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Abstract

The OECD job study (1994) argued that it is necessary to develop a better understanding for the relationship between growth and employment since growth may be linked with job destruction in some cases and job creation in others. A new study by *Edquist, Hommen and McKelvey* (2001) examines this relationship in the context of process versus product innovation. By distinguishing between these two types of innovation, these authors provide a series of hypotheses and questions that address some of the issues raised in the OECD study. But the study does not go beyond existing empirical analysis, often only drawing inferences from individual country studies. Our paper attempts to address some of these issues by providing a comprehensive analysis of growth and employment across the EU member states, including, wherever possible, the USA and Japan. As in the study by Edquist, Hommen and McKelvey, we relate growth and employment through innovation. The analysis relies on Eurostat industrial survey data, labour force survey data, and the 1997 Community Innovation Survey. Using panel data we examine the relationship between productivity, output and employment on the one hand and the impact of innovation on employment across industries and countries during the second half of the 1990s.

Introduction*

Europe has traditionally had a weak employment growth record in comparison with USA and Japan, which even worsened in the course of the 1990s. There are, however, some countries within Western Europe which exhibit substantial employment growth rates comparable to the international employment growth leaders. Our aim is to find out what distinguishes the fast growing countries from the ones with a particularly bad employment performance. In particular, we will look at the relationship between employment and output growth on the one hand, and innovation and employment growth on the other. We concentrate on manufacturing industries, in particular the linkage between productivity, output and employment growth, bearing in mind that this limits any conclusions which may be drawn for countries as a whole in respect to these variables. We take a cross-country perspective, comparing EU-member States, for which an innovation survey was undertaken in 1996 (Greece, the Netherlands and Portugal are excluded from certain calculations due to lack of comprehensive data)[1].

Employment in manufacturing industries has declined in practically all countries in Europe. This is a result of productivity increases, international reallocation of production as well as outsourcing of services from manufacturing to specialised business oriented services[2]. While productivity increases tend to have a clear positive relationship with output growth, the relationship of productivity with employment growth is not so straightforward. Technical change is generally the driving force behind productivity growth. It may not only have an impact upon the output/demand for the product of the innovating enterprise/industry, but also on the output/demand of other industries, which may be suppliers of intermediate products (inputs) or competitors on the product market (output), and real income or purchasing power of the consumer and thus the overall level of demand. In these circumstances, the income effect obviously tends to offset the substitution effect in output/demand, but the impact on the labour market may show up in employment as well as in wage adjustments.

In the following, we first look at certain theoretical aspects in terms of the expected impact of technological change on employment/wages and the functional mechanisms at work. Next, we analyse the actual impact of innovation, as measured in the innovation survey (10 manufacturing industries), on employment and to what extent wages come into the picture.

Effect of technological change on employment from a theoretical perspective

The question of the effect of technological change[3] on employment has been at the centre of economic theorising well before the times of the industrial revolution. Adam Smith provided a dynamic view of the process of mechanisation as it relates to the division of labour and the expansion of the market. David Ricardo took this view one step further by pointing out that mechanisation could have a long-term detrimental effect on employment because "machinery and labour are in constant competition". In other words job creation was by no means certain when new products and processes are introduced into the market. By the end of the nineteenth century,

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* Thanks are due to Julia Bock-Schappelwein and Peter Bartunek who have done the major part of the calculations in this paper, and Joe Isaac for critical remarks and advice.

[1] The survey enquires about innovations undertaken in the period 1994-96, following the OSLO-Manual, for value added and employment data we use the CRONOS-Data base of EUROSTAT, for Austria the WIFO-database was used to complement Cronos.

[2] For a detailed account of reallocation of labour within and between firms and industries see *Biffl* (1991).

[3] Technological change involves the invention and diffusion of a new technique, i.e., alterations to the production function.

neo-classical economists including Leon Walras, Stanley Jevons, and Karl Menger argued that automatic mechanisms would ensure that the capital-labour ratio would adjust such that enough new jobs are created to replace those destroyed. In other words, full compensation was no longer addressed in terms of employment, but in terms of the marginal productivity of capital.

While Smith suggested that the process of mechanisation might change the pre-existing capital-labour ratio, he also recognised that technical change and technological learning are important factors in economic growth. Allyn Young later pointed out that an enlarged division of labour both between and within firms could bring about these endogenous productivity gains. This idea formed the basis for *Kaldor*'s (1966) model of cumulative causation. In his model, expanding markets lead to external and internal increasing returns that, in turn, are transformed into expanding markets and the formation of new demand. The Verdoorn law, which links productivity gains to output growth, provided a way to account for these dynamics. However, while this approach provides a good account of a prolonged productivity slowdown, existing versions of this model do not address the issue of technological change and employment. Indeed, an interesting aspect of the Keynesian tradition is that the market does not provide an automatic mechanism for maintaining full employment.

While Kaldor and the post-Keynesians were able to show that productivity gains are endogenous, they have not been able to explain how the pace of diffusion (and spillovers), differences in product or process innovations, or the sectoral dimension can affect these gains. Indeed, the impact that these productivity gains may have on employment will depend on whether there was a product or process innovation, the pace of diffusion and the structure of employment by industry and skills. Productivity gains depend on the innovation process, which entails the creation of a new product or a new process of production and distribution. These innovations may then spread into various industries and regions, depending on the type of diffusion process taking place. The impact these innovations will have on employment will also depend on the structure of industry and the skill levels of that industry.

Technological change also becomes endogenous when firms are given the power to decide on R&D expenditures and other expenditures related to the innovation process. But the decision to invest in the production of new products and introduce new processes is not a simple one. There may be the rare cases of pure product innovation, i.e., involving no process change, and pure process innovation, entailing the production of no new product. In most cases, however, the creation of a new product will be linked with new processes of production and distribution, and new processes of production tend to be linked with a new quality of product. In the context of complex production processes captured by input-output tables, the product innovation of one industry (e.g., robots) may allow new production processes in other industries[4].

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[4] For a detailed account of the interlinkages involved see *Kalmbach* and *Kurz* (1992).

The introduction of new technology may result, for a given output, in a decline in labour or capital use or it may be neutral as to factor use. However, it always has an effect on the structure of employment by industry and skills.

Inventions are at the source of technological change. They entail the creation of a new product and/or a new process of production and distribution. If inventions find their way into commercial application, they are referred to as innovation, which may then spread into various industries and regions, depending on the type of diffusion process taking place.

Another characteristic of technological change, which has an impact on employment, is the extent to which it is embodied in the latest vintage or generation of a product/process only or, alternatively, to what extent it is disembodied, i.e., is transferable to the existing human and technical capital stock employed. At any point in time, production is taking place combining different vintages of human and physical capital, i.e., workers of different age with different levels of education/knowledge and skills who may be capable of handling only a limited range of different production modes (vintages). An analysis of the impact of technological change upon employment becomes very difficult, if it takes these complex relationships between production mode and human skills into account, or, in other words, if it goes beyond the assumption of homogeneous capital and disembodied technological change.

At its simplest, technological change may render the employment of one or more factors of production more efficient, i.e., the same output can be produced with less workers or, alternatively, the same number of workers may produce more output. The situation is, however, more complicated, if, for example, the elasticity of substitution between the factors of production are affected by the technology.

Another problem of measuring the impact of innovation on output and employment is that the lags involved between the expenditure on R&D, leading to innovations, and output may be very long and not directly linked to a firm or industry under consideration.

Analytically there is a distinction between the impact of innovation on employment at the firm level, the industry level and the national level.

1. The firm level

The effect of technological change on employment depends on the rate and nature of technological change, in particular the degree to which it is labour saving, labour using or neutral to labour use or the skill mix of labour use. In the case of neutral technological change, the same output may be produced with less labour input or, alternatively, output can be increased by keeping the employment level constant. Depending on the demand for the product in the goods market, the firm may reduce its employment level (in the case of limited output/demand) or keep its employment level constant as output is maximised (increasing product demand). In the case of labour saving technological change, the capital/labour ratio in production rises, which results in a more pronounced decline of employment than in the neutral case, given constant output and factor price ratios. The opposite holds in the case of capital saving technological change.

The innovation process may entail a changing skill structure of employment; it may be deskilling, skill raising or skill-polarising within the firm, it may, however, also lead to outsourcing of particular tasks (e.g., programming). In the latter case the effect of innovation may be a decline in manufacturing employment as jobs are shifted from manufacturing to business oriented services and thus changing the skillstructure of employment.

The introduction of a new product is generally expected to be linked to employment creation – even though cases are known, in which a firm switched from a successful to an unsuccessful product (for example in the car industry).

2. The industry level

The impact of innovation on the employment level of the industry depends on the pervasiveness of the new technology, the flexibility of wages and the adjustment speed of education and training institutions to the new needs. The faster the rate of diffusion of the new technology, the more pronounced the effect on employment. If real wages for the type of labour with less demand fall, the diffusion process may slow down as a result of renewed competitiveness of the old technology. Total employment may be positively affected by the technological change and/or work organisation, if the output effect is stronger than the substitution effect.

3. The economy level

Employment growth relative to other countries depends on productivity growth relative to other countries. The productivity increase as a result of the implementation of new technology may create a comparative advantage to manufacturing in the innovating country and thus allow employment growth as a result of increasing market shares. The increase in employment will of course be moderated by trade barriers and high transport costs. The countries/industries with smaller relative productivity increases are faced with increased import penetration and lower export performance.

Industries/economies with faster productivity growth tend to be those with higher output growth, an empirical relationship referred to as Verdoorn's Law[5]. The direction of causality is still disputed. One explanation for this relationship may be that faster productivity growth may be passed on to the consumer through lower prices thus allowing faster demand/output growth. Another, that continued learning, retraining and upskilling as well as investment in R&D are responsible for endogenous productivity growth, the fruit of which is shared among workers through rising wages and the consumers through declining prices thus contributing to demand growth. Because of this

[5] The Verdoorn relationship has been changing over time suggesting that there is a complex link between production and labour productivity.

relationship, the dampening effect of productivity increases upon employment growth is somewhat mitigated.

