

**Structural change, growth and innovation:
the roles of medium and low tech industries, 1980-2000**

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Abstract

It is often argued that high tech industries drive growth processes, and that they are the sources of growth in output, employment and productivity in the knowledge economy. This is a special case of a more general argument that economic growth is characterized by the creation of new and the replacement of old industries. ICT sectors are often treated as the most important examples of this enhanced role of high tech at the present time. This approach implies that low tech industries have declining shares of output for two reasons: their growth is lower (or they are declining absolutely) and they are relocating to low wage economies. That is, they exhibit trade-driven 'hollowing out'. If true, these claims would imply that shares of high tech output are rising significantly in growing economies, while low tech shares are falling significantly, and that countries with larger high tech sectors will exhibit higher growth rates. This paper examines such claims. The issues are explored using OECD manufacturing and trade data for the twenty-year period 1980-1999. We show that overall economic structures of OECD economies have changed, particularly reflecting the growth of financial services and social and community services. Within manufacturing, however, structural change has occurred but has been rather small, and does not account for the manufacturing growth that has occurred. We show that there is considerable variation in manufacturing structures across OECD economies, and argue that structural diversity would diminish over time if growth was high-tech driven. This does not occur - comparative structures persist over time, and growth performance across countries is not correlated with shares of high tech in manufacturing. The slowness of structural change means that low tech and medium low tech sectors remain by a wide margin the largest components of manufacturing output and employment in OECD economies. We examine trade patterns for low and medium low tech sectors, and show that changing domestic demand for low tech manufactures has largely been met by changing domestic production. There has been some widening of trade deficits, but this has been small: there is no trade-driven 'hollowing out'. We argue that these industries persist because of pervasive innovation within them: they are constantly renewed by technological upgrading, which accounts for their survival.

1. Introduction

There is a widespread view that economic growth, especially in advanced economies, rests on high technology industries. Such industries are usually defined as high R&D industries. The argument is that growth is characterized by structural change, with high tech activities becoming predominant for two reasons. First, it is claimed that high-tech industries are also high growth industries, so that there will be structural change as the weight of high tech industries in total output increases. Second, there is the idea that low tech industries are labour intensive and therefore footloose. In an internationalized world they will decline in advanced economies as price competition from low wage economies erodes their competitiveness. Such industries will either move to developing countries or disappear. This ‘hollowing out’ will also of course result in a structural shift towards high tech industries. These arguments imply a conclusion that has strong policy resonance: to maintain real incomes developed economies must reallocate resources away from low tech industries, instead fostering high tech activities in which low wage economies do not have competitive capabilities.

The aim of this chapter is to confront such claims with some basic evidence on structural change and trade in OECD manufacturing over the long run, and to discuss the results. We use OECD data on manufacturing, and the OECD’s definitions of high, medium, and low tech industries, to explore the extent of structural change, and the role of trade, in a number of economies over a twenty year period. This chapter has five sections. The first discusses arguments that place high tech industries at the centre of economic growth, and the hypotheses that can be derived from such arguments. The second outlines data and definitions. The third overviews the empirical evidence and assesses the hypotheses. We argue that although there is evidence of structural change in OECD manufacturing, such change is too small to support the claims of high-tech approaches to growth - low tech activities are declining only slowly, and they persist as major sectors of employment and output. We show that growth is not correlated with the possession of high tech sectors. The fourth section examines trade, and shows that the evidence does not support the claim

that trade is reducing low tech activities. The final section explores alternatives to high-tech views of growth. We argue that technological upgrading, in the form of continuous incremental product and process innovation, accounts for the growth and trade performance of medium and low technology industries, and for their continued major role in advanced economies.

It should be noted that this chapter has the limited ambition of discussing the direct or first-order impacts of high tech industries on structural change, growth and trade. It is intended as part of a series of studies that will explore these issues in greater detail and deeper statistical technique. In particular we do not here address indirect effects: it is often argued that high tech industries are important because they create new generic technologies that are widely used across industries, and that therefore drive productivity growth in other industries. Here we address only issues concerning the direct impacts of high tech industries, though we offer some critical comments on the ‘indirect hypothesis’ in the concluding section, particularly in relation to the argument of Pol, Robertson and Carroll in this book.

2. High Tech Industries and Structural Change Theories of Growth

Structural change theories of economic growth tend to rest on some form of product-cycle view of industry development, in which the relative size of an industry reflects phases of the product cycle, and in which innovation leads to industry replacement. So product cycles result in industry life-cycles, resulting in constant structural change. Kuznets gave a characteristically clear statement of this view:

‘(A) sustained high rate of growth depends upon a continuous emergence of new inventions and innovations, providing the basis for new industries whose high rates of growth compensate for the inevitable slowing down in the rate of invention and innovation, and upon the economic effects of both, which retard the rates of growth of older industries. A high rate of overall growth in an economy is thus necessarily accompanied by considerable shifting in relative importance among industries, as the old decline and the new increase in relative weight in the nation’s output’ (Kuznets 1959: 33)

Modern innovation economics has been strongly influenced by a larger-scope version of this approach, deriving from Joseph Schumpeter, and the ideas presented in his *Business Cycles*. That approach in turn drew on a reading of Kondratiev, seeing economic growth as the outcome of ‘long waves’ of technology-impelled change. The argument is that growth is cyclical, with a period of about fifty to sixty years, and can be understood in terms of the impacts of a relatively small array of radical technological innovations that generate surges of investment, productivity growth, and organizational change. Perhaps the most sustained analysis in these terms in recent years has been Freeman and Louçã, whose book is in large part an extended discussion of growth waves that are argued to be based on the “life cycle of a technology system” (Freeman and Louçã, 2001: 146). It is worth noting that this approach to structural change growth theory has achieved a certain take-up in policy circles. The conclusions of the OECDs ‘Growth Project’ included the claim that “Information and communication technologies (ICT) are transforming economic activity, as the steam engine, railways, and electricity have done in the past”, a formulation fully consonant with Schumpeter and the neo-Schumpeterian approach of Freeman and Louçã (OECD, 2001: 27).

This OECD formulation leads us to a final point about modern approaches to structural change. In recent years the focus on high tech industries has been complemented by a more specific focus on ICT. For example, Fagerberg et al, in a recent study of European growth, argue that:

... the problems that Europe faces in key areas such as growth, equality and employment are all related to its failure to take sufficient advantage of technological advances, particularly the ICT revolution...science-based industries, particularly those drawing heavily on ICT, have become the main driver of technological change and economic growth since the 1980s. (Fagerberg et al, 1999: 235)

These views are widely shared by those who see a ‘new growth regime’ based on ICT as an instance of ‘pervasive new technology’ forming the basis of new ‘long waves’ of growth (see for example Bassanini et al, 2000; Boyer, 2004; Amable and Petit, 2003).

What kinds of broad hypotheses are implied by structural change concepts of economic growth? Because the high tech industries are all located within manufacturing, we focus in this chapter primarily on the manufacturing sector, and argue that the following broad set of hypotheses are implied by structural change models of growth:

- The high-tech model requires that in the long run growth of manufacturing there should not only be a secular rise in the share of high technology industries in total manufacturing output, but also a positive and significant correlation between shares of high tech in total output and levels and growth rates of GDP.
- If the high tech model is correct then long term growth will be accompanied by a reduction in structural diversity. Specifically, if growth is driven by *changes* in the shares of these sectors, then cross-country growth will lead to a convergence in structure across countries. Across the whole sample of countries, the rank correlations of the shares of the various sectors, between the beginning and the end of the period, should be low.
- If ICT is the key high tech industry of the recent past, then ‘those countries which have experienced a rapid diffusion of ICT, or which have been involved in significant production of it, will be ahead of other countries, at least in the ascending phase of a long-term cycle’ (Amable and Petit, 2003: 223).
- As structural change proceeds there should be falling employment in low tech sectors, both as a result of high tech growth and of trade effects, as low and medium tech industries move to low wage environments.
- If low tech industries are moving to low wage economies, there should be a shift in the sources of supply in low tech products, with substantially rising import shares of low tech industrial products in total domestic demand.

In what follows, we explore the primary evidence related to such claims, and test them with simple correlations. Our aim here is an overview and discussion of the relevant data, and a set of simple but robust tests to assess whether the long run manufacturing evidence can plausibly support the ‘high tech’ structural change views of economic growth.

3. Data and definitions

To operationalise the concepts of high tech and low tech industries, we use the OECD sector classification as presented in Hatzichronoglou, 1997. The approach rests on a taxonomy of manufacturing industries developed in the mid-1980s (OECD 1986: 58-61). The OECD distinguished between industries in terms of R&D intensities, with those (such as ICT or pharmaceuticals) spending more than 4% of turnover being classified as high-technology, those spending between 1% and 4% of turnover (such as vehicles or chemicals) being classified as medium-tech, and those spending less than 1% (such as textiles or food) as low tech. This approach has since been modified to divide the ‘medium technology’ group into medium-high and medium-low. A second change recognises that direct R&D is only one indicator of knowledge content, and that attention should be paid also to R&D embodied in intermediate and capital inputs to low tech industries. The current classification is reproduced in Table 1 below.

TABLE 1. OECD classification of manufacturing industries by technological intensity

		ISIC 3 classification
High tech	Aerospace	35.3
	Computers, office machinery	30
	Electronics-communications	32
	Pharmaceuticals	24.4
Medium high tech	Scientific instruments	33
	Motor vehicles	34
	Electrical machinery	31
	Chemicals	24-24.4
	Other transport equipment	35.2+4+5
	Non-electrical machinery	29
Medium low tech	Rubber and plastic products	25
	Shipbuilding	35.1
	Other manufacturing	36
	Non-ferrous metals	27.2
	Non-metallic mineral products	26
	Fabricated metal products	28
	Petroleum refining	23
	Ferrous metals	27.1
Low tech	Paper, printing	21+22
	Textile and clothing	17+18+19
	Food, beverages and tobacco	15+16
	Wood products	20

The classification is based on Hatzichronoglou, 1997 utilizing ISIC Revision 2, but is here redefined according to ISIC Rev. 3. This required some minor adjustments. For example, in ISIC 2 Wood products included production of furniture, whereas in ISIC 3 furniture is classified under other manufacturing.

In addition to this classification of the above manufacturing industries, we also to a limited extent use the OECD definition of ICT producing industries. This set of industries, taken from Pilat and Devlin (2004), is shown in Table 2.

TABLE 2: OECD definition of ICT-producing industries

Office, accounting and computing machinery	3000
Insulated wire and cable	3130
Electronic valves, tubes, other electronic components	3210
Television and radio transmitters, line telephony etc.	3220
TV and radio receivers, sound or video recording, etc	3230
Instruments and appliances for measuring, checking, testing, etc	3312
Industrial processes control equipment	3313
Wholesale of machinery, equipment and supplies	5150
Renting of office machinery and equipment (incl. computers)	7123
Telecommunications	6420
Computer and related activities	7200

Most of the ICT producing industries are manufacturing industries, partly high tech and partly medium high tech according to the definitions above, while others are from outside the manufacturing sector. One of these, namely wholesale distribution of machinery and equipment (ISIC 5150), includes many activities not connected to ICT at all. Moreover it is a large sector, and including it significantly raises the volume of ICT activity.

