Machine Tool industry (i.e. applied physics and mechanical engineering).

Some of the above data support indeed the conjecture that, independently from the "bridges" between scientific research and industrial applications, in high technology sectors European potential corporate recipient are smaller, weaker and less receptive than transatlantic counterparts.

This is well highlighted also by those revealing cases where science is world top class, all the "transfer mechanisms" are in place but hardly any European firm is there to benefit. A striking example of this are computer sciences at Cambridge, *England*: an excellent scientific output is most exploited by *non-European* firms (from Fujitsu to Microsoft and many others).

Table 14: **Shares (%) of World Exports in Machine Tool Industry**

	2001	2003
Germany	20.67	23.52
Italy	9.50	10.05
US	5.06	4.52
Spain	2.27	2.89
France	2.78	2.53

*Source:* Our elaboration on UCIMU (Italian Machine Tools, Robots and Automation Manufacturers Association) data.

## **6 A conclusion with some modest proposals which might help European Innovative Performance**

To sum up, certainly the European picture is variegated with respect to the generation of both scientific knowledge and technological innovation. However, significant weaknesses reside in the European system of scientific research and a relatively weak European industry. The latter, we have argued, is characterized on average by comparatively lower presence in the sectors based on new technological paradigms — such as ICT and biotechnologies —, a lower propensity to innovate and a relatively weak participation to the international oligopolies in many activities.

Even if there is heterogeneity among EU countries, the same applies to US states.<sup>23</sup> Additional concerns for the European Union stem from lower labor mobility, diverse institutions, and linguistic barriers among its members. All those factors make convergence more problematic.

In turn, such a picture, calls for strong science policies and industrial policies.

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<sup>23</sup>On this point, we wish to stress that it is hard to compare indicators at the state level in the US with similar indicators for EU countries, given that the former reflects problems stemming from distinct fiscal incentives (e.g. Delaware statistics are biased by the fact that many US companies are legally incorporated in this state).

However, this is almost the opposite of what has happened. The emphasis on "usefulness" of research has led to a package of policies where EU support to basic research is basically non-existent, especially since the creation of the Framework Programmes.

*"Research proposals are expected to identify possible practical as well as scientific benefits; higher priority is being given to user involvement (including partial funding), universities are being invited to extract more revenue from licensing their intellectual property, and substantial public funds have been spent on "foresight" exercises designed to create exchange and consensus around future opportunities of applications" (Pavitt, 2001) (p.768).*

Similarly, with respect to industrial R&D, the focus on "pre-competitive" research has meant the emergence of a sort of limbo wherein firms — often in combination with academics — try to tap community money in areas that are marginal enough to not justify the investment of their own funds. Moreover, the networking frenzy has gone hand in hand with the growth in number and power of research bureaucrats (both at European and National level).

If our diagnosis is correct, this state of affairs is *bad for the research, wasteful for society and also bad for business*. Some general implications of the analysis above are the following.

First, *increase support to high quality basic science*, through agile institutions much alike the American National Science Foundation (NSF) relying on world-class peer-review and also physically located far away from Brussels. In that direction the constitution of a European Science Council is a welcome development (May, 2004).

Second, *fully acknowledge the difference within the higher education system be-*

tween (i) research-cum-graduate teaching universities, (ii) undergraduate teaching universities, and (iii) technical colleges.

The well placed emphasis of the role of the first type of institutions comes often under the heading of the "Humboldt model" as pioneered by Germany more than a century ago. However, nowadays the practice is mostly American, while Europe (especially Continental Europe) often offers in most universities a confused bland of the functions which is neither good for research nor for mass-level training.

Third, *push back the trends toward towards increasing appropriation of public research in favor of open research results.*

One often forgets that appropriability is socially justified only in so far it is an incentive to innovation itself. As we have argued above, appropriation of the output of public research does not perform that role. Of course this applies primarily to *basic* research while the picture is much more blurred for practically oriented disciplines such as engineering. Hence a lot of pragmatism is required. However, we would stand by the general point that too much of an emphasis on appropriability and IPR is likely to exert a pernicious influence on both the rates and directions of search. Moreover, it might also represent a significant hinderance to business-led innovation.

Our lag in the institutional changes leading to a much more property-based system of research as compared to the US for once might play in our favor in that it might be easier for us to stop and reverse the tendency (for a through discussion of the forgoing appropriability-related points, see Nelson (2004)).

Fourth, *build ambitious, technologically daring missions justifiable for their intrinsic social and political value.*

As Pavitt (2001) reminds us "Scandinavian countries and Switzerland are able

to mobilize considerable resources for high quality basic research without the massive defense and health expenditures of the world's only superpower": hence, he suggests, "also the larger European countries and the European Union itself, have more to learn from them than from the USA" (p.776).

Granted that, however, one should not rule out the importance of large scale far-reaching European programs with ambitious and technologically challenging objectives in the fields of e.g. energy conservation, health care, environmental protection (and perhaps also European re-armament, although there is not much agreement on it even among the authors of this work!).

Fifth, *re-discover the use of industrial policies as a device to foster a stronger, more innovative, European industry.*

We are fully aware that nowadays "industrial policy" is a bad word which cannot be mentioned in respectable company without being accused supporting Jurassic-era "national-champions", distorting competition, fostering production patterns which go against "revealed" comparative advantages, etc. We are tempted to answer "why not"?! Certainly the period — until the late seventies / early eighties — characterized by discretionary intervention of policy makers on the very structure of various industries has been characterized by many failures but also several successes. For instance, the European strength in telecommunications, the presence in semiconductors, the growing competitiveness in aircrafts, etc. are also the outcomes of the policy measures of the "interventionist" era. Today, even within the constraints of the new trade arrangements, much more, we think, can be done in order to strengthen the European presence in the most promising technological paradigms, were it not for a self-inflicted market worship (yet another commodity *largely* exported by the US, but consumed there quite parsimoniously

and pragmatically!).

Even if these modest proposals might be accused of conservatism, for once we do not mind at all be in the camp of those who try to defend and strengthen a system producing top level publicly funded open science — too often under threat by both the "property right" colonization and the "practical usefulness" advocates —, and, together, a pragmatic view of the role that public policies might have in fostering the growth of corporate actors able to efficiently tap an ever-growing pool of innovative opportunities.

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