Given this reasoning, one may distinguish 3 types of countries/industries:

1. The principal innovators: they are at the forefront of productivity growth (industries with an above average relative productivity growth); they may have an above average relative employment growth performance, since the expansion of output as a result of being the forerunner offsets the adverse employment effect of productivity growth.

2. The rapid followers: they keep up with technological change and can thus preserve market shares, thus allowing below average employment declines

3. Slow implementation/imitation of new technology: these industries fall behind in world market shares; their relative productivity performance is below average. The combined effect of low productivity and loss of market shares is in the long run the greatest job killer.

In the following section we try to find out which countries and industries belong to the rapid innovators and which are lagging behind. We start our analysis by estimating the relationship between productivity growth on the one side and wage and employment growth on the other for all countries and all industries in every country for the period 1990 to 1998, assuming that output/market growth is at the root of endogenous productivity growth. It is the driving force for product and process innovation. Thus globalisation and the associated market/demand growth, stimulate endogenous productivity growth which allows a growth in wages, while market growth facilitates employment growth. International trade theory/pattern suggests that labour saving innovation can be the motor behind rising exports which can lead to rising employment in the innovating country. A comparative advantage in the production of a product allows the country to specialise and reap productivity increases as a result of economies of scale.

Patterns of Output, Productivity, Employment and Wages in Manufacturing

In the 1990s, the EU (15) has been less successful than USA and Japan in terms of manufacturing output growth (1.3 percent between 1990 and 1999 compared to 4.3 percent in Japan and 3.4 percent in USA) and productivity growth (2.7 percent compared to 6.8 percent in Japan and 3.7 percent in USA). It has had a slightly smaller employment decline than Japan (–1.04 percent compared to –1.09 percent in Japan) but clearly greater employment losses in manufacturing than USA (–0.24 percent in USA). Wages per employee increased in each one of the three world regions, U.S. manufacturing workers being the most fortunate with a rise in the average wage rate of 2.56 percent p.a. (1989/1997), compared to 1.21 percent p.a. in the EU (1990/98) and 0.73 percent in Japan (1989/97).

Table 1: Average annual growth rates in manufacturing (output, productivity, employment and wages) in the 1990s

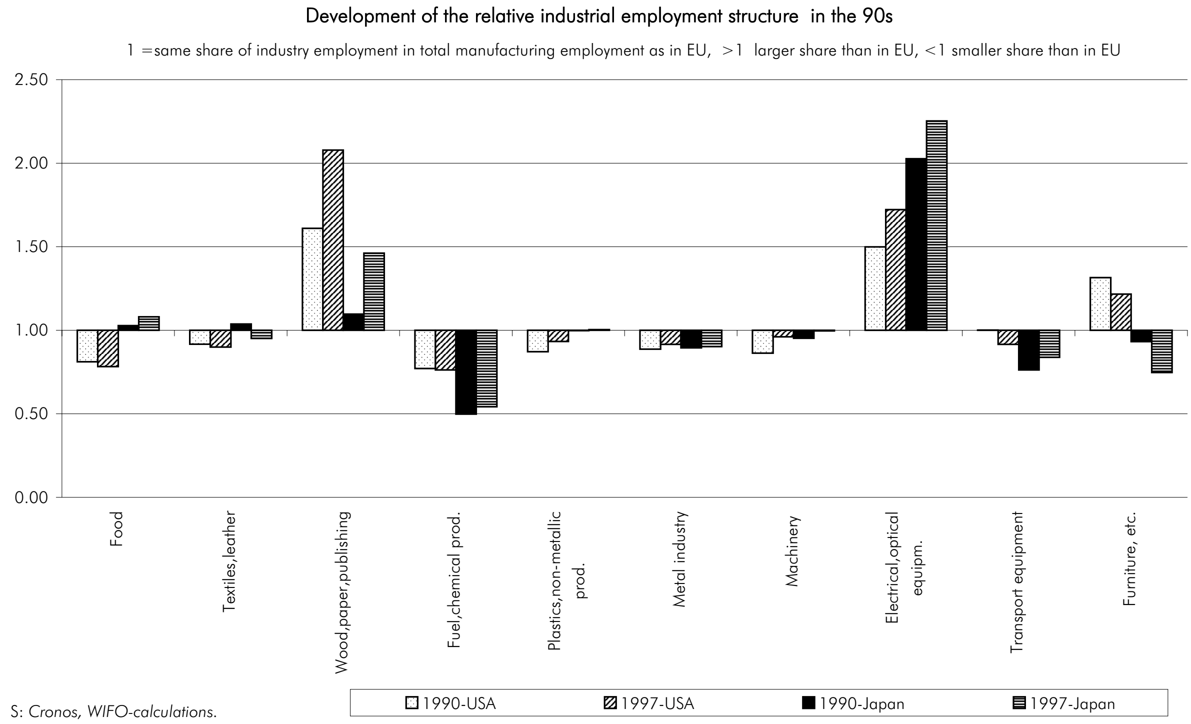
	Average growth rates (manufacturing)			
	Value added	Productivity	Employment	Wage/employee
EU	1.30	2.69	– 1.04	1.21
USA	3.43	3.69	– 0.24	2.56
Japan	4.34	6.81	– 1.09	0.73
Austria	5.91	7.24	– 1.27	1.95
Belgium	0.33	1.02	– 0.70	– 1.87
Denmark	3.76	1.16	2.92	9.00
Finland	1.80	1.99	– 0.30	1.32
France	2.62	3.04	– 0.39	2.92
Germany	1.77	3.82	– 1.94	0.31
Greece	1.91	3.36	– 1.96	0.91
Ireland	6.38	3.33	3.06	13.93
Italy	– 0.64	– 0.09	– 0.56	0.78
Luxembourg	3.31	5.04	– 1.59	2.06
The Netherlands	2.79	0.93	2.49	6.33
Portugal	3.37	4.67	– 0.08	2.75
Spain	1.03	1.13	– 0.21	2.61
Sweden	– 2.03	– 1.33	– 0.58	2.71
United Kingdom	– 0.35	1.92	– 2.42	0.48

S: Cronos, WIFO-calculations.

The (unweighted) industrial structure of the EU relative to Japan and USA provides little insight into the reasons for the comparatively weak employment performance of the EU. Differences between the various EU countries are significant in terms of options/opportunities for productivity growth as a result of increasing returns, scale economies, innovative activity etc. The extent to which countries/industries are willing to let their workers share in the output and productivity growth in terms of employment and wage rises also differs significantly within the EU such that a clear understanding for the reasons behind the comparatively weak employment performance of the EU is hard to establish by comparing average output, productivity and employment data only.

Subject to these qualifications, Graph 1 shows that the EU tends to have a larger employment share than USA and Japan in heavy industries (basic metals, chemicals, coke, refined petroleum products), in manufacturing of machinery and transport equipment (cars), the manufacture of rubber, plastic and other non metallic products, and in some consumer goods industries (food, textiles and clothing). In contrast, the USA and Japan have larger employment shares than the EU in the production of wood/paper products and publishing, and in the manufacturing of electrical and optical equipment. The United States are also stronger in the manufacturing of furniture and other not classified manufacturing than the EU, but the EU is stronger in these areas than Japan.

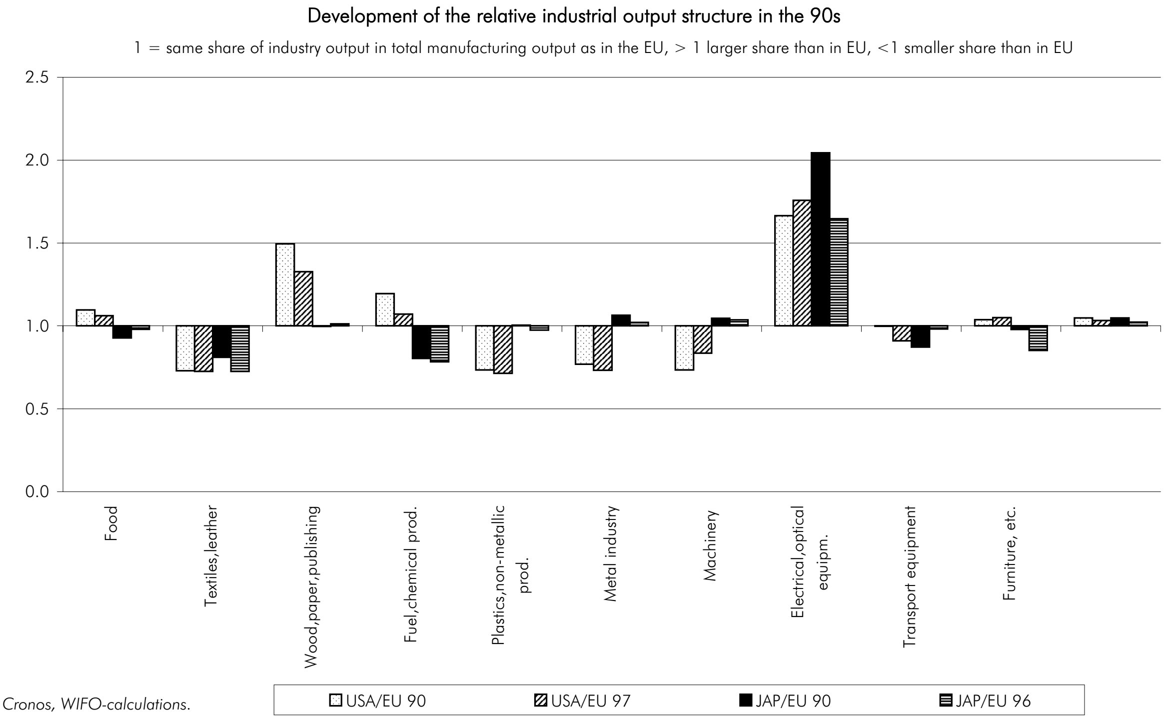
Graph 1: Development of the relative industrial employment structure in the 1990s



S: *Cronos, WIFO-calculations.*

If we look at the industrial output structure, we get a somewhat different picture because of significant differences in productivity levels between these industries across regions. USA and Japan have a much higher share of electrical and optical equipment in total output than the EU – a picture we also get from the relative employment front. On the other hand, while in the USA (relative to the EU), output in wood/paper and publishing has a more than proportionate share in manufacturing output, this is not so in Japan; suggesting a lower productivity level in the latter. Also, as in food production, the share of chemicals, coke and refined petroleum products in total manufacturing output, is larger in USA than in the EU, even though the employment share is smaller, suggesting a much higher capital intensity and labour productivity in USA compared to the EU. In Japan, in contrast, labour productivity is higher in metal industries and the manufacturing of machines than in the EU, thus having a higher output share and a smaller employment share in total manufacturing than the EU. In food production on the other hand, USA has by far the highest productivity level compared to the EU and Japan, thus explaining the comparatively low employment share compared to the EU and Japan while having a higher share in total manufacturing production.

