



Is Europe Becoming the Most Dynamic Knowledge Economy in the World?

DANIELE ARCHIBUGI
Italian National Research Council

ALBERTO COCO
Italian National Research Council

Abstract

The article discusses the condition and perspective of the European Union in the knowledge economy and the feasibility of the goal given by the European Council at the summits held in Lisbon (March 2000) and Barcelona (March 2002), that is, to increase European R&D expenditure to 3 per cent of GDP by 2010. The article focuses on two aspects: comparative performance with its direct counterparts, in particular the USA; and intra-European distribution of resources and capabilities. A set of technological indicators is presented to show that Europe is still consistently behind when compared to Japan and the US, especially in R&D investment and the generation of innovations. A small convergence occurs in the diffusion of information and communication technologies (ICTs), the sector most directly linked to the concept of the 'new economy'. In the field of knowledge collaboration, Europe takes opposing paths in the business and academic worlds. Within Europe, the level of investment in scientific and technological activities is so diverse across countries that it does not merge into a single continental innovation system.

Introduction

At the Lisbon summit in March 2000, the European Council declared its intention of making the European research area (ERA) the greatest knowledge economy in the world. At the Barcelona summit in March 2002 it was stated that Europe should reach a ratio of R&D to GDP equal to 3 per cent by 2010.

© Blackwell Publishing Ltd 2005 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA



How realistic are these targets? And, how is Europe doing in the technological race five years after the first announcement of these goals?

The aim of this article is to present some evidence on the dynamics of technological change in Europe, compared to the performance of its direct competitors, the United States and Japan. It is often argued that a new cluster of innovations, information and communication technologies (ICTs), and associated productivity growth is leading us into a 'new economy' that will deliver an expansion of employment and improved standards of living (for an overview, see Temple, 2002). On the basis of the impressive performance of the US economy in the 1990s, it has often been suggested that wealthy nations will rely on their ability to adjust to these transformations, and that those countries not able to adjust will be marginalized and will lose the competitive race. The accompanying prediction indicates that Europe will have slower long-term economic growth than the US because of its insufficient adjustment to the rules of the 'new economy' (Soete, 2001; Daveri, 2002). In other words, if the old continent continues to lag behind the US and Japan in technological dynamism, this could jeopardize the achievement of the 'European dream' in domains such as welfare, public education and health care (see Rifkin, 2004); hence the need to upgrade the European knowledge base in the most aggressive way.

The idea that there is a 'new' economy is certainly fascinating, and it is hardly surprising that it has been so prominent in the business world, the political community and the press. John Maynard Keynes knew very well that expectations play a fundamental role in fostering the business cycle, and the hope that something as intriguing as a 'new' economy could be with us has helped some corporations to support their stock market prices, some politicians to be elected or re-elected, and the media to increase their sales.

The academic community is not immune from these tendencies, although its function should be to take ideas that have spread too quickly with a pinch of salt,¹ and it is no surprise that a good share of the optimism vanished with the stock market recession that began in September 2000. A dose of scepticism does not imply sharing the belief that there is nothing new under the sun: now and then something new does occur in economic and social life. Major changes have taken place in the last decade and some key components can be singled out, in particular:

1. The exploitation of knowledge has become more and more systematic, with an increasing propensity by business companies to exploit know-how in the search for profit and growth opportunities (Granstrand, 1999; Suarez-Villa, 2000).

¹ For a critical assessment of over-optimism about the new economy, see Freeman (2001).

2. The transfer across space of commodities, financial resources, expertise and information has become much easier; while technical feasibility has increased exponentially, economic costs have been dramatically reduced (Antonelli, 2001; Freeman and Louca, 2001; Held and McGrew, 1999).
3. The number of players able to enter both old and new fields has also increased, leading to an accelerated pace of economic competition (Archibugi *et al.*, 1999; Mowery and Nelson, 1999).

The combination of these three aspects has something in common with what has been labelled a 'new economy', but we have included in the definition the assumption neither that ICTs will automatically translate into steady productivity growth nor that stock market values would increase spectacularly (see Freeman, 2001). In fact, scholars who study long-term economic and social development have chosen terms such as 'knowledge-based economy', which emphasizes the role played by know-how and competencies in the economic sphere. We prefer to use the term 'globalizing learning economy' (Lundvall and Borras, 1998; Archibugi and Lundvall, 2001), since this seems to capture better the key role played by human learning in the economic and social landscape, and to connect technological innovations to the social infrastructures and competencies needed to exploit them. The term 'globalizing' (rather than 'global' or even 'globalized') should help to remind us that the vast majority of the world's population is still excluded from access to know-how that has already become obsolete in developed countries (UNDP, 2001).

Whatever term we use, we must face a new reality: long-term economic growth, employment and welfare on the old continent will be more and more associated with its capability to generate, acquire and diffuse new knowledge. It is therefore not surprising that there is a major policy concern within governments, businesses and trade unions about ways to promote scientific and technological activities, to foster innovation in firms, and to upgrade the competencies of human resources. These are seen as key conditions for increasing employment and retaining market share in an enhanced competitive world economy.

This is eloquently reflected in the so-called 'Lisbon strategy', which focuses on a wide range of topics but puts the 'knowledge economy' at the heart of its economic policy. The European Council in Lisbon (March 2000) set the strategic goal for the next decade 'to become the most dynamic and competitive knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion, and respect for the environment'. The European Council in Barcelona (March 2002) further quantified these targets and agreed that 'overall spending on R&D and in-

novation in the Union should be increased with the aim of approaching 3% of GDP by 2010. Two-thirds of this new investment should come from the private sector.²

These targets are in the right direction, but it must also be stressed that they are very ambitious (for an assessment, see Soete, 2002; Schibany and Streicher, 2003; Commission, 2003). Unfortunately, the European summits have not been sufficiently explicit about the instruments to be made available, and some basic questions remain unaddressed (for a much needed attempt to assess the Lisbon strategy, see the Kok Report, 2004). In particular, how will the private sector be induced to increase its own R&D so substantially? How should the growth in R&D be distributed between the various member countries? What role should individual governments and the European Commission institutions play?

In order to develop a proper innovation strategy, Europe must acknowledge that it is composed of a number of states which retain substantial autonomy.³ What the old continent gains in variety and diversity, it loses through a lack of cohesion and central policy decision-making. Europe is an agglomeration of different innovation systems. While some regions of the European Union are strongly integrated in knowledge transmission, others continue to be peripheral and excluded by major technology transfer flows. The recent enlargement from EU-15 to EU-25 has increased the variety of innovation systems. One of the core issues that should be addressed at both the national and European policy level, therefore, is how to integrate the different local and national components into a single innovative system comparable to that in America or Japan.

While all capitalist economies are undergoing transformations associated with the knowledge-based economy, Europe is also engaged in major institutional changes. For decades European integration was driven by a variety of common policies such as a custom unions, a common agricultural policy and, more recently, a common monetary policy. But in spite of the efforts created by the various multi-annual framework programmes since the early 1980s, European integration is not yet driven by a science and technology policy. No more than 4.6 per cent of the European Commission's total budget is devoted to research and technological development (RTD); less than 6 per cent of the total amount spent by EU governments is on RTD (Sharp, 2001). In spite of the growing amount of resources that the EU has dedicated to RTD, this is still a small portion of the budget. Science policy is one of the many fields where 'European inertia' is dominant (see Banchoff, 2002).

