Manufacturing and the Knowledge Economy

A Knowledge Economy Programme Report

Prepared by Ian Brinkley, January 2009
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1. Manufacturing and the knowledge economy

In this report we argue that modern manufacturing has the potential to be a lead knowledge economy sector as the recession forces our economy to restructure away from an over-dependence on financial services.

The knowledge economy is a phrase often used but seldom defined. It essentially describes a process whereby the economic competitiveness and performance of organisations and firms is increasingly determined by their investment in ‘knowledge based’ or intangible assets such as R&D, design, software, human and organisational capital, and brand equity and less by investment in physical assets such as machines, buildings, and vehicles1.

One indicator of the scale and pace of this change is shown in the ratio between business investment in tangibles and business investment in intangibles. In 1970 UK business investment in intangibles was worth 40 per cent of investment in tangibles. By 2004 the ratio was 130 per cent. Recent research using the same methodology shows similar results for the US, Finland and the Netherlands2.

Figure 1: Changing investment priorities in the knowledge economy

![Graph showing changing investment priorities in the knowledge economy](image)


**Note:** Ratio of investments in tangibles (machines and buildings) to intangibles (R&D, software, design and development, brand equity, workforce training, organisational capital). Investment in tangibles = 1.0, so investment in intangibles in 1970 = 0.4, and in 2004 = 1.3.

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1 The Knowledge Economy: How Knowledge is Reshaping the Economic Life of Nations Knowledge Economy Interim Report, March 2008.
In our interim report we hypothesised that the shift was driven by changes in markets, technologies, and globalisation underpinned by an increasingly better educated and qualified workforce. More wealthier, diverse and sophisticated consumers have supported demand for higher value added goods and services. In addition, new general purpose technologies based around accelerating computer power at rapidly falling prices acted primarily on the supply side; globalisation accelerated the changes by opening up bigger and more diverse markets and facilitating the exchange of ideas and technologies across national borders.

However, apart from a limited number of high tech sectors, manufacturing is often omitted from this story. This report shows that the shift towards a knowledge economy has affected manufacturing deeply. The highly visible shift towards high tech industries in global markets is underpinned by a much wider change towards knowledge based manufacturing.

That change in turn is making the terms ‘manufacturing’ and ‘services’ as conventionally understood increasingly redundant. The terms ‘high tech’ and ‘low tech’ are becoming a less helpful way of describing the structure of modern manufacturing.

Rather than manufacturing firms, we increasingly have firms that do some manufacturing as part of the integration of services and manufacturing in the production process. These changes have gone further and faster in our high tech industries which continue to operate at the technological cutting edge of the knowledge economy. For these firms and the overall health of the sector, along with the economy, investment in R&D remains a central concern. But the shift towards more knowledge based manufacturing has affected all manufacturing industries, including those classified as ‘low tech’, where spend on other non-scientific knowledge assets is just as critical as R&D investment.
The re-assessment of the manufacturing sector set out in this report is taking place against a recession of uncertain depth and duration, with some forecasters suggesting unemployment could increase to as much as 3 million on the ILO measure\(^3\). In the previous downturn, when ILO unemployment also hit 3 million, the rough distribution of job losses was 40 per cent in manufacturing, 40 per cent in services, and 20 per cent in construction.

There has been some speculation that this will be a ‘middle class’ recession with large numbers of jobs going from financial services and some of the associated high value added services. This is overstated. Manufacturing, construction and lower value added services are still likely to make up the majority of job losses. Nonetheless, we expect the overall distribution of job loss to shift towards services (including some higher value added services) and away from manufacturing for three reasons below.

Firstly, manufacturing is significantly smaller in employment terms than in 1990. Secondly, manufacturing does not have to contend with an over-valued exchange rate, albeit this benefit is offset in the short term by the collapse in some overseas markets. Thirdly, we argue that the sector is more resilient than in the past, because it has become more knowledge based.

There is little hard evidence to back up this assessment as yet, because we only have at most two quarters data on manufacturing employment levels since the economy entered recession. The full impact on manufacturing employment is likely to be delayed, as some companies will resort to short-time working, cuts in overtime, and recruitment freezes as their initial response to falling orders.

Manufacturing job losses are accelerating and manufacturing employment is falling faster than in services. However, manufacturing employment appears to be falling less rapidly than at the same point in the 1990s downturn. Moreover, some of the job losses in manufacturing would have occurred anyway as employment had been falling for structural reasons in the run up to the current recession.

But beyond the short term crisis in financial, property and labour markets, there are some major questions about how the economy could restructure towards industries that are able to take up the economic slack in the recovery. We think one of them could be the modern manufacturing sector. Our arguments and evidence for taking such a view are set out below.

\(^3\) International Labour Organisation (ILO) definition. The ILO measure is derived from the quarterly household Labour Force Survey (LFS) and defines the unemployed as all those who looked for work in the four weeks before the survey and are able to start a job in two weeks time. This is the government’s preferred measure of unemployment and is quite different to the much lower claimant count measure. The later includes only those registered and in receipt of unemployment related benefits.
The financial services sector will grow more slowly in the future and may even shrink as a share of GDP. For the UK, this has serious implications. Our financial sector\(^4\) is the biggest of the OECD’s major economies and has been growing rapidly in terms of value added (although not in employment). The financial services sector provides around a third of all knowledge service based exports and is a significant investor in knowledge based intangible assets. In contrast, the UK’s manufacturing sector is smaller compared with most other major economies measured as shares of value added. This is shown below\(^5\). A major challenge for policy makers and others thinking about the medium to long term post-recession shape of the economy is how far the balance between the share of value added provided by manufacturing and the share of value added provided by financial services will change.

**Figure 2: Rebalancing the economy? Manufacturing and financial services as a share of value added in 2005**

![Bar chart showing the share of value added from manufacturing and financial services for selected countries in 2005](image)

Source: EU KLEMS database

All OECD economies have been subject to huge industrial changes over the past thirty years. As part of that change the share of manufacturing has fallen as a share of value added in all major economies. The share of value added in knowledge based services\(^6\) has increased in all major economies. The share of more traditional services such as retailing and hospitality has remained more or less stable. These patterns have been broadly true for all the advanced industrialised economies since 1970.