Graph 2: Development of the relative industrial output structure in the 1990s



S: *Cronos, WIFO-calculations.*

Across industries in the various countries and, to a lesser extent, across countries in the various industries, there is a clear positive relationship between productivity growth and output growth (Verdoorn law, Graph 3) on the one hand, and employment and output growth (Kaldor's law, Graph 4) on the other. As shown in equation 1, these two relationships are basically complementary mirror images of each other, in which total output growth (q) is defined as a function of productivity growth (p) and employment growth (e)[6].

1. $q = p + e$

2. $p = a_1 + b_1 q$

3. $e = a_2 + b_2 q$

The Verdoorn coefficient b_1 captures the stimulating effect of the expansion of the market and structural change on productivity and is 0.4 for the EU; added to the mirror Kaldor coefficient b_2 (0.7) the total should in principle be equal to 1. This implies that in the case of a rise in output by 1 percent, something like two thirds show up in a rise in employment and a third in a rise in productivity. As shown in Table 2, in the case of the U.S., a larger proportion of output growth is

[6] For more detail see *Knell* (2001), *Rayment* (1981), *Kaldor* (1966, 1975), *Verdoorn* (1949).

the result of productivity increases while a smaller one comes from employment growth. In Japan output growth arises to a larger extent than in USA from productivity increases (0.7 compared to 0.4)), allowing very little to be derived from relative employment growth (0.3 compared to 0.5).

Table 2: Regression analysis of the Verdoorn-Kaldor relationship in manufacturing for the EU, USA and Japan

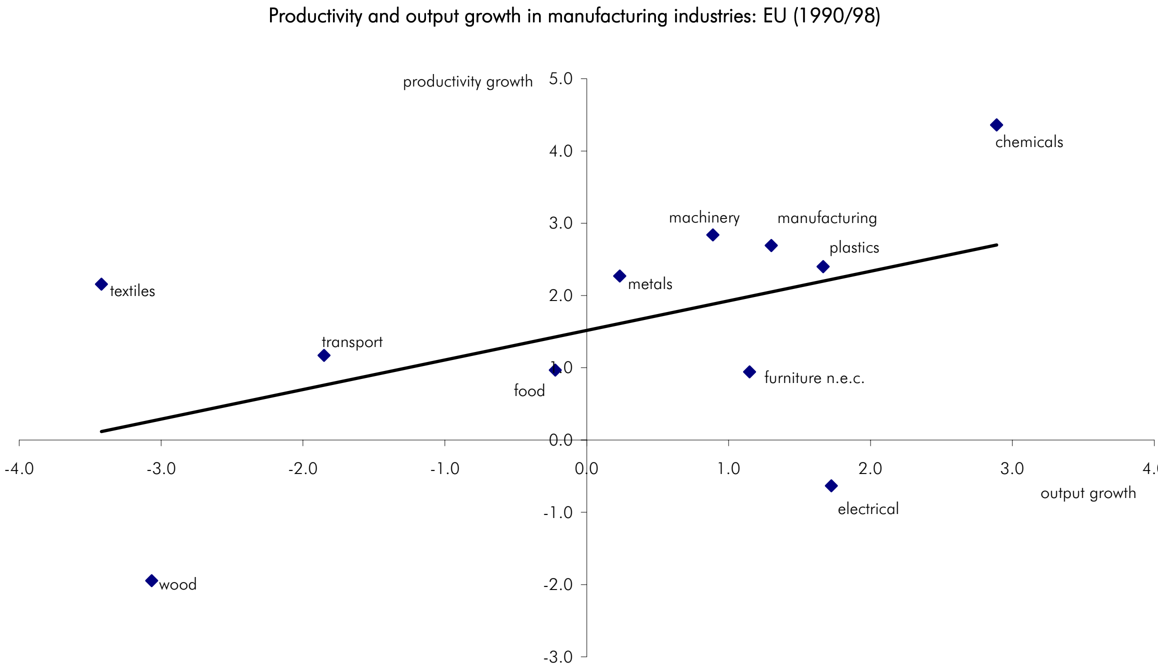
	Intercept a_1/a_2	t-value for a_1/a_2	Regression coefficient b_1/b_2	t-value for b_1/b_2	F-ratio	R^2	DW	Signif.
			Productivity growth on output growth in manufacturing					
EU	1.5	2.831	0.447	1.501	2.252	0.233	2.858	0.168
USA	2.361	4.443	0.431	3.202	10.256	0.351	2.098	0.007
Japan	3.654	4.189	0.684	4.223	17.832	0.484	1.534	0.03
Manufacturing across countries	1.04	0.577	0.76	4.683	21.933	0.578	1.8	0.0
			Employment growth on output growth in manufacturing					
EU	– 1.4	– 4.557	0.706	2.988	8.931	0.498	0.989	0.015
USA	– 2.219	– 4.402	0.545	4.185	17.512	0.480	2.094	0.292
Japan	– 3.540	– 4.506	0.324	2.223	4.942	0.206	1.536	0.000
Manufacturing across countries	– 1.0	– 1.610	0.29	0.961	0.923	0.16	1.916	0.091
			Employment growth on productivity growth in manufacturing					
EU	– 1.6	– 2.747	0.166	0.555	0.308	0.05	1.2	0.253
USA	0.404	0.592	– 0.317	– 1.002	1.003	0.100	2.293	0.343
Japan	– 3.6	– 0.567	0.4	– 0.436	0.190	0.09	2.4	0.33
Manufacturing across countries	0.22	– 0.599	– 0.19	– 0.500	0.250	0.07	1.820	0.352

S: Cronos, WIFO-calculations.

It should follow that we would expect employment growth to be greater in Europe than in the USA and Japan – but this is not the case for the United States relative to the EU as shown in Table 1. An explanation for this paradox could be that USA tends to be at the forefront of productivity growth in manufacturing as a result of its greater specialisation in industries with increasing returns. USA may also be at the forefront of technological development thus securing output growth through expanding markets and/or new products. USA is thus able to obtain employment growth in total manufacturing beyond that experienced in the EU; Japan, in contrast, is not able to raise employment growth beyond EU growth, as productivity growth is at the expense of employment growth to a larger extent than in Europe.

We now show the clear positive relationship between productivity growth and output growth across the various industries (Graph 3) and employment and output growth across the various industries (Graph 4) in Europe.

Graph 3: Productivity and output growth in manufacturing industries (EU 1990/98): $p = a_1 + b_1 q$



S: *Cronos, WIFO-calculations.*

In the 1990s, the industry with the highest output growth and associated productivity growth in the EU, has been the production of coke, fuel, petroleum products, chemicals and man made fibres, followed by the production of rubber and plastic products, machine production and metal industries.

In contrast, only one industrial group experienced positive employment and output growth in the EU, i.e., furniture and miscellaneous non-classified production (Graph 4). But there was a clear positive relationship between output growth and employment growth for all industries.

If we look at productivity and employment growth simultaneously (Graph 5), i.e., we compound the Verdoorn and Kaldor relationship into one, the outcome is uncertain; it can only be determined empirically. In our case we get a positive (but statistically insignificant) relationship for the various industries in the EU. Under partial equilibrium analysis, the positive relationship runs counter to the general notion of the impact of productivity growth on employment growth. Such analysis does not take the market/demand growth effect of technological change into account. Only where there are constraints to output/demand growth, will productivity growth have a negative impact on employment growth[7]. Constraints to output or demand growth could be high transport costs, regulated markets (production quotas are common in certain industries, e.g., iron and steel output