² All documentation on the Lisbon strategy is available at http://europa.eu.int/comm/lisbon_strategy/index_en.html.

³ Amable and Petit (2001), Maurseth and Verspagen (1999), Garcia-Fontes and Geuna (1999) and, more broadly, the chapters collected in Archibugi and Lundvall (2001) present some evidence and considerations of the absence of a proper European innovation system.



Section I presents a broad set of data describing the technological status of Europe, with regard to both investments – by means of expenditure on R&D – and to performance in innovative activities – by means of other technological indicators. We compare EU-15 and EU-25 with North America and Japan, and we highlight recent evolution. Particular attention is devoted to ICTs, since this sector is more strictly linked to the concept of the ‘new economy’, and it represents the main infrastructure of the knowledge society. Section II analyses the phenomenon of scientific and technological collaboration since it is assumed, on the one hand, that it reveals much about the ‘attractiveness’ of various regions of the world and, on the other hand, that it is a key policy asset in the design of an EU strategy. Finally, in the last section, we discuss the strategies Europe is using to achieve a more prominent role in the globalizing learning economy.

I. Which News about the European Technology Gap?

Like North America and Japan, Europe is a leading player in the generation of scientific and technological competencies. The combined R&D budget of the EU-25 is more than two-thirds that of the US, and nearly the double that of Japan. In terms of scientific articles, the output of the EU is substantially higher than that of the US, but this strongly reflects the size of the EU, which has a population much larger than the US or Japan (see Table 1). Tables 2–6 report intensities for advanced countries, and they show that there are increasing signals that Europe is losing ground in the most dynamic and technologically advanced part of the economy. The evidence presented shows the performance of EU-15 and EU-25 in comparison to the US, Japan and certain other advanced countries. The aim is to assess: the evolution over time of the three main geographical areas in the technological race; intra-European variety in technological expertise; and the occurrence of convergence or divergence within Europe.

R&D and Patents

The concern about an increasing technological gap is certainly not new: as early as the 1960s we heard about ‘the American challenge’ (Servan-Schreiber, 1968), and similar concerns were reiterated in the 1980s and in the 1990s (see, e.g., Patel and Pavitt, 1987; Archibugi and Pianta, 1992). Europe is not the only region concerned about its technological performance. Similar worries were echoed in America (Kennedy, 1988; Pianta, 1988; Nelson, 1989) and we would doubtless find comparable statements in the Far East as well. But saying that the neighbour’s grass is always greener cannot dismiss the issue



Table 1: Some Indicators of Size in the Triad, Latest Available Year

	<i>USA</i>	<i>EU-15</i>	<i>EU-25</i>	<i>Japan</i>
Population	291,044,000	379,744,000	453,900,180	127,210,000
GDP in current international US\$m PPP	10,871,090	10,130,480	11,100,791	3,582,515
Gross domestic R&D expenditure in current US\$m PPP	277,100	189,464	198,596	106,838
Scientific and technical articles	228,015	277,403	296,646	64,073
Internet users	158,891,319	134,625,097	150,798,005	57,090,350

Source: OECD Statistics, Main Science and Technology Indicators 2004-1 for gross R&D expenditure; NSF (2004) for scientific articles; Worldbank, World Development Indicators (2004) for other indicators.
Notes: PPP GDP is gross domestic product converted to international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GDP as the US dollar has in the United States. Population and GDP refer to 2003; gross domestic R&D expenditure and internet users to 2002; scientific articles to 2001.

of poor performance by the European economy in key aspects of knowledge-based production.

Table 2 reports data about R&D intensity. As regards gross R&D expenditure (GERD) as a percentage of GDP, the EU-25 intensity is equal to 1.83 per cent, substantially lower than the US (2.71) and Japan (3.11). In the second half of the 1990s Japanese R&D intensity grew more than in the US, while the intensity of the EU-15 grew very little. Within EU-25, there emerges a clear divide between north and south. The country with the highest level, Sweden, has an R&D intensity that is eight times higher than the country with the lowest, Latvia. Equally widespread gaps persist in the EU-15. The coefficient of variations has held steady, indicating that there has been no overall convergence.

A similar pattern emerges in terms of business R&D (BERD) as a percentage of the domestic product of industry (DPI), reported in the right-hand columns of Table 2. In this case, the difference between the first and the last EU-25 country is even higher: Sweden has a BERD intensity 25 times higher than Poland. Some contrasting tendencies also emerge: industrial R&D has decreased in eastern European countries such as Poland and Slovakia, while it has increased in almost all western European countries. As a consequence, the coefficient of variation has increased for EU-15 and, even more, for EU-25.

Table 3 shows the patents granted in the USA and applied for in Europe per million people. Overall, the data show a remarkable increase in the number of patents at both patent offices as a consequence of the increasing competitiveness over intellectual property rights (see Andersen, 2004). For patents

Table 2: Gross R&D Expenditure as a % of GDP by Country, 2001–02 and 1996–97, and Business Expenditure on R&D as a % of GDP, 2002 and 1998

	<i>GERD</i> (% of GDP) in 2001–02	<i>GERD</i> (% of GDP) in 1996–97	<i>Mean Annual</i> <i>Rate of Growth</i> 1996–97 to 2001–02	<i>BERD</i> (% of GDP) in 2002	<i>BERD</i> (% of GDP) in 1998	<i>Mean Annual</i> <i>Rate of Growth</i> 1998 to 2002
USA	2.71	2.57	1.1	1.87	1.94	–0.9
Japan	3.11	2.80	2.1	2.32	2.10	2.5
EU-15	1.89	1.81	0.9	1.34	1.14	4.2
EU-25	1.83	1.73	1.1	1.17	1.08	2.0
Austria	1.92	1.66	3.0	n.a.	1.13	n.a.
Belgium	1.99	1.84	1.6	1.64	1.35	5.0
Denmark	2.13	1.90	2.3	1.75	1.33	7.1
Finland	3.43	2.63	5.5	2.41	1.94	5.6
France	2.20	2.26	–0.5	1.37	1.35	0.4
Germany	2.50	2.28	1.9	1.75	1.57	2.8
Greece	0.65	0.51	5.0	0.21	0.19	5.1
Ireland	1.16	1.31	–2.4	0.80	0.90	–2.9
Italy	1.11	1.03	1.5	0.55	0.52	1.4
Netherlands	1.96	2.03	–0.7	1.03	1.05	–0.5
Portugal	0.81	0.62	5.5	0.32	0.16	18.9
Spain	0.90	0.83	1.6	0.56	0.47	4.5
Sweden	3.67	3.67	0.0	3.32	2.74	10.1
UK	1.87	1.86	0.1	1.87	1.18	12.2
Czech Rep.	1.31	1.14	2.8	n.a.	n.a.	n.a.
Estonia	0.60	0.57	1.0	n.a.	n.a.	n.a.
Hungaria	0.99	0.69	7.5	0.36	0.268.5	
Latvia	0.46	0.44	0.9	n.a.	n.a.	n.a.
Lithuania	0.56	0.61	–1.7	n.a.	n.a.	n.a.
Poland	0.64	0.71	–2.1	0.13	0.28	–17.5
Slovak Rep.	0.90	0.93	–0.7	0.37	0.52	–8.2
Slovenia	1.54	1.43	1.5	n.a.	n.a.	n.a.
Canada	1.81	1.69	1.4	1.05	1.07	–0.5
Norway	1.66	1.66	0.0	0.96	0.92	1.4
Switzerland	2.73	2.73	0.0	n.a.	n.a.	n.a.
EU-15						
Coeff. of var.	0.47	0.47		0.64	0.59	
Max/min	5.60	7.20		15.80	17.10	
EU-25						
Coeff. of var.	0.58	0.58		0.77	0.68	
Max/min	8.00	8.30		25.50	10.50	

Source: OECD Statistics, Main Science and Technology Indicators 2004-1; Worldbank (2004).