The following analysis uses the OECD's STAN database, which comprises data at 2 and 3 digit levels for the manufacturing sectors of OECD economies. This data is national accounts-compatible, has had errors and omission removed, and is available for some countries over a long time period. Our analysis looks at the 20-year period 1980-1999. We show results for those OECD countries for which we have sufficient

data on value added, employment, production, exports and imports for the whole period 1980-1999. There are 11 countries for which complete data is available: Austria, Denmark, Finland, France, Italy, Japan, Norway, Portugal, Spain, Sweden and USA. The two most important countries which are excluded, on account of insufficient data, are thus Germany and Great Britain. However where possible we bring in data from these countries, and others; if necessary we shorten the time period of the analysis to do so. Value added is in constant 1995 US dollars. Purchasing power parities have been used to convert national currencies to dollars. The price deflator for GDP has been used to adjust for changes in price level. Data on GDP measured in constant 1995 US dollars for the various countries during the period 1980-1999 has been taken from the OECD *Statistical Databases on Annual National Accountss*. Three-year moving averages at the beginning and end of the 20 year period are used to compute growth rates, so most of our long run growth calculations are for 1981-1998.

4. Structural change across the OECD: output, growth, productivity, employment and trade

This section first explores the overall process of structural change in OECD economies, and then the changing structure of manufacturing value added for the four technology classes of industries for the period 1980-1999. It then discusses the persistence of industrial structures across countries, correlations between high tech industries and growth performance, and trends in productivity and employment.

4.1 The background: overall structural change 1980-99

Before turning to structural change within manufacturing, it is important to note that the period 1981-1999 also exhibits significant structural change between manufacturing and other sectors. The basic dimensions of such change are shown in Table 3, which focuses on employment rather than output because of problems in the measurement of services output. Table 3 breaks services – a large and heterogeneous sector - into four major components.

TABLE 3: Share of total employment in the economy by nine sectors. 1981 and 1998. Average (unweighted) for fifteen countries.

	1981	1998	Change
Agriculture, hunting, forestry and fishing	8.7	5.0	-3.7
Mining and quarrying	0.7	0.4	-0.3
Total manufacturing	21.8	16.7	-5.1
Electricity, gas and water supply	0.9	0.7	-0.2
Construction	7.3	6.6	-0.7
Services:			
Wholesale and retail trade; restaurants and hotels	18.7	19.8	1.1
Transport, storage and communication	6.6	6.3	-0.3
Finance, insurance, real estate and business services	8.5	13.0	4.5
Community social and personal services	26.9	31.4	4.5
Sum all sectors	100	100	0

The share of services in employment grew strongly, from 60.7% to 70.5% of total employment. The main share growth in services occurred in two broad areas: financial services, and community and social services (the latter including such activities as health care and education). The percentage point increases in share were equal between these sectors, but because financial services was starting from a much lower base its growth rate of employment was higher. In two countries (USA and the Netherlands) the growth of the share of financial services in employment was at least four percentage points greater than the growth in share of social and community services. In three countries (Japan, Finland and Spain) the social and community services share grew by at least four points more than financial services.

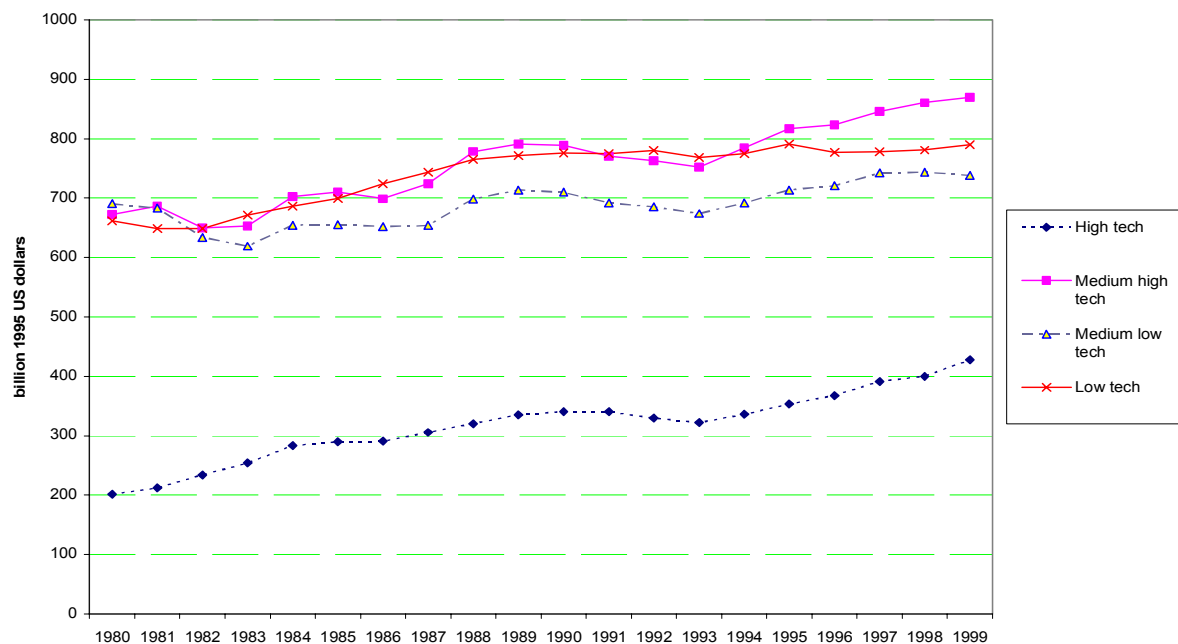
This overall process of structural change is important for two reasons. First, whether or not we regard overall growth as being driven by technology intensive activities depends to a considerable extent on how we assess the nature of rapidly growing service activities. Here it should be pointed out that neither of the service activities whose share is growing is particularly R&D intensive (although there are some R&D-intensive activities within them). Second, it is worth noting that more than fifty percent of service employment is in two sectors: wholesale and retail trade, and community and social services. These are not high tech activities as conventionally

defined. A final point to note here is that growth in technology-intensive activities within manufacturing may not translate into changes in the shares of such activities in overall GDP, because the decline in the share of manufacturing in GDP and employment may outweigh rising shares within manufacturing. This point will be illustrated in more detail in the sections below.

4.2 Structural change in OECD manufacturing

Constant-price manufacturing value added has risen, although with cyclical fluctuations, across the OECD over the past twenty years in all technology sectors. Between 1981 and 1998 total value added in manufacturing as a whole for these eleven countries combined grew by 26.4 per cent, implying a compound annual growth rate (CAGR) of 1.4 per cent per year.

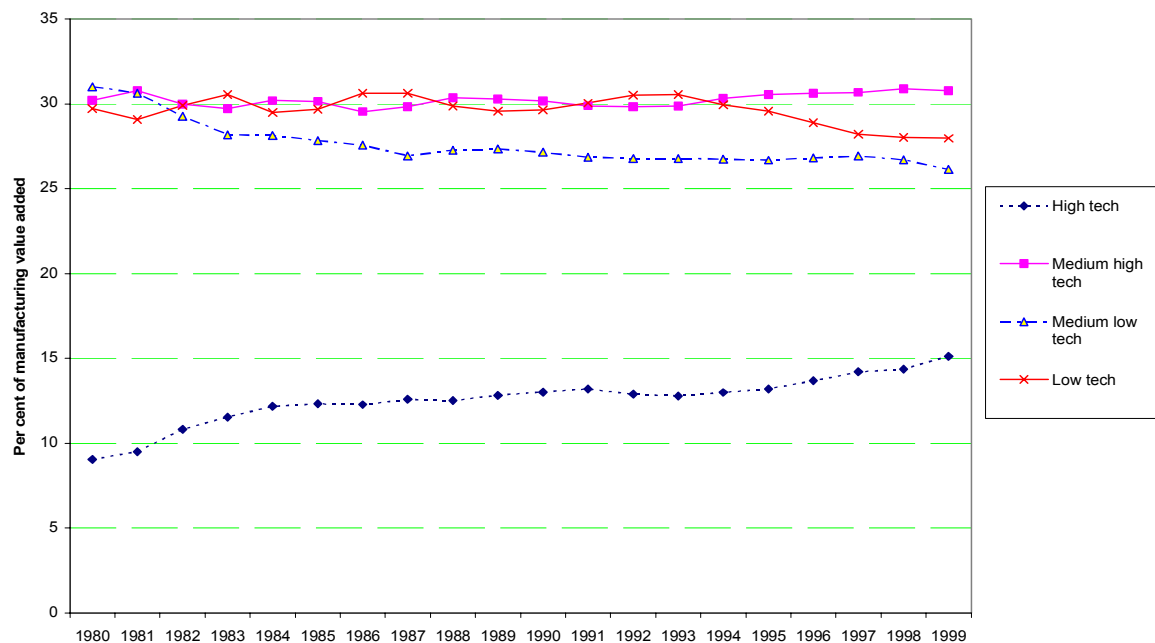
FIGURE 1. Value added in billion 1995 US dollars, 11 countries combined. 1980-1999



The high tech industries have by far the highest growth: 88.3 per cent (CAGR 3.8 per cent per year). High growth in high tech in part reflects a much lower starting point than the medium or low tech categories (the absolute increments to output in high and medium high tech sectors are roughly the same). The medium high tech category saw growth about equal to manufacturing as a whole with 28.2 per cent (CAGR 1.5 per cent per year). The two low tech categories have growth of value added below

manufacturing as a whole. Medium low tech has 10.8 per cent growth (CAGR 0.6 per cent per year), and low tech 20.0 per cent (CAGR 1.1 per cent per year). These growth rate differentials mean that the high tech industries' share of manufacturing value added grows steadily during these years, while the shares of the two low tech categories decline. Figure 2 shows the dimensions of this. Inspection of Figure 2 suggests two periods of change with a static interval: a rise in the share of high tech in the early 1980s, followed by a decade of roughly stable share, followed by another rise after 1995.

FIGURE 2. Share of value added in manufacturing, four industry groups. 1980-1999. 11 countries combined.

