The future of productivity in manufacturing

Strategic Labour Market Intelligence Report

Anne Green, Terence Hogarth, Erika Kispeter, David Owen

Institute for Employment Research, University of Warwick

Peter Glover

Senior Research Manager

UK Commission for Employment and Skills

February 2016

ies institute for employment studies

SQW

WARWICK INSTITUTE *for* EMPLOYMENT RESEARCH IER

ce cambridge econometrics

Foreword

In September 2015, UKCES commissioned a consortium of research organisations led by the Institute for Employment Studies (IES) and SQW to prepare a series of a series of strategic labour market intelligence reports on the challenges and opportunities for increasing productivity in four sectors and two cross-cutting themes.

The recent poor productivity performance of the UK economy, especially since the end of the recession of 2008-09, has become a major concern for economists and policy-makers. Unlike previous recessions, job losses were not as high as might have been expected[1] but real wages have declined, falling by an average of 1.7 per cent per year between 2008 and 2014.[2] Productivity growth too has been very modest: this has become known as the 'productivity puzzle'. As a consequence, the UK, which was already some way behind many other major developed economies on this measure, has fallen back even further. The overall level of productivity in the United States' economy is now 31 per cent higher than that of the UK, while Germany's is 28 per cent higher.[3]

A number of possible explanations have been put forward for this. Some commentators believe that businesses hoarded labour on relatively low wages rather than investing in capital, leading to stagnation in output per worker. Others have suggested risk aversion by financial institutions has reduced access to loans for investment. The result, it is argued, has been inefficiency in the allocation of resources in the economy, and an absence of the 'creative destruction' processes that can help drive up productivity.

One thing that is apparent from the data that exists on productivity is that it differs from sector to sector. In recent years, for example, there have been high levels of productivity growth in the transport equipment and administration/support sectors, but falls in productivity in the finance and the chemicals and pharmaceuticals sectors[4]. Any research or commentary on productivity needs to unpack some of the characteristics of sector productivity.

[1] Unemployment rose from 1.62m in February 2008 to 2.68m in October 2011 on ONS data.
[2] Calculated by the Institute of Fiscal Studies based on ONS Annual Survey of Hours and Earnings. See http://www.ifs.org.uk/uploads/Presentations/Understanding%20the%20recession_230915/SMachin.pdf
[3] Figures from the Office for National Statistics for GDP per hour worked, 2013. Published at http://www.ons.gov.uk/ons/rel/icp/international-comparisons-of-productivity/2013---final-estimates/info-icp-feb-15.html
[4] Cook, J. Pledges, Puzzles and Policies: what's in store for innovation and enterprise?, Viewpoint Series, SQW, http://www.sqw.co.uk/files/5514/3359/6668/Innovation_policy_post-election_-_Viewpoint_final.pdf

In April 2015, Sir Charlie Mayfield, Chairman of the UK Commission for Employment and Skills (UKCES), set up the Productivity Leadership Group, a cross business group of senior leaders seeking to find practical ways to increase the productivity of British business. Business leaders came together in specific sectoral and cross cutting groups to focus on shared problems and opportunities (Manufacturing, Digitisation, Food and Drink, Measurement, Better Workplace Practices, Retail and Creative)[5].

In September 2015, UKCES commissioned a consortium of research organisations led by the Institute for Employment Studies (IES) and SQW to prepare a series of a series of strategic labour market intelligence reports on the challenges and opportunities for increasing productivity in four sectors and two cross-cutting themes (IES, SQW, the Institute for Employment Research (IER), and Cambridge Econometrics (CE)). The research consortium produced six papers:

1. Robin Brighton, Chris Gibbon and Sarah Brown, *Understanding the future of productivity in the creative industries*, SQW
2. Annette Cox, Graham Hay, Terence Hogarth, Graham Brown, *Productivity in the Retail Sector: Challenges and Opportunities*, IES
3. Anne Green, Terence Hogarth, Erika Kispeter, David Owen, *The future of productivity in manufacturing*, Institute for Employment Research, University of Warwick
4. Terence Hogarth and Erika Kispeter, *The future of productivity in food and drink manufacturing*, Institute for Employment Research, University of Warwick
5. David Mack-Smith, James Lewis, Mark Bradshaw, *State of Digitisation in UK Business*, SQW
6. Penny Tamkin and Ben Hicks, *The Relationship between UK Management and Leadership and Productivity*, IES.