Notes: Col. 2 – Greece, Ireland, Italy, Switzerland: 2001 data only; col. 3 – Greece, Norway, Portugal and Sweden: 1997 data only; col. 5 – Greece and Sweden: refer to 2001; col. 6 – Greece, Sweden and Norway: refer to 1999. The mean annual growth rates for BERD are adjusted to the effective number of years.

Table 3: Patents Granted at the USPTO and Patents Applied at the EPO by Country, 2002–03 and 1997–98

	<i>Mean Annual Granted Patents at USPTO per m people</i>	<i>Mean Annual Granted Patents at USPTO per m people</i>	<i>Mean Annual Rate of Growth 1996–97 to 2000–01 (%)</i>	<i>Mean Annual Applied Patents at EPO per m people 2002–03</i>	<i>Mean Annual Applied Patents at EPO per m people 1997–98</i>	<i>Mean Annual Rate of Growth 1996–97 2000–01 (%)</i>
USA	301	260	3.0	107	80	5.9
Japan	277	214	5.3	135	106	5.1
EU-15	71	54	5.6	136	96	7.3
EU-25	59	45	5.7	114	80	7.4
Austria	70	48	7.8	120	88	6.4
Belgium	65	59	1.9	131	94	6.8
Denmark	89	68	5.3	153	105	7.8
Finland	161	102	9.6	297	155	13.8
France	66	57	3.1	120	92	5.4
Germany	138	98	7.0	265	183	7.7
Greece	2	1	8.1	5	3	9.0
Ireland	38	20	13.8	65	41	9.6
Italy	30	25	4.2	61	46	5.6
Luxembourg	81	49	10.3	350	239	7.9
Netherlands	84	65	5.3	356	217	10.4
Portugal	1	1	3.6	3	2	12.1
Spain	7	5	6.9	16	10	9.0
Sweden	179	118	8.6	287	181	9.7
UK	63	52	3.7	81	68	3.5
Cyprus	1	1	-0.6	29	17	11.4
Czech Rep.	4	1	21.9	5	2	16.8
Estonia	3	0	48.4	3	2	3.7
Hungary	6	4	9.8	6	3	13.1
Latvia	1	0	33.1	0	0	9.1
Malta	5	3	14.1	28	8	28.7
Poland	0	0	1.7	1	0	22.1
Slovak Rep.	1	0	22.9	2	1	13.1
Slovenia	9	6	6.6	19	10	14.5
Canada	109	77	7.3	42	21	14.7
Norway	55	32	11.7	70	46	8.7
Switzerland	183	155	3.3	504	352	7.4
EU-15						
Coeff. of var.	0.73	0.69		0.78	0.74	
Max/min	158.30	124.90		103.50	123.20	
EU-25						
Coeff. of var.	1.20	1.16		1.22	1.20	
Max/min	487.90	574.40		821.00	853.00	

Source: Authors' elaboration from US Patent and Trademark Office and European Patent Office data.

Table 4: Scientific and Technical Articles by Country, 2000–01 and 1995–96

	<i>No. of Scientific Publications in 2000–01 per m People</i>	<i>No. of Scientific Publications in 1995–96 per m People</i>	<i>Mean Annual Rate of Growth 1995–96 to 2000–01 (%)</i>
USA	700	759	-1.6
Japan	444	390	2.6
EU-15	556	510	1.7
EU-25	493	448	1.9
Austria	548	446	4.2
Belgium	571	534	1.3
Denmark	927	847	1.8
Finland	963	829	3.0
France	527	510	0.7
Germany	529	472	2.3
Greece	294	207	7.3
Ireland	425	343	4.4
Italy	376	325	2.9
Luxembourg	81	58	6.8
Netherlands	784	800	-0.4
Portugal	195	104	13.3
Spain	374	300	4.5
Sweden	1.133	1.074	1.1
UK	824	805	0.5
Cyprus	88	65	6.4
Czech Republic	248	205	3.8
Estonia	250	171	7.9
Hungary	236	179	5.6
Latvia	67	64	0.8
Lithuania	76	52	8.1
Malta	76	42	12.6
Poland	143	118	3.8
Slovak Republic	182	215	-3.3
Slovenia	448	231	14.1
Canada	736	832	-2.4
Norway	716	675	1.2
Switzerland	1.149	1.052	1.8
EU-15			
Coeff. of variation	0.51	0.57	
Max/min	14.0	18.5	
EU-25			
Coeff. of variation	0.73	0.82	
Max/min	17.0	25.4	

Source: ?

Table 5: ICT Expenditure on GDP, 2001–02 and 1996–97

	<i>ICT Expenditure (% of GDP) 2001–02</i>	<i>ICT Expenditure (% of GDP) 1996–97</i>	<i>Mean Annual Rate of Growth (%) 1996–97 to 2001–02</i>
USA	7.2	7.7	-1.7
Japan	7.5	6.9	2.2
EU-15	6.5	5.7	3.4
EU-25	6.5	5.6	4.1
Austria	6.2	5.0	6.0
Belgium	6.8	6.0	3.5
Denmark	7.5	6.6	3.3
Finland	6.7	6.0	3.2
France	7.1	6.3	3.4
Germany	6.5	5.4	4.9
Greece	5.5	4.0	8.1
Ireland	5.1	5.6	-2.3
Italy	5.0	4.2	4.7
Netherlands	7.2	6.8	1.5
Portugal	6.1	4.9	6.0
Spain	4.8	4.0	5.0
Sweden	8.9	7.7	3.7
UK	7.9	7.7	0.7
Czech Republic	8.4	5.9	9.1
Hungary	7.7	4.4	14.9
Poland	5.6	2.5	22.7
Slovak Republic	6.6	4.0	13.8
Slovenia	4.8	3.3	10.2
Canada	7.3	7.4	-0.2
Norway	5.6	5.7	-0.3
Switzerland	8.2	7.6	1.8
EU-15			
Coeff. of variation	0.17	0.21	
Max/min	1.86	1.95	
EU-25			
Coeff. of variation	0.18	0.27	
Max/min	1.86	3.14	

Source: Worldbank, World Development Indicators 2004 (data from ITU).