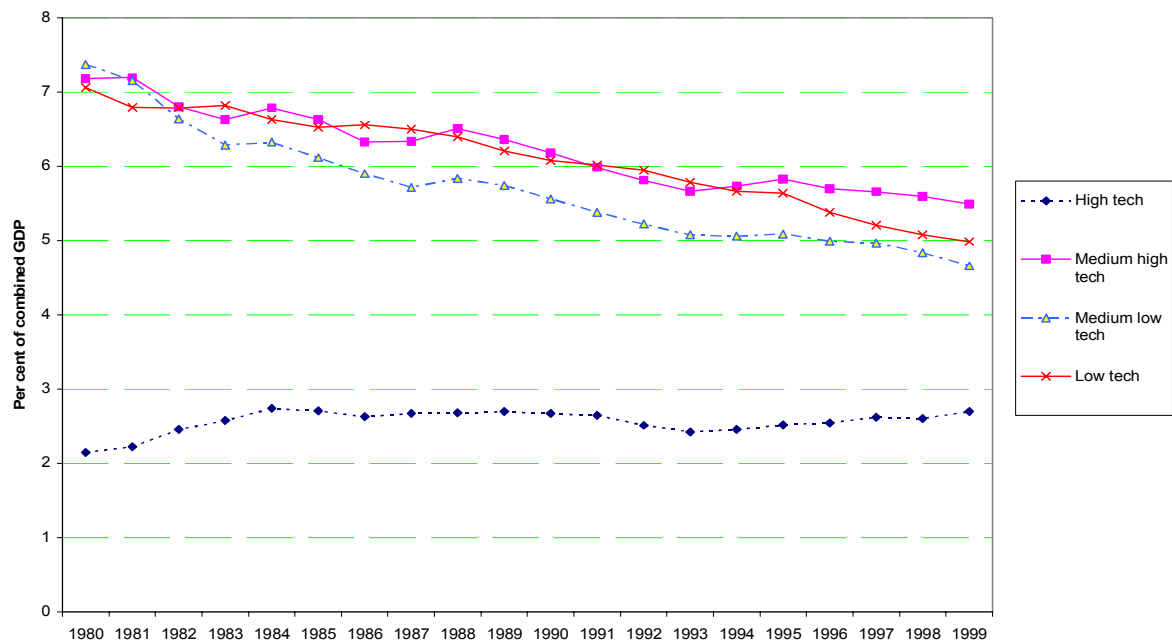


Thus the share of the high tech industries in manufacturing value added rises from 9.8 percent to 14.6 per cent in the course of these years. There is little change in the share of the medium-high tech sector, so declining shares are found in the medium-low and low tech sectors. However, these declines are not marked, and so these sectors remain by a wide margin the largest components of the manufacturing sector in OECD economies. Although down from 59.9 per cent in 1981, the two low tech categories together still accounted for 54.7 per cent of manufacturing value added in 1998. The compound rate of decline in the share of these low tech sectors is 0.5% per year; the CAGR of the high tech share is 2.2% per year. These trends are of course open to

interpretation, and the power of compound change over long periods is well known, but we would argue that over a period of two decades, when economies are allegedly being reshaped by major high technology changes, these are not substantial structural shifts.

As noted above, it is important to bear in mind wider structural change during this period, reflecting the growth of services sectors. While manufacturing as a whole had a growth of 26.4 per cent, the growth of total value added in the 11 countries, i.e. the growth of combined GDP, was 62.2 per cent (CAGR of 2.9 per cent per year). The shares of high, medium and low tech manufacturing in GDP reflect the falling share of manufacturing as a whole, shown in Figure 3 below.

FIGURE 3. Manufacturing shares of value added in total economy. 1980-1999. 11 OECD-countries combined.



For this sample, the share of manufacturing as a whole in GDP decreases from 23.3 to 18.1 per cent. This means that the share of high tech manufacturing increases marginally, from 2.3 to 2.6 per cent of GDP. For the other three manufacturing categories the decline is evident from the figure: the two low tech categories together see shares of GDP drop from 13.9 per cent in 1981 to 9.9 per cent in 1998.

4.3 Identifying sectoral contributions to growth

The fact that high tech sectors are growing faster than medium or low tech sectors in manufacturing output does not necessarily mean that high tech contributes more to overall manufacturing growth. High tech sectors are small, so even high growth rates can have a relatively small overall impact. To gain a clearer picture of the sectoral composition of economic growth, we can start with the accounting point that the growth rate for any multi-sectoral economy is the weighted sum of the growth rates of the sectors, where the weights are the initial shares of each sector in output. For the overall economy, or for the manufacturing as a whole, therefore

$$g = \sum_{i=1}^n g_i s_i$$

where g is the overall growth rate and g_i and s_i are sectoral growth rates (i.e. sectoral CAGRs) and initial shares of output respectively. That is to say, in looking at how the overall growth rate is shaped, we need to consider first how the different sectors are growing, and then at how large those sectors are. If we do this over reasonable time periods we can get a picture of what kind of sectoral growth pattern is really driving aggregate economic growth. These sectoral contributions are calculated for the high, medium and low tech sectors in Table 4 below.

Table 4: Contributions of the four sectors to the overall manufacturing growth during the whole period 1981-1998

	(1) Growth 1981-98	(2) Initial period share of VA	(3) Contribution to overall growth rate (1x2)	(4) Contribution to growth rate, per cent
High tech	88.3	0.097776	8.6	32.7
Medium high tech	28.2	0.303374	8.6	32.5
Medium low tech	10.8	0.303162	3.3	12.4
Low tech	17.0	0.295688	5.9	22.4
Total manufacturing	26.4	1	26.4	100

There is no significant difference in the contributions to growth from the high tech and medium high tech sectors: each contributes about 32.5 per cent of the growth in manufacturing value added between 1981 to 1998. Taken together, the low tech and the medium low sectors combined contributed about the same. So the slower growth

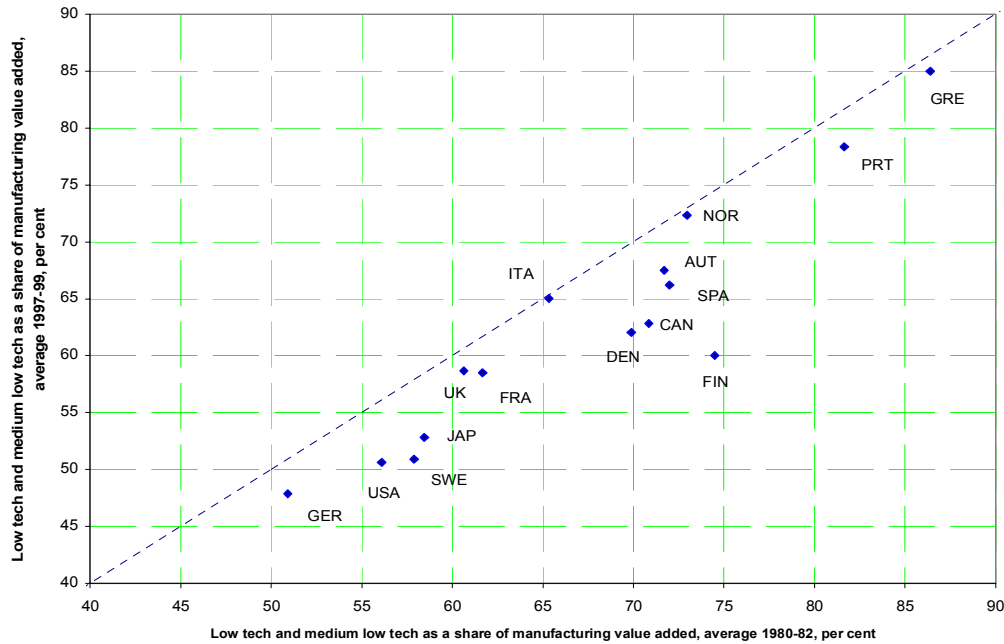
of medium low and low tech sectors was offset by their much larger size, and they continue to contribute in an important way to manufacturing growth.

4.4 Variation across countries: do sectoral compositions persist?

This section looks at variation across countries in the shares of high, medium and low tech industries in manufacturing value added and GDP, at the beginning and the end of the period 1980-1999. The key point here is that there is a substantial amount of structural diversity between countries. The question is, does this diversity persist over time? If the high tech argument is correct, and growth is driven by the expansion of high tech sectors, then the distribution of industries should alter over the long run. In the following we explore whether this happens. Here we are able to add four countries to the 11 countries considered above, namely Canada, Germany, Greece and United Kingdom.

Considering the two low tech sectors together, there is quite substantial variation across the countries in the shares of the shares of these sectors in manufacturing value added, from about 50 per cent in Germany, USA and Sweden to about 80 and even 85 per cent in Portugal and Greece, as Figure 4 shows.

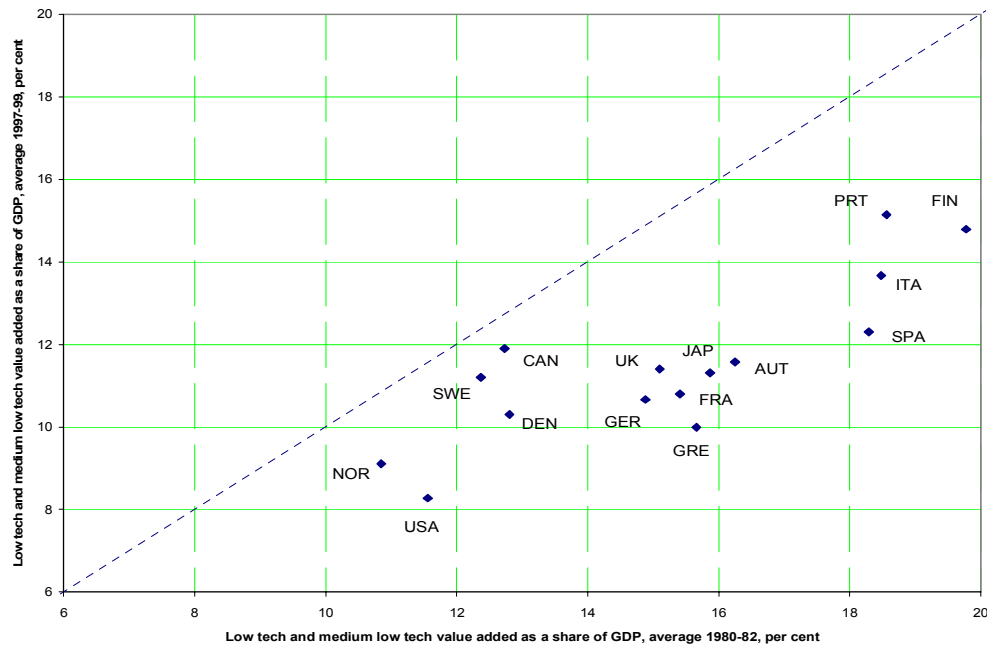
FIGURE 4. Share of low tech and medium low tech industries in total manufacturing. Value added in 1981 and 1998. 15 OECD countries.



The decrease in share from 1981 to 1998 which we found for the 11 countries combined, is found also for the individual countries. All countries lie below the 45 degree line in the figure, although a couple of them only very slightly. However there is little difference in the *relative* position of the countries between the two points in time: the countries which have a high share of low tech industries in 1981 also tend to have a high share in 1998, and vice versa. Thus, the correlation coefficient (Pearson's r) between the shares in 1981 and in 1998 is very high, 0.94. This suggests a high degree of structural persistence.

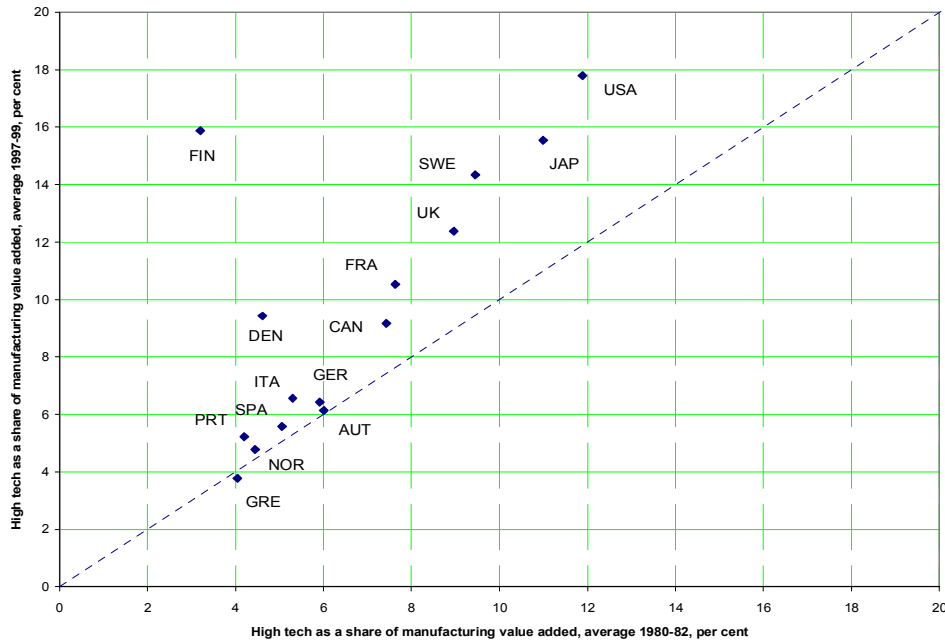
In overall GDP the share declines of these sectors are larger. The share of the low tech industries in GDP is the product of the share of the low tech industries in manufacturing value added and the share of manufacturing value added in GDP; since both are falling over the period we expect to see larger share declines.