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\(^4\) Standard Industrial Classification definition – financial intermediation, pension and insurance services, ancillary financial services

\(^5\) EU KLEMS database for 2005. More recent national figures show a higher share for financial services and lower for manufacturing

\(^6\) OECD definition of communication, financial, business, heath and education services
In the UK, these changes have been even more marked than in most of the rest of Europe. In the UK the share of manufacturing in total value added declined from 35 per cent to below 15 per cent between 1970 and 2005. The share of knowledge services went up from 23 per cent to 46 per cent. The share of more traditional services remained at just under 30 per cent. The chart below compares the UK against the EU15 average.

When looking at charts of this sort it would be easy to conclude that manufacturing no longer mattered as a growth sector or as a source of new jobs and the future for Western economies lies with the knowledge based services. However, we argue in this paper that this view is outdated for three reasons:

- The decline in manufacturing as a share of value added can only be partly attributed to loss of competitiveness to low wage overseas competition;
- The rise in knowledge based services is in part driven by the manufacturing sector;
- The manufacturing sector is restructuring towards new business models based on large scale investments in knowledge based assets.

7 In addition, other industries such as agriculture, construction and energy and water also declined as shares of value added over this period.
3. Why manufacturing has fallen as a share of value added

It would be quite wrong to give the impression that manufacturing in the UK does not face immense challenges or that the above explanations mean that we have nothing to worry about. The UK’s manufacturing trade deficit has grown to alarming levels, even if we take into account internationally traded services generated and supported by manufacturing activities. The fall in the exchange rate will help reduce the imbalance in the short term, and net trade (the difference between the growth in imports and exports) is expected to help increase GDP over the next year or so. However, serious underlying structural problems remain around the effective utilisation of skills and science and technology that current policy is addressing, as recognised by both DIUS and BERR in recent White Papers.

Nonetheless, we think the long term potential of modern manufacturing as a knowledge economy based sector has been seriously under-estimated. In the remainder of this section, we look at the reasons why manufacturing as a share of value added has declined in all advanced OECD economies, including the UK.

The impression is sometimes given that manufacturing is being wiped out by competition from low wage producers. This view is given added credibility by the high visibility of some imported goods such as electronics and clothing and news stories of factory closure due to international competition.

A common assumption is that a rise in imports automatically means that a particular industry is failing, reinforced by the fact that exports by the same industry are by definition invisible to domestic consumers. For example, the UK’s highly successful pharmaceuticals industry has seen import penetration – measured as the value of imports as a share of total UK demand – go up from 16 per cent to 33 per cent between 1992 and 2004, according to the ONS. The increase in import penetration of 17 percentage points in just over a decade looks alarming. However, over the same period exports measured in the same way (value of exports as a share of total UK demand) went up from 29 per cent to 43 per cent, an equally impressive rise. The industry exports and imports more but remains a highly competitive manufacturing sector.

Modern economies do not specialise in the way the more simplistic trade models predicted. The models predicted that over time they would specialise in industries producing goods in which they had a comparative advantage. There is clearly some specialisation, so that for example the UK’s exports are disproportionately generated by high tech industries such as aerospace and pharmaceuticals rather than textiles and clothing which others can produce more efficiently. But the trend towards greater industrial specialisation in major economies has overall been modest.
and industrialised economies typically both import and export goods and services over a wide range of industries.

Modern trade theories help explain this by taking into account the diversity, size and complexity of domestic markets. As well as helping to explain why most large economies both import and export goods such as cars, it also explains why firms facing low wage competition can respond in other ways than exiting the industry. A recent study of the US\textsuperscript{9} concluded that: ‘manufacturing firms escape competition from low wage countries by upgrading their mix of products to one that is more consistent with US comparative advantage.’

Much attention has been given to the rapid rise in imports from China as a prime cause of the decline in UK based manufacturing. Less widely recognised is that this rise has been accompanied by a large decline in imports from Japan and other South East Asian economies. Some of the imports from China are goods that we previously imported from Japan. Moreover, goods imported from China currently account for just over 10 per cent of all goods imported, or about the same as Belgium.

With all these complications in mind, estimating how far low wage imports can be blamed for the decline of UK manufacturing is fraught with difficulty. The ‘best guess’ from available research\textsuperscript{10} is that jobs lost directly attributable to low wage trade is around 30 per cent of the total. This is a large number of jobs and their loss can cause severe structural problems in localities more highly dependent on manufacturing. However, this suggests that around 70 per cent of manufacturing jobs would have been lost even if China and Eastern Europe had remained closed economies.

Price effects

The most obvious reason for manufacturing to fall as a share of value added is that manufacturing prices have been falling relative to services, because manufacturing is on average more productive than services and more likely to face international competition. As a result, over the past decade the price of manufactured goods in the UK has on average fallen by 20 per cent and the price of services has increased by on average 50 per cent\textsuperscript{11}. These price effects also disguise increases in actual production. For example, in 2007 the UK built more passenger cars than in 1977, but their value as a share of GDP is significantly lower because technological developments and increased efficiency have driven prices down.

\textsuperscript{9} Bernard et al Firms in International Trade CEP Discussion Paper No 795 May 2007
\textsuperscript{10} Coutts, Glynn and Rowthorne, Cambridge Journal of Economics, November 2007
\textsuperscript{11} Retail Price Index, Office for National Statistics
The fastest growing markets in the world have been in emerging economies. For manufacturers, it makes sense to locate new production facilities closer to where their growing markets are, in much the same way as Japanese car companies opened factories across Europe to access growing European markets. A recent research paper\(^{12}\) shows that European manufacturing multi-nationals increased their total number of plants globally outside Europe with the overwhelming reason being market access:

‘While some of the plants abroad have been established to tap into low cost labour, most of the plants abroad have been established to tap into new markets. The market is still the main driving factor behind the international plant network…’

This raises further difficult questions on how to judge the relative success of UK based manufacturing industry from the amount of production they undertake in their home market. Globally successful manufacturing firms will over time do less of their total manufacturing at home. As a result, measures such as the trade balance in physical goods and domestic output growth will not be giving an accurate picture of the underlying strength of firms in the sector. For example, a 2002 report on the UK print and publishing industry\(^{13}\) noted that:

‘as well as being exported, books are licensed to local publishers, or produced overseas by the company itself or sent electronically to be printed on demand in local markets. The revenue from these activities is treated in different ways by different publishers, but generally the results are opaque to the outside observer’.