Table 6: Internet Users (% of Population) by Country, 2002 and 1997

	<i>Internet Penetration 2002 (%)</i>	<i>Internet Penetration 1997 (%)</i>	<i>Mean Annual Rate of Growth 1997–2002 (%)</i>
USA	55.1	22.1	20
Japan	44.9	9.2	37
EU-15	35.5	6.1	42
EU-25	33.3	5.5	44
Austria	40.9	9.4	34
Belgium	32.8	4.9	46
Denmark	51.3	11.4	35
Finland	50.9	19.4	21
France	31.4	4.3	49
Germany	41.2	6.7	44
Greece	15.5	1.9	52
Ireland	27.1	4.1	46
Italy	35.2	2.3	73
Luxembourg	37.0	7.1	39
Netherlands	50.6	14.1	29
Portugal	19.4	5.0	31
Spain	15.6	2.8	41
Sweden	57.3	23.7	19
UK	42.3	7.3	42
Cyprus	29.4	5.1	42
Czech Republic	25.6	2.9	55
Estonia	32.8	5.5	43
Hungary	15.8	2.0	51
Latvia	13.3	2.0	46
Lithuania	14.4	0.9	74
Malta	20.9	4.0	39
Poland	23.0	2.1	61
Slovak Republic	16.0	1.9	53
Slovenia	37.6	7.6	38
Canada	51.3	15.5	27
Norway	50.3	29.4	11
Switzerland	35.1	7.7	35
EU-15			
Coeff. of variation	0.35	0.75	
Max/min	3.70	12.47	
EU-25			
Coeff. of variation	0.42	0.87	
Max/min	4.31	26.33	

Source: Worldbank, World Development Indicators 2004 (data from ITU).

granted at the US Patent Trademark Office (USPTO), the high ratio reflects the fact that inventors and firms are patenting in their own domestic market but, for Japan and European countries, it is reasonable to assume that they have a comparable propensity to patent in the US, since for both of them the US is an economically crucial market. It emerges that Japan has a ratio more than four times higher than the EU-25 average. Not even the European countries with the highest propensity to patent, Switzerland and Sweden, have the same intensity as Japan. Many European countries, in both the east and the south, report no or negligible patent activity in the US. The dispersion within the EU is extraordinarily high. It is difficult to find other aspects of economic and social life where the distance between the top and the bottom European countries is so wide (on regional variations in the European systems of innovations, see Chesnais *et al.*, 2000; Cantwell and Iammarino, 2001).

Patents granted in the US are complemented by patent applications at the European Patent Office (EPO). Even in the European market, Japan has a patent propensity above the average of the members of the EU (respectively, 135 and 114 patents per million people), and the US is also close to the EU average (107 patents per million people). The higher growth rates in patent applications at the EPO for both EU-15 and EU-25 show that the construction of the European market is underway, but with remarkable regional variations. Eastern and southern countries do not yet seem to participate in the generation of commercially exploitable innovations. This is hardly surprising in the light of the very low business R&D performed. In southern countries such as Spain, Portugal and Greece, business R&D seems to be limited mostly to imitation and learning.

While patents reflect inventive and innovative activities that are proprietary in nature and developed mainly for commercial purposes, scientific literature informs mainly about the activities of the academic community. However, scientific literature has become more and more relevant for high-technology industries in the last few decades, and it is an important source of industrial competitiveness (see Tijssen, 2001). Table 4 reports the number of scientific and technical articles published in the sample of journals monitored by the Science Citation Index of the Institute for Scientific Information. It is often said that the Science Citation Index is biased in favour of the English-speaking academic community, and this is probably true, but many top-ranking countries are not-English speaking. In this aspect of science and technology (S&T) activity, the gap between Europe and the US is smaller. In terms of intensity, the EU-25 average is below the US (respectively, 493 and 700 articles per million people) and above Japan (444 articles per million people), but EU-25 scientific production has grown in recent years, while US scientific production has declined.

Within EU-25, the ratio between the highest (Sweden) and the lowest (Latvia) country is almost 17 to 1: the European dispersion in indicators of academic activities (mainly funded with public money) is substantially lower than for technological activities (mainly funded by business companies). Over time a limited convergence has occurred at both the EU-15 and EU-25 levels. This improved European performance in the area of academic activity reflects the satisfactory overall level of human resources, confirmed by the proportion of graduate or PhD students in science and technology (Commission, 2003).

Unfortunately, as shown by the *Third European Report on Science and Technology Indicators* (Commission, 2003), Europe does not easily succeed in turning this rich variety of human resources into an adequate proportion of researchers in the workforce, especially in the business world. Many talents nurtured in Europe with taxpayers' resources do not find adequate jobs on the continent, and often find it convenient to move to the other side of the Atlantic.

Summing up, what does this battery of indicators tell us?

- First, the evidence has allowed us to quantify how Europe is lagging behind the other two major areas, in both investment and performance in technology. In total R&D investment, the gap between Europe and Japan is even increasing, and that with the US is not reducing. This is a particularly worrying signal since R&D is one of the main inputs for the generation of knowledge and therefore an engine of long-term economic and social growth.
- Second, the gap is more evident in business-related indicators than in publicly funded research. The indicators of technological activities, such as business R&D and patents, provide weak signs of catching up. In scientific publications Europe is reducing the gap with the US. Other indicators on human resources (Commission, 2003) confirm the impression of potentially good intellectual capital in the EU that does not translate into more researchers in the workforce, especially in the industrial sector.
- Third, there are huge differences between European countries. In almost all the indicators taken into account, a group of small and medium-sized countries, such as Switzerland, Sweden, Norway, Finland, the Netherlands and Denmark, show performance that is on a par with or even higher than the US and Japan. Switzerland and Norway are not members of the EU, and the others are rather small to be able to raise the EU average.
- Fourth, it is evident that the integration of ten new member countries (plus the former East Germany (DDR)) has just begun and that these countries are at a very different overall technological level from the

EU-15 group. Eastern countries such as Slovenia, the Czech Republic, Estonia and Hungary are on a par with and sometimes even above southern European countries such as Italy, Spain, Portugal and Greece, but the overall European area at the periphery of scientific and technological advance, limited up till now to southern Europe and Ireland, has now become larger. Growth rates in the ten new countries have, on average, been slightly higher than the EU-15 but, overall, the low-tech area of the EU has considerably increased.

Challenges for Europe in ICT

We turn our attention to the ICT sector, the most closely associated with the new economy (Daveri, 2002). Here Europe, despite originally lagging behind in comparison to the US and Japan (see Gambardella and Malerba, 1999; Fagerberg *et al.*, 1999; Vivarelli and Pianta, 2000), is slowly catching up. Table 5 shows that the US and Japan, respectively, invest 7.2 per cent and 7.5 per cent of their GDP in ICT while EU-25 invests 6.5, but in the second half of the 1990s EU-25 continued to grow at an annual rate of 4.1 per cent, higher than Japan (2.2 per cent) and in the opposite direction from the US, which experienced a decline (-1.7 per cent). Within the EU, a mild but significant convergence has occurred between the 15 and the 25 countries. The eastern European countries for which data are available show an even greater growth rate. Consequently, EU-25 dispersion has been substantially reduced.

If we consider the composition of the ICT sector, while the 1980s saw the dramatic rise of Japan and other East Asian economies in hardware technologies (for an overview, see Freeman, 1987; Mathews, 2000), in the 1990s the US managed to recover its traditional economic leadership in knowledge-intensive industries by exploiting and disseminating ICT in the service sector. Within the triad, Japan and the other East Asian economies continue to have a prominent position in the generation of the 'hardware' component, while the US has a dominant position in the 'software' field. Europe has neither. It should, however, be noted that Europe has recently increased expenditure in the software area, following a general trend towards so-called 'weightlessness', that is, the increase of the share of soft components in ICT (Daveri, 2002; European Informative Telecommunications Observatory, 2001).