FIGURE 5. Share of low tech and medium low tech manufacturing industries in total economy. Value added in 1981 and 1998. 15 OECD countries.



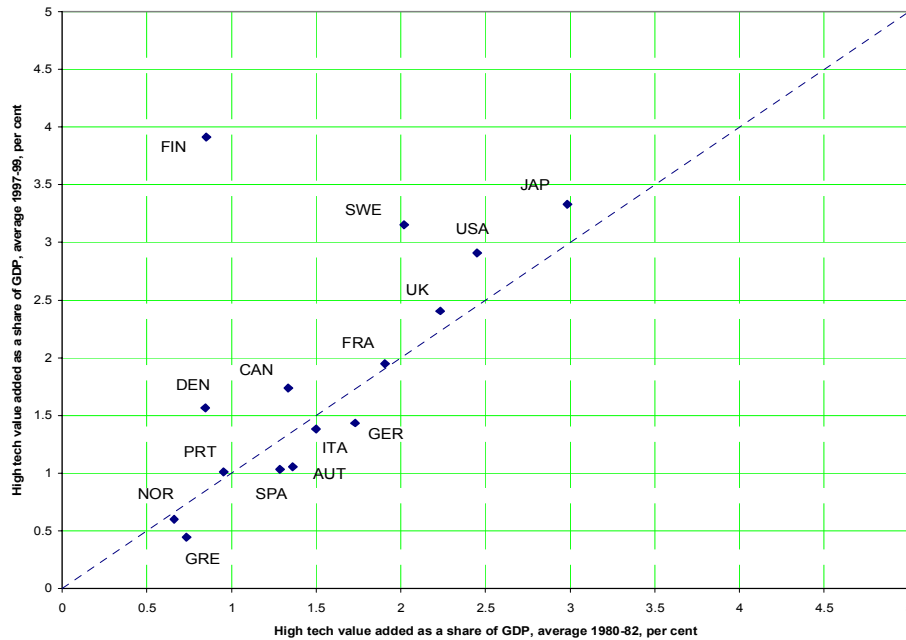
The general picture across the countries is that the share of manufacturing in GDP declines, though less in Sweden and Canada. All countries are here clearly below the 45 degree line. However the correlation coefficient (Pearson's r) between the shares in 1981 and in 1998 is 0.83, which is still very high: so as growth proceeds, comparative structures persist. Turning to high tech industries in Figure 6 we find a similar picture.

FIGURE 6. Share of high tech industries in total manufacturing. Value added in 1981 and 1998. 15 OECD countries.



The share of manufacturing value added accounted for by high tech industries also varies very substantially across the countries, from 18 per cent in USA to 4 per cent in Greece in 1998. The increase in the share of manufacturing value added accounted for by high tech industries which we found for 11 countries combined also applies to each individual country, although some of them only increase the share of high tech industries slightly or even not at all. In general, countries with relatively higher shares of high tech in the initial period (USA, Japan, Sweden, UK, France and Canada) increased those shares. Finland is an important outlier, having increased the share of high tech industries in manufacturing value added from 3.2 per cent in 1981 to 15.9 per cent in 1998, largely as a result of the growth of one company, Nokia. This contributes substantially to lowering the correlation coefficient between high tech industry shares across countries between 1981 and 1998. Without Finland this coefficient is 0.95, including Finland it drops to 0.69.

FIGURE 7. Share of high tech manufacturing industries in total economy. Value added in 1981 and 1998. 15 OECD countries.



The share of high tech manufacturing industries in GDP as a whole also varies substantially across countries, from 0.4 per cent in Greece to 3.9 per cent in Finland in 1998. For the 11 countries above combined the share of high tech in GDP increased somewhat between 1981 and 1998. Here six countries lie below the 45 degree line, with nine above. Again, Finland is the outlier, having increased the share of high tech manufacturing industries in GDP from 0.9 per cent in 1981 to 3.9 per cent in 1998. Thus the Pearson's r correlation coefficient between the country shares in 1981 and 1998 is 0.90 when we exclude Finland, but drops to 0.59 when Finland is included. These high correlations between industrial structures at the beginnings and end of the period suggest that overall growth in the OECD is not accompanied by structural change – there is no lessening of structural diversity over time.

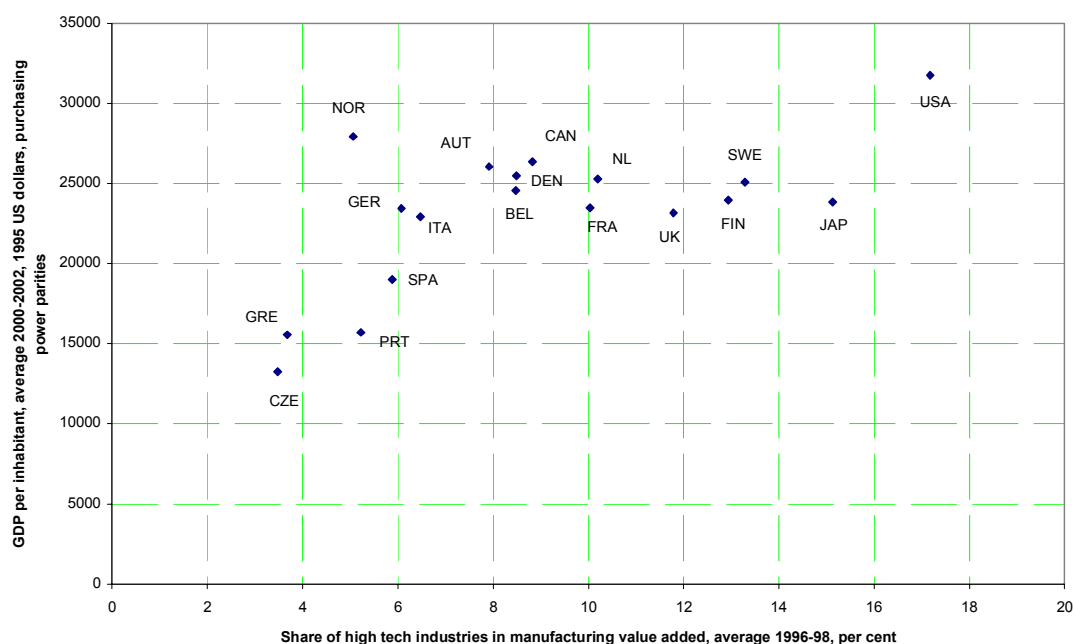
4.5 Does technological intensity account for economic growth?

The preceding sections showed that structural change has been slow and that there are quite persistent differences across countries in their shares of the different technology intensity classes of industries - some economies are clearly more 'high tech' than others. Those countries which had a high share of high tech industries relative to other

countries in 1981 also tend to have a relatively high share in 1998. However these points do not mean that the structural change hypothesis is wrong. It could be the case that despite comparative structural stability, OECD growth is concentrated in those countries that have high shares of high tech industries. So if the structural change approach to growth is correct, countries with higher shares of high-tech in output ought to exhibit higher growth rates within the overall panel of countries. This section therefore asks whether economies which are characterized by a high share of high tech industries are also the economies which have the best growth performance. Conversely, do economies with a high share of low tech industries tend to have a weak growth performance?

High tech shares can be linked either to the level of income or to its rate of growth. Looking at levels first, there is indeed a relationship between technological intensity and the level of income across national economies. Figure 8 below shows the relationship between the share of manufacturing value added accounted for by high tech industries in 1997 (or more precisely the average of 1996, 1997 and 1998), along the x-axis, and the level of GDP per inhabitant in 2001 (more precisely average of 2000, 2001 and 2002), along the y-axis.

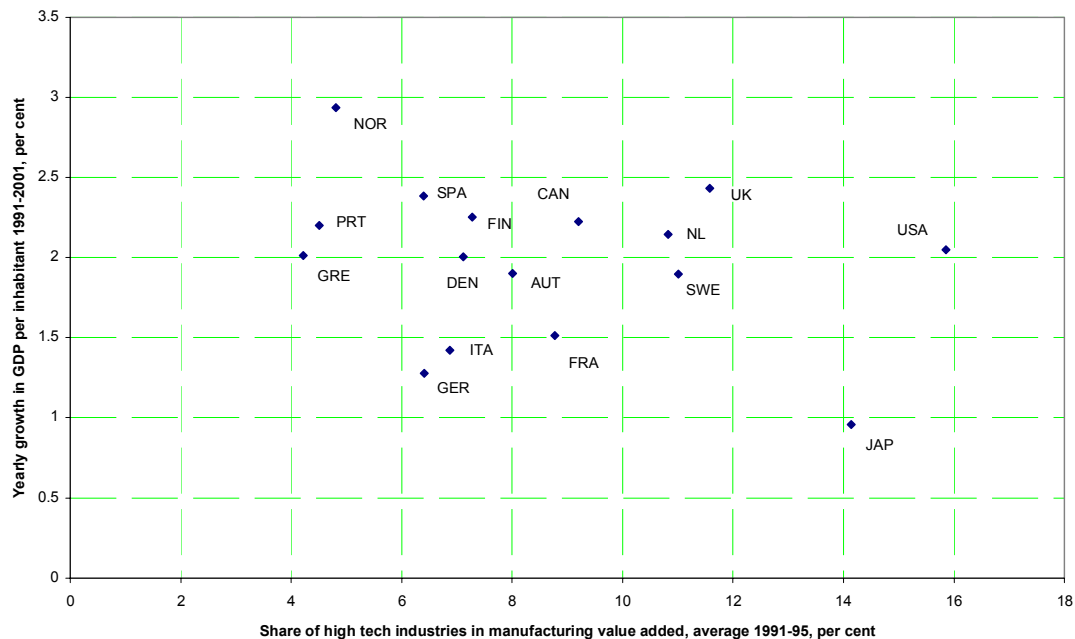
FIGURE 8. GDP per capita. Average 2000-2002, 1995 US dollars (y-axis); share of high tech industries in manufacturing value added. Average 1996-1998 (x-axis).



The (Pearson's r) correlation coefficient is here 0.65, significant at the 1 per cent level. Thus, the higher the share of high tech industries in manufacturing value added, the higher is GDP per inhabitant. There are of course important questions to raise about the causal links here. The basic issue is which way the causality runs, since high tech industries (in particular aerospace, ICT, and pharmaceuticals) have in practice been created via substantial government support, and have invariably been initiated by substantial publicly-supported R&D infrastructures (Mowery and Rosenberg, 1989, and Bruland and Mowery, 2004 provide good overviews of the histories of this). There may therefore be a pattern of causality that runs from high levels of income, to government budgetary positions, to the creation of industries – that is, some R&D-intensive industries may be a consequence of high income, not a cause of it.