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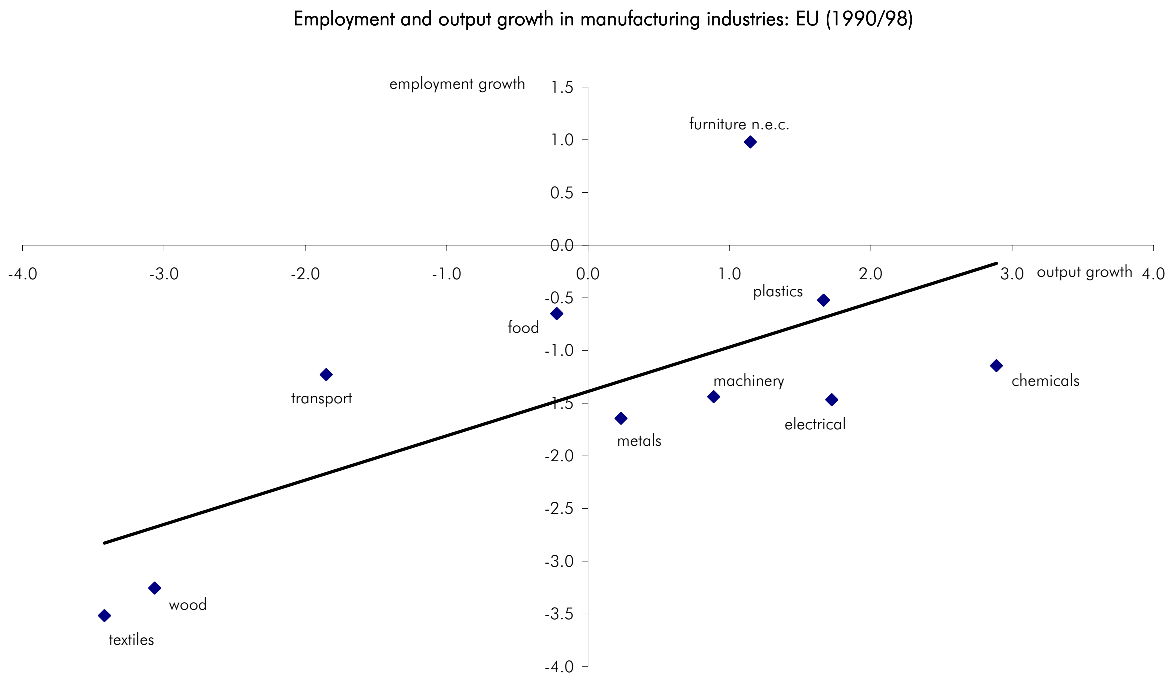
[7] Of course there are cyclical fluctuations to output growth, which we have not controlled for in this paper.

in the EU, oil production by the OPEC countries), or monopolistic industries, which favour profit rather than employment maximisation.

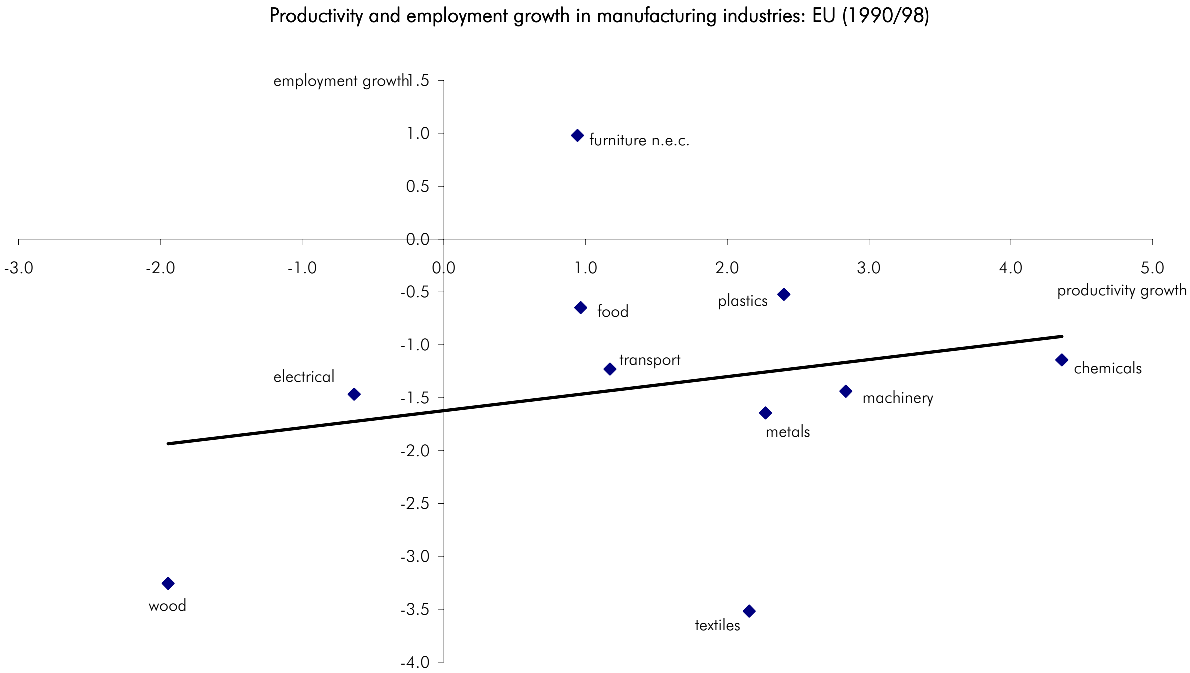
Graph 4: Employment and output growth in manufacturing industries (EU 1990/98): $e = a_2 + b_2 q$



S: *Cronos, WIFO-calculations.*

The consolidated information of a positive relationship between productivity growth and employment growth in manufacturing in the EU in Graph 5 is basically the dividing line between b_1 and b_2. It is thus the result of a steeper slope of employment on output growth compared to productivity on output growth. This is another way of saying that the employment intensity of technical change is higher in the EU than in Japan which is the result of various factors linked to the different industry mix. In the EU, chemicals and machinery had the strongest productivity increases in manufacturing in the 1990s, which were accompanied by substantial declines in employment. At the other end of the spectrum are electrical equipment and wood, paper, publishing with negative productivity growth and at the same time the most pronounced employment losses. Furniture production etc., in contrast, has had both relatively high productivity growth and increases in employment. In the latter industries countries in the EU are amongst the technological leaders and may therefore reap employment growth from gaining in market shares.

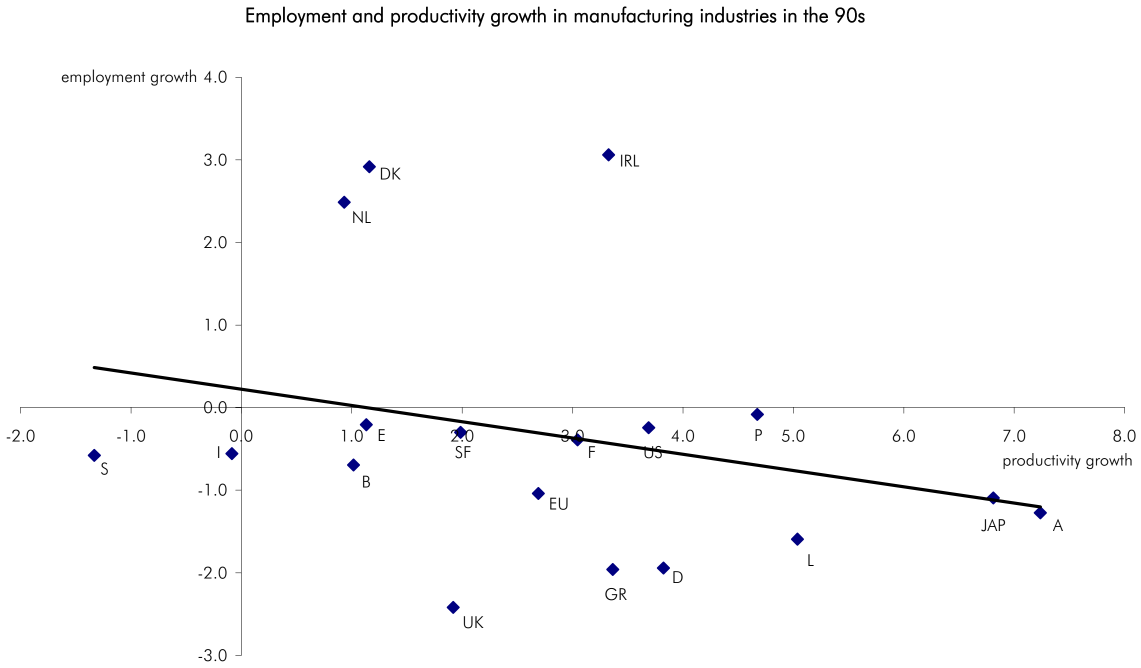
Graph 5: Employment and productivity growth in manufacturing across countries: 1990/98



S: *Cronos,WIFO-calculations.*

Across countries the relationship between employment and productivity growth is slightly negative (Graph 6). There are countries in the EU which are productivity leaders in one or other industry, thus favouring employment growth in areas of increasing market demand. There are others, however, in which the relationship is negative. Austria and Japan are the two countries with the strongest productivity increases in manufacturing in the 1990s, which were accompanied by substantial declines in employment. At the other end of the spectrum are Denmark and the Netherlands with comparatively small productivity growth but substantial employment growth in total manufacturing. Ireland, in contrast, has had both high productivity and employment growth. Further, Denmark and the Netherlands were also amongst the countries with a positive employment and productivity growth record; while Portugal, USA and France had substantial productivity increases while reducing employment only slightly. In contrast, the U.K., Germany, Greece and Luxembourg were doing very well on the productivity growth front but at the cost of employment.

Graph 6: Employment and productivity growth in manufacturing across countries: 1990/98



S: *Cronos, WIFO-calculations.*

Cripps and *Tarling* (1973) have tested the relationship between productivity growth and employment growth for the 1960s and early 1970s in the various manufacturing industries across countries with limited success in terms of explanatory power.

