CHAPTER IV
The impact of innovation on manufacturing performance

This chapter discusses the influence of innovation on production and productivity growth. It focuses on manufacturing, first at the aggregate level, then at the level of sectors and industries. The data confirm the key role of capabilities, knowledge , ICT and research output in growth and productivity. The industry pattern of productivity growth appears to be similar across countries and to have recently become even more similar, with technology-driven industries now taking the lead in productivity increase in Europe also. With respect to the forces facilitating innovation and growth, lagging European countries are catching up, albeit slowly, and some European countries compare well with the US.

As discussed in Chapter I, the US is forging ahead in productivity growth. Following a long period of more rapid productivity growth in Europe, productivity growth accelerated in the US during the last decade and is now higher than in Europe and in Japan[43]. Between the first and the second half of the 1990s the US experienced an acceleration in terms of both output and productivity. In contrast, in the EU productivity decelerated by 0.7 percentage points despite acceleration in output of 1.1 percentage points The next section investigates these trends in the manufacturing sector.

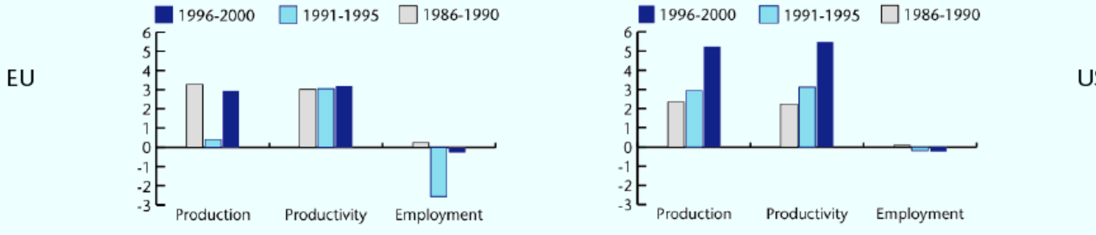
4.1. Manufacturing production and productivity growth in the EU and the US

Labour productivity in EU manufacturing increased at 3 per cent per year during the 1990s and, in contrast to productivity in the whole economy, a modest acceleration was registered between the first and the second halves of the decade. Nevertheless, this acceleration was less strong than in the US (see Graph IV.1). The highest productivity growth in the EU during the nineties was recorded in Ireland, Finland, Austria and Sweden; in these four countries, productivity in manufacturing rose faster than in the US (see Graph IV.2). The lowest growth rates were recorded in Portugal, Spain and France (less than 2 % p.a.). In the second half of the 1990s, three countries saw productivity increase faster than in the US, eleven countries experienced productivity growth lower than in the US, and in Spain productivity growth was negative (see Table IV.1).[44]

In manufacturing production, EU growth, which had been superior to that in the US in 1986–90, declined at a lower rate than US growth in the 1990s (1.7 % annually compared to 4.1 % annually in the US). Countries with low growth recorded barely more than 1 % annually for the decade, while countries with high growth achieved around 4 %, with the exception of Ireland (11.2 %) and Finland (6.2 %). Nevertheless, an important acceleration took place in almost all Member States between the first and the second half of the 1990s.

43 This is true not only for labour productivity, both for the whole economy and for manufacturing, but also for total factor productivity.
44 If ranked according to the acceleration observed between the first and the second halves of the nineties, Finland, France, Ireland and Germany spurred up productivity fastest while Denmark, Austria and Portugal came in next.

Graph IV.1: Performance in manufacturing in EU and US

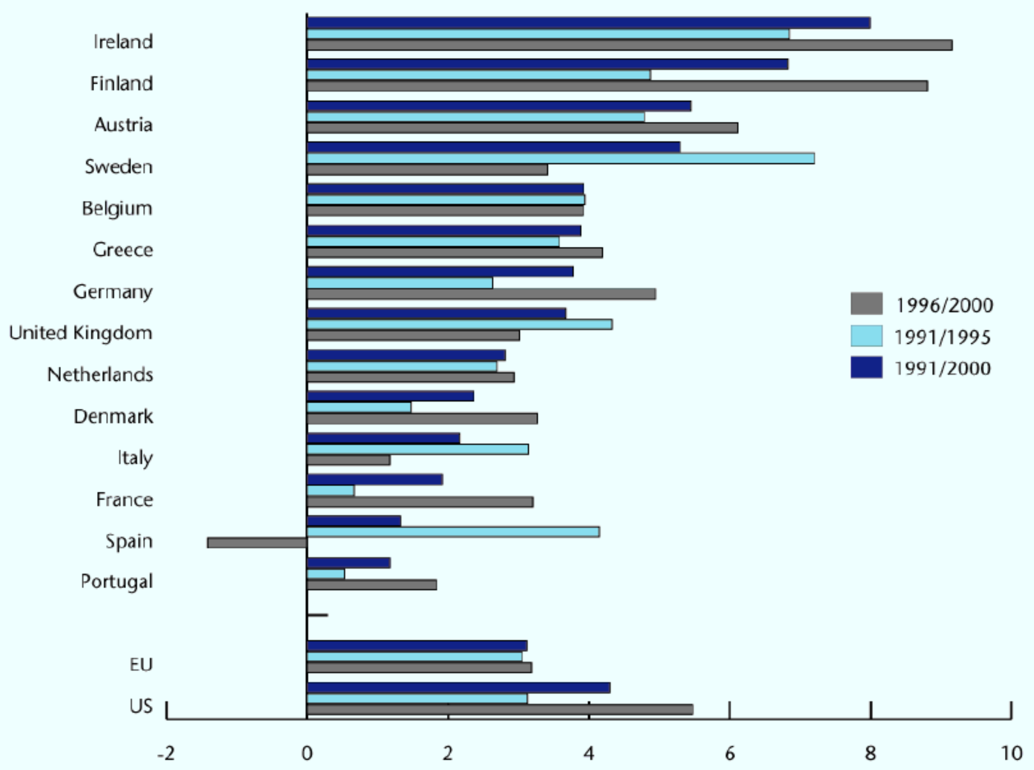


Note: Average annual growth in per cent. Productivity is measured as manufacturing production per employee.

Source: WIFO calculations using EUROSTAT (New Cronos); 1999-2000 estimate, Economic Forecasts 2000-2002 (European Commission).

Graph IV.2: Productivity growth in manufacturing

(countries ranked according to growth in the 1990s)



Source: WIFO calculations using EUROSTAT data (New Cronos); 1999-2000 estimate, Economic Forecasts 2000-2002 (European Commission).

4.2.The underlying forces

As discussed in Annex II.1, modern growth theories suggest that innovation is a crucial determinant of growth. Innovation can be achieved through different channels – through own R&D activities leading to new products or processes, but also through a diffusion effect associated with imported technology or inputs or due to the presence of multinational firms; or through spillover effects that magnify the benefits of own R&D efforts. For this reason, when evaluating the innovative strengths of a country, indicators other than the ones directly related to own innovation (such as measures of R&D effort) must be taken into account. In particular, equally relevant are indicators on the ability of a country to build on and to make the most of existing knowledge and innovation through a process of diffusion and adoption. Stern et al.(2000) in fact shows that innovative performance depends not only on research input but also on other variables such as the existing stock of knowledge, the openness of the country to international trade and investment and the share of GDP spend on higher education.