Be that as it may, we do not find any such relationship when we compare the high tech share in manufacturing value added with the rate of growth of GDP per inhabitant. How do high tech shares, in the early 1990s, relate to growth performance over the decade of the 90s as a whole? This is illustrated in Figure 9.

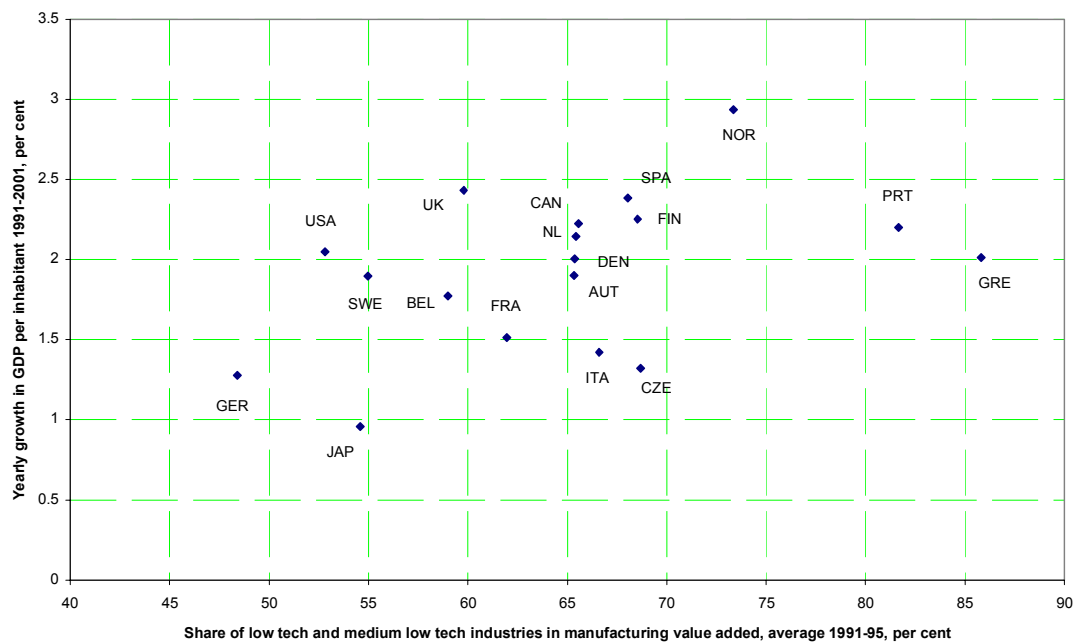
FIGURE 9. Annual compound growth rate in GDP per capita. 1991-2001. Percentages (y-axis); share of high tech industries in manufacturing. Value added. Average 1991-1995. Percentages (x-axis).



In fact, the correlation coefficient (Pearson's r) is negative, -0.28 , and moreover is not statistically significant (p-value 0.29). Considering the same linear relationship for the whole period 1980-2001 the correlation coefficient (Pearson's r) is -0.03 and not significant. We cannot conclude, therefore, that high tech economies are also the high growth economies.

In the same way, Figure 10 shows the relationship between growth in GDP per inhabitant from 1991 to 2001 and the share of low tech and medium low tech industries combined in manufacturing value added.

FIGURE 10. Annual compound rate in GDP per capita. 1991-2001. Percentages (y-axis); share of low tech and medium low tech industries combined in total manufacturing. Value added. Average 1991-1995. Percentages (x-axis).



The linear relationship here is if anything positive, which would mean that the *low tech* countries have the best growth performance: Pearson's r is 0.43. But this is barely significant: it is significant at the 10 per cent level, but not at the 5 per cent level.

Looking at the linear relationship between annual compound growth rate of GDP per capita in a 22 year period (1980-2001) and the shares of low tech and medium low tech value added combined in total manufacturing (average 1991-1995) we find again a correlation coefficient $+0.08$, which is not significant. Thus, the important point here is the absence of any convincing evidence for a hypothesis that low tech economies are low growth economies. If anything, there is weak evidence in the data that low tech economies are higher growth economies than the high tech economies.

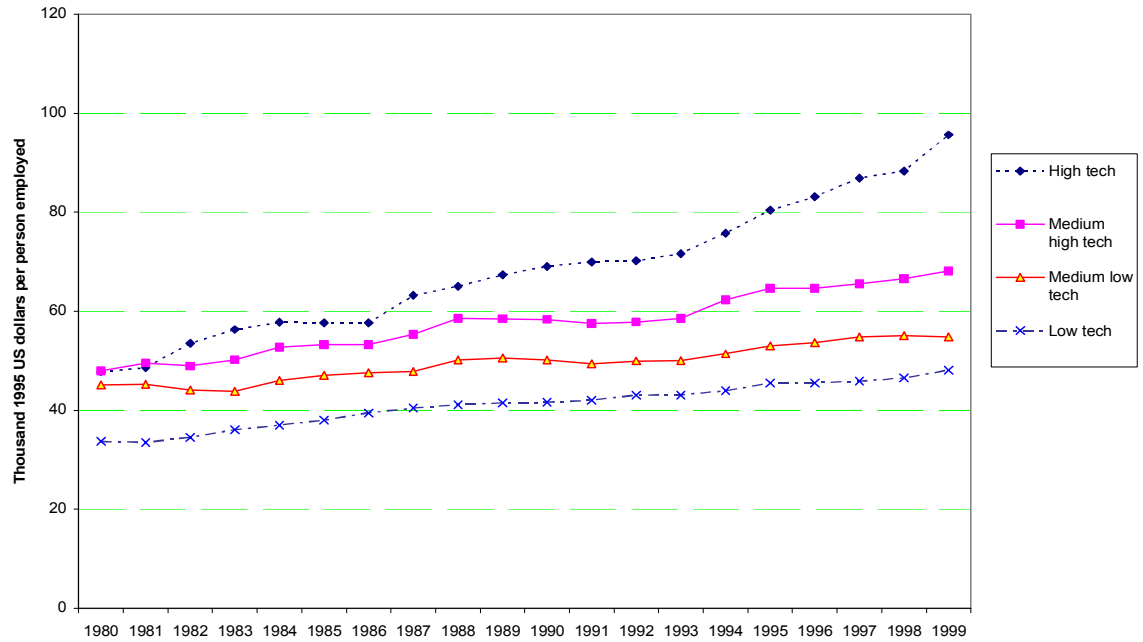
We do find a very clear relationship between the share of GDP accounted for by manufacturing as a whole in the period 1991-1995 and growth in GDP per inhabitant from 1991 to 2001. The correlation coefficient is here -0.73 , significant at the 0.1 per cent level. That is, the higher the initial-period share of manufacturing in GDP, the lower the growth rate of GDP per inhabitant from 1991 to 2001. Thus, if we look at the relationship between the share of low tech and medium low tech manufacturing industries combined not only in manufacturing value added but in GDP as a whole in 1991-1995, on the one hand, and growth in GDP per inhabitant from 1991 to 2001, on the other, we find a slightly negative ($r = -0.33$) but not significant relationship. This seems to reflect primarily the manufacturing share and not low tech as such. Thus, if we in the same way look at the relationship between the share of high tech manufacturing industries in total GDP and growth in GDP per inhabitant, we find a more negative ($r = -0.48$) and a weakly significant relationship (significant at the 10 per cent but not at the 5 per cent level).

This overview suggests something of the complexity of attempting to link industry technology intensity to income levels and growth rates. The key point to emerge, however, is that there is no convincing support for structural change growth models resting on high tech industries.

4.6 Productivity trends, 1981-99

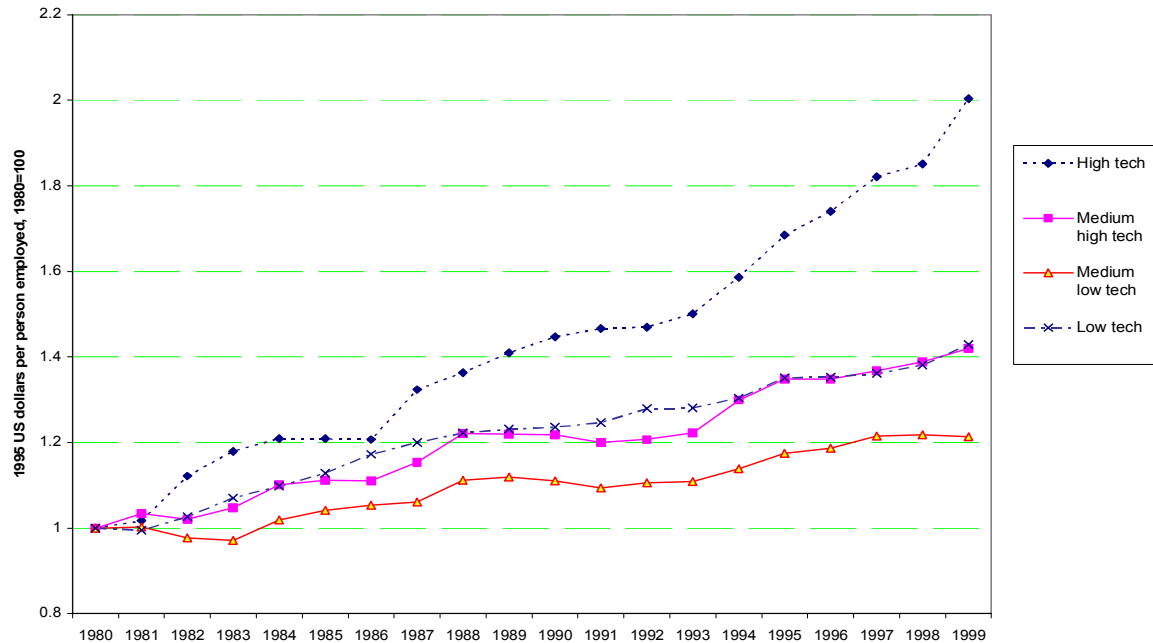
In the following we use a simple measure of productivity, namely value added per person employed in manufacturing in the 11 OECD countries combined. Again value added is measured in constant 1995 US dollars.

FIGURE 11. Value added per person employed. 11 OECD countries combined. Value added in constant 1995(thousand) US dollars. 1980-1999.



Here there is a clear result: the higher the technological intensity, the higher the level of value added per person employed. However, Figure 12 displays a more complicated picture.

FIGURE 12. Value added per person employed. 11 OECD countries combined. Value added in constant 1995 US dollars. 1980-1999. 1980=1.



The high tech industries have by far the fastest productivity development measured as constant 1995 US dollars as indices with 1980 as a benchmark. The medium low tech industries have the slowest growth. The medium high tech and the low tech industries lie in between, with almost the same growth rate trend from 1981 to 1998. The high tech industries have a productivity growth of 3.5 per cent per year, while the medium low tech industries have a productivity growth of 1.2 per cent per year. The medium high tech and the low tech industries have a productivity growth of about 1.9 per cent per year during this period. We turn now to how the growth and productivity trends affect employment.

4.7 Manufacturing employment 1980-1999

If we compare growth rates in productivity to growth rates in value added, we find that only for the high tech industries does the positive effect on employment from growth of production outweigh the negative effect on employment from the growth of productivity. This is shown in the figure below.

FIGURE 13. Number of persons engaged (in million employees). 1980-1998. 11 OECD countries combined.