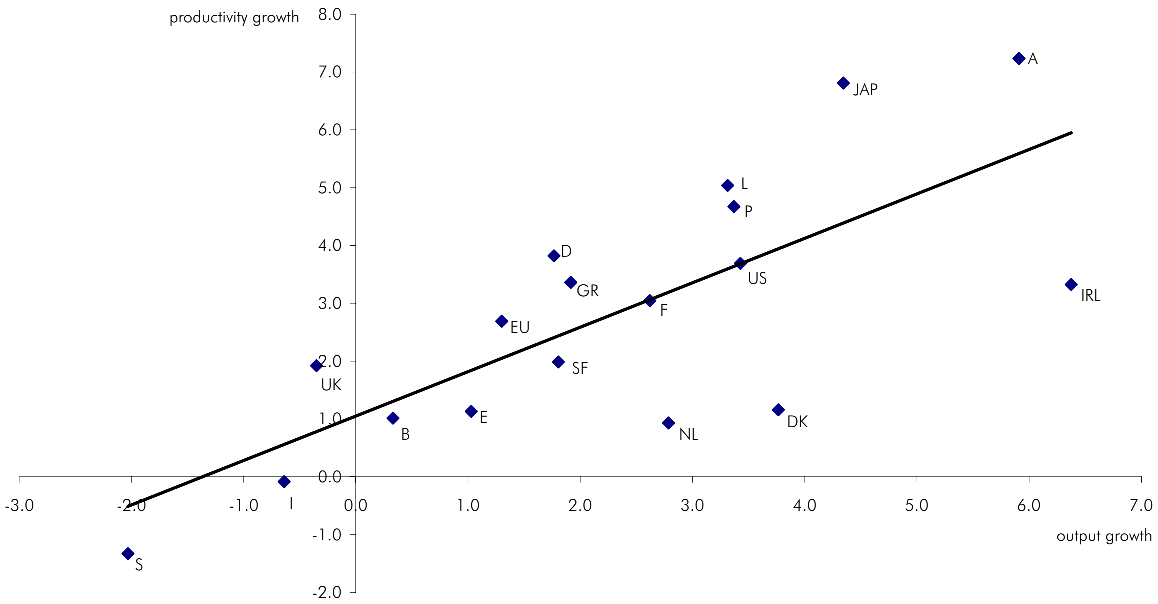
The Cripps-Tarling relationship is, of course, based on simplified economic theory but it also limits our understanding of the functional mechanisms at work in the case of technological change and its eventual impact on employment.

The countries with the highest productivity and output growth in the 1990s were Austria, Ireland and Japan, whereas Sweden, Italy and the U.K. were at the opposite end (Graph 7).

Employment and output growth were highest in Ireland, Denmark and the Netherlands, and lowest in the U.K., Sweden and Italy (Graph 8). The Cripps-Tarling relationship does not shed light on the reasons for the substantial differences of employment intensity of output growth between countries. We will show later that an extension of the Kaldor and Verdoorn Law is able to provide more insight in the functional mechanisms at work.

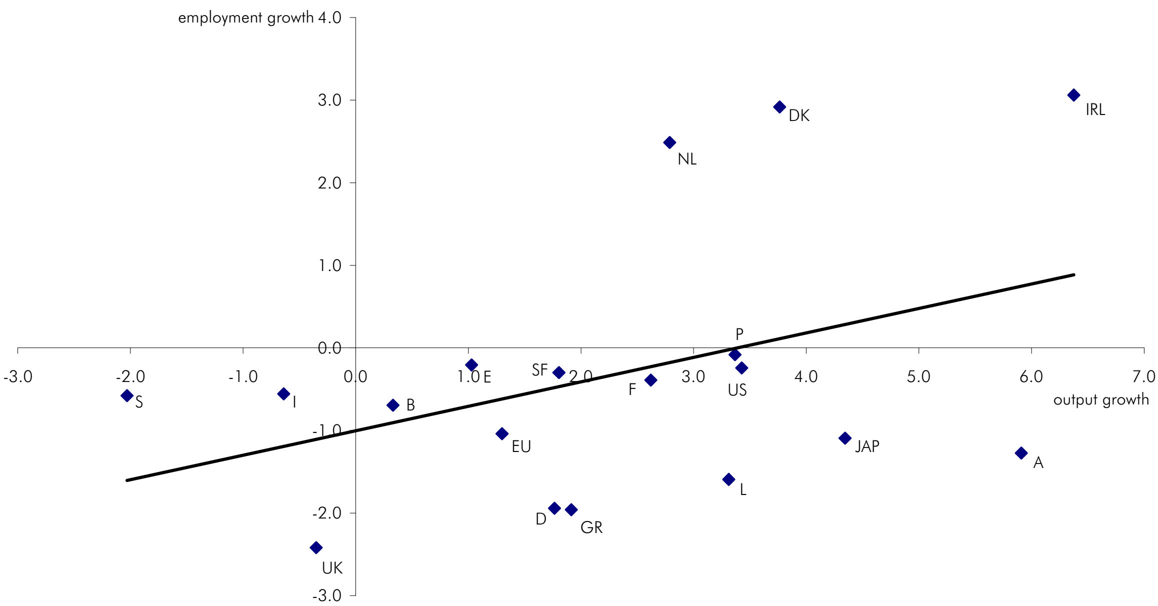
Graph 7 and 8: Productivity, employment and output growth in manufacturing industries in the 1990

Productivity and output growth in manufacturing industries in the 90s



S: *Cronos, WIFO-calculations.*

Employment and output growth in manufacturing industries in the 90s

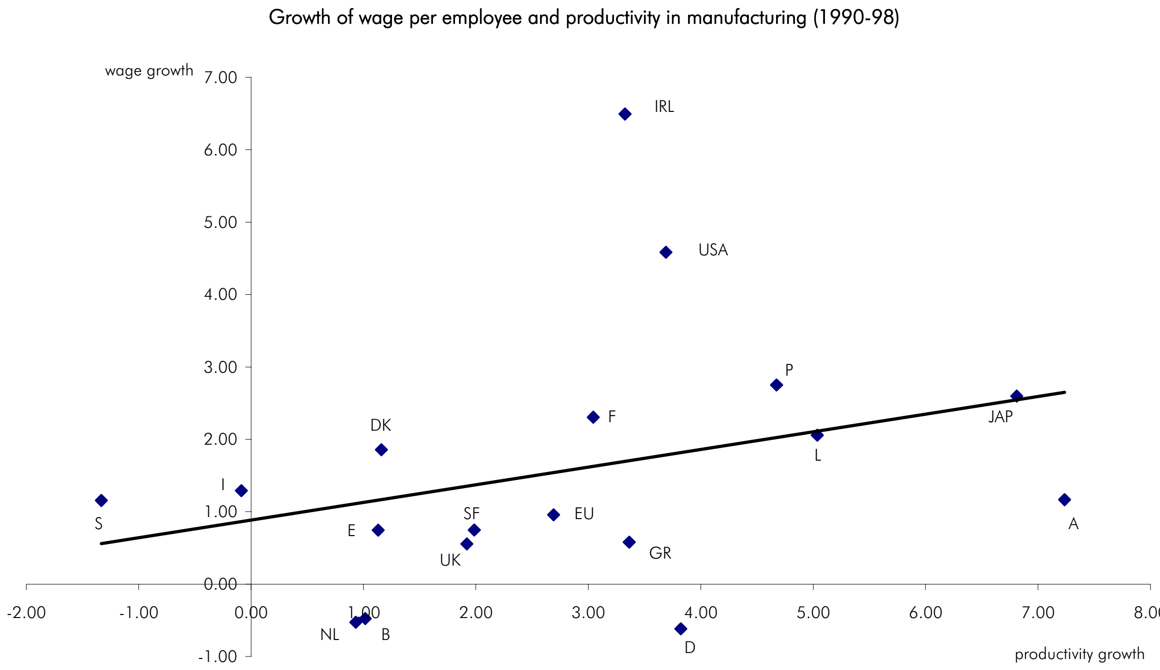


S: *Cronos, WIFO-calculations.*

Looking now at the development of wages in manufacturing relative to productivity growth, there is a clear (highly significant) positive relationship between productivity growth and the growth of the wage rate across countries (Graph 9). However, across industries this relationship is relatively weak (Graph 10). This suggests that the competitive position, as reflected by national productivity, of countries as a whole rather than the productivity performance of an industry across countries determines to what extent workers can expect wage increases. This provides an important guide to wage policy, as *Salter* (1969) has pointed out some time ago.

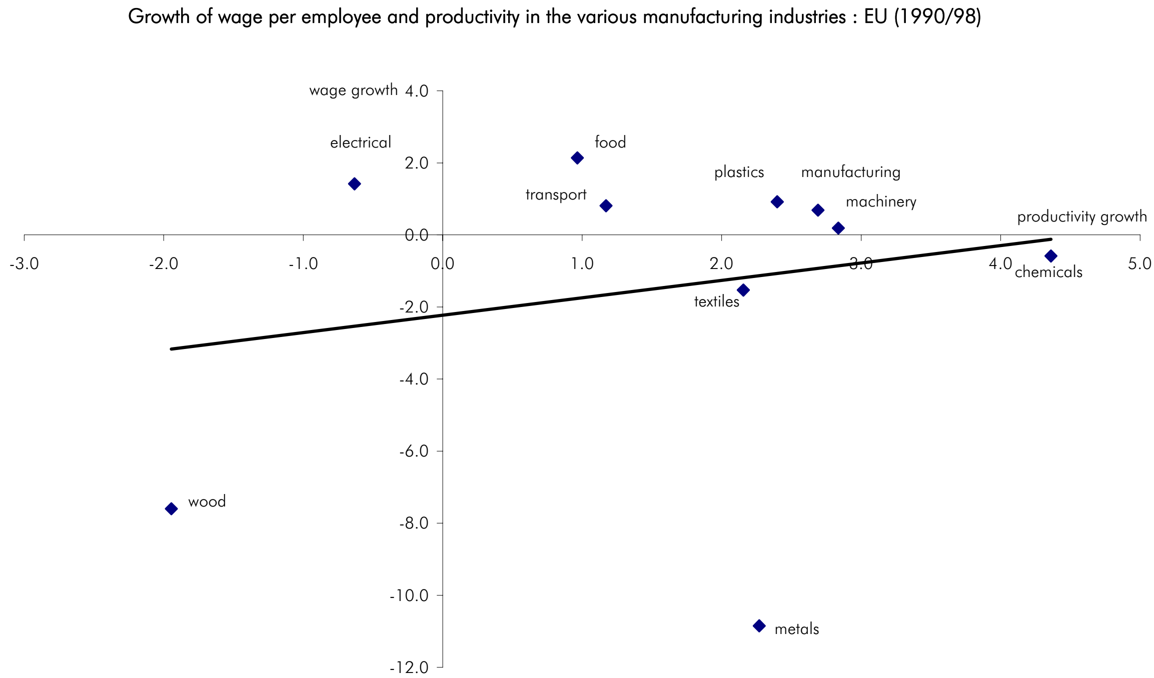
It may be inferred from industries which have both above average productivity and employment growth, that they have been successful in introducing new products or opening up of export opportunities. i.e., enlarging the market. Examples would be furniture production in Denmark, electrical equipment manufacturing in Finland, and production of plastics in Ireland.