One indicator of the diffusion of technology complements these data: internet penetration. In fact, ICT is important not only for the highest gain in productivity it directly creates, but because, thanks to its diffusion, it enables other sectors to increase their productivity also; in other words it entails positive externalities. Besides, while both R&D and patent-based indicators capture the technological activities developed in the manufacturing industry, internet use is an indicator that provides information on both the manufacturing and the



service components of the economy. Table 6 shows that the penetration in the US and Japan is much higher than in the EU. Although the EU is catching up, it is still at levels below its counterparts. In Europe, however, the Nordic countries have a higher penetration than the US. The ratio between the country with the highest (Sweden) and the lowest (Latvia) penetration is more than 4 to 1. Not surprisingly, the trend shows a marked convergence between EU countries, with eastern European countries catching up. An indispensable infrastructure for the diffusion of knowledge like the internet is essential for eastern European countries to acquire technical expertise from the core countries. Summing up, in ICT Europe lags behind the US and Japan, but is reducing the gap.

II. International Technological and Scientific Collaboration

The section above has shown that intra-European variety in knowledge is very high, and some consistently developed regions are counterbalanced by others that are unable to generate the technological innovations that they use. It therefore becomes crucial to identify the channels that allow the dissemination of technical expertise across the continent. One of them is represented by collaboration between economic agents located in different regions.

In the last decade, a new source of knowledge has become progressively more important: technological collaboration between firms. While the academic community has always had a tendency to share its knowledge with other partners, it was assumed that corporations were much more reluctant to share their know-how with potential competitors. The need to split the costs and risks of technological development, along with the need to acquire the expertise of other partners, has acted as a strong motivation to undertake strategic technology agreements. These are defined as: partnerships that involve a two-way relationship; tend to be contractual in nature with no or little equity involvement by the participants; and are strategic in the sense that they are long-term planned activity (Mytelka, 2001, p. 129).

Strategic technology agreements are not only a source of knowledge; they also inform where companies seek expertise. Some evidence of the available statistics on inter-firm technological collaboration is reported in Table 7, based on the database developed by John Hagedoorn and his colleagues (see Hagedoorn, 1996; National Science Foundation, 2002). As many as 60 per cent of the total strategic technology alliances recorded are international in scope. This form of generating technological knowledge has increased considerably in significance, and the number of recorded agreements nearly tripled between 1980–82 and 1998–2000.

The largest and most increasing number of alliances take place within the US: 45.8 per cent of all the strategic technological alliances recorded in



Table 7: Distribution of Strategic Technology Alliances Between and Within Economic Blocs, 1980–2000

	1980–82		1989–91		1998–2000	
	No.	%	No.	%	No.	%
Interregional Alliances						
Eur–Jap	16	7.9	25	6.2	19	3.5
Eur–USA	48	23.6	101	25.0	173	31.9
Jap–USA	43	21.2	57	14.1	38	7.0
Subtotal	107		183		230	
Intraregional Alliances						
Europe	37	18.2	74	18.3	53	9.8
Japan	9	4.4	7	1.7	11	2.0
USA	50	24.6	140	34.7	248	45.8
Subtotal	96		221		312	
Total	203		404		542	

Source: Authors' elaboration from National Science Foundation (2002).

1998–2000 occurred between American firms only, against 24.6 per cent in the 1980–82 period (NSF, 2002). Moreover, US firms have strong ties on both the Atlantic and the Pacific shores: in the 1998–2000 period, US companies participated in as many as 84.7 per cent of the recorded technology alliances. On the contrary, the share of intra-European strategic technological alliances has substantially declined: they accounted for 18.2 per cent in 1980–82, and less than 10 per cent in 1998–2000. They have even decreased in absolute terms in the last decade (from 74 in 1989–91 to 53 in 1998–2000).

European policy-makers should be concerned by the strong propensity of European firms for American, rather than European, partnerships. It is not necessarily a bad thing that European firms have agreements with American firms, but it is certainly worrying that there are so few intra-European agreements. Policies carried out at the European level, especially at European Commission level, to foster co-operation in R&D and innovation on the continent, have not been able to push for the greater cohesion of European industry (Narula, 1999). The first possible explanation would be that the total amount of resources devoted to science and technology is much greater in US firms and that, obviously, firms engage in technology alliances with partners who have adequate expertise. The greater flow of alliances in the US would therefore simply be the outcome of the amount of investment in knowledge by US companies. In order to control for this factor, we divided the number of European alliances undertaken by the total amount of, respectively, European, US and Japanese

Table 8: Propensities for Strategic Technical Partnerships, 1980–2000

Propensity of European Firms for European, US and Japanese Technological Partners

No. of Agreements Involving European Firms by BERD of the Region (in US\$ bn at Constant \$ PPP)

<i>Period</i>	<i>Europe</i>	<i>USA</i>	<i>Japan</i>
1980–82	0.80	0.61	0.71
1989–91	1.03	0.86	0.50
1998–00	0.62	1.07	0.32

Propensity of US Firms for European, US and Japanese Technological Partners

No. of Agreements Involving US Firms by BERD of the Region (in US\$ bn at Constant Dollars PPP)

<i>Period</i>	<i>Europe</i>	<i>USA</i>	<i>Japan</i>
1980–82	1.03	0.64	1.90
1989–91	1.41	1.20	1.15
1998–00	2.03	1.54	0.65

Source: Our elaboration from NSF (2002) (data from MERIT database) and from OECD Statistics, Main Science and Technology Indicators 2001–02.

Notes: The number of strategic technological agreements recorded by the MERIT database have been divided by the Business Expenditure on R&D of the region expressed in constant 1992 purchasing power parity US\$ bn. It indicates, for example, that in 1980–82 there were 0.8 strategic technology agreements involving European firms for each US\$ bn of European BERD.

business enterprises' R&D expenditure (BERD). This provides an indicator of the propensity of European companies towards collaboration in each of these regions. The results are reported in Table 8.

Although the attractiveness of the US economy proves to be a bit smaller in relative terms, European companies' greater propensity for American partnerships is confirmed. There are 1.07 European–US partnerships for each billion \$US BERD, while the equivalent figure for intra-European partnerships is just 0.62. Moreover, the European business community has considerably changed its propensity for partnership over the last ten years: in the 1980–82 and 1989–91 periods, European companies had a larger propensity for European than American partners. The figures were, respectively, 0.80 and 0.61 agreements for each billion \$US BERD in 1980–82, and 1.03 and 0.86 in 1989–91. The lower part of Table 8 reports the propensity of American companies to undertake alliances. US companies are now keener to embark on joint ventures with European partners, and this is a result of the overall increase of their engagement in collaborations, but internal partnerships continue to be relevant. If

the new economy is represented – among other things – by strategic technology partnerships, the evidence suggests that this strongly leans towards the US rather than towards Europe or Japan.

Partnerships and collaborations promoted by public research institutions and universities play an equally crucial role in the international dissemination of knowledge. They can take a variety of forms: joint research centres, the exchange of students and academic staff, or sharing scientific information. One of the ways to measure this is by looking at internationally co-authored scientific papers. A dramatic increase in internationally co-authored papers – also facilitated by the diffusion of the internet and email communication – is evident in all countries (Table 9). From 1986 to 2001, the percentage of internationally co-authored papers has doubled in the majority of countries, and this represents a clear signal of globalization in the generation of knowledge. European countries are individually keener to collaborate than the US and Japan. This is not surprising, given the smaller size of the scientific community in each country. From a dynamic viewpoint, the rate of increase has been higher in the USA and Japan than in European countries, but this is due to the fact that growth in national scientific articles in the USA has declined (see Table 4 above, and NSF 2002, Table 5.41). These data clearly show that the academic community in Europe is a valuable asset for the acquisition of knowledge and expertise beyond the borders of countries. Eastern European countries, which in 1986 had limited access to collaboration outside their bloc, have started to undertake joint programmes: in 2001, more than half of the scientific papers generated in eastern Europe were the result of international collaboration, with an internationalization that is equal to, and sometimes even greater than, western European countries of the same size.