Many of the trade flows in manufactured goods are within the same company as part of a global supply chain, with high value added components shipped from the West to assembly factories in Asia, with the assembled product shipped back to the West. As a result, much of the value added remains in the West, even though much of the actual manufacturing occurs elsewhere. Although China has doubled world exports in consumer electronics and office machinery over the past decade, the OECD\(^{14}\) notes that ‘while China is no longer just a low wage country assembling cheap manufacturing, in the high tech field it specialises mainly in labour intensive and low value added parts of the production chain’. However, this will not be obvious to consumers and others seeing just the rapid increase in imported goods labelled ‘made in China’.

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\(^{13}\) DTI (2002) Publishing in the Knowledge Economy

\(^{14}\) Rae and Sollie, OECD 2007
4. Manufacturing in the UK’s knowledge economy

In our work on the knowledge economy, we have used the OECD\Eurostat definition of technology and knowledge based manufacturing. The OECD classification is based on R&D intensities (R&D expenditure as a share of sales). The current OECD definition of the knowledge based industries includes a substantial part of the manufacturing sectors. This includes high tech sectors such as pharmaceuticals, aerospace and advanced electronics as well as the medium to high tech sectors such as chemicals, cars, and other engineering industries.

A summary of the manufacturing sector according to the OECD definition is set out in the table below. Recent BERR statements and analyses have combined the high tech and high to medium tech sectors as a single ‘high tech’ sector. For the purposes of this paper we have retained the more common conventional OECD definitions of high tech and high to medium tech manufacturing.

Table 1: Technology defined manufacturing – OECD definitions

<table>
<thead>
<tr>
<th>High technology (R&amp;D &gt; 5% of sales)</th>
<th>SIC</th>
<th>Medium-High technology (3 - 5% of sales)</th>
<th>SIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pharmaceuticals</td>
<td>24.4</td>
<td>Chemicals</td>
<td>24</td>
</tr>
<tr>
<td>Office machinery and computers</td>
<td>30</td>
<td>Machinery and equipment</td>
<td>29</td>
</tr>
<tr>
<td>Communication equipment</td>
<td>32</td>
<td>Electrical machinery</td>
<td>31</td>
</tr>
<tr>
<td>Instruments</td>
<td>33</td>
<td>Motors</td>
<td>34</td>
</tr>
<tr>
<td>Aerospace</td>
<td>35.3</td>
<td>Other transport equipment (exc ships)</td>
<td>35</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Medium-Low technology (1 - 3% of sales)</th>
<th>SIC</th>
<th>Low technology (less than 1% of sales)</th>
<th>SIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel production</td>
<td>23</td>
<td>Food, drink, tobacco</td>
<td>15-16</td>
</tr>
<tr>
<td>Rubber and plastics</td>
<td>25</td>
<td>Textiles, clothing, footwear</td>
<td>17-19</td>
</tr>
<tr>
<td>Mineral products</td>
<td>26</td>
<td>Wood and wood products</td>
<td>20</td>
</tr>
<tr>
<td>Basic metals</td>
<td>27</td>
<td>Paper and paper products</td>
<td>21</td>
</tr>
<tr>
<td>Fabricated metal products</td>
<td>28</td>
<td>Publishing, printing, recorded media</td>
<td>22</td>
</tr>
<tr>
<td>Building and repair of ships and boats</td>
<td>35.1</td>
<td>Furniture, other manufacturing, recycling</td>
<td>36-37</td>
</tr>
</tbody>
</table>

Source: OECD/Eurostat

High and high to medium tech industries provided about 10 per cent of total value added across the knowledge based industries in 2005, according to EU estimates\(^\text{15}\). This compares with 11 per cent from high tech services and 14 per cent from financial services. In comparison, the

\(^{15}\) EU KLEMS database. OECD definitions of knowledge based industries
business service sectors provided around 30 per cent of value added across the knowledge based industries and health and education services around 30 per cent.

**Figure 4: Manufacturing in the UK’s knowledge based industries**

Knowledge and technology based manufacturing provides most exports. High and medium high tech industries now provide the overwhelming majority of our exports. This reflects the boom in world demand over the past twenty years in high value added manufactured goods such as pharmaceuticals, aerospace, and advanced electronics and the contraction of some low tech export markets such as textiles and clothing. This is a common experience across the OECD. In addition, in the UK the car industry has restructured significantly and today is heavily export orientated.

Source: EU KLEMS database

**Note:** Share of value added in knowledge based industries 2005, OECD definition. HMT is high to medium tech. High tech services are communications, computer services, R&D.
The latest statistics from the UK authorities shows that in 2007 nearly 70 per cent of all manufacturing goods exported came from the high to medium tech ‘knowledge economy’ manufacturing sectors. About 28 per cent were generated by the high tech sectors alone. In contrast, low tech manufacturing industries provided only about 14 per cent of UK manufactured exports.

The UK has an exceptionally strong contribution to exports from high tech manufacturing industries compared with other OECD economies. A recent study by the OECD found that in 2005 about 34 per cent of UK manufacturing exports came from high tech industries compared with 36 per cent in the US, 27 per cent from Japan, 21 per cent in Germany and 24 per cent in France. Indeed, of the 28 OECD economies examined in the study, only five had higher shares (US, Ireland, Netherlands, Cyprus and Malta) and three of those were small economies specialising in high tech export industries.

**Figure 5: High tech manufacturing exports as share of total manufacturing exports in 2005**

![High tech manufacturing exports as share of total manufacturing exports in 2005](image)

Source: OECD definitions, Rae and Sollie OECD 2007

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There is an unambiguous shift towards high tech manufacturing exports in the UK and across the OECD. In the UK the share of manufacturing exports provided by high tech industries went up from 20 per cent of UK manufacturing exports in 1983 to 34 per cent in 2005 according to the OECD\textsuperscript{17}. This is hardly surprising. World demand for high tech products has been growing strongly and the OECD economies have been able to exploit their science and technology bases to remain competitive in world markets. The chart below shows the growth in exports in current US$ across some of the high tech industries between 1995 and 2005 for some of the major OECD economies.