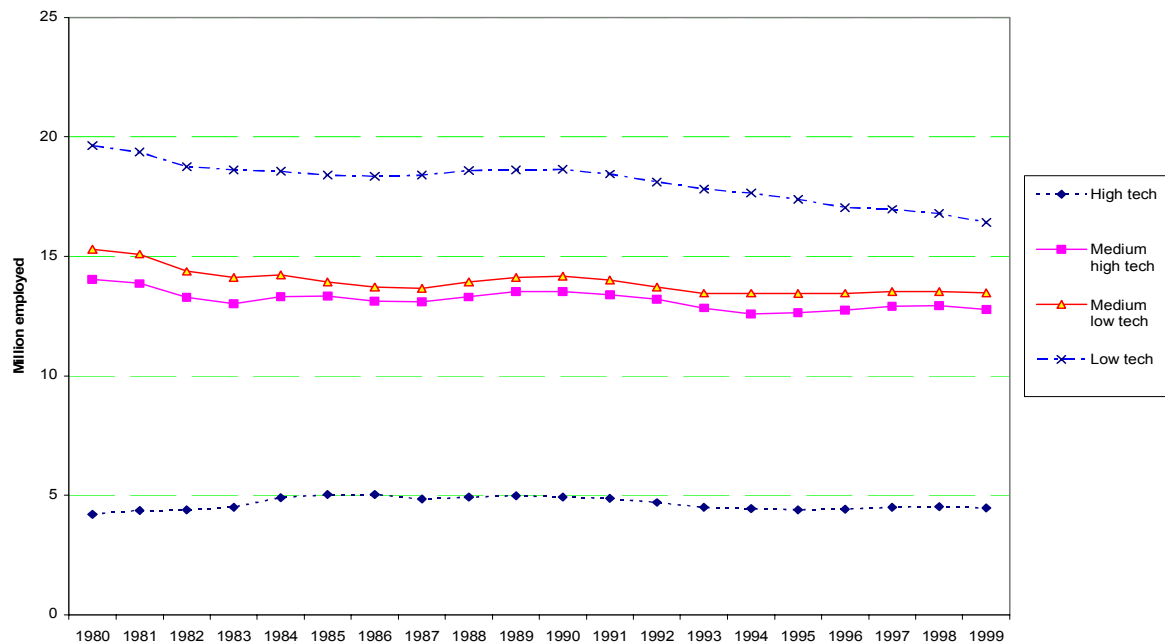
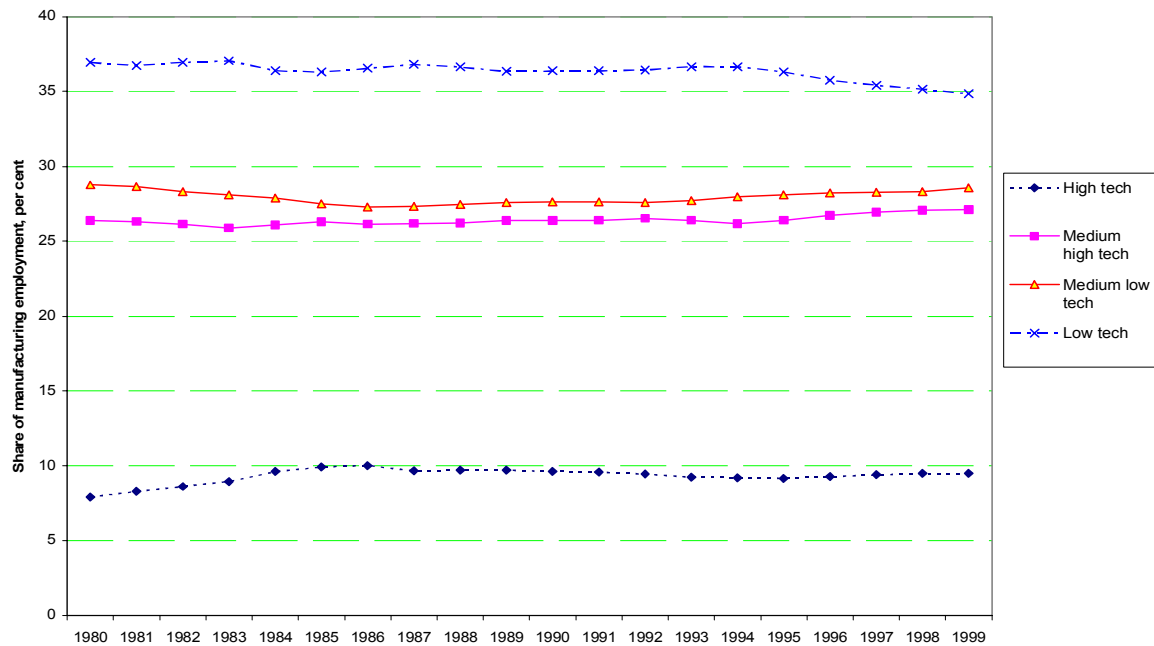


Figure 13 shows that the high tech industries have growth in employment during the period, but this growth is very small. The other three categories have decreases in employment, and the decreases are larger the lower the technological intensity. For high tech industries we have altogether a growth in employment from 1981 to 1998 of 181,000 persons or 4.2 per cent, from 4.32 million to 4.50 million. The medium high tech industries have a decline of 850,000 persons or 6.2 per cent, from 13.7 million to 12.9 million. For the medium low tech industries employment decreases by 1.4 million persons or 9.5 per cent, from 14.9 million to 13.5 million employed. Finally, employment in the low tech industries decreases by 2.5 million persons or 13.1 per cent, from 19.2 million to 16.7 million. Altogether, employment in manufacturing decreases by 4.6 million persons or 8.8 per cent in these 11 countries, from 52.2 million to 47.6 million. Once again, however, we face questions about just how substantial these changes are, since the declines in employment are slow, and the employment levels are persistent, as Figure 14 below indicates.

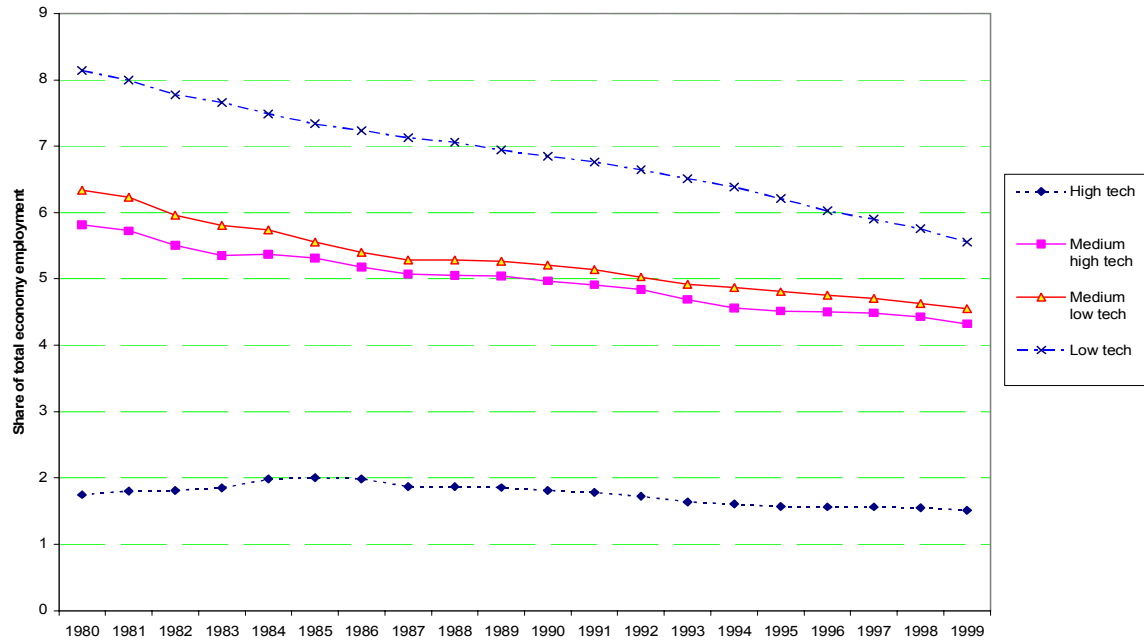
FIGURE 14. Shares of employment in total manufacturing. 1980-1999. 11 OECD countries combined.



In terms of shares, high tech industries increase their share of employment in manufacturing from 8.3 per cent in 1981 to 9.5 per cent in 1998. The low tech and medium low tech industries combined decreased their share of manufacturing employment from 65.4 per cent in 1981 to 63.5 per cent in 1998. Over a twenty year period, these are marginal differences in employment shares in manufacturing – so employment shares persist in such industries in the OECD.

However while employment in manufacturing as a whole decreases by 8.8 per cent from 1981 to 1998, employment in the whole economy of the 11 countries combined increased by 50.2 million persons or 20.8 per cent, from 241.5 million to 291.7 million. This means that all four manufacturing categories decreased their share in total economy employment, as Figure 15 shows:

FIGURE 15. Shares of employment in total economy. 1980-1999. 11 OECD countries.



Manufacturing as a whole exhibits a declining share of employment from 21.6 to 16.3 per cent. The two manufacturing low tech categories together show declining shares of total employment from 14.1 per cent in 1981 to 10.4 per cent in 1998. The high tech manufacturing industries' share of total employment goes slightly down from a quite low level of 1.8 per cent in 1981 to 1.5 per cent in 1998. Taking the growth, productivity and employment data together, the slower growth of both output and productivity in medium and low tech sectors means that productivity growth in these sectors translates into very slowly declining levels of employment; and – in the context of service sector growth – sharply falling shares of total employment. However it is important to note that the persistent employment *levels* in both low tech and manufacturing as a whole suggest that structural change is not a replacement process: that is, as service activities grow, they increase their weight in the economy, but manufacturing is not replaced as an activity.

In the same way as for value added above, the share of the different classes of manufacturing industries, and the development in these shares over the period in question, vary across countries. The share of the two low tech categories in manufacturing employment in 1998 varies from 57 per cent in Sweden to 85 per cent

in Portugal. In the 11 countries combined the share falls from 1981 to 1998, just as with output. This is also the case for most of the individual countries, although in a couple of countries there is no change or a very slight increase. The correlation between the shares in 1981 and 1998 is very high, with a Pearson's r of 0.91. The shares of the low tech and medium low tech manufacturing industries in total economy employment also vary. In 1998 the variation in the share of low tech and medium low tech manufacturing industries in total employment is from 8.1 per cent in the USA to 17.7 per cent in Portugal. This share dropped in all of the countries from 1981. However the correlation between the shares in 1981 and 1998 is very high, with a Pearson's r of 0.96.

In 1998 the share of the high tech industries in manufacturing employment varies from 2.9 per cent in Portugal to 11.5 per cent in Japan. For the 11 countries combined we saw that this share increased from 1981 to 1998. For the individual countries, about half of them exhibit little change during this period, while for the other half this share increases. Again Finland is an outlier, with an increase from 2.8 per cent to 9.2 per cent. The Pearson's r correlation between the country shares in 1981 and 1998 is 0.76, but if we exclude Finland it rises to 0.94.