Graph 9: Productivity growth and the wage rate in manufacturing by countries 1990/98 (w = 0.88 + 0.24p)



S: *Cronos, WIFO-calculations.*

Graph 10: Productivity growth and the wage rate in manufacturing by industries: EU 1990/98 (w = –2.2 + 0.5p)



S: *Cronos, WIFO-calculations.*

Table 3: Manufacturing industries: Ranking by relative productivity advantage in the various countries (1998)

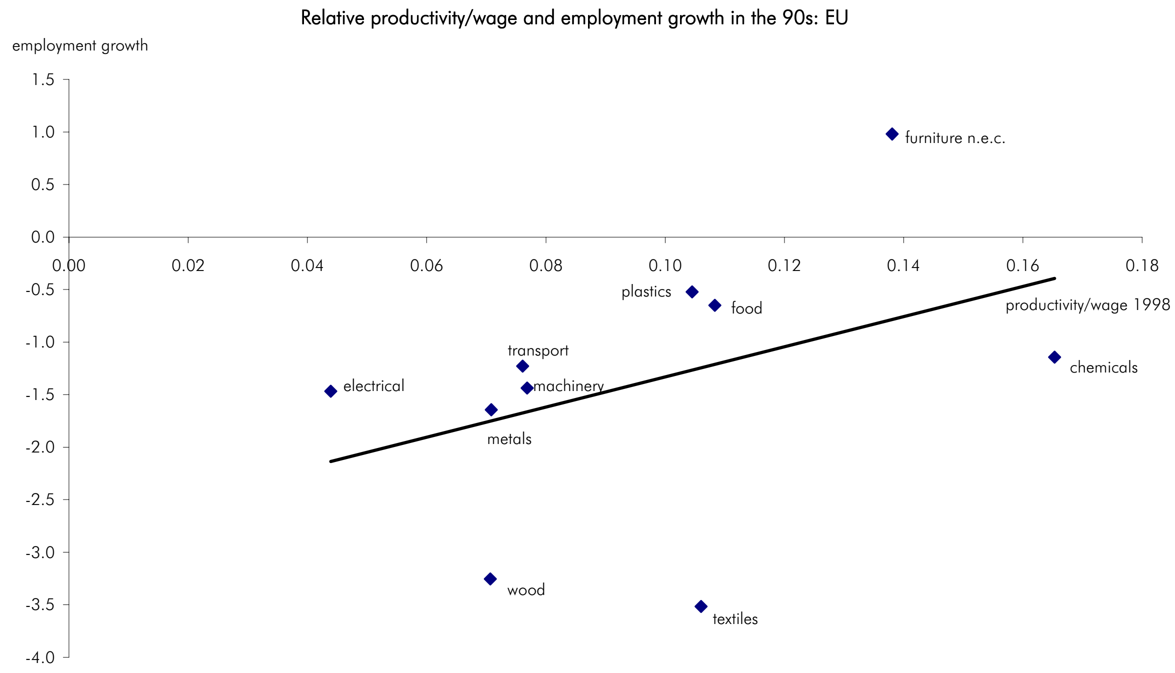
	Food	Textiles	Wood	Chemicals	Plastics	Metals	Machinery	Electrical equipm.	Transport equipm.	Furniture n.e.c.
USA*)	1	11	13	4	12	12	11	2	5	8
Japan**)	10	12	11	2	8	1	1	13	2	2
Austria	—	5	9	3	6	5	9	5	8	—
Belgium	9	4	12	6	4	3	2	12	9	9
Denmark*)	4	1	5	10	3	10	8	10	11	1
Finland	12	9	1	13	10	8	12	1	12	10
France	7	6	8	9	7	9	7	6	4	6
Germany	11	3	4	11	5	6	3	8	6	3
Ireland**)	5	13	7	1	13	13	13	9	13	—
Italy	2	2	2	8	2	2	4	11	10	4
Spain	6	8	10	5	1	4	5	4	1	7
Sweden	8	10	3	12	11	11	10	3	3	11
U.K.*)	3	7	6	7	9	7	6	7	7	5

S: Cronos, WIFO-calculations. — *)1997, **)1996.

We now want to find out the relative productivity advantage[8] enjoyed by each country in respect of particular industries. This is measured in terms of the productivity level of the industry relative to the whole manufacturing sector in each of the various countries in 1998 (P_{ic}/P_c, in which i = industry 1, 2,…10 and c = country 1,2,…15).

One can tell from Table 3 that USA has the highest relative productivity advantage in food, followed by Italy, U.K. and Denmark; in contrast, in the textiles and clothing industry number one in relative productivity advantage is Denmark, followed by Italy and Germany. In the wood, paper and pulp production and publishing, Finland has the highest relative productivity performance, followed by Italy and Sweden. In chemicals, fuel and petroleum refinery products, Ireland is number 1, followed by Japan and Austria, and so on.

Graph 11: The relative production cost advantage (P/W 1998) of industries favoured employment growth: EU 1990-98



S: *Cronos, WIFO-calculations.*

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[8] The relative productivity advantage may be the result of better resource endowment, climate, technology etc. We are constrained by the lack of internationally consistent data on capital use in the various industries, therefore we use only labour productivity for the calculation of relative productivity advantage.

The employment growth which may result from the relative productivity advantage which a country has in respect of a particular industry, will be hampered, the extent dependent on product demand elasticity, if any consequential relative wage increase reduces the cost advantage of the industry. We measure the relative wage cost in the various industries for 1998 (W_{ic}/W_c), and calculate the comparative productivity/labour cost advantage by industries in the EU. We can see from Graph 11 that there is a positive relationship between employment growth and the production cost advantage, the ratio between relative productivity and relative wages, by industry.

They are those industries which had the highest relative production cost advantage as a result of an above average ratio of relative productivity/wage at the end of the 1990s which experienced the largest output growth, thus mitigating employment declines in the 1990s. In Europe these were furniture and other production areas, followed by plastics, chemicals and food production.

We now consider the impact of innovation on productivity and output growth by industry.

Innovation Patterns

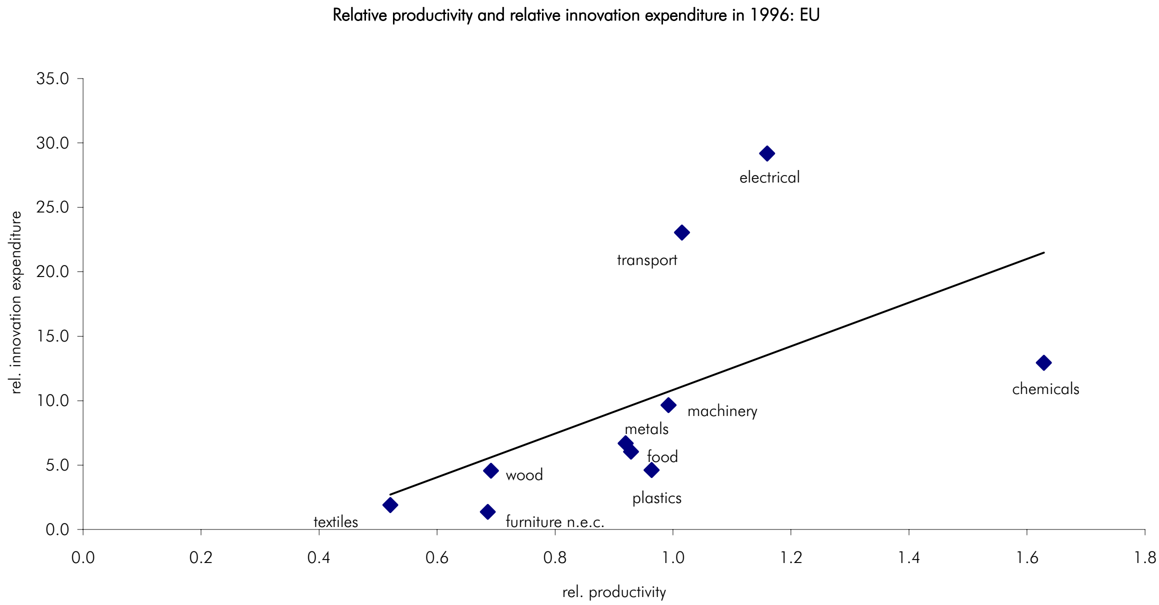
In order to obtain robust and internationally comparable innovation data, innovation surveys have been undertaken in the 1990s on the basis of the Oslo manual (OECD/Eurostat 1997[9]). For the purposes of this paper we are using the Community Innovation Survey (CIS), which is concerned with changes, which take place at the individual firm level. Expenditures on changes which involve new technology to the firm (not more of the same, e.g., more copies of IT equipment) and/or which deal with technologically improved products and processes, are picked up by the survey. Innovation expenditure is thus different from R&D.

We calculate the relative innovation intensity of industries in a country, measured in terms of innovation expenditure by industry as a proportion of total innovation expenditure in manufacturing (I_{ic}/I_c). We also calculate the relative productivity position of 10 manufacturing industries in the EU (P_{ic}/P_c) for 1996, the end of the period under examination in the innovation survey (1994-96), and relate it to the relative innovation intensity in the various industries.

There is a positive relationship between the relative productivity and the relative innovation intensity. We see that the industries with the highest expenditure on innovation – chemicals, coke, fuel and refinery products and manufacturing of electrical equipment – also had the best relative productivity position (Graph 12).

[9] This manual serves as a guide for data collection on technological innovation; it was prepared in the early 1990s in response to the recommendations of the OECD Group of National Experts on Science and Technology (NESTI).