Table IV.1: Growth performance in manufacturing

	Production of manufacturing					Productivity of manufacturing				
	Growth p.a. in per cent				Acceleration Second half minus first half	Growth p.a. in per cent				Acceleration Second half minus first half
	1986/1990	1991/1995	1996/2000	1991/2000		1986/1990	1991/1995	1996/2000	1991/2000	
Belgium	3.5	1.3	3.4	2.3	2.1	3.4	3.9	3.9	3.9	0.0
Denmark	1.6	3.0	3.6	3.3	0.6	2.6	1.5	3.3	2.4	1.8
Germany	3.5	- 0.8	3.6	1.4	4.4	2.0	2.6	4.9	3.8	2.3
Greece	0.2	- 0.7	3.2	1.3	3.9	0.5	3.6	4.2	3.9	0.6
Spain	3.4	0.9	2.4	1.6	1.5	2.1	4.2	- 1.4	1.3	- 5.6
France	2.2	- 0.4	3.7	1.6	4.1	3.8	0.7	3.2	1.9	2.5
Ireland	8.3	10.2	12.2	11.2	2.0	7.7	6.8	9.2	8.0	2.3
Italy	3.2	1.4	1.8	1.6	0.4	3.8	3.1	1.2	2.2	- 2.0
Netherlands	1.8	1.4	3.6	2.5	2.2	0.0	2.7	2.9	2.8	0.3
Austria	4.5	2.4	5.6	4.0	3.2	5.8	4.8	6.1	5.4	1.3
Portugal	4.9	- 0.8	2.8	1.0	3.7	5.0	0.5	1.8	1.2	1.3
Finland	2.7	2.8	9.8	6.2	7.0	4.6	4.9	8.8	6.8	3.9
Sweden	2.1	3.2	5.1	4.2	1.9	2.1	7.2	3.4	5.3	- 3.8
United Kingdom	3.4	0.6	1.1	0.8	0.5	3.5	4.3	3.0	3.7	- 1.3
EU	3.3	0.4	2.9	1.7	2.5	3.0	3.0	3.2	3.1	0.1
Japan	4.5	- 0.6	1.1	0.2	1.7	4.0	1.0	3.0	2.0	2.1
US	2.4	2.9	5.2	4.1	2.3	2.3	3.1	5.5	4.3	2.3
Standard deviation EU countries	1.91	2.80	3.05	2.78		2.05	2.00	2.78	2.04	
Standard deviation Triad	1.08	1.84	2.09	1.95		0.86	1.22	1.37	1.15	

Source: WIFO calculations using EUROSTAT data (New Cronos); 1999-2000 estimate, Economic Forecasts 2000-2002 (European Commission).

This section examines the relation between indicators on research, the knowledge base, ICT and capabilities, and growth of output and productivity. Each indicator is subject to measurement problems and can account for only part of the growth differences; together they establish a system of growth forces which relate to the performance differences of EU countries in the 1990s. Clearly, these indicators do not capture all aspects relevant for fostering and implementing innovation. Factors such as the presence of multinational firms, the degree of labour mobility between universities and firms or across countries, or the openness of an economy, are important determinants of the absorptive capacity of a country and of the extent to which spillovers can successfully take place.[45]

The present discussion concerns exclusively the manufacturing sector.[46] There is evidence that it is the manufacturing rather than the service sector that drives productivity growth and differentials thereof.[47] Moreover, examination of the manufacturing sector allows the use of additional information on research intensity at sectoral level. Other than the indicators related to knowledge, innovation and ICT, this section also uses information contained in the Community Innovation Survey to verify the importance of capabilities.[48] These variables are presented in Table IV.2. Also, a measure of the speed of structural change may indirectly add information regarding the need, as well as the potential, for change, building a bridge to the country profiles presented in Annex 1. Finally, the potential relation between the growth forces and the performance indicators is evaluated by means of rank correlations and the results are reported in Table IV.2. It should be stressed that correlation indicates only the closeness of a relation but proves no causality. Graph IV.3 shows the relationship between productivity growth and each of the underlying forces.

45 One area where these factors are particularly important biotechnology, which is discussed in Chapter V of the Report.

46 Results for macroeconomic growth are already available in the OECD growth project (OECD 2001) and it is not necessary to repeat them here. Its main results and one of the core findings - that in OECD countries the acceleration of total factor productivity in the total economy is significantly related to increases in the business research intensity - are reported in Annex III.2.

47 See, for example, Scarpetta et al. (2000).

48 Though the indicators chosen are all linked to, and suggested by, theories of economic growth and are also partly related to the empirical evidence discussed earlier, a certain ambiguity remains as to which indicators should be used; first, because most indicators are poor proxies for the processes considered important; and, second, because each single indicator is flawed by several measurement problems. These obstacles are partially overcome by using rank correlations (which are more robust than simple quantitative indicators) and by looking at the combined rankings of several indicators.

• Research indicators

Growth of production and productivity are positively related to research inputs, patents and publications. Although the relationships are not particularly close, those between growth and publications and between productivity growth and patents are statistically significant (see Table IV.2 and Graph IV.3). Sweden and Finland rank high according to both research and performance indicators; Germany ranks high in patents and research input, but has only a moderate position in output growth and productivity; the UK, which is among the leading countries with respect to research indicators, displays low productivity growth. In contrast, Austria is far better ranked in growth performance than in research indicators. The southern countries – Greece, Spain, Portugal and Italy – rank low in all research indicators and in performance indicators. Ireland, the fastest growing economy, has seen an increase in its research input and output, and enjoys a high share of technology-driven industries, but lags behind compared to research-intensive countries.

• Knowledge base

To capture the concept of knowledge base, human capital indicators (such as secondary and tertiary education and human resources in technology as discussed in Chapter II) are combined with indicators of production and use of ICT. Sweden (see Graph IV.3) ranks highest according to human capital indicators and Denmark and Belgium also rank high, reflecting high expenditure on higher education. The UK performs less well in this category, and Austria and Ireland rank better in human capital than according to research and ICT (see Graph IV.3). For ICT, Ireland ranks high in consumption and in the production share of ICT industries in manufacturing, but only moderately with respect to diffusion (Internet hosts and computers per resident). Germany and Belgium rank lower in ICT production and computers per resident. The Member States ranking lower in this category are the same as those for R&D indicators.

Finally, all correlations are positive and the share of the work-force with tertiary education, computers per resident and Internet hosts are significantly correlated with production growth (see Table IV.2).

• The role of capabilities

The results show that indicators meant to capture the notion of firms' capabilities are closely related to growth. There is a consensus that capabilities are decisive for the performance of firms, but also that they are difficult to measure. Four indicators from the CIS innovation survey which proxy some aspects of capabilities are used here, (see Table IV.2). Innovation expenses relative to sales,[49] and the share of firms that report co-operative and continuous research are significantly related to production growth; the last two are also related to productivity growth. However, the share of new products in sales does not find decisive statistical support.

According to the capability indicators, Ireland and Austria rank lower than according to the performance indicators, while the opposite holds for Germany, France and the United Kingdom. Greece, Spain, Italy and Portugal rank low in terms both of performance and capability indicators – and in particular rank the lowest in innovation expenditure and in the share of firms reporting co-operative activities and continuous research. In contrast, Finland and Sweden rank high in both dimensions.

• Growth and speed of change

The speed of change of industrial structure[50] is significantly related to productivity growth, being highest in the case of Ireland where productivity growth is also the highest. Finland, which registers high productivity growth, ranks fourth in the speed of change indicator. At the lower end, Germany, Italy and the UK display both slow speed of change and slow productivity growth. Austria's and Sweden's productivity has increased despite slow structural change, while in Portugal rapid change combines with low productivity growth – see Table IV.2 and Graph IV.3.

Given the complexity of the relationship between the innovation system and productivity growth, no close statistical correlation between any single indicator and growth performance should be expected. When information on the possible growth factors is combined in a single indicator (called "combined indicator" in Table IV.2 and Graph IV.3), measurement errors in the individual series are reduced, and the results indicate that a statistically significant relation between the variables exists.

49 Innovation expenditure include software, acquisition of patents, know-how, trademarks, training, industrial design, etc. Some of these reflect activities that allow firms to build up a competitive advantage and make use of knowledge that is in principle available, but requires specific abilities to get hold of. Thus innovative expenditure signals elements addressed by the capability approach but not contained in research expenditure.

50 This indicator measures the sum of absolute changes in the shares of sectors or industries in total manufacturing between a base year and the final year. It is a proxy reflecting changes in demand, but it also indirectly measures rigidities, see Aiginger (2000) and European Commission (2000). In the correlations, a comprehensive indicator was used which combines changes in value added, exports and employment at the 2–digit and 3–digit level (see Aiginger, 2001A).