Does the academic community also share the same preference as European firms have for American rather than European partners? Table 10 reports the distribution of internationally co-authored collaborations in the Triad.⁴ EU-15 is by far the greatest collaborator for the American academic community. In 1995–97 as much as 60.3 per cent of US internationally co-authored papers involved an EU-15 partner. Also Europeans have a strong propensity to collaborate with each other. This fact could be misleading, since a paper co-authored by a Dutch and a Belgian is classified as ‘international’, while a paper co-authored by a Californian and a New Yorker is classified as national. But what is significant in these data is the evolution over time (and this is not affected by the different size of the countries): by comparing the first period (1986–88) to the last (1995–97), it emerges that intra-EU collaborations are increasing in proportion (from 56.6 to 69.4 per cent of all internationally co-authored papers), while EU–US collaborations are decreasing for the EU as a whole (from 31.9

⁴ Unfortunately, we have no up-to-date data for the EU-25 at this level of disaggregation.

Table 9: % of Internationally Co-authored Scientific Papers in Selected Countries in all Scientific papers, 1986, 1994, and 2001

	% Internationally Co-authored		Annual Growth Rate (%)		
	in 2001	in 1994	in 1986	1994–2001	1986–1994
USA	23.2	15.8	9.2	5.6	7.0
Japan	19.7	13.7	7.5	5.3	7.8
Austria	50.8	39.9	25.2	3.5	5.9
Belgium	53.6	43.6	29.9	3.0	4.8
Denmark	50.6	39.8	24.4	3.5	6.3
Finland	42.9	32.4	18.7	4.1	7.1
France	43.3	32.5	21.0	4.2	5.6
Germany	41.7	30.6	20.1	4.5	5.4
Greece	41.5	37.4	26.6	1.5	4.3
Ireland	46.7	36.8	26.7	3.5	4.1
Italy	39.7	32.7	22.9	2.8	4.6
Netherlands	44.9	32.0	19.8	5.0	6.2
Portugal	53.0	46.1	34.8	2.0	3.6
Spain	37.9	29.1	17.0	3.8	7.0
Sweden	46.3	36.2	22.2	3.6	6.3
UK	36.9	25.1	15.7	5.7	6.0
Cyprus	66.9	71.7	14.3	-1.0	22.3
Czech Republic	51.6	42.9	17.2	2.7	12.1
Estonia	55.3	51.4	3.4	1.1	40.4
Hungary	54.8	48.7	29.0	1.7	6.7
Latvia	59.8	55.7	3.4	1.0	41.8
Lithuania	60.5	46.4	3.4	3.9	38.6
Poland	48.1	43.6	21.4	1.4	9.3
Slovak Republic	56.3	34.4	17.2	7.3	9.1
Slovenia	44.3	38.8	30.4	1.9	3.1
Canada	38.4	28.3	18.9	4.5	5.2
Norway	46.9	36.9	21.9	3.5	6.8
Switzerland	53.5	44.5	32.2	2.7	4.1

Source: Our elaboration from NSF (2004) (data from ISI).

Notes: National rates are based on total counts: each collaborating country is assigned one paper (a paper with three international co-authors may contribute to the international co-authorship of three countries). We could not calculate the EU total, as it would contain multiple counting. Since in 1986 they were not yet created, we attributed to Estonia, Latvia and Lithuania the percentage of the USSR, as well as attributing to the Czech Republic and the Slovak Republic the data of Czechoslovakia and to Slovenia the percentage of Yugoslavia.

Table 10: Distribution of Internationally Co-authored Papers across Collaborating Countries, 1986–88 and 1995–97

Country	1995–97			1986–88		
	USA	Japan	EU-15	USA	Japan	EU-15
USA	9.6		60.3		8.2	54.9
Japan	45.6		39.4	54.0		33.3
EU-15	29.0	4.5	69.4	31.9	3.1	56.6

Source: Authors' elaboration from NSF (2000), data from ISI.

Notes: Rows report the percentage of the total number of international co-authorships of the country. Columns indicate the relative prominence of a country in the portfolio of internationally co-authored articles of every country. Row percentages may add to more than 100 because articles are counted in each contributing country and some may have authors in three or more countries. As regards the EU, internationally co-authored articles also include those between member countries.

to 29.0 per cent) as well as for each EU-15 member country. Looking at the data from an American perspective, the above tendency is enhanced: the share of intra-US articles in all US co-authored articles declines from 78 to 68 per cent, while co-authorship with authors based in the EU-15 has grown from 11 to 19 per cent (National Science Foundation, 2000, Table 6.51).

We therefore note an inverse tendency: the European business community has an increasing propensity for technological alliances with US firms, while the European academic community has an increasing propensity for intra-European partnership. One of the main policies used by the European Commission in the last decade, through the instrument of the framework programmes, has been to promote collaborations between European institutions and firms. The data reported suggest that these policies have been much more successful in creating a European research area (ERA) in academia than in business. The limited resources the European Commission disposes of (about €4,000 million a year in the last approved sixth framework programme) have not been enough to meet the needs of European industry, while they have proved to be more effective as regards training and the promotion of researchers' mobility.

There is a third important form of collaboration, which is between enterprises on one side, and universities on the other. The advantage of this kind of co-operation is that it allows a quick conversion of scientific knowledge into commercial applications with a direct and immediate economic return. One way to measure it is by looking at the share of university R&D financed by industry. The EU shows a little progress, but it still lags behind the US and Japan in the overall resources for financing R&D expenditure of universities (Commission, 2003; Garcia-Fontes and Geuna, 1999).



III. A Single Europe for Science and Technology?

The evidence confirms that, in some vital areas of knowledge and competence-building, Europe is lagging behind. Contrary to what happened for many periods since the end of the Second World War, in the 1990s the gap between Europe and the US grew larger. In recent years, the gap between Europe and Japan has increased even more. While Europe is catching up in the diffusion of ICTs, its distance from the United States and Japan in terms of the generation of business innovation continues to be steady. It is therefore understandable that a major policy concern in Europe is identifying the strategies that would allow catching up and upgrading its scientific and technological competence.

In addressing a European strategy for innovation, it should be remembered that the continent has vast regional disparities, and that they are much wider in terms of scientific and technological competencies than in other aspects of economic life such as income, production or consumption. In the last 15 years, Europe underwent major political changes that also affected its science and technology capabilities. Germany, which for a long time was the technological engine of Europe, has had to face a major regional problem: the integration of the east. The UK, heart of many centres of scientific excellence and the European country with the highest number of Nobel laureates, has underfunded its universities for over 20 years.⁵ The 1995 enlargement integrated into the EU three small and highly dynamic countries, Sweden, Finland and Austria, but the 2004 enlargement brought ten countries with no such sophisticated dowry of scientific and technological infrastructures. The scientific community in eastern Europe suffered hardship for many years, and the transition to capitalist economies has been particularly tough, given the academic competencies developed during the socialist regimes. Overall, EU-25 has a larger population and an expanded market, but more vulnerable scientific and technological capabilities and a reduced R&D intensity. The peripheral areas, once confined to southern Italy, Spain, Portugal and Greece, have now been extended to the east.