We would like to thank the following UKCES colleagues for their assistance with the delivery of the project: Vicki Belt, Duncan Brown, Richard Garrett, Peter Glover, Hayley Limmer, Aoife Ni Luanaigh.

Penny Tamkin (IES), Michael Frearson (SQW), Susan Mackay (SQW)

Project leadership team

[5] The findings of this group have now been reported (see https://howgoodisyourbusinessreally.co.uk/)

The study reported here complements the work the Business Leadership Group for **manufacturing** through an assessment of the factors driving productivity growth in the sector. It highlights that leadership, management and development of skills aligned with ambitious product market strategies are essential to move up the value chain and to reap productivity enhancements. Ambitious employers need to invest in recruitment, retention and replenishment of a broad mix of skills, especially technical skills at high and intermediate level. ICT skills are also crucial to embrace the opportunities that Industry 4.0 brings for UK manufacturing.

Table of Contents

Tables and figures

Executive Summary

Introduction

The UK has experienced a slowdown in labour productivity since the global financial crisis. The UK fares relatively poorly in comparison with international competitors in terms of productivity trends. Manufacturing makes a positive contribution to UK productivity growth.

The manufacturing sector in the UK

The manufacturing sector is of strategic importance to the UK economy. Increasingly production is at the centre of a more complex manufacturing value chain, with more value than formerly derived from pre- and post-production processes. Yet the manufacturing sector is diverse, characterised by different employment structures in high, medium and low technology / value industries.

Output in manufacturing peaked in 2007 and has since remained below the pre-recession level. The sector has seen ongoing employment decline but there has been a marked shift in employment profile towards more highly-qualified workers. This is significant given the positive role played by skills in driving productivity.

Key drivers of change in manufacturing

Social, technological, economic, environmental and political drivers will all have implications for the changing nature of manufacturing. In the medium-/long-term The mass personalisation of low-cost products, distributed production and digitised manufacturing value chains mean that manufacturing will need to become more responsive and closer to customers. Developments in emerging economies and changing levels of personal wealth offer potential new markets for manufacturing. Technological developments – particularly the 'internet of things' (Industry 4.0) - offer opportunities for new products and processes. Increased sustainability is a further key driver of change in manufacturing.

Despite projected employment decline, replacement demand means that there will be a sustained demand for manufacturing workers, especially (but not exclusively) with high level technical skills. The ageing of the population means that there will be a need to accommodate more older workers. The talent pool for employers to draw on will need to be increased and replenished – with a particular focus on STEM and problem solving skills, and employers will need to ensure that skills are utilised effectively.

Labour productivity performance in manufacturing

Labour productivity is higher in manufacturing than the UK average across all sectors. The UK manufacturing sector saw productivity growth from 1990 to 2014, in a context of employment decline. But productivity fell markedly during the recession, and has struggled to recover to pre-recession levels, suggesting an overall decline in efficiency in the sector. There is considerable heterogeneity in experience within the manufacturing sector, with high value manufacturing displaying highest productivity, but also marked volatility over time.

The UK's labour productivity performance is relatively strong vis-à-vis EU competitors, but lags behind that in the US. However, the UK has been slower than other key EU economies to see recovery in productivity following recession.

Factors facilitating and inhibiting productivity growth

Investment in manufacturing fell markedly in the recession in comparison with the economy as a whole, albeit investment is now on an upward trajectory. Manufacturing accounts for a relatively high level of business expenditure on R&D but there remain longstanding concerns about ground to be made up vis-à-vis international competitors in linking research and innovation to commercial products. Best practice in manufacturing is most prevalent in foreign-owned and multi-national companies with UK sites, and in large establishments; it is particularly apparent in the aerospace and automotive sectors. The UK fares relatively poorly on an international comparative basis in terms of the quality of management. This has implications for best practice.