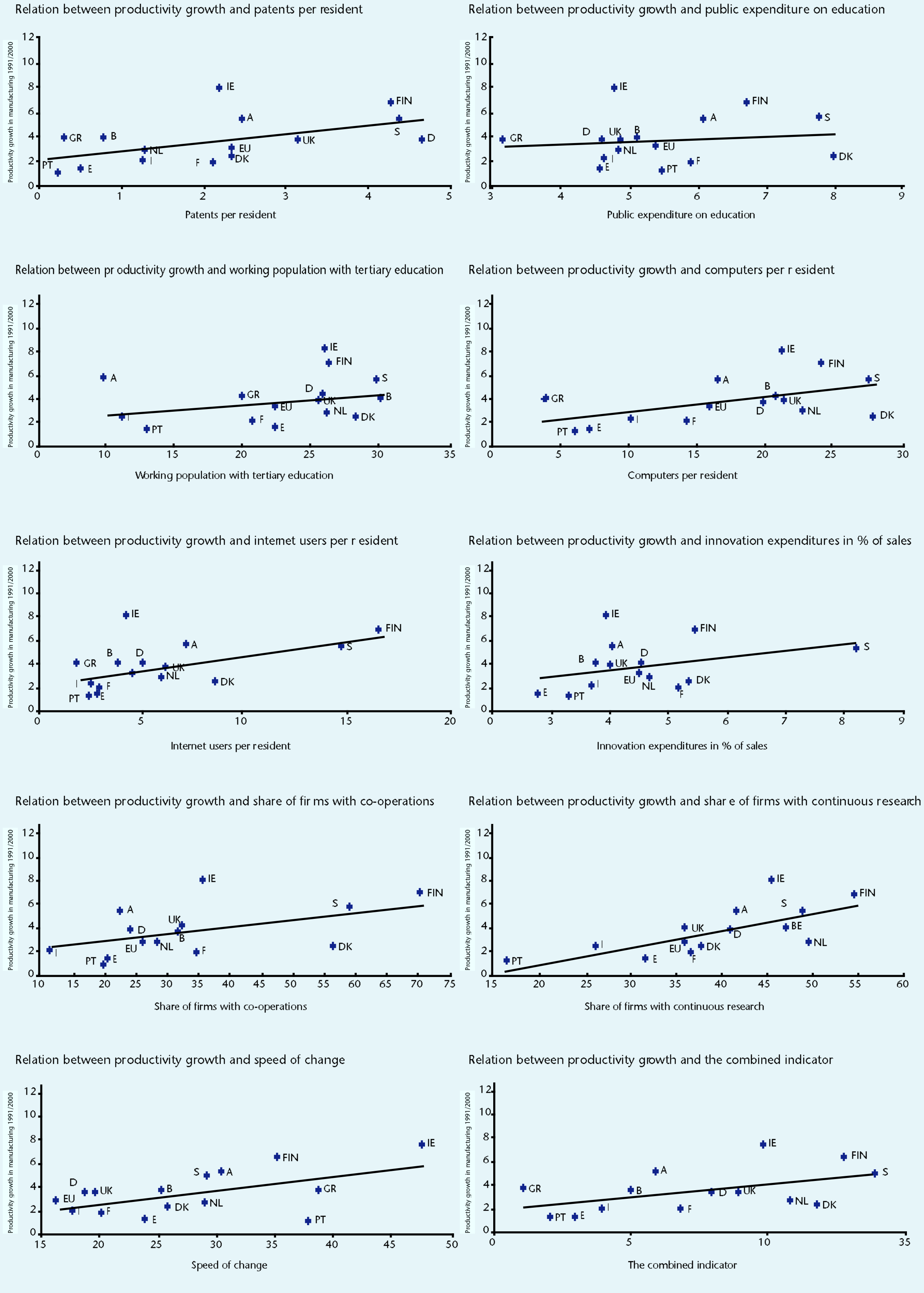
Table IV.2: Correlation, across EU countries, between growth and underlying forces
(rank correlation coefficients, p value in parentheses)

	Production growth manufacturing[1]		Productivity growth manufacturing[1]	
Research				
R&D/GDP	0.3319		0.3187	
	(0.2464)		(0.2668)	
R&D personnel as a % of the labour force	0.4374		0.3626	
	(0.1178)		(0.2026)	
Patents per inhabitant	0.3670		0.5253	
	(0.1967)		(0.0537)	*
Publications per inhabitant	0.4593		0.3363	
	(0.0985)	*	(0.2398)	
Human Capital				
Public expenditure on education	0.4813		0.1736	
	(0.0814)	*	(0.5528)	
Percentage of the population that has attained at least upper secondary education by age group (1998)	0.3758 (0.1854)		0.4110 (0.1443)	
Percentage of the population that has attained at least tertiary education (1998)	0.4316 (0.1234)		0.4094 (0.1460)	
Human resources in science and technology by country	0.3451		0.2703	
	(0.2269)		(0.3499)	
Working population with tertiary education	0.4681		0.3670	
	(0.0914)	*	(0.1967)	
Information and Communication Technologies				
ICT expenditure as a % of GDP	0.3011		0.2440	
	(0.2955)		(0.4006)	
ICT production as a % of total manufacturing	0.4559		0.2967	
	(0.1022)		(0.3030)	
PCs per inhabitant	0.6484		0.4681	
	(0.0121)	**	(0.0914)	*
Internet users per inhabitant	0.6088		0.5341	
	(0.0209)	**	(0.0492)	**
Cellular mobile subscribers per 100 capita	0.4286		0.2396	
	(0.1263)		(0.4094)	
Capabilities				
Innovation expenditures as a % of sales	0.5431		0.3444	
	(0.0447)	**	(0.2278)	
Share of new/improved products as a % of sales	0.4462		0.3495	
	(0.1098)		(0.2207)	
Share of co-operations	0.6084		0.4596	
	(0.0210)	**	(0.0983)	*
Share of firms with continuous research	0.7582		0.6396	
	(0.0017)	**	(0.0138)	**
Other				
Structural change indicator (speed of change)[2]	0.4154		0.4637	
	(0.1397)		(0.0949)	*
Combined indicator	0.6264		0.4593	
	(0.0165)	**	(0.0985)	*

[1] Growth 1991/2000; [2] Aiginger (2001).

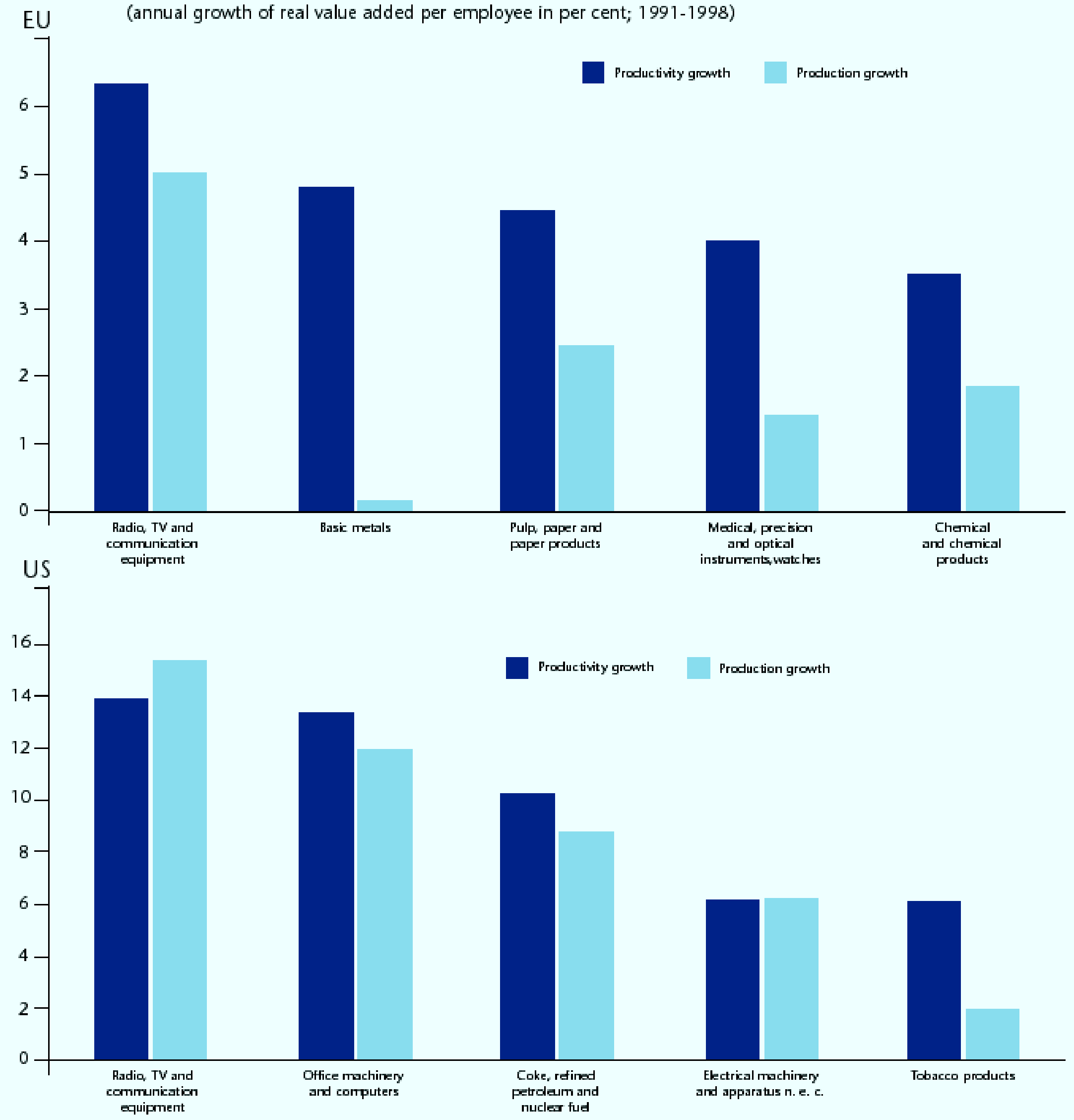
Note: * (**) denotes significance at 10 % (5 %) level; for growth drivers: average of the nineties (usually up to 1998).