\textbf{Figure 6: Growth in high tech exports by sector 1995-2005}

![Chart showing growth in high tech exports by sector](chart.png)

\textit{Source: OECD database}

\textbf{Note:} All figures US dollars, current prices.

However, in some areas the rise of China and other South East Asian economies has provided a competitive challenge. The high tech sector ‘office machinery and computers’ has shown little growth in exports for most major OECD economies including the UK. Between 1995 and 2005 exports increased by just 12 per cent for the US, were virtually static for the UK, and declined by 20 per cent for France and 35 per cent for Japan. Germany was a major exception, with exports doubling in value over this period (all figures current US$)\textsuperscript{18}.

However, some of this story is the expansion of OECD owned manufacturing capacity in Asia to produce these goods for export to the West. This expansion is the primary reason why the ‘high

\textsuperscript{17} OECD STAN database; OECD Economic Working Paper No 586, table 2

\textsuperscript{18} OECD Science and Technology indicators
The tech’ content of China’s exports appears to rival that of the leading OECD economies. According to the OECD study by Rae and Sollie, high tech goods from Chinese based factories accounted for about 36 per cent of total Chinese exports, roughly double the share ten years ago, while the share from the rest of South East Asia was even higher at 48 per cent. However, the authors caution about reading too much into these classifications: ‘While China is no longer just a low wage country assembling cheap manufactures, in the high tech field it specialises mainly in the labour intensive and low value added parts of the production chain.’

However, the chart also shows an odd anomaly, with the UK aerospace sector appearing to do less well in terms of export growth using the conventional measure of exports of physical goods. Over the past decade aerospace exports from the UK went up by 16 per cent compared with 85 per cent from France, 104 per cent from the US, and 144 per cent from Germany.

It is possible that UK aerospace has been more much more focused on home markets than in other economies over the past decade. This is unlikely, as the export share has remained remarkably stable over the past decade at round 50 per cent of total UK demand. Nor have we seen a significant increase in import penetration since the mid 1990s. There are two other possibilities. Firstly, UK aerospace companies may be expanding capacity overseas to get closer to their key markets and access cutting edge technologies. Secondly, their success and ability to compete is becoming more dependent on their ability to exploit knowledge based intangibles such as R&D, design and consultancy and therefore showing up in service exports, licensing and royalty agreements, and repatriated profits from overseas operations rather than physical goods exports from the UK.

It would be easy to conclude from the above charts and the highly visible collapse of more traditional industries such as textiles and clothing that low-tech manufacturing has largely migrated overseas. However, the UK retains significant numbers of jobs in medium to low tech manufacturing (as defined by the OECD). In 2006 they employed about 2.1 million people, somewhat more than in the more technology intensive industries. In 2006 high tech manufacturing provided about 8 per cent of all manufacturing jobs, and high to medium tech another 35 per cent.

Employment measures will understate the contribution of more capital intensive sectors such as high tech. Looking at the latest available figures for gross value added from the Annual Business Inquiry (AB) shows that high tech manufacturing contributed about 16 per cent to manufacturing value added in 2006, or twice the high tech manufacturing’s share of employment. However, even on this measure, the share of value added generated in low tech manufacturing was twice
that of high tech manufacturing. The structure of UK manufacturing in terms of employment and value added is shown in the charts below.

**Figure 7: The structure of UK manufacturing in terms of employment and value added**

<table>
<thead>
<tr>
<th>Employment in manufacturing in 2006</th>
<th>Value added in manufacturing in 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low tech 35%</td>
<td>Low tech 35%</td>
</tr>
<tr>
<td>Medium to high 35%</td>
<td>Medium to high 35%</td>
</tr>
<tr>
<td>High tech 8%</td>
<td>High tech 16%</td>
</tr>
<tr>
<td>Medium to low 22%</td>
<td>Medium to low 22%</td>
</tr>
</tbody>
</table>

*Note:* Total employment, Labour Force Survey basis, Eurostat.

*Note:* Gross value added.

Source: ABI, Office for National Statistics

An immediate question is whether this structure is typical of other advanced economies and if it might explain why parts of UK manufacturing have historically struggled to compete. A manufacturing base with an exceptionally large low tech sector could find itself at a severe competitive disadvantage as emerging economies move up the high value added chain.

The latest OECD estimates are for 2003 and these show that low tech manufacturing accounted for about 38 per cent of UK manufacturing value added. This was much higher than in Germany and Japan, where low tech manufacturing accounted for just 23 per cent of value added, and higher than in France and Sweden where low tech manufacturing accounted for around 33 per cent of value added. However, it was similar to the share in the United States, Italy, Finland and Denmark and lower than in Canada and the Netherlands.

The UK’s share of low tech manufacturing is clearly higher than the world leading manufacturing nations of Germany and Japan, but is not obviously out of line with other G7 economies or the Nordics and Netherlands. Moreover, even in Germany and Japan low tech manufacturing
Manufacturing contributes around 25 per cent of manufacturing value added, and in most of the economies we have looked at the share is between 30 and 40 per cent. There must be good reasons why such industries have survived the onslaught from low wage competition, given their openness to international trade.

However, even if low wage manufacturing still survives today, this may not be a stable position. A common assumption is that manufacturing has been aggressively restructuring away from low tech towards high tech manufacturing industries in the face of low wage competition. In the future the share of low to medium tech could therefore inevitably shrink and the share of high to medium high increase.

Over the past 35 years the share of high tech manufacturing in total manufacturing value added has gone up in all the major advanced industrialised economies. So has the share of the high to medium tech sectors as a whole, as the latest BERR analysis\(^{19}\) shows. However, what is striking is that the change is relatively modest for most economies and appears to have slowed since 1990. This is shown in the chart below. The main exception is Japan where there has been a significant and clear upward trend throughout this period (perhaps reflecting significant outsourcing of lower value added manufacturing to China).