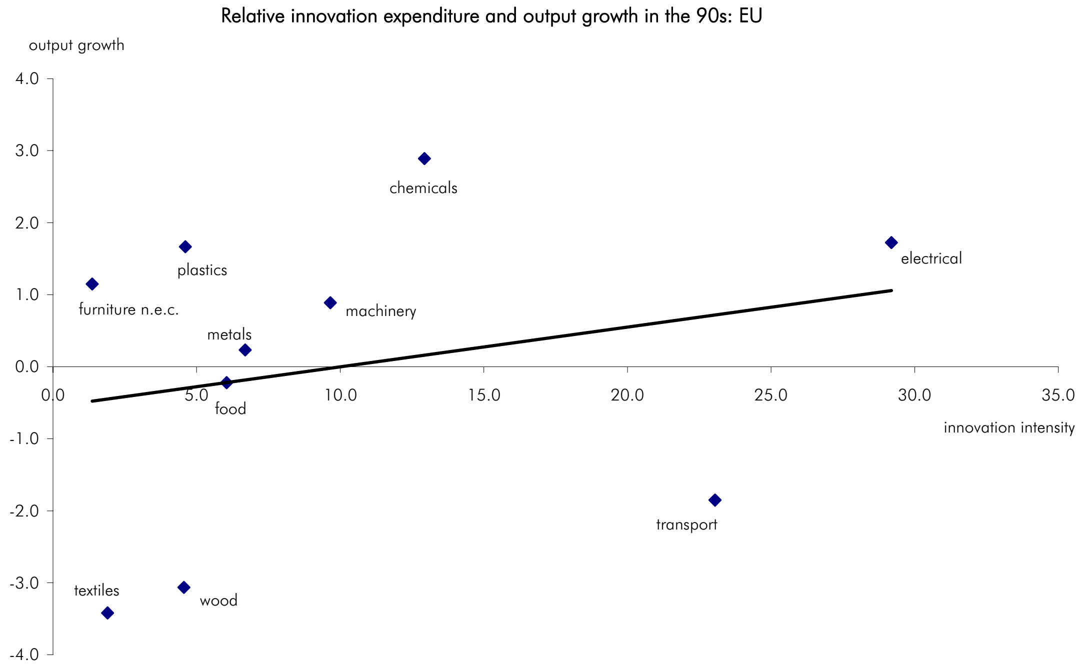
Graph 12: Relative productivity and innovation intensity of manufacturing industries in the EU in 1996



We know already from the empirical results above that productivity growth is positively affected by output growth; we now want to extend the equation 2 by including relative innovation expenditure as an explanatory variable for productivity growth. Graph 13 shows a clear positive relationship between innovation expenditure on output growth, which leads one to expect a reinforcement of the impact on productivity.

Since employment growth is positively affected by output growth, innovative activity could reduce the generally negative impact of productivity growth on employment by a positive effect on output growth. We want to test this hypothesis and extending the Kaldor-Verdoorn relationship by examining the relative production cost advantage and innovative intensity. We hope to thereby improve the explanatory power of these equations on an industry and country level.

Graph 13: Relative innovative intensity and output growth in the EU in the 1990s



S: *Cronos, WIFO-calculations.*

Modelling the Relationship

We start out with the Verdoorn relationship. We extend the regression of productivity growth on output growth by adding the relative innovation intensity of a country in the various industries as an explanatory variable in order to establish whether this improves the explanatory power of the equation.

1. $$p_c = a + bq_c + c\left(\frac{I_{ic}}{I_c}\right)$$

Next we turn to the Kaldor equation, i.e., the regression of employment on output growth; which we extend by including relative productivity advantage obtained through technical change relative to the wage cost advantage as explanatory variables. The reason for including wage costs is that productivity advantages in production may not automatically reduce unit production cost if wage cost increases are relatively greater than productivity growth. The third step in the Kaldor relationship is to extend it further by adding innovative intensity.

2. $$e_c = a + bq_c + c\frac{\left(\frac{P_{ic}}{P_c}\right)}{\left(\frac{W_{ic}}{W_c}\right)} + d\left(\frac{I_{ic}}{I_c}\right)$$

Results and policy implications

The regression results show that the extension of the original Verdoorn and Kaldor relationship improves the explanatory power of the equations in many instances (Table 4). Productivity growth is very well explained by output growth in most countries, exceptions are Germany, Denmark and Austria. Once we include innovation expenditure into the regression, the explanatory power increases in 5 countries: Denmark, France, Italy, Spain, and the U.K..

The explanatory power of output growth for employment growth is in some countries very high, e.g., in Austria, Ireland, and Finland. Output growth does not, however, explain employment developments in Belgium, Spain and Sweden. If we add the relative production cost advantage as an explanatory variable to the equation, our fit improves only for two countries (taking adjusted R^2 as an indicator), namely France and Italy. If we further add relative innovation expenditure, the regression coefficient improves for Denmark, France, and Italy.

Given these results (Table 4), we should expect Denmark, France, and Italy as well as the U.K. and Spain to be among the major innovators in the EU in the 1990s. In order to verify this we rank the countries by their relative innovation intensity in various industries. Table 5 shows this ranking of innovation expenditure (share of industry expenditure in total expenditure). As it turns out, Denmark, Ireland and Italy show up among the first 3 relative innovators in 4 industries, France, U.K. and Belgium in 3 industries. Also Austria shows up among the top innovators in 5 industries. Since Austria is the only country with such high relative innovative activity and no associated employment growth, one would expect Austria to be either a follower, i.e., a late starter in technological change, thus not being able to reap the employment advantage of the first innovators, or else innnovate in industries with limited market growth or monopolistic markets. It could also mean that the type of innovation has a small impact on productivity in some industries, e.g., textile and clothing.

Table 4: Regressions of EU by country

$$p_c = a + bq_c$$

	a	t-value for a	Regression coefficient b	t-value for b	F-ratio	R^2	adj. R^2	DW
Austria	4.381	*6.957*	0.055	*0.336*	0.113	0.018	– 0.145	1.302
Belgium	2.236	*3.943*	1.260	*7.248*	52.532	0.868	0.851	2.005
Denmark	– 0.246	*– 0.352*	0.001	*0.007*	0.000	0.000	– 0.125	1.759
Finland	0.179	*0.319*	0.394	*3.634*	13.203	0.623	0.576	1.593
France	1.510	*3.249*	0.282	*1.096*	1.202	0.131	0.022	2.105
Germany	3.863	*6.769*	0.026	*0.088*	0.008	0.001	– 0.124	1.648
Ireland	– 0.398	*– 0.343*	0.550	*4.502*	20.267	0.743	0.707	0.848
Italy	– 0.407	*– 1.172*	0.327	*1.672*	2.795	0.259	0.166	3.276
Spain	0.815	*1.919*	0.597	*1.955*	3.823	0.323	0.239	1.506
Sweden	1.578	*2.224*	0.946	*6.739*	45.417	0.850	0.832	2.163
U.K.	3.035	*9.176*	0.559	*5.292*	28.008	0.778	0.750	0.982

$$p_c = a + bq_c + c\left(\frac{I_{ic}}{I_c}\right)$$

	a	t-value for a	Regression coefficient b	t-value for b	Regression coefficient c	t-value for c	F-ratio	R^2	adj. R^2	DW
Austria	4.437	*2.813*	0.060	*0.270*	– 0.005	*–0.040*	0.048	0.019	–0.374	1.328
Belgium	3.159	*2.527*	1.398	*5.751*	– 0.056	*–0.833*	25.605	0.880	0.845	2.035
Denmark	– 0.821	*– 1.244*	– 0.129	*– 0.723*	0.096	*2.009*	2.018	0.366	0.184	1.808
Finland	0.781	*0.821*	0.549	*2.447*	– 0.082	*–0.794*	6.611	0.654	0.555	1.531
France	1.189	*2.566*	0.196	*0.822*	0.043	*1.657*	2.104	0.375	0.197	1.604
Germany	3.510	*4.442*	0.020	*0.066*	0.035	*0.674*	0.231	0.062	–0.206	1.442
Ireland	– 0.118	*– 0.013*	0.652	*3.468*	– 0.070	*–0.752*	9.602	0.761	0.687	1.033
Italy	– 1.504	*– 3.168*	0.423	*2.841*	0.121	*2.750*	6.325	0.644	0.542	2.865
Spain	0.246	*0.373*	0.516	*1.667*	0.049	*1.116*	2.593	0.426	0.261	1.185
Sweden	1.428	*1.357*	0.919	*4.614*	0.017	*0.205*	20.010	0.851	0.809	2.113
U.K.	2.461	*4.922*	0.559	*5.657*	0.057	*1.461*	17.058	0.830	0.781	1.089

$$e_c = a + bq_c$$

	a	t-value for a	Regression coefficient b	t-value for b	F-ratio	R^2	adj. R^2	DW
Austria	– 3.087	*– 9.778*	0.719	*8.759*	76.712	0.927	0.915	1.435
Belgium	– 2.114	*– 3.902*	– 0.218	*– 1.313*	1.725	0.177	0.075	2.001
Denmark	0.525	*0.556*	0.971	*3.677*	13.518	0.628	0.582	1.685
Finland	– 0.469	*– 0.865*	0.492	*4.685*	21.953	0.733	0.700	1.733
France	– 1.295	*– 3.146*	0.634	*2.779*	7.721	0.491	0.428	2.023
Germany	– 2.849	*– 7.579*	0.729	*3.724*	13.871	0.634	0.588	1.491
Ireland	0.794	*1.314*	0.575	*6.415*	42.302	0.855	0.834	1.037
Italy	0.428	*1.168*	0.701	*3.402*	11.571	0.591	0.540	3.212
Spain	– 0.693	*– 1.755*	0.473	*1.666*	2.776	0.258	0.165	1.477
Sweden	– 1.251	*– 1.735*	0.094	*0.665*	0.442	0.052	– 0.066	2.041
U.K.	– 2.336	*– 12.639*	0.243	*4.118*	16.956	0.679	0.639	1.043