Graph IV.3: Forces underlying productivity growth



Graph IV.4: Sectors with the highest increase in productivity, EU and US

(annual growth of real value added per employee in per cent; 1991-1998)



Source: WIFO calculations using EUROSTAT data (New Cronos).

To sum up, among the various sets of indicators, those meant to capture the notion of capabilities appear to bear the closest relation with manufacturing growth performance, supporting the relevance of evolutionary theories and of approaches emphasising the absorptive capacity of firms.[51] None of the available indicators on human capital shows a significant relation with productivity growth in manufacturing, and only public expenditure in education and working population with tertiary education bear a significant relation with production growth. Among the indicators on ICT, Internet penetration and number of PCs per inhabitant display a positive relation with both production and productivity growth in manufacturing, while ICT production or expenditure do not appear to be significantly related to the performance, indicators.

Concerning research, R&D inputs, R&D intensity and R&D personnel in the labour force are not significantly related to growth performance while research outputs – patents and publications per resident – bear a significant relation with performance, the first with productivity growth and the second with production growth. Note that, in general, the indicators are more closely related to production growth than to productivity growth.[52]

51 The indicators also offer a partial explanation for the acceleration of production growth in the nineties, as compared to the eighties. Best again are indicators from the category including capabilities (innovation/sales ratio, co-operations, continuous research), as well as human capital, ICT share in value added and speed of change. On the other hand, no satisfactory correlations provide an explanation of the acceleration of growth in the second half of the nineties, as compared to the first. The reason is that the distribution of growth between the two halves of the nineties is determined by the business cycle, economic crises and measurement problems.

52 For the combined indicator, significance levels are 2 % for production growth and 10 % for productivity growth.

4.3. Productivity growth and research intensity at sectoral level in the EU and the US

In the second half of the 1990s productivity increased fastest in technology-driven industries, while in the first half it grew fastest in capital-intensive industries[53]. The experience of the second half of the decade suggests that a close connection between research intensity and productivity growth across sectors could be present. However, the experience of the first half weakens this relationship since own–research input is typically low in capital–intensive industries.[54]

• Technology, restructuring, and productivity growth

Graph IV.4 presents data on manufacturing production and productivity growth in the EU and the US for the period 1991–1998. High–tech industries with strong productivity growth in the EU are electronic equipment and medical equipment, but productivity also increased very fast in capital–intensive industries like basic metals, pulp and paper, and chemicals. In the last two sectors, apparent productivity growth was influenced by reductions in employment.

The smallest increases are found in the cases of apparel, leather and the food sector. Textiles registered an average growth in productivity and a steep decline in employment. In printing and publishing, productivity increases were modest and employment was on the increase.

In the second half of the 1990s, technology–driven industries recorded marked increases in productivity growth. None of the capital–intensive industries mentioned above recorded an increase in productivity growth between the first and second halves of the decade.[55] In the early 1990s, the greatest productivity increase took place in capital–intensive industries (4.1 %), followed by technology–driven industries (3.4 %), with labour-intensive and marketing–driven industries trailing in productivity performance. In the latest years, however, technology–driven industries increased productivity most strongly (4.8 %). This suggests that this group accounts for a large part of the acceleration in productivity growth observed during this period. Capital–intensive industries experienced a modest 2 % productivity growth during this latter period (see Graph IV.5).[56]

• Impact of technology on US industry

In the US, the role of technology-driven industries in productivity growth is even more important than in the EU. First, their share in manufacturing is larger than in the EU (see Graph IV.6). Second, in the US these industries recorded an average annual productivity increase of 8.3 % in the 1990s – a much higher rate than the 3.5 % achieved by the EU technology-driven industries. In technology-driven industries, productivity accelerated from 5.4 % per year in the first half of the decade to 13.3 % per year in the second. In 14 industries, productivity increased at double–digit rates in the period 1996–1998, most of which are technology-driven industries. In Europe, only four industries enjoyed such large productivity increases[57]

• Sectoral research intensity in the EU and the US

Graph IV. 7 presents data on research intensity during the 1990s, measured by R&D expenditure over production, for the 11 highest and lowest research intensity sectors in the EU and the US.

The data show that the telecommunications equipment sector has the highest research intensity among European sectors. In the leading sectors, research relative to sales declined in the late 1990s, while productivity growth increased.

In the US, office machinery, other transport, and telecommunications equipment are the most research – intensive sectors. Productivity – notoriously difficult to measure in these industries – increased during the 1990s, partly in the second half (in office machinery and in aerospace), and partly in the first. The ranking of sectors by research intensity is very similar in the US and the EU, but research intensity is higher in the US in 16 of the 22 sectors. Three sectors with low research activity are leading in increases: leather, textiles and printing recorded large increases in research intensity.

53 For a classification of industries according to main inputs used see Table IV.7 at the end of the chapter.

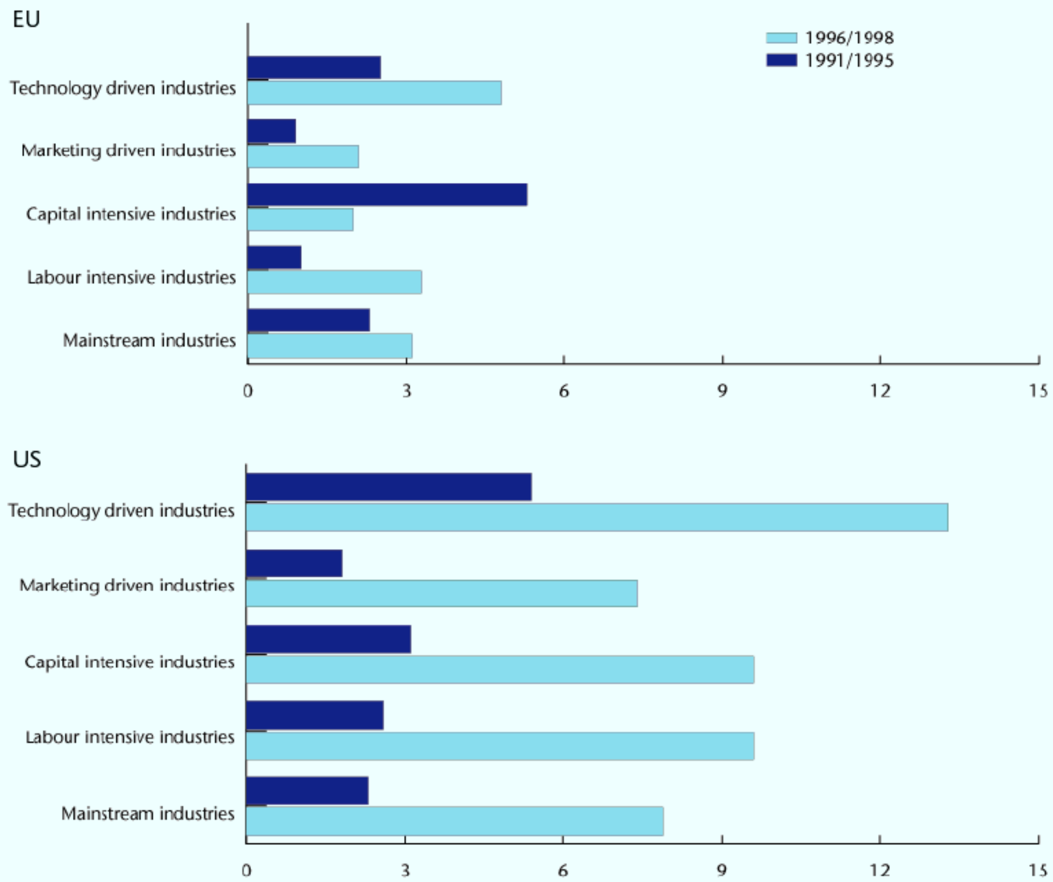
54 Productivity is measured by real value added per employee, and research intensity by research outlays as a percentage of value production. Real value added (when not available from SBS) was estimated using nominal value added from SBS and price data from STAN (OECD). ANBERD was used for research and development, and STAN for production (both provided by the OECD). For the correlations, a combined indicator of productivity (with nominal and real value added and production value as the numerator) was also used, which should help to eliminate noise and measurement errors in each of the series. The results reported here are robust across indicators.