**Figure 8: Manufacturing shifts towards high tech... but change is gradual rather than dramatic**

![Chart showing the share of high tech manufacturing in total manufacturing value added for various countries over time.](chart.png)

*Source: OECD database*

**Note:** Share of high to medium tech based manufacturing in total manufacturing value added.

\(^{19}\) BERR (2008) Economic Working Paper No.2. figure 9. BERR use the term high tech to include both high tech sectors (pharmaceuticals, aerospace, electronics) and high to medium tech sectors (cars, chemicals, mechanical and electrical engineering)
For the UK, the share of high and high to medium high tech base manufacturing has increased from 34 per cent in 1970 to 40 per cent of manufacturing value added in 2005 according to data from the EU KLEMS database. National UK data shows high tech industries as a share of manufacturing value added have increased slightly, from just under 15 per cent in 1995 to just over 16 per cent in 2006. Over the same period the share of low tech industries has remained unchanged, and the share of medium tech industries has declined a little.

In a knowledge based economy the role of non-technology based innovation is also important, especially in industries who do not typically invest heavily in R&D but who do invest significantly in other ‘intangible’ knowledge based assets such as design, organisational capital, and brand equity. Medium to low tech manufacturing also innovates and draws on the science and technology base, even though it typically invests little in R&D. In a report undertaken for the EU Commission in 2003, Smith et al20 argued that:

‘… low and medium technology industries are of great and continuing importance in advanced economies…LMT industries intensively create and deploy many forms of production relevant knowledge, including basic science results and…they are central to the knowledge economy’.

The continued existence of large ‘low tech’ manufacturing industries is consistent with the basic concept of the knowledge based economy applying across all sectors. The more widely accepted definitions of the knowledge economy set out in the 1998 Competitiveness White Paper and defined by the Economic and Social Research Council’s in 200621 both emphasise that the exploitation and application of all forms of knowledge and technology apply across all industries – from the highly traditional to those at the cutting edge of technological advance.

The low tech sector today is dominated by just two sectors – paper, publishing and printing and food, drink and tobacco. One reason why these industries survive today when other low tech sectors such as textiles, clothing and footwear are shrinking dramatically is that they are much less exposed to low wage competition. For example, import penetration in publishing and printing in 2004 was just 6 per cent (albeit this measures only the value of physical products produced by the industry). However, we suggest it is also because both have become more knowledge based and, in the way Smith suggests, have exploited and deployed knowledge and the science and technology base in order to survive.

21 Brinkley, Defining the Knowledge Economy, The Work Foundation 2006
Modern manufacturing has been reshaped by exactly the same forces driving our transformation into a knowledge based economy. There are two closely related major consequences of these changes.

- Firstly, modern manufacturing invests more heavily in knowledge based intangible assets than services and provides large numbers of knowledge intensive jobs;

- Secondly, the conventional boundaries between manufacturing and services are blurring as manufacturers incorporate high value added services into the production process.

Some people interpret the shift towards investment in intangible assets as simply another way of describing the economic shift from manufacturing to services with investment by manufacturing in physical assets such as plant and machines falling as a share of GDP and investment by services in knowledge based intangibles increasing as a share of GDP. This is only partially right.

The recent joint BERR and DIUS Manufacturing Strategy Review\textsuperscript{22} include some recent updates of investment in intangibles by the manufacturing sector. In 2004 manufacturing invested around £32 billion in intangibles. This is more than twice the level of manufacturing investment in physical assets recorded by the conventional national accounts definition of investment of just under £14 billion. The ratio between investment in intangibles and investment in tangibles was therefore higher in manufacturing (2.3 to 1.0) than in the rest of the economy (1.3 to 1.0).

About 25 per cent of all intangible investment by manufacturing was accounted for by R&D – not surprising as the most R&D intensive sectors are in manufacturing and the sector accounts for 75 per cent of all R&D performed across the economy as a whole. However, another 25 per cent was accounted for by new architectural and engineering design. This high investment is linked to the strong manufacturing performance in generating knowledge based technical service exports – described in more detail below. Firms providing training and investment in organisational capital accounted for another 33 per cent. The remaining 17 per cent was largely accounted for by investment in software and brand equity. The chart below provides details.

The study of intangibles in the Netherlands quoted above\textsuperscript{23} also provides a break-down by industrial sector and shows similar results. In 2004 manufacturing in the Netherlands invested

\textsuperscript{22} \textit{Manufacturing: New Challenges, New Opportunities}, BERR, DIUS September 2008
about 13.5 per cent of value added in intangibles, the highest rate of investment in intangibles of all the sectors examined with the exception of financial and business services (14.6 per cent). The distribution of investment in intangibles by manufacturing in the Netherlands was also similar to investment in manufacturing in the UK.

As manufacturing becomes more knowledge based, the distinctions between manufacturing and services are becoming much less relevant. The conventional accounts and official statistics describe a world where manufacturing and services operate in separate and discrete sectors. This is becoming an increasingly inaccurate depiction of how, in reality, manufacturing and service activities are becoming integrated in a common production process. The next section looks at this phenomenon.
Traditional views of manufacturing and services have changed significantly over time. In the 1960s for example manufacturing was seen as such a key driver of the overall sector that the government of the day imposed an employment tax on services to ensure manufacturing would not be held back by labour shortages. By the 1980s high value added services, including the fast growing financial service industries, were increasingly seen as the key economic drivers in advanced industrialised economies. Such views however assumed that manufacturing and services as occupying quite separate boxes in the economy.

More recent analyses of the manufacturing sector give more emphasis to linkages – so that for example it was and still is frequently argued that although manufacturing employment has declined the sector indirectly supports many jobs in the service sector. This is clearly true, although the range of estimates about the full extent of these linkages can be considerable. For example, one recent estimate suggested that for every job in manufacturing there were two jobs in manufacturing related services and that 75 per cent of EU GDP and 70 per cent of employment across Europe was related to manufacturing.

In a review of the literature on services, Daniels and Bryson in 2001 noted that in the late 1980s some academics recognised the potential problems in continuing to see manufacturing and services as separate activities. One study published in 1987 noted that the:

‘distinction between goods and services… may sometimes become increasingly archaic and irrelevant because the integration of different types of production is growing and the traditional distinction is masking the fundamental changes which are emerging from modern technologies, new patterns of demand, and social behaviour’.