Compared with the UK economy as a whole, manufacturing is characterised by a greater incidence of high or very high product market strategies, but a below average incidence of establishments using high performance working practices. Manufacturing has a higher proportion of skill-shortage vacancies than average, especially in professional and skilled trades occupations. These skill shortages are longstanding and are likely to inhibit productivity growth.

Training spend per employee is slightly lower than across the economy as a whole, although high value and medium value establishments are more likely than the UK average to have staff on apprenticeships. The evidence also suggests that shortcomings in management and leadership act as a brake on productivity. Manufacturing has lower scores on a range of training activity indicators compared with the UK economy average.

Conclusion: What can employers and public policy do?

Leadership, management and development of skills aligned with ambitious product market strategies are essential to move up the value chain and to reap productivity enhancements.

Industry 4.0 brings new challenges and opportunities for UK manufacturing. In particular, it highlights the importance of ICT skills and investment in the IT and telecommunications infrastructure.

To enable them to further develop their current strategic objectives and develop new strategies, ambitious employers need to invest in recruitment, retention and replenishment of a broad mix of skills – not only those that are production-specific – albeit technical skills at high and intermediate levels remain centrally important. More generically, supportive public policy can help foster an environment conducive for fostering innovation and productivity increases.

1 Productivity growth in the UK

Chapter Summary

- This chapter sets the broader context for understanding the future of productivity in manufacturing.
- The UK has experienced a slowdown in labour productivity since the global financial crisis.
- The UK fares relatively poorly in comparison with international competitors in terms of productivity trends.
- Manufacturing makes a positive contribution to UK productivity growth.

1.1 Introduction

This report is concerned with the future of productivity in the manufacturing sector. It provides an overview of key features of manufacturing in the UK and then outlines key drivers of change in manufacturing over the medium-term, since these have implications for manufacturing. It sets out labour productivity performance in manufacturing in the UK, making reference to selected international comparators. Factors facilitating and inhibiting productivity growth are identified. A final synthesis discusses the way in which employers can enhance productivity, with particular emphasis on the contribution employment and skills policy can make to enhancing productivity.

1.2 The productivity puzzle

In common with most western economies, the UK has experienced both a slowdown in long run output growth and labour productivity in the period following the global financial crisis in 2007/8. This may reflect a cyclical adjustment, albeit a prolonged one, to what proved to be a particularly deep recession. Relatively weak productivity growth is seen to have resulted from:

- firms hoarding workers and skills in an attempt to avoid the costs of recruiting skilled workers during the recovery phase;

- weak investment in capital per worker – resulting from firms being cautious about investing in new technology and a reluctance of the banks to lend money to business;
- relatively strong growth in low skill, low productivity employment in the immediate aftermath of recession.

These were seen to be cyclical problems that would begin to disappear as growth accelerated (Barnett et al., 2014). More pessimistically, some commentators have pointed to what may be a longer run structural adjustment in western economies bringing about a new secular stagnation (Summers, 2014). This means that the recent prolonged period of weak output growth is more than just a hangover from the global economic crisis. While there are multifarious causes, attention has focused upon (Gordon, 2012; Eichengreen, 2014):

- weak technical progress;
- falling aggregate demand (individuals are saving rather than spending and firms are unwilling to invest even at near zero interest rates);
- slowing total factor productivity because of insufficient investments in infrastructure, education and training.