55 Taking the acceleration of productivity alone as a criterion shows several industry–specific and cyclical effects not linked to innovation; for example, in the petroleum industry productivity accelerated, while in pulp and paper it declined.

56 All these tendencies are replicated if nominal data or a combined productivity indicator is used.

57 These were telecom equipment, motor vehicles bodies, weapons and ammunition, and aircraft and spacecraft.

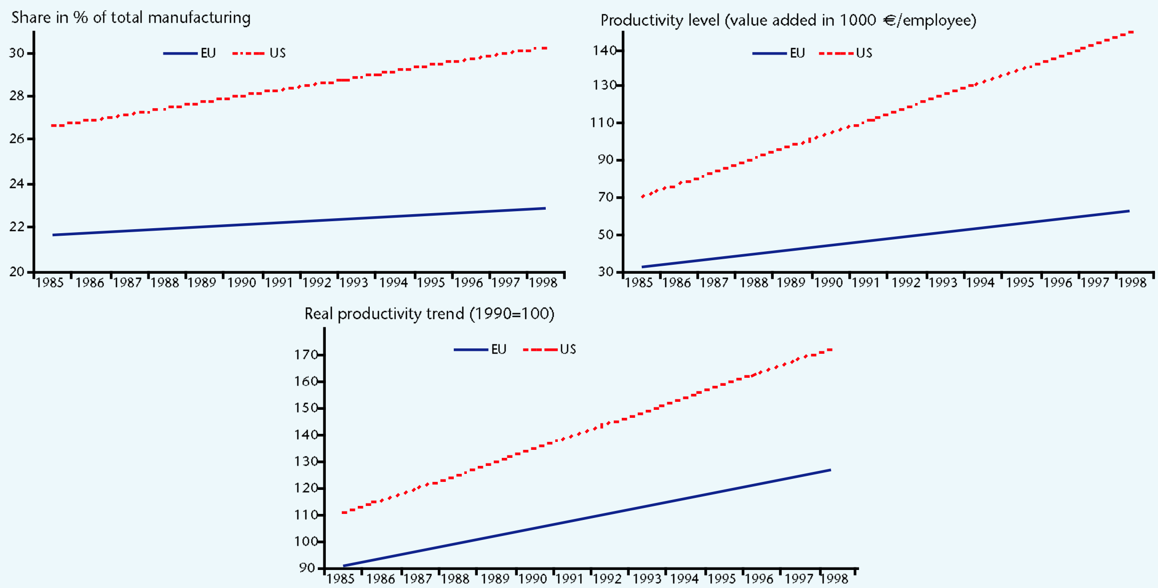
Graph IV.5 : The role of technology-driven and capital intensive industries in EU and US productivity growth



Note: Productivity is measured as real value added per employee. For the industry classification see table IV.7.

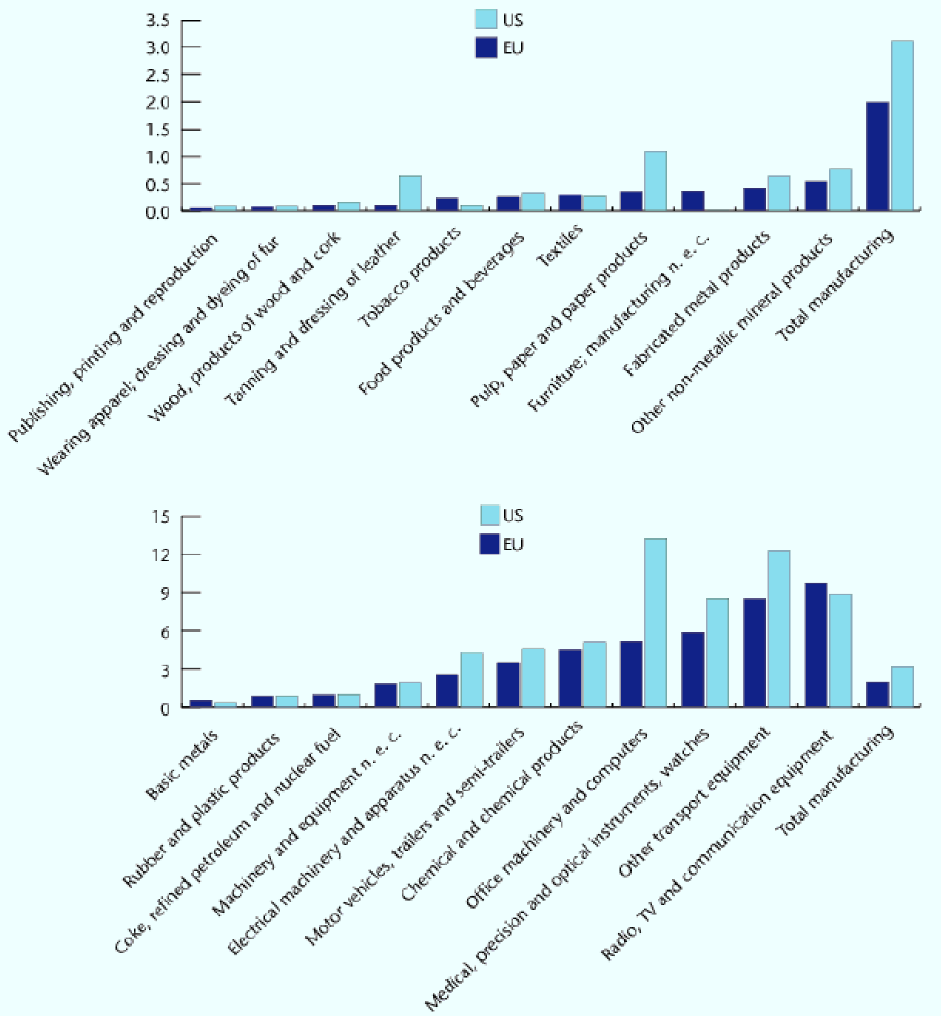
Source: WIFO calculations using EUROSTAT data (New Cronos).

Graph IV.6: Share, productivity level and productivity growth of technology–driven industries



Source: WIFO calculations using EUROSTAT data (New Cronos).

Graph IV.7: Research intensity across sectors in the EU and the US



Note: Research intensity is measured as R&D expenditure as per cent of production (average 1990/1997).

Source: WIFO calculations using EUROSTAT (New Cronos) and OECD (STAN) data.