Jeremy Howels has developed the concept of ‘service encapsulation’ based on work in the UK around case studies where manufacturing firms that have moved into services: ‘manufactured goods are not offered to consumers in their own right but rather in terms of their wider service attributes’. Howells gives a number of examples, ranging from the familiar and straight-forward, such as motor car manufacturers who offer finance and other services and office machine manufactures offering leasing and maintenance services, to the more sophisticated and complicated such as both General Electric and Rolls Royce offering hours of flight time rather than just aero-engines and AstraZeneca offering cancer healthcare services as well as cancer drugs.

26 Howells, J, Innovation, Consumption and Knowledge, CRIC Discussion paper No 62 August 2003
A recent study by the OECD shows manufacturing across the G7 has changed substantially in the face of competitive pressure and technological advance. According to the OECD study:

‘manufacturing activity in OECD countries increasingly incorporates high value added services. This change seems due to business models that increasingly emphasise intellectual assets and high value added services, such as R&D, financial and after-sales services instead of manufacturing as such. This distinction between manufacturing and services is blurring, complicating empirical analysis with data by economic activity.’

Manufacturing organisations have increasingly recognised this change. In a recent speech, the Chair of the CBI Manufacturing Council suggested that the term manufacturing should be replaced altogether with the description ‘businesses that manufacture’ because

‘...manufacturing businesses are far more subtle than a shop floor. They are complex businesses which need to excel across an extended value stream which includes design, development, marketing, selling, distribution, and of course production.’

A recent assessment of the fastest growth manufacturing sub-sectors by the EEF found that traditional measures such as capital and R&D intensity only provided a partial explanation of success. This is fully consistent with our suggestion that the reason why so much low tech industry has survived in the major OECD economies is that they have become more knowledge intensive and are more responsive to markets. The study concluded:

‘Successful UK sectors are no longer competing simply on the basis of unit costs, but on offering customers tailored products and solutions; supporting these with after sales services and taking the lead in responding to environmental regulations and changing consumer tastes’.

A similar conclusion was offered in the 2006 statement from the High Level Group of the Manufuture European Technology Platform who describes what they call a shift from products to product/services. The Group argued that: the business focus must shift from designing and selling physical products, to supplying a system of products and services (product/services or extended products) that are jointly capable of fulfilling users’ demands, while also reducing total life-cycle costs and environmental impacts.

28 Andy Reynolds Smith, CBI Manufacturing Dinner October 2007
29 Modern Manufacturing – the high performers EEF/BDO June 2008
In their 2007 report, the then House of Commons Trade and Industry Committee’s report on manufacturing and skills noted:

‘Design, logistics, after-sales service and marketing, for example, have grown in importance as part of the total value of the product. This means that these activities, traditionally seen as part of the service sector, are becoming central to manufacturing companies and to maintaining their competitiveness in a globalised economy. The traditional hard and fast distinction between the manufacturing and service sectors is therefore becoming less and less helpful to a true understanding of the UK economy31’.

In a recent paper for the DTI Manufacturing Forum, Finbar Livesey32 suggested grouping manufacturing under four headings – product manufacturers who concentrated on production; service led producers such as Rolls Royce with a strong production base but with an increasing share of value added coming from services; service manufacturers like GB Innomech who do some one-off and specialist manufacturing but concentrate primarily on R&D and design; and system integrators such as IBM who have moved out of direct manufacturing entirely.

The integration of manufacturing and services has also been flagged up in a number of sector and sub-sector studies undertaken by the former DTI between 2002 and 2005 in support of the government’s evolving manufacturing strategy. In some areas the linkage is not new – for example, car-makers around the world have sold, financed and serviced cars through networks of franchised dealers. However, the 2002 DTI report on the retail end of the automotive industry noted that some manufacturers were moving to more direct control of retail operations through joint ventures and manufacture owned outlets or by direct relationships with customers placing orders directly with factories33.

However, the process can operate in the opposite direction. According to the 2002 DTI report Publishing in the Knowledge Economy, the historic link between the manufacturing process of printing has become decoupled from publishing. Publishing companies have moved beyond paper print to electronic publishing, conferences and exhibitions, training, and audio-visual media. The report argues that this process has gone further in the UK than in the rest of Europe. Similarly, within music publishing sales and revenues from physical products such as CDs are falling rapidly and revenues from broadcast and online services and live performances are rising34.

31 Better Skills for Manufacturing, House of Commons Trade and industry Committee, April 2007
32 Livesay, 2006 Defining High Value Manufacturing, Institute for Manufacturing. The Manufacturing Forum has been replaced by a BERR High Level Manufacturing Group
33 DTI Automotive Innovation and Growth Team, Distribution, Competition and Consumer Sub-Group, 2002
34 Financial Times, October 22 2008
This decoupling is being taken to its logical conclusion in the new Standard Industrial Classification for official statistics to be published by the Office for National Statistics. At present, printing, publishing and recorded media are all classified as part of the manufacturing sector. Under the new classifications, publishing and recorded media move into a new 'information services' industry. A similar change has already taken place in the US statistics for the same reasons.

However, the disadvantage of such re-classifications is that it still puts manufacturing and services in separate boxes and could reinforce some perverse conclusions. As technological and market changes shift activity within manufacturing firms towards services and away from manufacturing, so the apparent share of manufacturing within the economy will appear to diminish. This trend will accelerate as firms move more manufacturing activity overseas in search of new markets, and retain the higher value added more service based activities – such as R&D and design – in the UK.

We may end up with a measure of manufacturing activity that captures only ‘pure’ manufacturing by firms for whom manufacturing remains the principal or only activity. This is hard to get away from within the current statistical framework, as classification by principal activity is the fundamental building block for the industrial classification system at both national and international level. However, it does suggest we need to develop some wider measures of activity by manufacturing firms in the UK, building on some of the pioneering work done in DIUS and BERR in developing company based measures of value added.