$$e_c = a + bq_c + c\frac{\left(\frac{P_{ic}}{P_c}\right)}{\left(\frac{W_{ic}}{W_c}\right)}$$

	a	t-value for a	Regression coefficient b	t-value for b	Regression coefficient c	t-value for c	F-ratio	R^2	adj. R^2	DW
Austria	– 2.466	– 3.142	0.679	7.121	– 5.085	– 0.868	37.158	0.937	0.912	1.495
Belgium	– 1.204	– 0.984	– 0.258	–1.456	– 9.445	– 0.848	1.244	0.254	0.041	1.620
Denmark	1.385	0.746	0.879	2.594	– 4.703	– 0.558	6.228	0.644	0.542	1.478
Finland	– 0.807	– 0.537	0.509	3.898	2.763	0.248	9.720	0.735	0.660	1.746
France	– 2.092	– 2.804	0.641	2.912	7.090	1.262	4.943	0.585	0.467	2.136
Germany	– 3.434	– 3.994	0.783	3.671	4.245	0.761	6.860	0.662	0.566	1.678
Ireland	1.342	1.505	0.642	5.307	– 8.965	– 0.832	20.808	0.870	0.826	1.014
Italy	– 0.430	– 0.551	0.723	3.640	7.700	1.296	7.315	0.670	0.576	3.417
Spain	– 0.052	– 0.040	0.540	1.745	– 5.229	– 0.687	1.533	0.305	0.106	1.432
Sweden	– 0.784	– 0.553	0.073	0.455	– 3.304	– 0.391	0.274	0.073	– 0.192	2.110
U.K.	– 2.755	– 5.655	0.189	2.259	4.768	0.931	8.770	0.715	0.633	1.729

$$e_c = a + bq_c + c\frac{\left(\frac{P_{ic}}{P_c}\right)}{\left(\frac{W_{ic}}{W_c}\right)} + d\left(\frac{I_{ic}}{I_c}\right)$$

	a	t-value for a	Regression coefficient b	t-value for b	Regression coefficient c	t-value for c	Regression coefficient d	t-value for d	F-ratio	R^2	adj. R^2	DW
Austria	– 2.277	– 1.973	0.696	5.551	– 5.129	– 0.789	– 0.019	– -0.249	20.146	0.938	0.891	1.295
Belgium	– 2.057	– 1.169	– 0.372	– 1.515	– 8.685	– -0.735	0.047	0.703	0.939	0.319	– 0.034	1.727
Denmark	4.071	2.382	0.941	3.913	– 13.683	– 1.836	– 0.174	– 2.788	10.567	0.840	0.767	1.502
Finland	– 0.825	– -0.500	0.494	1.714	2.491	0.196	0.007	0.061	5.559	0.735	0.603	1.741
France	– 1.556	– 1.774	0.697	3.135	4.283	0.705	– 0.029	– 1.112	3.819	0.656	0.484	1.770
Germany	– 3.186	– 2.009	0.770	3.233	3.154	0.382	– 0.010	– 0.192	3.957	0.664	0.496	1.550
Ireland	0.879	0.725	0.536	2.367	– 4.685	– 0.333	0.050	0.586	12.435	0.878	0.805	1.230
Italy	1.187	1.270	0.615	3.607	2.589	0.422	– 0.115	– 2.120	8.725	0.812	0.717	2.835
Spain	0.034	0.063	0.570	1.790	– 2.362	– 0.278	– 0.040	– 0.836	1.211	0.377	0.066	1.156
Sweden	– 0.564	– 0.302	0.100	0.459	– 3.685	– 0.397	– 0.018	– 0.204	0.172	0.079	– 0.381	2.050
U.K.	– 2.895	– 3.926	0.180	1.904	5.493	0.897	0.006	0.269	5.096	0.718	0.577	1.778

Table 5: Ranking of industries by country by relative innovation intensity

	Food	Textiles	Wood	Chemicals	Plastics	Metals	Machinery	Electrical equipm.	Transport equipm.	Furniture n.e.c.
Austria	7	3	3	8	1	2	4	8	7	1
Belgium	6	5	1	1	4	1	10	9	9	4
Denmark	1	8	5	10	3	7	1	5	8	2
Finland	10	10	—	11	10	10	7	1	—	11
France	9	7	10	4	8	8	8	3	3	8
Germany	8	9	9	9	9	4	3	4	2	9
Ireland	3	6	8	2	2	9	11	2	10	7
Italy	5	1	7	6	5	3	2	10	5	3
Spain	4	4	6	3	6	5	9	11	4	5
Sweden	11	11	4	5	11	11	6	7	1	10
U.K.	2	2	2	7	7	6	5	6	6	6

S: Cronos, WIFO-calculations.

Typology of industries/countries which are technological leaders as a result of innovation

We now look at the countries in which certain industries have become technological leaders and in which the relative wage situation allows an above average employment growth. In Table 6, we present the first 5 countries in terms of their relative technological leadership in an industry, their innovative intensity and their employment growth. Since we only have innovation survey data for EU countries, we cannot include USA and Japan in the ranking of innovative intensity. However, given the high productivity ranking of USA and Japan in certain industries, it is fair to assume that they would also be among the top innovators. As for the EU, we can see that the same countries tend to be among the top 5 performers in every one of the three rank orders.

In those cases in which a country is among the top innovators in the mid 1990s without being among the top leaders in relative productivity, e.g., Austria in plastics and wood, we may infer that it is investing in new technology to catch up in order to preserve jobs in the longer run. As noted earlier, Austria's relative prominence in innovations is also not matched by employment growth.

These calculations show that we cannot safely assume that employment growth will result from productivity growth in a particular industry, as suggested by Cripps and Tarling, but that it is also necessary to consider the technological leadership of the industry and its relative wage position, both of which impact on output growth, the former positively and the latter negatively. Although productivity growth is the major driving force behind wage growth, the latter would be at the expense of employment growth if it undermines the competitive position of the industry, a point of particular relevance to wage policy.

Table 6: First five countries in every industry: ranking by productivity, innovation intensity and employment growth in the 1990s

	Food	Textiles	Wood	Chemicals	Plastics	Metals	Machinery	Electrical equipm.	Transport equipm.	Furniture n.e.c.
Relative productivity – ranking										
1.	USA	DK	SF	IRL	E	JAP	JAP	SF	E	DK
2.	I	I	I	JAP	I	I	B	USA	JAP	JAP
3.	UK	D	S	A	DK	B	D	S	S	D
4.	DK	B	D	USA	B	E	I	E	F	I
5.	IRL	A	DK	E	D	A	E	A	USA	UK
Relative innovation intensity – ranking										
1.	DK	I	B	B	A	B	DK	SF	S	A
2.	UK	UK	UK	IRL	IRL	A	I	IRL	D	DK
3.	IRL	A	A	E	DK	I	D	F	F	I
4.	E	E	S	F	B	D	A	D	E	B
5.	I	B	DK	S	I	E	UK	DK	I	E
Employment growth – ranking										
1.	DK	I	DK	IRL	DK	DK	DK	IRL	IRL	DK
2.	F	USA	IRL	DK	IRL	SF	IRL	SF	DK	IRL
3.	IRL	DK	USA	S	USA	IRL	I	DK	B	S
4.	USA	B	I	SF	I	I	USA	A	JAP	I
5.	JAP	E	F	JAP	F	USA	SF	F	A	F

Table 7: Ranking of employment growth by industries in the 1990s

	Food	Textiles	Wood	Chemicals	Plastics	Metals	Machinery	Electrical equipm.	Transport equipm.	Furniture n.e.c.
USA	4	2	3	6	3	5	4	6	9	6
Japan	5	9	7	5	7	8	8	10	4	13
Austria	11	12	6	13	6	10	9	4	5	8
Belgium*)	8	4	12	10	8	9	13	12	3	11
Denmark	1	3	1	2	1	1	1	3	2	1
Finland	13	11	9	4	12	2	5	2	13	10
France	2	8	5	7	5	6	7	5	10	5
Germany	6	13	10	12	11	13	12	13	7	12
Ireland	3	6	2	1	2	3	2	1	1	2
Italy	10	1	4	8	4	4	3	9	11	4
Spain	7	5	8	11	9	11	6	11	6	7
Sweden	9	10	13	3	13	7	10	7	8	3
U.K.	12	7	11	9	10	12	11	8	12	9

S: Cronos, WIFO-calculations. — *) Only 1995-97.

Concluding observations

The basic objective of this paper was to examine the relationship between employment and technology using a simple growth model that incorporates the Kaldor-Verdoorn law. Although confined only to manufacturing industries, empirical analysis shows that the law still holds in the 191990s. As expected, the direct measure of the effect of productivity growth on employment growth, pioneered by Cripps and Tarling, does not hold well. But since the original formulation of the law cannot explain the impact technological change can have on employment, we extended the model to include the relative production cost and expenditures on new product and process innovation. This extension adds considerable explanatory power to the original model and helps to better understand the role of product and process innovation on the employment structure.

The insight we gain from our statistical analysis may be simply stated as follows:

- There is generally a positive relationship between productivity growth and output growth in a wide range of industries in the EU member countries, USA and Japan.
- However, the increases in productivity and output do not in many cases translate into increased employment in particular industries, as suggested by Cripps and Tarling.
- It is also necessary to consider the leadership of industries in innovations – technological and/or product. Such leadership generally has a positive impact on output and employment.
- Moreover, it is further necessary to consider the relationship between wage and productivity movements. The evidence shows that wages in the different industries tend to move in line with national productivity rather than with the productivity of those industries.
- Although productivity is a major driving force behind wages growth, this finding is of particular relevance for wage policy because it emphasises that the positive impact of industry productivity on employment may be negated by relative wage movements which undermines the competitive position of the industry.

These conclusions may readily be drawn from economic theory. But their empirical verification for the EU countries strengthens the basis for economic policy.

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