• Research intensity and productivity growth

Productivity growth in the 1990s and research intensity are significantly related across sectors (see Table IV.3). This holds for the EU as a whole and for the US, but not for the majority of the member countries individually. International spillovers in research could be one reason for the lack of correlation at country level. Research intensity does not relate closely to production growth – with the notable exceptions of Finland and Sweden. Lags do not change the closeness of the relation. [58]

Electronic equipment, instruments and computers are sectors with both high research intensity and high productivity growth.[59] Additionally, chemicals and motor vehicles are in the top third of the sectors for both indicators (see Graph IV.8). In the chemical sector, biotechnology undoubtedly accounts for these results. Leather and apparel and the food industry have low research intensities and low productivity growth.

Textiles combines low research and low production growth, and although apparent productivity is about average, competitive pressure has led to decreasing employment (- 3.9 % between 1991 and 1998). Other transport is the sector with the second highest research input but production and productivity

58 This is a usual finding in the presence of feedbacks and co-movements and given an "intrinsic" research intensity at a given level of aggregation (for lags to matter, a lower level of aggregation would be necessary).

59 The position varies according to the productivity indicator. For the combined indicator (production value, nominal plus real value added) these rank first, third and seventh among 22 sectors, respectively.

Table IV.3: Correlation between production and productivity growth and research intensity across sectors
(rank correlation coefficients, with p value in parentheses)

	Production				Productivity			
	Contemporaneous		Lagged		Contemporaneous		Lagged	
Belgium	0.4681		0.5031		0.5042		0.5076	
	(0.0280)	**	(0.0170)	**	(0.0167)	**	(0.0159)	**
Denmark	0.2410		0.1851		0.1508		0.1154	
	(0.2799)		(0.4097)		(0.5030)		(0.6092)	
Germany	-0.0390		0.0412		0.1191		0.0977	
	(0.8633)		(0.8555)		(0.5974)		(0.6654)	
Spain	0.1530		0.2095		0.0548		0.0457	
	(0.4966)		(0.3494)		(0.8087)		(0.8398)	
France	0.3698		0.3902		0.5483		0.5731	
	(0.0902)	*	(0.0726)	*	(0.0082)	***	(0.0053)	***
Italy	0.0186		0.0186		0.0457		0.0887	
	(0.9344)		(0.9344)		(0.8398)		(0.6948)	
Netherlands	0.0954		0.0751		0.3642		0.3134	
	(0.6727)		(0.7398)		(0.0956)	*	(0.1556)	
Finland	0.4421		0.4071		0.0830		0.0491	
	(0.0394)	**	(0.0600)	*	(0.7134)		(0.8281)	
Sweden	0.5370		0.5618		0.3145		0.3710	
	(0.0100)	***	(0.0065)	***	(0.1540)		(0.0892)	*
United Kingdom	0.2784		0.2998		0.3123		0.3439	
	(0.2097)		(0.1752)		(0.1571)		(0.1171)	
Average over	0.2535		0.2343		0.6894		0.6996	
EU countries	(0.2549)		(0.2939)		(0.0004)	***	(0.0003)	***
Japan	-0.0536		-0.0243		0.3947		0.3913	
	(0.8126)		(0.9146)		(0.0691)	*	(0.0717)	*
US	0.3066		0.3427		0.4771		0.4579	
	(0.1652)		(0.1184)		(0.0247)	**	(0.0321)	**

Notes: Contemporaneous: production (productivity) growth 1991/1998 vs. research intensity 1991/1998; lagged: production (productivity) growth 1991/1998 vs. research intensity 1985/1995. For production (productivity) three indicators are combined: nominal production (STAN), nominal value added (New Cronos), real value added (New Cronos; WIFO estimate). * (**, ***) denotes significance at 10 % (5 %, 1 %) level.

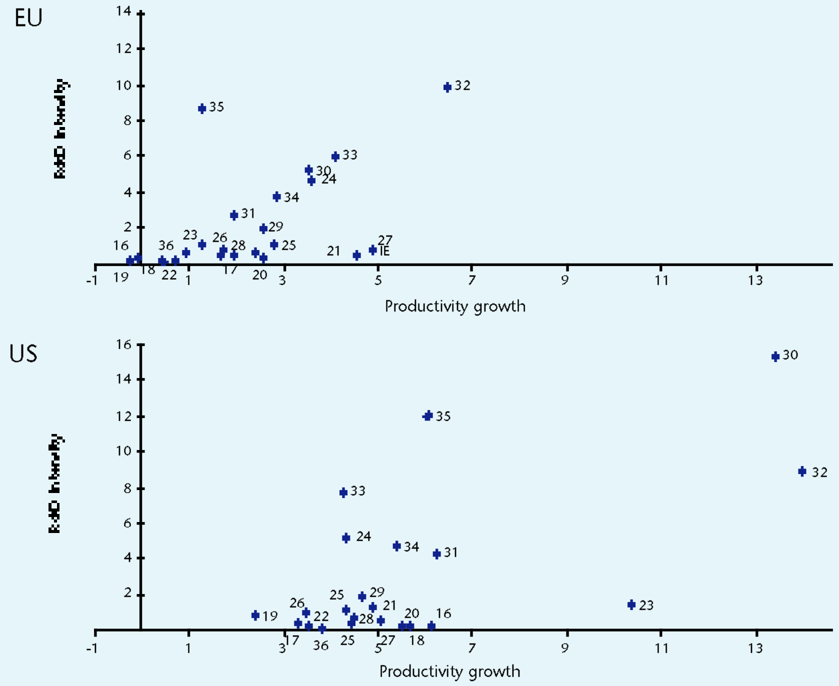
WIFO calculations using EUROSTAT (New Cronos) and OECD (STAN) data.

increases are low, possibly reflecting the wide diversity of this sector (from aircraft and spacecraft to railways). In addition, the locations of research and production in this sector are not the same and are sometimes even outside Europe. Electrical machinery belongs to the top three sectors in research intensity and has a moderate position in productivity growth. Publishing and printing is a sector with low direct research intensity but is implementing new forms of technology at a very fast speed, via technology investments embodied in equipment and intermediate inputs. It is a high-growth sector, but its employment is also increasing, so that apparent productivity performance is below average (ranking the fourth lowest, as measured by real value added per employee).

Table IV.4 is a matrix classifying sectors according to productivity and research intensity in the EU and in the US. The purpose is to uncover regularities across these variables in the two regions. It is clear, to begin with, that high research intensity is not associated with low productivity growth either in the EU or in the US. In the EU, low research intensity is not associated with high productivity growth either. However, this is so in two sectors (tobacco products and wearing apparel and dressing and dyeing of fur) in the US.

Electronic equipment displays high research intensity and high productivity growth in 10 of 11 EU countries. This favourable position is attained five times for instruments and three times for other transport. For motor vehicles, chemicals and office machinery, the matrix contains two entries. On the other hand, in at

Graph IV.8: Sectoral productivity and research intensity, EU and US (in per cent)



15	Food products and beverages	26	Other non-metallic mineral products
16	Tobacco products	27	Basic metals
17	Textiles	28	Fabricated metal products
18	Wearing apparel; dressing and dyeing of fur	29	Machinery and equipment n. e. c.
19	Tanning and dressing of leather	30	Office machinery and computers
20	Wood, products of wood and cork	31	Electrical machinery and apparatus n. e. c.
21	Pulp, paper and paper products	32	Radio, TV and communication equipment
22	Publishing, printing and reproduction	33	Medical, precision and optical instruments, watches
23	Coke, refined petroleum and nuclear fuel	34	Motor vehicles, trailers and semi-trailers
24	Chemical and chemical products	35	Other transport equipment
25	Rubber and plastic products	36	Furniture; manufacturing n. e. c.

Source: WIFO calculations using EUROSTAT (New Cronos) and OECD (STAN) data.

Table IV.4: Research intensity and productivity growth: sectoral evidence

EU	Low productivity growth	High productivity growth
Low research intensity	Food products and beverages Tanning and dressing of leather Wearing apparel; dressing and dyeing of fur Publishing, printing and reproduction	
High research intensity		Radio, TV and communication equipment Medical, precision and optical instruments, watches Office machinery and computers Chemical and chemical products Motor vehicles, trailers and semi-trailers

US	Low productivity growth	High productivity growth
Low research intensity	Food products and beverages Textiles Publishing, printing and reproduction Furniture; manufacturing n. e. c.	Tobacco products Wearing apparel; dressing and dyeing of fur
High research intensity		Office machinery and computers Other transport equipment Radio, TV and communication equipment Motor vehicles, trailers and semi-trailers Electrical machinery and apparatus n. e. c.