The enormous differences between European member countries make it clear that fully exploiting the advantages of knowledge is crucial to developing strategies for the transmission and diffusion of competencies across areas. Only by reducing regional disparities will it be possible to obtain overall European scientific and technological competence comparable to those of the US and Japan. A stronger integration between national policies, as well as between the academic and the business communities, is needed, which in turn requires major changes in the institutional setting and in the incentives existing in publicly funded research centres.

⁵ In the second half of the 1990s, UK expenditure on tertiary education was stagnant and, in 1999, UK expenditure on tertiary education as a percentage of GDP was lower than the EU-15 average and half that of the US (see Commission, 2003, pp. 217–18).



We have seen that in Lisbon, European governments committed themselves to transforming Europe into the most competitive and dynamic knowledge-based economy in the world, and that in Barcelona they set a more ambitious target of raising R&D expenditure up to 3 per cent of GDP by 2010. At the same time, the business sector has been asked to contribute most of this effort which, by 2010, should finance two-thirds of the total R&D expenditure (while in 2002 business-financed R&D in the EU-25 was just 55.4 per cent (see OECD, 2004).

It is self-evident that there is considerable divergence between the announcement of the political target and the instruments made available. Too little commitment has been made to reach such an ambitious target, and it is strange that governments (which have direct control of public expenditure) put the largest burden on to the business community. The aim of 3 per cent in the R&D/GDP ratio, moreover, appears very difficult to achieve without a major commitment on the part of all the main economic players (national governments, the European business community and EU institutions). For example, it implies an increase in research personnel of the magnitude of about 100,000 people a year, which seems difficult to realize within the current EU qualified workforce (Schibany and Streicher, 2003). The Kok Report (2004) has recently attempted a much-needed assessment of the targets set in Lisbon and Barcelona. The report, on the basis of the recent evolution of the world economy, has urged national governments to increase their commitments, but there has been a significant shift: fulfilling the Lisbon and Barcelona targets are now seen as 'desirable' rather than 'achievable'.

Each country makes its own attempt to upgrade its scientific and technological potential, and certainly the achievements of any one are more likely to generate externalities that can be beneficial for the whole European Union. The evidence reported in this article clearly indicates that a small club of European countries has a scientific and technological intensity on a par with, and often superior to, that of the US. The Scandinavian countries have followed a distinctive approach to competence-building based on: firstly, a highly competent and qualified labour force, generated through massive investments in education and training; secondly, a specialization in high-tech industries, through R&D investments in ICT, biotechnology and electronics; and, thirdly, close collaboration between the business sector on the one hand, and government and the academia on the other (Commission, 2003). This model should inspire European policy-making much more than the American one, which is based on firms competing for market share and public procurement, and R&D public investment concentrated in national priorities such as defence and space.

There is also much to learn from the policies of individual nations. A small country like Ireland is managing to improve its technological potential by



making the country attractive for multinational corporations, and is slowly moving out of the group of R&D-laggard countries. This is not the first time that European governments have preferred to follow an autonomous route in catching up, and when this has happened the EU as a whole has received indirect benefits. European nations are so linked to each other that science and technology outcomes and policies are bound to a common European faith.

The most direct national route to achieving the Lisbon and Barcelona targets will be to increase governments' financial commitments, but this conflicts, among other things, with the Maastricht parameters on public expenditure. Indirect measures include tax incentives to industry, but it is doubtful what 'leverage' effect they will display. A greater effort from the private sector is surely necessary, as is also demonstrated by the low level of venture capital financing in Europe in comparison to the US and Japan (Commission, 2003). This form of financing is particularly significant for the promotion of innovative activities by small firms (the so-called start-ups).

With regard to policies that can be directed from Brussels, there is an apparent trade-off between the use of resources for the diffusion of knowledge in the peripheral parts of the continental economy (widening) or for generating new knowledge in the core countries (deepening). The various framework programmes (FPs) have partially managed to overcome this trade-off, however. Through the FPs, the European Commission progressively revises and enlarges the areas of intervention enhancing intra-European co-operation in the so-called pre-competitive research fields. This may serve the twin objectives of encouraging learning in the peripheral areas and advancing knowledge in the core areas.⁶

In the last approved sixth FP, the greatest amount of resources has been dedicated to information society technology and nano-technologies (€4,925 million for the next four years). The strategic importance of this sector has been recognized, not only for the new jobs and business that 3G wireless communication systems, software architecture and opto-electronics networks can create, but also because it perfectly meets the requirement of 'ambient intelligence', that is, the target of linking economic growth and welfare. The other 'priority' research areas – biotechnology, environment and energy – are devoted to the same aim.

While these actions are admirable, it is also true that the European Commission's instruments are too limited. The ambitious targets will require a much

⁶ The meaning and effectiveness of pre-competitive research have long been debated (Geuna, 2001). Financing research in one firm or one country could imply awarding advantage to some organizations and disadvantaging others, thus infringing EU competition policy. But in the field of science and technology, the outcomes are likely to provide benefits to stake-holders larger than those receiving the funding. In fact, the European Commission funding schemes generally require the involvement of firms and institutions from several member countries.



larger commitment of national resources in terms of the funding of existing centres of excellence (especially when they have been kept under severe financial restriction), to generate the human resources needed for both the public and business institutions, to start up new problem-oriented institutions. Regulation, standards, procurement, competition, real services and large-scale co-operative civilian projects, in addition to the (limited) financial instruments (Lundvall, 2001), are essential ingredients in the creation of a European research area.

It is evident that successful management of the learning economy will require a much higher political commitment that should be comparable to the efforts European governments have devoted to creating a single currency. Lundvall (2001) has suggested establishing a 'European High Level Council on Innovation and Competence Building' chaired by the President of the EU and with at least as much political weight as the European Central Bank. This will be a clear sign in Europe that there is a political commitment to becoming 'the most competitive and dynamic knowledge-based economy in the world' in a decade. But words without facts will only allow us to observe at the end of the decade that the aim of R&D at 3 per cent of GDP has not been reached and that the European technology gap has further increased.

Correspondence:

Daniele Archibugi
 Italian National Research Council
 Via dei Taurini, 19
 00185 Rome, Italy
 Tel: (+39) 06 4993 7838
 email: daniele.archibugi@cedrc.cnr.it

References

- Amable, B. and Petit, P. (2001) *The Diversity of Social Systems of Innovation and Production during the 1990s* (Paris: Cepremap).
- Andersen, B. (2004) 'If "Intellectual Property Rights" is the Answer, What is the Question? Revisiting the Patent Controversies'. *Economics of Innovation and New Technology*, Vol. 13, No. 5, pp. 417–42.
- Antonelli, C. (2001) *The Microeconomics of Technological Systems* (Oxford: Oxford University Press).
- Archibugi, D. and Lundvall, B.-Å. (eds.) (2001) *The Globalising Learning Economy* (Oxford: Oxford University Press).
- Archibugi, D. and Pianta, M. (1992) *The Technological Specialization of Advanced Countries. A Report to the EEC on International Science and Technology Activities* (Boston: Kluwer).