5. Production, domestic demand and trade. Trends, 1980-1999

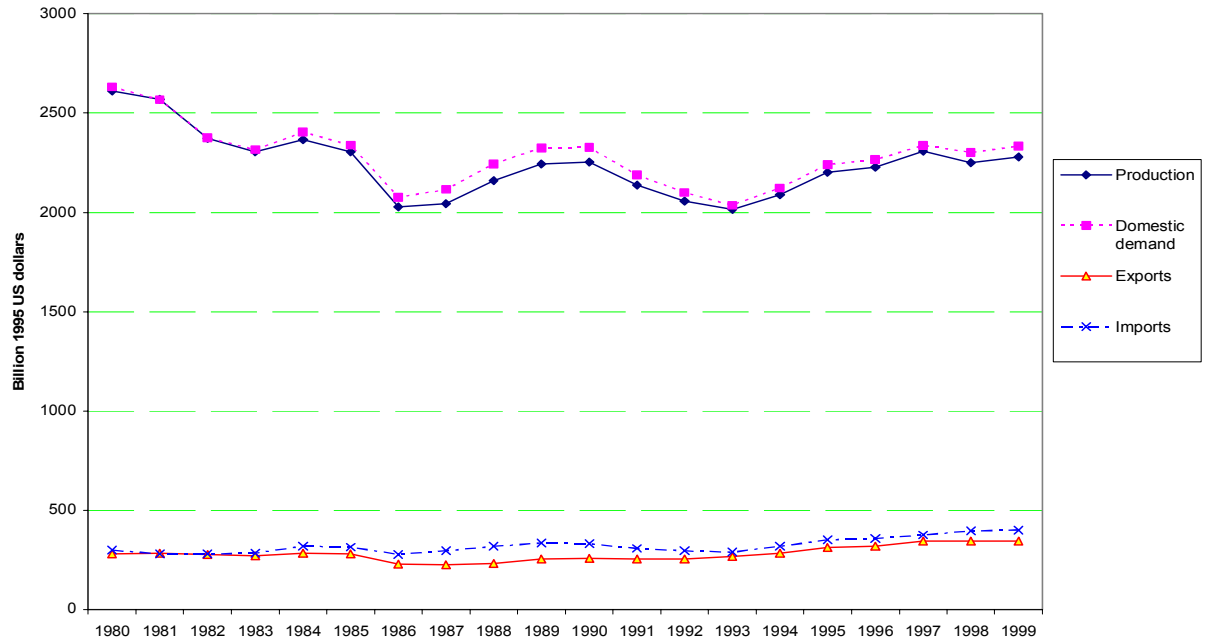
We have seen that although the low tech and medium low tech industries persist over the long run, they tend to lose ground against high tech industries. An important question is to what extent this reflects falling or stagnant demand for low tech products, or to what extent it reflects declining international competitiveness and import penetration. This issue is at the core of arguments concerning the relocation of industry from advanced to developing countries.

To explore this issue, we look here at the development of production, exports and imports. Subtracting the trade surplus from production we get domestic demand: that is to say, total domestic demand is equal to output minus exports plus imports. Of course, in considering output trends there is also world demand to consider, which would be important if growth in demand in developing countries varied substantially

across the technological intensity categories, but we do not have data on this at the moment. However such issues are not of central concern here. The ‘hollowing out’ theory of structural change requires that there should be an increasing gap between domestic demand and domestic production on medium-low and low tech industries, with rising trade deficits over time in these industries, and substantial import penetration in the long run.

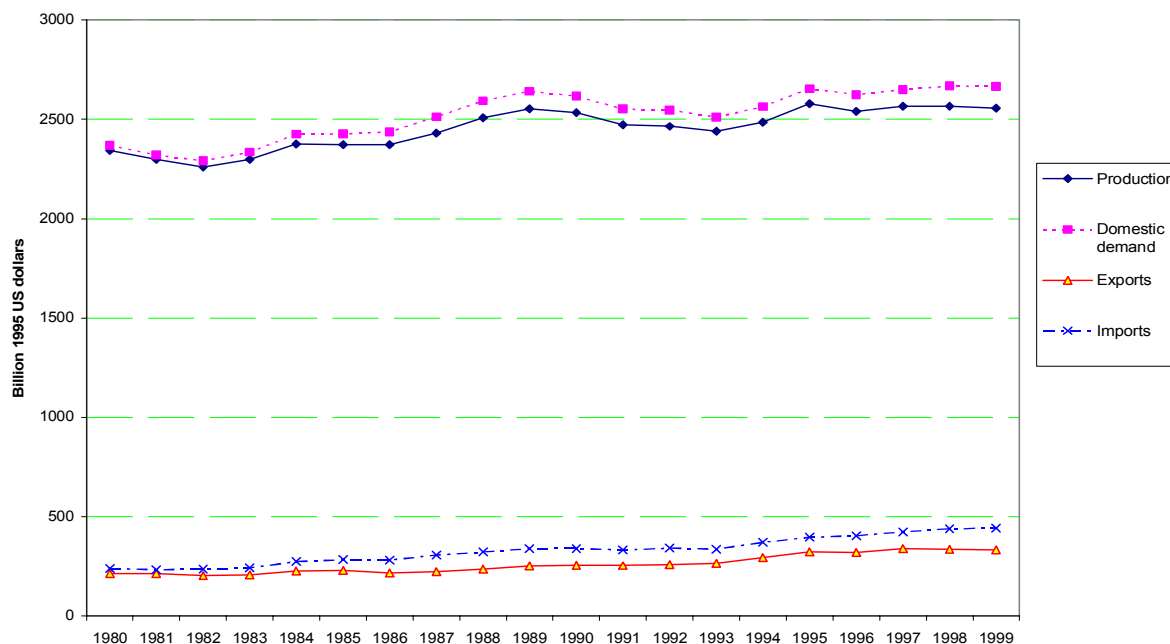
Looking first at the medium low tech industries, for the OECD group as a whole, Figure 16 shows that production seems to follow domestic demand quite closely: by far the largest part of domestic demand is provided by domestic production. Between 1981 and 1998 production declined somewhat, by 9.5 per cent, while domestic demand declined by 7.9 per cent. Production would have had to decline by only 8.0 per cent if the trade balance was not to worsen. The actual decline of production of 1.5 percentage points more than this thus expresses a widening of the trade balance. The trade deficit in the medium low tech industries showed a change from 0.3 per cent of domestic demand in 1981, to 1.9 per cent in 1998. However a change in the trade balance equivalent to 1.6 percent of consumption over an eighteen year period is hardly dramatic. Therefore this sector at least shows no signs of significant import penetration. Both exports and imports grew throughout the period, by 23.6 and 36.6 per cent, respectively. The average of exports and imports as a proportion of domestic demand thus grew from 11.2 per cent to 15.8 per cent: trade becomes marginally more important over time, but there is little sign of major relocation or changes in sources of supply.

FIGURE 16. Production, exports, imports and domestic demand in medium low tech industries 1980-1998, 11 OECD countries combined. Billion 1995 US dollars.



In the low tech industries too, production seems to follow inland demand closely. Production increases by 11.4 per cent from 1981 to 1998, while inland demand by 14.4 per cent. To cover the growth in demand production would have had to grow by 14.5 per cent. In fact it grows by 3.1 percentage points less than this, with an equivalent widening of the trade balance.

FIGURE 17. Production, exports, imports and domestic demand in low tech industries 1980-1998, 11 countries combined. Billion 1995 US dollars.



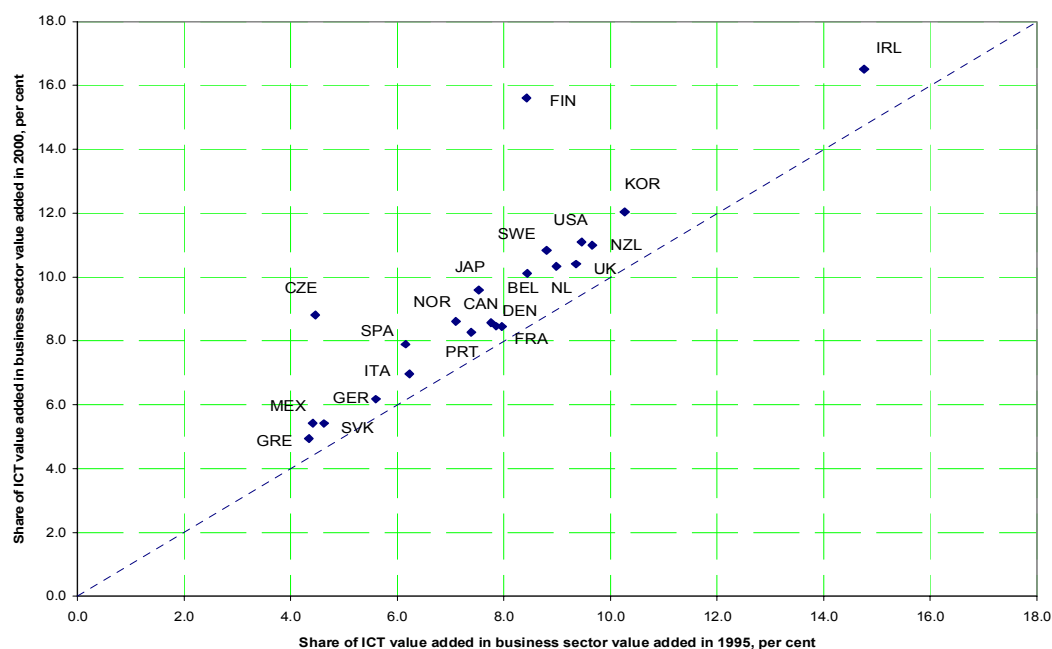
In 1981 the low tech industries had a trade deficit of 1.2 per cent of domestic demand, which by 1998 had grown to 3.7 per cent. Both exports and imports grew during this period, exports by 61.3 per cent, imports by 84.7 per cent. The average of exports and imports as a proportion of domestic demand has grown from 9.5 per cent in 1981 to 14.5 per cent in 1998. The level of trade is thus about the same as in the medium low tech industries.

In conclusion, the differences in growth rates of production across the four manufacturing tech classes seem to be closely mirrored by differences in the growth of domestic demand. There has been a certain widening of the trade balance in the medium low and low tech sectors, but this is by no means sufficient to explain such structural change as has occurred, and hence there is no evidence to support the 'hollowing out' hypothesis,

6. The ICT sector, 1995-2000

Lastly, we look at the development in value added and employment in the ICT producing sector for a number of countries between 1995 and 2000.¹ The table below shows the share of total business sector value added accounted for by the ICT producing industries (using the definition in Section 3 above) in 1995 and 2000.

FIGURE 18. Shares of ICT value added in total business sector in 1995 (x-axes); Shares of ICT value added in total business sector in 2000 (y-axes). 18 OECD countries.