Remark: A sector is included in a box if, during the 1990s, its research intensity is in the lower or upper tercile (upper: top seven) of the sectors and its productivity growth is in the lower or upper tercile.

Source: WIFO calculations based on EUROSTAT (New Cronos) and OECD (STAN) data.

least three countries, food, wood products, and pulp and paper combine low research intensity and low productivity growth. Publishing and printing is an exception in that in six countries research intensity and productivity growth are low, but production growth is high.

4.4. Productivity growth in 3–digit industries

This section extends the study of the patterns of productivity growth across the EU and the US to the 3-digit industry level. In the 1980s, productivity growth across industries in the EU differed significantly from the pattern observed in the US. However, the 1990s witnessed a convergence in the industry hierarchy of productivity growth, as shown by a positive and significant correlation between the two regions' productivity growth at industry level.[60] This similarity became more evident in the second half of the 1990s, and the correlation between the respective EU and US variables reached its highest value in the last years of the decade. The results, based on rank correlation coefficients, are presented in Table IV.5. Even the acceleration in productivity is significantly related, at least at 2-digit level.

Several factors are behind these findings. Technology–driven industries, which had a disappointing productivity performance in the 1980s, started to experience a reversal of fortune in the early 1990s. In the EU, during this period, productivity in these industries was growing slowly (see Graph IV.6), possibly as a result of slowness in the adoption of new technologies and timid structural reforms, and partly reflecting the impact of the recession of the early 1990s and the recurrent ERM crises. Competitive pressures, on the other hand, led to an increase in apparent productivity in capital–intensive industries. In the second half of the 1990s productivity increased the most in technology–driven industries, in both the EU and the US, but at a significantly higher rate in the latter. The weak similarity in the early 1990s was probably a reflection of the macroeconomic difficulties experienced in Europe, but in the second half of the decade techno-

60 The rank correlation is 0.51 for sectors and 0.22 for industries (both significant at the 5 % level).

Table IV.5: Correlation between productivity growth in the EU and the US

Rank correlation between productivity growth in EU and the US across sectors and industries

	Sector level			Industry level		
	Correlation		p-value	Correlation		p-value
Periods						
1986/1990	- 0.3416		0.1197	0.0826		0.4165
1991/1995	0.5234	**	0.0124	0.0418		0.6813
1996/1998	0.5539	***	0.0075	0.2429	**	0.0154
1991/1998	0.5088	**	0.0156	0.2170	**	0.0310
1986/1998	0.4749	**	0.0255	0.2712	***	0.0066
Acceleration second half minus first half	0.4241	**	0.0492	0.0824		0.4175
Individual years[1]						
1987	0.3645	*	0.0953	0.2512	**	0.0121
1988	0.1226		0.5866	0.1400		0.1669
1989	0.0493		0.8274	0.1045		0.3032
1990	0.6900	***	0.0004	0.2739	***	0.0061
1991	0.6499	***	0.0011	0.1490		0.1410
1992	- 0.0731		0.7446	0.1082		0.2862
1993	0.1795		0.4242	0.0532		0.6008
1994	0.1454		0.5185	0.2127	**	0.0345
1995	0.0419		0.8531	0.0868		0.3928
1996	0.5336	**	0.0105	0.2646	***	0.0081
1997	0.7672	***	0.0000	0.4908	***	0.0000

1 Three years moving average (e.g. 1987: growth between 1986 and 1988).
Note: * (**, ***) denotes significance at 10 % (5 %, 1 %) level.

Source: WIFO calculations based on EUROSTAT (New Cronos) data.

Table IV.6: Industries with high productivity growth in the EU (top 25)

Nace Rev. 1		Growth of productivity EU				Share of value added EU 1990	Growth of productivity US				Share of value added US 1990	Top 25 in EU and US	
		1991/1998		1996/1998			1991/1998		1996/1998			91/98	96/98
		% p.a.	Rank	% p.a.	Rank	%	% p.a.	Rank	% p.a.	Rank	%		
272	Tubes	8.0	1	8.8	6	0.5	4.9	37	10.1	24	0.3		YES
247	Man-made fibres	7.0	2	1.0	64	0.3	6.4	17	12.3	10	0.6	YES	YES
322	TV, and radio transmitters, apparatus for line telephony	7.0	3	16.4	1	1.5	11.0	3	13.8	9	1.7	YES	YES
342	Bodies for motor vehicles, trailers	6.4	4	13.5	2	0.5	8.5	6	17.0	4	0.7	YES	YES
211	Pulp, paper and paperboard	6.1	5	4.1	31	1.6	5.6	23	10.7	21	2.4	YES	YES
323	TV, radio and recording apparatus	6.0	6	6.2	16	0.8	1.5	91	- 0.2	96	0.1		
284	Forging, pressing, stamping and roll forming of metal	5.4	7	7.7	8	0.7	4.7	43	8.3	47	0.6		
343	Parts and accessories for motor vehicles	5.4	8	4.7	28	1.8	5.4	25	9.7	28	1.8	YES	
271	Basic iron and steel, ferro-alloys (ECSC)	5.3	9	1.2	63	2.5	7.5	9	10.7	20	1.0	YES	YES
321	Electronic valves and tubes, other electronic comp.	5.1	10	5.5	20	0.7	16.0	1	23.3	2	2.6	YES	YES
273	Other first processing of iron and steel	5.1	11	5.5	21	0.4	6.9	14	11.7	14	0.5	YES	YES
223	Reproduction of recorded media	4.9	12	6.5	14	0.1	- 2.8	99	- 3.3	98	0.0		
296	Weapons and ammunition	4.8	13	10.7	3	0.2	6.9	15	9.3	34	0.4	YES	
241	Basic chemicals	4.7	14	0.4	73	4.7	4.6	45	8.9	40	4.6		
202	Panels and boards of wood	4.7	15	7.9	7	0.3	7.1	12	7.7	55	0.4	YES	
176	Knitted and crocheted fabrics	4.5	16	6.2	17	0.1	4.8	39	9.5	32	0.1		
332	Instruments for measuring, checking, testing, navigating	4.4	17	6.1	18	1.3	6.3	18	9.1	36	2.9	YES	
201	Sawmilling, planing and impregnation of wood	4.3	18	9.5	5	0.4	8.4	7	15.1	7	0.5	YES	YES
244	Pharmaceuticals	4.2	19	3.6	36	2.6	4.2	58	9.1	38	2.9		
275	Casting of metals	4.1	20	5.1	24	0.8	4.6	44	6.4	66	0.7		
274	Basic precious and non-ferrous metals	3.9	21	2.3	51	1.1	3.5	70	3.2	90	1.2		
297	Domestic appliances n. e. c.	3.9	22	3.0	43	0.9	4.7	41	9.0	39	0.6		
156	Grain mill products and starches	3.8	23	3.6	38	0.4	8.6	5	12.0	13	1.1	YES	YES
335	Watches and clocks	3.7	24	2.9	45	0.1	0.8	94	11.6	16	0.1		YES
300	Office machinery and computers	3.5	25	7.0	10	2.1	13.4	2	25.1	1	2.4	YES	YES
	Subtotal of 25 high productivity growth sectors					26.3					30.3	14/25 Y	12/25Y
	Total manufactuirng	2.6		3.0		100.0	5.5		9.9		100.0		

Source: WIFO calculations based on EUROSTAT (New Cronos) data.

logical forces appear to have played a crucial role in determining the pattern.

As already mentioned, the impact of technology–driven industries on overall productivity is greater in the US than in the EU. First, productivity increased faster in these industries; second, in the beginning of the 1990s, the share of technology–driven industries was 22 % in the EU and 26 % in the US; and, third, the productivity lead of the US – however difficult it may be to measure productivity levels – was particularly large in these industries, so that the dynamics of this sector took place on top of a strong starting position.