This in turn raises the question of whether we should judge the success of manufacturing – and especially the high tech sectors – on their global or UK production. In the more extreme case, if a UK firm moves almost all its manufacturing overseas because that is where its primary markets are but retains almost all of its R&D and design at home, would we then cease to regard it as a UK manufacturing company? Few would argue that substantial overseas investments by US, German and Japanese manufacturing firms was a consequence of industrial failure, even though in statistical terms it contributed to the relative decline of manufacturing production carried out in their domestic economies.

There is therefore a significant body of evidence of the change in the manufacturing-service boundary, but it largely rests on case studies. The best known and most widely quoted is Rolls Royce, which over twenty five years has developed a business model where high value added...
services have been associated with high value added products to the point that over 50 per cent of total profits today come from the services.\textsuperscript{36}

The aggregate evidence on just how widespread the practice is across the rest of the manufacturing sector is more limited, and based on indirect indicators such as the role of manufacturing firms in generating knowledge based services and in the changing composition of the manufacturing workforce. We look at each of these indicators in turn.

The UK has proved a highly successful specialist in knowledge service exports (service sector exports excluding transport, travel, and government services). Between 1995 and 2006 knowledge service exports grew by 170 per cent in current prices, to reach over £75 billion and generate a surplus worth over 3.5 per cent of GDP.

Exports from the financial services sector (primarily the City) provided just over a third of knowledge service exports. However, in the remaining two thirds manufacturing itself is a significant generator of knowledge service exports such as business services, royalties and licence fees and technical and trade related services. According to recent research\textsuperscript{37} about 25 per cent of all exports of business services and between 40 and 45 per cent of trade and technical related service exports were generated by manufacturing companies. The study concluded:

\textit{‘the propensity to import and export services appears to be higher in manufacturing than services. Trade in producer services may therefore be even more important for manufacturing than services.’}

The charts below shows the share of business service exports generated from the manufacturing sector, based on the author’s estimates of the average value of exports over the period 1997-2003, and the latest distribution of knowledge service exports for 2006.

The knowledge economy can be summarised as bringing together of general purpose technologies (both tangible and intangible) and a well educated workforce. Knowledge based manufacturing incorporates both these trends. The manufacturing workforce is changing to reflect the greater emphasis on intangible assets and service orientated functions. This is partly driven by technological change – production worker jobs are more vulnerable to displacement.

\textsuperscript{36} A recent account of the Rolls Royce model and the competitive challenges was set out in a presentation by Mike Terrett, Rolls Royce COO, at the December 2008 Work Foundation Manufacturing and the Knowledge Economy seminar. The slides are available on the Knowledge Economy website at The Work Foundation

\textsuperscript{37} Hizzen, Pisu and Upward \textit{A Portrait of Trade in Services}, Report to the DTI, June 2006
by labour saving technologies than in non-production roles. But it is also part of the increased investment in knowledge based assets and the shift towards value added service activities.

Mapping these changes across time is not straightforward, as both the standard occupational and industrial statistical codes have changed and we have no consistent measures of skills levels. The researchers who constructed the KLEMS database have divided the workforce into ‘high skill’, ‘medium skill’ and ‘low skill’. However, they recognise that the measure is educational attainment rather than skill, with ‘high skill’ classified as all those with degree level education and ‘low skill’ as basic education.

Across both the economy as a whole within the manufacturing sector we have seen the same long term trend towards an increasingly better educated workforce. The change in the UK has been dramatic. In 1970 the better educated constituted just over 1 per cent of the workforce, but by 2005 this had increased to nearly 20 per cent. The less well educated with just basic schooling declined from nearly 60 per cent to about 12 per cent over the same period.

Manufacturing has seen similar trends. In 1970 the better educated made up less than 1 per cent of the manufacturing workforce, but by 2005 this had increased to nearly 13 per cent. In 1970 the less well educated made up 70 per cent of the manufacturing workforce and in 2005 that share had shrunk to about 17 per cent.
Even more remarkably, the share of better educated workers appears to have increased at much the same rates in both high to medium tech industries (OECD definition) and the rest of manufacturing. However, we cannot from this data distinguish between high tech industries such as aerospace and pharmaceuticals and high to medium tech industries such as cars and chemicals. It is highly likely that the high tech manufacturing industries would show a much higher and stronger rate of growth in well-educated labour.

Another way at looking at change over time is the composition of the workforce. We would expect more people to be employed in service facing functions and fewer in production functions. These changes are partly driven by labour saving technologies displacing manual rather than non-manual workers and partly by the integration of business services into the manufacturing process.

A common proxy for ‘knowledge workers’ is the top three occupational groups (managers, professionals, technical). This is not an ideal measure of knowledge content of jobs, as we show below, but it is the only measure readily available to show change over long periods of time.
In 1984 about 51 per cent of employment in UK manufacturing consisted of production workers (skilled and semi-skilled manual) and another 14 per cent worked in unskilled jobs. By 2004 the share of production workers had fallen to 43 per cent with another 11 per cent in unskilled work. In contrast, the ‘knowledge worker’ occupations (managers, professionals and associated jobs) had increased from 26 per cent to 35 per cent, and other non-manual jobs (administrative, sales, personal services) increased from 12 per cent to 15 per cent. Although the knowledge-based high to medium tech manufacturing sectors employ a much higher share of knowledge workers than the rest of manufacturing, the shift towards more knowledge workers has occurred at much the same rate across both tech based manufacturing and non-tech based manufacturing. This supports our view that the transformation to a knowledge economy is taking place across all sectors, albeit at different speeds and degrees, and not just those classified as technology or knowledge intensive.

The shift away from a predominantly production based workforce is even greater if we look at the manufacturing wage bill rather than the numbers employed. The BERR Manufacturing Review shows the distribution of wages across the workforce. In 2006 production and service professionals accounted for nearly half of all manufacturing earnings compared with just under 28 per cent by production workers. This shown in the chart below.

However, measures of knowledge workers based simply on occupation or level of educational qualification are imperfect measures of knowledge job content. For example, the occupational label ‘managers’ in the UK embraces both corporate and professional managers and the manager of a bar or corner shop. Formal education levels are not the same as skills, and do not pick up the experience and development individuals acquire in employment.

As part of the knowledge economy programme, we have undertaken a major survey of the UK workforce designed to assess the extent to which daily tasks at work involve the complex analytical, leadership and innovative tasks associated with knowledge work.