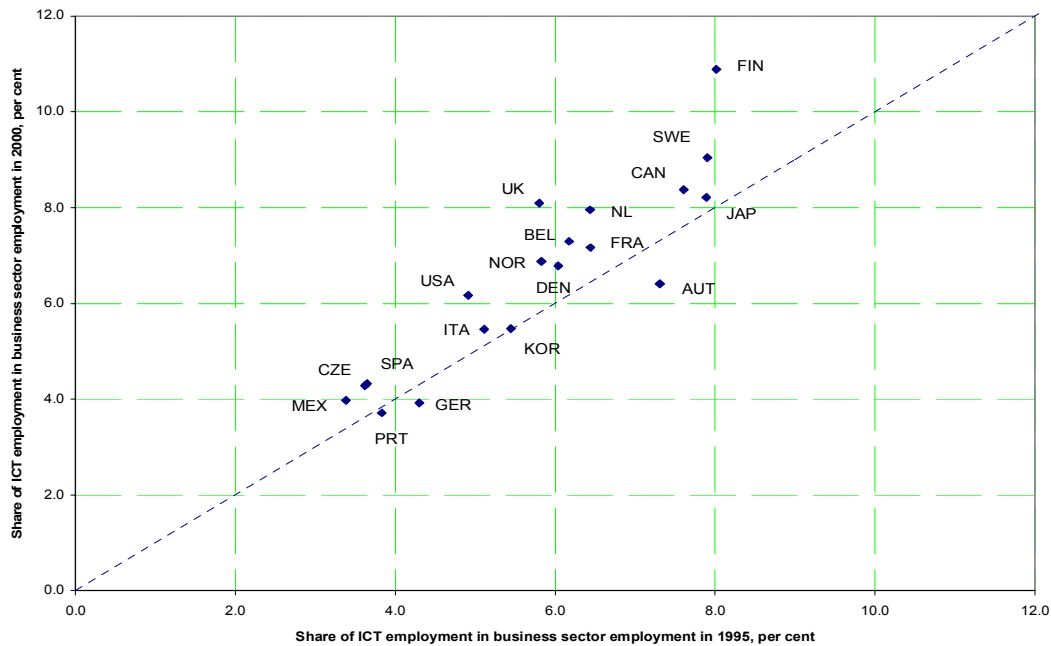


Again there is substantial variation across countries, from 4.9 per cent in Greece to 16.5 per cent in Ireland in 2000. In all the countries the share of the ICT producing sector in business sector value added increases over a relatively short time period. The unweighted averages here are 7.7 per cent in 1995 and 9.3 per cent in 2000. The correlation between the 1995 and 2000 series is very high, 0.86. Again, Finland is an outlier in this regard, where the ICT share has increased from 8.4 to 15.6 per cent in the course of five years. It should be noted that this is not straightforward production

¹ The data used here can be found at www.oecd.org, under the heading *Information and communication technologies, the ICT sector*, under the Statistics portal.

data. As noted above, it also included wholesale distribution of electrical products, presumably because this gives some guide to activities that diffuse ICT equipment; (but this category also includes many non ICT products).

FIGURE 19. Shares of ICT employment in total business sector in 1995 (x-axes); Shares of ICT employment in total business sector in 2000 (y-axes). 18 OECD countries.



In terms of employment, the variation across countries is again substantial, ranging in 2000 from 3.7 per cent in Portugal to 10.9 per cent in Finland. In a couple of countries the share of ICT has gone down from 1995 to 2000, but the general trend is upwards. The unweighted mean is 5.8 per cent in 1995 and 6.5 per cent in 2000. The correlation between the shares in 1995 and in 2000 is very high, 0.91.

A central question in this connection will be to what extent engaging in ICT producing sectors is important for economic growth, and to what extent the *utilization* of ICT in other sectors of the economy is what matters most. If engaging in ICT production on a large scale is essential, this would lend support to the more traditional high tech focus, implying reallocation towards the (high tech) ICT producing sectors from other sectors of the economy, and perhaps from low tech sectors in particular. However, if the utilization of ICT throughout the rest of the economy and not so much engaging in ICT production itself is what matters, this would be more compatible with

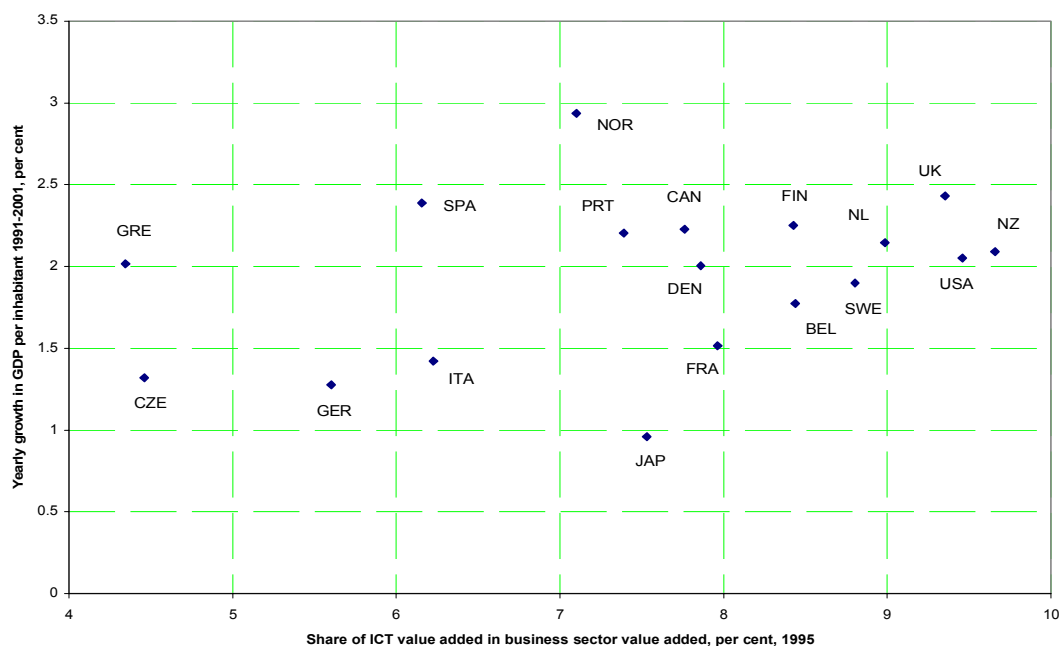
continued involvement also in low tech industries, provided these industries are continuously transformed through the utilization of ICT. According to Boyer, intensity of ICT utilization seems to be the crucial factor here (Boyer, 2004: 2, 25), not ICT production. This is also the conclusion reached in an IMF working paper by Bayoumi and Haacker (2002).

Amable and Petit (2003) also make the point of different countries pursuing different growth models. They seek to explain differences in macroeconomic performance across countries using a range of econometric models. Along with variables expressing institutional and more traditional macroeconomic conditions, they have two variables on ICT-producing and ICT-using sectors, respectively. The main conclusion of this empirical work is that the findings are fragile, something which they attribute to the heterogeneity of growth models across countries. (Amable and Petit 2003: 222-226).

We find no particular links between ICT and growth. Although we do not report the results here, we examined the correlation between the same economic growth variables and a number of indicators of ICT production and ICT use in different countries. These include share of the ICT sector in business sector value added, share of ICT sector in business sector employment, investment in ICT as a proportion of gross fixed capital formation, share of ICT employment in business sector services employment, ICT expenditures as a proportion to GDP 1999. Some of these variables are measured both in 1995 and 2000, which means that we also have a measure for the change in some of these magnitudes. We found at best a weak confirmation of a positive relationship at the national economy level between the intensity of ICT production and ICT utilization, on the one hand, and the growth variables, on the other. Most of the coefficients were weakly positive, but only a few were statistically significant.

Figure 20 provides an example for the weak relationship between ICT shares of total business value added and the annual compound growth rate in GDP per per capita. The figure displays no correlation between these two variables.

*FIGURE 20. Shares of ICT industries' value added in total business sector (x-axes)
Annual compound growth rate in GDP pr capita. 1991-2001 (y-axes).*



7. Conclusions

Advocates of high tech approaches to economic growth have often avoided even the most cursory reference to quantitative evidence, and so it is important to confront the claims of high tech approaches with the evidence. In the countries examined here there has been a clear tendency for the share of low tech industries in manufacturing to decline during the period 1980-1999, while the share of high tech industries has increased. This applies to both production (whether value added or gross production) and employment. However, these changes do not appear to be dramatic. We conclude that among the OECD countries studied here, structural change within manufacturing is not a key feature of the growth process. However there has been structural change at the level of the economy as a whole, with a sustained rise in the share of services (both public and private). Of course this change does not support the structural change view of growth, since services tend to be considerably less R&D intensive than manufacturing.

An important conclusion of this work that there is substantial variation across the countries when it comes to the shares of output and employment accounted for by high tech industries - there are quite different sectoral mixes that persist over time. In

this context we found no evidence of any simple relationship between technological intensity of the industrial structure and economic growth at the total economy level. There is no simple relationship to the effect that the high tech economies are also the high growth economies. This suggests that different economies can follow different routes to economic growth. Countries play different roles in an economic system which is differentiated at the international level, and in which there is a division of labour among the highly developed economies.

Our analysis suggests that while new sectors emerge within the economy, and some sectors disappear, this does not account for the processes of growth which actually occur across the OECD. The growth trajectories of the advanced economies seem to rest as much on such sectors as engineering, food, wood products, and vehicles and so on, as they do on such sectors as ICT or biotech. Medium and low tech industries have persisted over the past decades despite the claims that we are undergoing a kind of structural revolution. We would hypothesize that they are unlikely to disappear in the future either. Why is this? Our argument would be that these industries are far more dynamic and innovative than usually believed. Our view, which is spelled out in other chapters in this book, is that the persistence of low and medium tech industries derives from the fact that innovation in advanced economies has two broad but separate dimensions. On the one hand there are science-based or at least R&D-based innovations that create new industries or activities by opening up technological and commercial opportunities. Aerospace, ICT, and pharmaceuticals fall into this category. On the other hand, there are innovation processes that technologically upgrade existing industries and activities. Such changes are often ignored because of asymmetric attention by analysts to arbitrarily selected new technologies. However technological upgrading in medium and low tech industries is pervasive and can be both incremental and radical. Incremental change upgrades and endogenously changes industries over the long run. Radical innovations in medium and low tech activities, such as the container revolution, or new forms of adhesives, or new materials in textiles and clothing, can have important growth impacts. We argue that the persistence of low and medium tech industries suggests the need for much closer attention to the both of these forms of innovation, and we hypothesize that these industries survive in the OECD economies because they exemplify such omnipresent forms of innovation and knowledge creation. This implies that growth is primarily based not on the creation of

new sectors but on the internal transformation of sectors which already exist. Overemphasizing the role of high tech activities high tech ignores this major dimension of change in advanced economies.

There are those who would agree with the broad views expressed here, but argue that innovation and growth in medium and low tech industries is nevertheless shaped by high tech sectors, because high tech sectors supply intermediate and capital inputs that embody the knowledge intensity of high tech. Without entering these arguments in detail, we would raise objections resting on the fact that only one high tech sector really supplies inputs to a wide range of other sectors, and that is ICT. There is no question that the incorporation of ICT components into medium or low tech products and processes is a key element of innovation within those sectors at the present time. However this is only one element of innovation in such sectors, and we would argue that medium and low tech innovation simply cannot be reduced to the use of ICT. More significantly, there is a causality issue here as well: medium and low tech sectors may not be passive recipients of ICT, but via their complex demands for inputs may actually be the shaping force behind the development of ICT as a technology and industry. This is the approach taken in Pol, Carroll, and Robertson (2002), and considerably further developed in their chapter in this book. Their argument is that there are strong interactions between industries, as well as pervasive innovation across them, creating backward and forward linkages that should be seen in an integrated way. In this framework it is the innovative capacity of industries receiving high tech inputs that shapes both high tech growth and overall growth. We would argue that only such an approach can explain the growth and trade trends that have been explored in this chapter. The combined arguments of these chapters suggest that medium and low tech industries continue to play a key role in the technological evolution of the advanced economies, a role that will be maintained in the future.

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