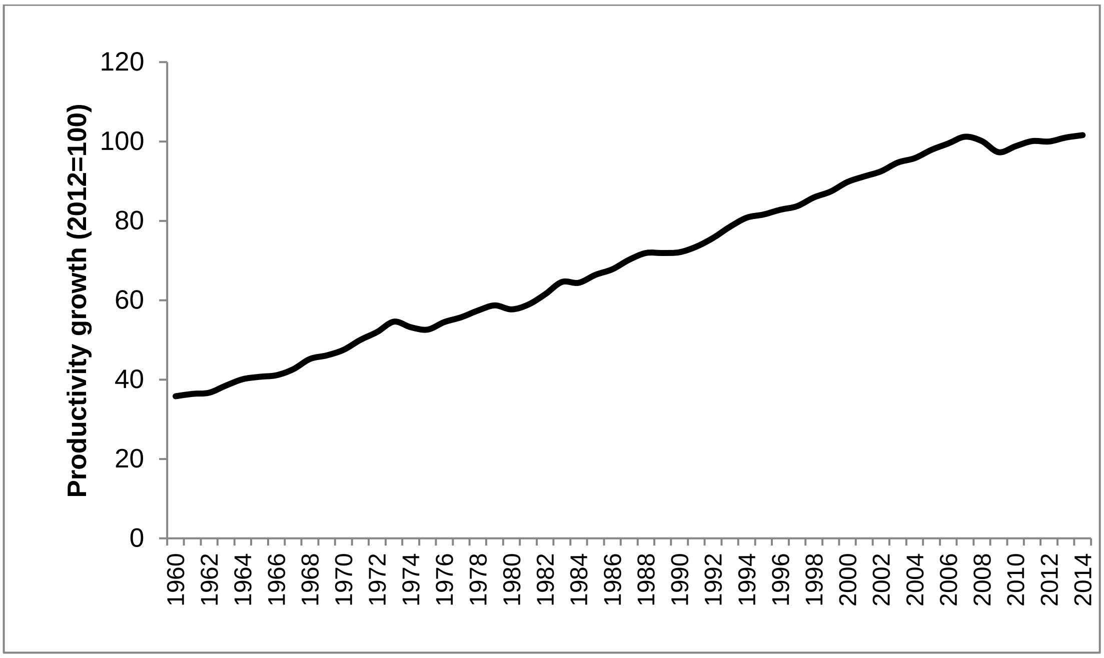
Although the diagnoses derive from analysis of the US economy, and are not without contention, they serve to illustrate the multiplicity of factors that might underlie the recent performance of many western economies.

It is perhaps also worth noting that there are a range of measurement issues related to measuring productivity: not least the capacity to measure the value of outputs generated by the IT revolution (Mokyr, 2014); and being able to accurately count hours of work (the denominator for measures of productivity) in economies where an individual's hours of work can be flexible.

1.3 UK productivity

In the pre-2007 period the UK economy experienced relatively strong productivity growth and was able to close the productivity gap it had long experienced with many of its main competitor countries. Figure 1.1 shows the long run trend in productivity measured by output per hour worked. It shows how over the most recent past productivity growth has flattened out. It is estimated that between 1979 and 2007 productivity grew at around 2.3 a year, but between 2007 and 2014 the growth rate was -0.1 per cent, with the result that by 2014, productivity was 17 per cent lower than it would have been had growth continued at 2.3 per cent a year (Dolphin and Hatfield, 2015).

Figure 1.1 Output per hour worked 1960-2014 (2012 = 100)