Among the top 25 industries in both regions, three are electronic industries (equipment, computers, valves and tubes) and two are motor-vehicle industries (bodies for motor vehicles and parts and accessories for motor vehicles). Weapons and ammunition, and instruments are other high–technology industries in which productivity increased substantially both in the EU and in the US (see Table IV.6). Most other industries in the top 25 group are capital–intensive industries, ranging from man–made fibres to steel and pulp and wood. Technology–driven industries with high productivity increases in the EU which are not among the industries with high productivity growth in the US are pharmaceuticals, electronic apparatus, and recorded media. In general, of the 25 industries with the highest productivity increases in the 1990s in the EU, 14 are also among the first 25 in the US.[61] The similarities at the lower end of the spectrum are less marked. Of the 25 industries with the lowest productivity increases in Europe, only 10 are in the same group in the US, among which are five textile industries, oils and fats and motorcycles.

Comparison of the individual countries with the EU average shows that patterns of productivity growth have become similar across Member States. In 11

61 Of the 25 industries with the highest productivity increases in the EU between 1996 and 1998, 12 belong to top 25 group in the US.

Table IV.7: Industry taxonomy

Industries classified according to inputs used

	Mainstream manufacturing		**Marketing–driven industries**
1730	Finishing of textiles	1510	Meat products
1770	Knitted and crocheted articles	1520	Fish and fish products
1750	Other textiles	1530	Fruits and vegetables
1760	Knitted and crocheted fabrics	1540	Vegetable and animal oils and fats
2120	Articles of paper and paperboard	1550	Daiy products; ice cream
2430	Paints, coatings, printing ink	1560	Grain mill products and starches
2510	Rubber products	1570	Prepaed animal feeds
2520	Plastic products	1580	Other food products
2610	Glass and glass products	1590	Beverages
2660	Articles of concrete, plaster and cement	1600	Tobacco products
2680	Other non-metallic mineral products	1910	Tanning and dressing of leather
2720	Tubes	1920	Luggage, handbags, saddlery and harness
2870	Other fabricated metal products	1930	Footwear
2910	Machinery for production, use of mech. power	2210	Publishing
2920	Other general purpose machinery	2220	Printing
2930	Agricultural and forestry machinery	2230	Reproduction of recorded media
2950	Other special purpose machinery	2450	Detergents, cleaning and polishing, perfumes
2960	Weapons and ammunition	2820	Tanks, reservoirs, central heating radiators and boilers
2970	Domestic appliances n. e. c.	2860	Cutley, tools and general hardware
3110	Electric motors, generators and transformers	3350	Watches and clocks
3130	Isolated wire and cable	3630	Musical instruments
3140	Accumulators, primary cells and primary batteries	3640	Sports goods
3150	Lighting equipment and electric lamps	3650	Games and toys
3540	Motorcycles and bicycles	3660	Miscellaneous manufacturing n. e. c.
3550	Other transport equipment n. e. c.		**Capital intensive industries**
	Labour intensive industries	1710	Textile fibres
1720	Textile weaving	2110	Pulp, paper and paperboard
1740	Made-up textile articles	2310	Coke oven products
1810	Leather clothes	2320	Refined petroleum products
1820	Other wearing apparel and accessories	2410	Basic chemicals
1830	Dressing and dyeing of fur; articles of fur	2470	Man-made fibres
2010	Sawmilling, planing and impregnation of wood	2630	Ceramic tiles and flags
2020	Panels and boards of wood	2650	Cement, lime and plaster
2030	Builders' carpentry and joinery	2710	Basic iron and steel, ferro-alloys (ECSC)
2040	Wooden containers	2730	Other first processing of iron and steel
2050	Other products of wood; articles of cork, etc.	2740	Basic precious and non-ferrous metals
2620	Ceramic goods	3430	Parts and accessories for motor vehicles
2640	Bricks, tiles and construction products		**Technology–driven industries**
2670	Cutting, shaping, finishing of stone	2420	Pesticides, other agrio-chemical products
2810	Structural metal products	2440	Phamaceuticals
2830	Steam generators	2460	Other chemical products
2840	F oging, pressing, stamping and roll forming of metal	3000	Office machinery and computers
2750	Casting of metals	3120	Electricity distribution and control apparatus
2850	Treatment and coating of metals	3210	Electronic valves and tubes, other electronic comp.
2940	Machine-tools	3220	TV, and radio transmitters, apparatus for line telephony
3160	Electrical equipment n. e. c.	3230	TV, radio and recording apparatus
3420	Bodies for motor vehicles, trailers	3310	Medical equipment
3510	Ships and boats	3320	I n sutnents for measuring, checking, testing, navigating
3520	Railway locomotives and rolling stock	3330	Industrial process control equipment
3610	Furniture	3340	Optical instruments and photographic equipment
3620	Jewellery and related articles	3410	Motor vehicles
		3530	Aircraft and spacecraft

Source: DBA and COMPET. WIFO calculations.

countries during the 1990s, the ranks in each country are significantly related to the corresponding EU ranks.[62] The only countries where the correlation is not significant are Denmark, Ireland and Finland. In the case of France, Spain, the Netherlands and Austria, the correlation is significant both for sectors (2-digit level) and for industries (3-digit level). Three small countries (Belgium, Portugal and Sweden) have, together with two large countries (France and Spain), the closest conformity to EU productivity growth patterns.[63]

If there is a strong pattern of variation in productivity growth across industries, countries with a higher share of industries that have experienced high productivity growth should themselves experience higher productivity growth. This is to some extent the case. For example, if the US had had the EU production structure, its increase in productivity would have been slower by half a percentage point in the 1990s. The reason is that the high productivity growth in technology–driven industries would have had less weight compared to the actual US data. However, if the EU had had the US production structure, it would not have had a higher productivity increase since several of the capital–intensive industries, in which productivity increases in the EU were specifically strong, would have had less weight. According to the same hypothesis, Greece (because of its high share of capital–intensive industries) and Ireland (because of its greater share of technology–driven industries than the US) would have registered the greatest reduction in productivity growth, while the highest gains would have been achieved in the Netherlands and Belgium.

4.5. Concluding Comments

Innovation, leading to new products and production processes, is an important determinant of productivity improvements and economic growth. But innovation is also a complex process intertwined with factors such as the strength of the knowledge base, institutional arrangements, qualification of the labour force, openness of the economy and overall ability to take on board improvements achieved in other countries or sectors. Other than through own innovation, an economy may also improve its performance as a result of innovation diffusion or through technology embodied in inputs and new capital goods, which in turn may magnify the benefits of own research efforts. Indicators proxying different aspects that facilitate innovation and growth are indeed shown to be related to productivity and economic performance in manufacturing. The relationship is not necessarily significant for each indicator separately, conceivably due to the complex nature of innovation, the complementarity required between certain factors, and the multiple roads to innovation and growth.

In the 1990s, EU technology-driven industries experienced the highest productivity growth, followed by capital-intensive industries, where this high growth took place mainly in the first half of the decade. In the US, technology-driven industries took the lead in productivity growth in every sub-period.

The good performance of capital-intensive industries in the EU during the first half of the 1990s is most probably the result of the restructuring that took place in these industries and hints at the importance of embodied technology in innovation diffusion and its effect on economic performance.

In the 1990s, research intensity and productivity growth are significantly related across sectors, both in the US and within the EU, though not in each Member State individually. This relationship reveals the role of research efforts for innovation and performance; on the other hand, the lack of such relationship at country level may be a sign of international spillovers at work.

In terms of patterns of productivity growth, there appears to have been increasing convergence between the US and the EU. While in the 1980s the US hierarchy of productivity growth across industries was significantly different from that in the EU, in the 1990s these patterns became more and more similar. This is partly the result of the lag, relative to the US, in productivity performance of technology-driven industries. In the EU, it was not until the second half of the 1990s that technological forces appear to have played a determining role in the industrial pattern of productivity growth; while competitive forces, driving the restructuring of capital-intensive industries, are most likely behind the developments of the first half of the decade.

62 The selection criterion is the rank correlation for productivity growth (combined indicator) at the 90% level of significance at a minimum of one level of aggregation (2– or 3–digit level).

63 The relation between country and EU performances in productivity growth remains close when working with the short period 1996 to 1998, and is better when using the acceleration of productivity growth during this period vs. the first half of the nineties. Only four countries exhibit no significant relation between own acceleration of productivity and that of the EU: Belgium, Ireland, the Netherlands and Greece.

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