- Archibugi, D., Howells, J. and Michie, J. (eds) (1999) *Innovation Systems in the Global Economy* (Cambridge: Cambridge University Press).
- Banchoff, T. (2002) 'Institutions, Inertia and European Union Research'. *Journal of Common Market Studies*, Vol. 40, No. 1, pp. 1–21.
- Cantwell, J.A. and Iammarino, S. (2001) *Multinational Enterprises and Regional Systems of Innovation in Europe* (London: Routledge).
- Chesnais, F., Ietto-Gillies, G. and Simonetti, R. (eds) (2000) *European Integration and Global Corporate Strategies* (London: Routledge).
- Commission of the European Communities (2003) *Third European Report on Science and Technology Indicators 2003* (Luxembourg: CEC).
- Commission of the European Communities (2002) *Sixth Framework Programme (2002–2006)*. Available at «www.cordis.lu».
- Daveri, F. (2002) 'The New Economy in Europe, 1992–2001'. *Oxford Review of Economic Policy*, Vol. 18, No. 3, pp. 345–62.
- European Informative Telecommunications Observatory (EITO) (2001) *Yearbook 2001*, Frankfurt. Also available at «www.eito.com».
- European Patent Office (EPO) (various years). *Annual Report*, from 1995 to 2003. Also available at «www.european-patent-office.org».
- Fagerberg, J., Guerrieri, P. and Verspagen, B. (eds) (1999) *The Economic Challenge for Europe: Adapting to Innovation-based Growth* (Aldershot: Edward Elgar).
- Freeman, C. (1987) *Technology Policy and Economic Performance. Lessons from Japan* (London: Pinter).
- Freeman, C. (2001) 'A Hard Landing for the "New Economy"? Information Technology and the United States National System of Innovation'. *Structural Change and Economic Dynamics*, Vol. 12, No. 2, pp. 115–39.
- Freeman, C. and Louca, F. (2001) *As Time Goes by: From the Industrial Revolutions to the Information Revolution* (Oxford: Oxford University Press).
- Gambardella, A. and Malerba, F. (eds) (1999) *The Organization of Economic Innovation in Europe* (Cambridge: Cambridge University Press).
- Garcia-Fontes, W. and Geuna, A. (1999) 'The Dynamics of Research Networks in Europe'. In Gambardella, A. and Malerba, F. (eds) *The Organization of Economic Innovation in Europe* (Cambridge: Cambridge University Press).
- Geuna, A. (2001) 'The Changing Rationale for European University Research Funding: Are There Negative Unintended Consequences?'. *Journal of Economic Issues*, Vol. 35, No. 3, pp. 607–32.
- Granstrand, O. (1999) *The Economics and Management of Intellectual Property. Towards Intellectual Capitalism* (Cheltenham: Edward Elgar).
- Hagedoorn, J. (1996) 'Trends and Patterns in Strategic Technology Partnering Since the Early Seventies'. *Review of Industrial Organization*, Vol. 11, No. 5, pp. 601–16.
- Held, D. and McGrew, A., with Goldblatt, D. and Perraton, J. (1999) *Global Flows: Politics, Economics and Culture* (Cambridge: Polity).
- Kennedy, P. (1988) *The Rise and Fall of the Great Powers* (London: Unwin Hyman).

- Kok, W. *et al.* (2004) *Facing The Challenge. The Lisbon Strategy for Growth and Employment. Report from the High Level Group* (Brussels: European Commission). Also available at «http://www.europa.eu.int/comm/lisbon_strategy/index_en.html».
- Lundvall, B.-Å. (2001) 'Innovation Policy in the Globalising Learning Economy'. In Archibugi, D. and Lundvall B.-Å. (eds) (2001) *The Globalising Learning Economy* (Oxford: Oxford University Press).
- Lundvall, B.-Å. and Borrás, S. (1998) *The Globalising Learning Economy: Implications for Innovation Policy*, European Commission, DG XII, Brussels.
- Mathews, J. (2000) *Tiger Technology: The Creation of a Semiconductor Industry in East Asia* (Cambridge: Cambridge University Press).
- Maurseth, P.B. and Verspagen, B. (1999) 'Europe: One or Several Systems of Innovation?'. In Fagerberg, J., Guerrieri, P. and Verspagen, B. (eds) (1999) *The Economic Challenge for Europe: Adapting to Innovation-based Growth* (Aldershot: Edward Elgar).
- Mowery, D. and Nelson, R. (eds) (1999). *The Sources of Industrial Leadership* (Cambridge: Cambridge University Press).
- Mytelka, L.K. (2001) 'Mergers, Acquisitions, and Inter-firm Technology Agreements in the Global Learning Economy'. In Archibugi, D. and Lundvall B.-Å. (eds) (2001) *The Globalising Learning Economy* (Oxford: Oxford University Press).
- Narula, R. (1999) 'Explaining the Growth of Strategic R&D Alliances by European Firms'. *Journal of Common Market Studies*, Vol. 37, No. 4, pp. 711–23.
- National Science Foundation (NSF) (2000, 2002) *Science and Engineering Indicators* (Washington DC: US Government Printing Office).
- Nelson, R. (1989) 'US Technological Leadership. Where Did it Come From and Where Did it Go?'. *Research Policy*, Vol. 19, No. 2, pp. 117–32.
- OECD (2001–2004) *Main Science and Technology Indicators* (Paris: Organization for Economic Co-operation and Development).
- Patel, P. and Pavitt, K. (1987) 'Is Western Europe Losing the Technological Race?' In Freeman, C. (ed.) *Output Measurement in Science and Technology* (Amsterdam: North-Holland).
- Pianta, M. (1988) *New Technologies across the Atlantic: US Leadership or European Autonomy?* (Hemel Hempstead: Harvester-Wheatsheaf).
- Rifkin, J. (2004) *The European Dream. How Europe's Vision of the Future is Quietly Eclipsing the American Dream* (New York: Tarcher).
- Schibany, A. and Streicher, G. (2003) 'Aiming High. An Assessment of the Barcelona Targets'. Institute of Technology and Regional Policy, Vienna, Working Paper No. 06.
- Servan-Schreiber, J.-J. (1968) *The American Challenge* (Harmondsworth: Penguin).
- Sharp, M. (2001) 'The Need for New Perspectives in European Commission Innovation Policy'. In Archibugi, D. and Lundvall, B.-Å. (eds) (2001) *The Globalising Learning Economy* (Oxford: Oxford University Press).
- Soete, L. (2001) 'The New Economy: A European Perspective'. In Archibugi, D. and Lundvall B.-Å. (eds.) (2001) *The Globalising Learning Economy* (Oxford: Oxford University Press).



- Soete, L. (2002) 'The European Research Area: Perspectives and Opportunities'. Paper presented at the International Workshop on Research Policy: Incentives and Institutions, Rome, 28 November.
- Suarez-Villa, L. (2000) *Invention and the Rise of Techno-Capitalism* (Lanham: Rowman & Littlefield).
- Temple, J. (2002) 'The Assessment: The New Economy'. *Oxford Review of Economic Policy*, Vol. 18, No. 3, pp. 241–64.
- Tijssen, R.J.W. (2001) 'Global and Domestic Utilization of Industrial Relevant Science: Patent Citation Analysis of Science–Technology Interactions and Knowledge Flows'. *Research Policy*, Vol. 30, No. 1, pp. 35–54.
- UNDP (2001) *Human Development Report* (New York: United Nations).
- US Patent and Trademark Office (USPTO) Patent Database 2001, available at «<http://www.uspto.gov>».
- Vivarelli, M. and Pianta, M. (eds) (2000) *The Employment Impact of Innovation* (London: Routledge).
- World Bank (2001–2004) *World Development Indicators* (Washington, DC: Query Database).