The survey shows that the proxy measures of knowledge work of educational attainment or occupational label significantly understates the number of knowledge intensive jobs in the manufacturing sector. When jobs are grouped by their actual knowledge content, we find that

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38 Working Futures 2004-2014, SSDA; The Work Foundation estimates. BERR has undertaken an analysis using both the educational and occupational measures for the period 1994 and 2006 and shows a similar shift towards better educated and ‘knowledge intensive’ occupations. Five Dynamics of Change in Global Manufacturing (2008) BERR Economics Paper No.2, Figure 16, p42
39 Five Dynamics of Change in Global Manufacturing (2008) BERR Economics Paper No.2, Figure 16, p42
40 Fauth and Brinkley (2008), Knowledge Workers (forthcoming)
nearly 40 per cent of jobs in high to medium high tech manufacturing are knowledge intensive. This is virtually the same as in knowledge intensive services.

Nearly 30 per cent of jobs in high to medium high tech manufacturing involved some knowledge tasks and another 33 per cent involved little or no knowledge content. The manufacturing workforce is more polarised between jobs with high knowledge content and jobs with little or no knowledge content than high tech services where only 23 per cent of jobs involved little or no knowledge content. The chart below shows the share of the workforce in high to medium tech manufacturing compared with knowledge intensive services (using the OECD definitions for both).
Manufacturing and services – traditional boundaries are blurring

Figure 13: Manufacturing requires as many knowledge intensive jobs as services

Source: The Work Foundation’s Knowledge Worker Survey (provisional results)
The analysis presented in this paper should put any doubts that manufacturing is clearly part of the UK’s knowledge based economy to rest. Indeed, we would go further and argue that there is a good case to regard a much wider range of manufacturing industries beyond the high-tech sector as part of the UK’s ‘knowledge economy’.

Manufacturing has responded to changes in markets, new technologies and globalisation in the same way as knowledge intensive services. This sector is a major investor in intangibles and employs a workforce far more involved in knowledge intensive tasks than the conventional measures of ‘knowledge workers’ would suggest.

We think this ability to change in response to market demands helps explain why the UK – in common with other major OECD economies – retains so much ‘low tech’ manufacturing. This in turn makes the terms ‘high tech’ and ‘low tech’ less helpful as a way of distinguishing between more and less knowledge based manufacturing, because they are based on investment in only one sort of knowledge asset, R&D.

As part of the transition towards a knowledge based economy the boundaries between manufacturing and services are blurring. It increasingly makes more sense to think of firms who do some manufacturing rather than manufacturing firms as they integrate services into the production process. These firms now employ more people in service facing roles than production roles. They have become major generators of service related exports, underpinning the UK’s highly successful development of knowledge based service exports.

The conventional statistical measures that place manufacturing and services in separate boxes is therefore giving an incomplete picture and one that undervalues the potential contribution of manufacturing to future economic prosperity. Manufacturing’s position is often judged by physical production and investment in physical assets. These are of course both very important, but manufacturing invests twice as much in knowledge based assets as it does in factories, office, machines and vehicles.

An increasingly difficult issue is whether we should be judging the success of UK manufacturing companies and the manufacturing sector as a whole just against the physical production they carry out in the UK. Manufacturing multi-nationals have always moved production to get closer to their primary markets and the evidence suggests market access reasons still dominate location decisions. We would expect successful companies to follow this established pattern, so that more production is done overseas and less at home.
The recent BERR/DIUS strategy review of manufacturing provides a good policy framework for the long term framework for developing a modern manufacturing base. Much depends on the speed and scale of implementation of the measures proposed. However, we suggest efforts should focus in particular on four areas.

Firstly, manufacturing should be seen as a priority sector for the post-recession knowledge based economy. The financial services sector will recover and the City will retain a major role in global markets, but over the medium term the sector will not grow as rapidly as it has done and may in the short term contract as a share of GDP. Manufacturing can take on a stronger role in global markets in the upturn, building on the short term advantage of a more competitive exchange rate.

This in turn should be a major factor in the difficult decisions currently facing government in deciding whether to extend financial and other forms of support to sectors outside financial services. There will be several criteria against which the government will judge whether intervention can be justified, but a critical one should be ensuring the sector comes through the downturn so that it is able to play a more strategic role in a better balanced post recession economy. The same judgements used to justify the fiscal measures set out in the PBR – timely, targeted and temporary – should also be applied to the manufacturing sector.

Secondly, a globally focused set of policies concentrated on the high tech sectors in order to sustain the UK’s manufacturing success in global markets. High tech industry now provides the vast majority of exports and will do so even more in the future. At the centre of such a strategy must be support for R&D taking account of the support on offer in other OECD economies, the effective utilisation of the science and technology base and the future supply of high quality skills. All these areas are already a key focus for the Strategy Review and the real question is whether the resources will be forthcoming at a time when public spending overall is likely to be constrained.

Thirdly, more domestically focused policies for all manufacturing sectors, but giving more attention to so-called ‘low tech’ manufacturing within the UK. The UK along with other OECD economies has successfully retained large ‘low tech’ manufacturing sectors and we should build on the comparative advantage that implies. The traditional approach to manufacturing has concentrated, understandably, on high tech and the Strategy Review follows that tradition. In knowledge based manufacturing we also need a ‘low tech’ strategy to complement the traditional ‘high tech’ one.
Conclusions and implications

Fourthly, there are significant implications for the role of manufacturing in regional development. The private sector knowledge based services are heavily based in parts of the South of England and some major cities in the Midlands and North. Large parts of the country have seen little in the way of knowledge service jobs. Modern manufacturing has a different and more balanced geography. A resurgent manufacturing sector could provide new centres of growth and regeneration for those areas that so far have struggled to participate in the wider economic benefits of the knowledge economy.
Contact details

Prepared by:
Ian Brinkley

The Work Foundation
21 Palmer Street
London
SW1H 0AD

Tel: 020 7976 3606
Email: ibrinkley@theworkfoundation.com
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The Work Foundation
21 Palmer Street
London
SW1H 0AD

Telephone: 020 7976 3500
Email: enquiries@theworkfoundation.com
Website: www.theworkfoundation.com