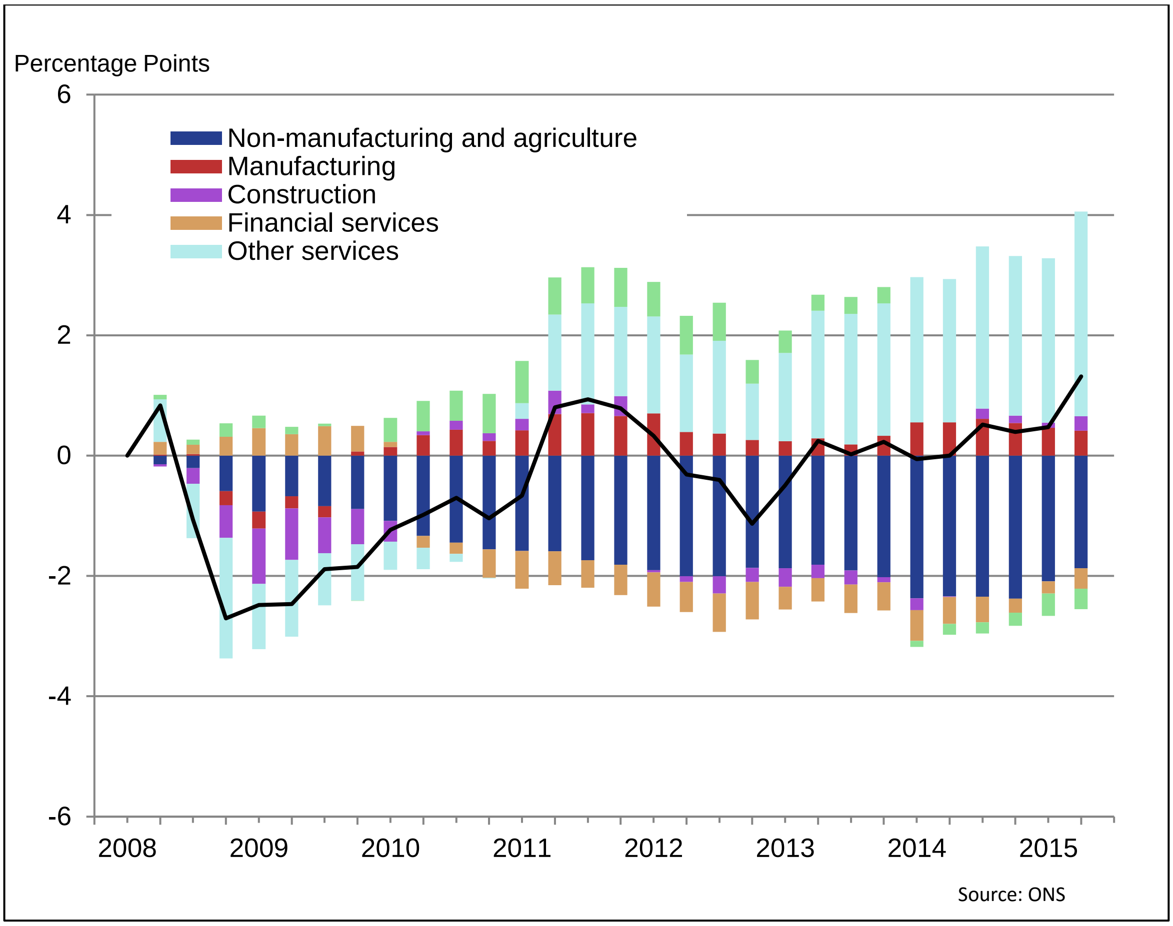


Source: ONS output per hour worked series

Labour productivity is the ratio between output (value added) and labour inputs. The latest ONS statistics for 2015Q2 suggest that recent growth in productivity has been driven by increases in value added and a small decrease in hours worked. In Q2, 2015 productivity was on the increase - output per hour was the highest ever recorded - but remained 15 per cent below an extrapolation based on the trend prior to the economic downturn (ONS, 2015a).

There is a strong industry component to productivity growth (see Figure 1.2). In particular, the service sector – other services excluding financial services - appears to be the driver of growth. In the period since Q4 2012, the non-manufacturing production and agriculture sector has contributed close to zero to productivity, whereas the other sectors have added around 3 per cent to productivity.

Figure 1.2 Cumulative Contributions to Quarter on Quarter Growth of Whole Economy Output per Hour



Source: ONS Productivity Statistics Q2 2015

Historically, the manufacturing sector has been a driver of productivity growth within economies. Potentially, employers in the manufacturing sector have more scope to increase labour productivity by substituting labour with machinery and by outsourcing various activities including low-value elements of the production process.

Parts of the service sector, such as the education and the arts, cannot achieve these types of productivity gain or at least not to the same extent (for example, an orchestra cannot increase its productivity by playing faster or by, for instance, outsourcing the string section to a lower-cost ensemble) (Baumol and Bowen, 1966). But these sectors are in competition with the ones realising productivity gains, for labour (and skills) and, accordingly, pay wages at least equal to them.[6]

Manufacturing is able to offset the potential for wage-push inflation by continually raising its productivity levels (and, consequently, reducing the size of its workforce).[7] Within the manufacturing sector performance has been variable as shown in Table 1.1. The highest levels of productivity, measured in output per job in chemical and pharmaceuticals but productivity growth has been relatively modest in this sector. In contrast, rubber & plastics, and transport equipment both record more modest levels of productivity per hour, but much higher levels of growth.

Table 1.1 Output per hour worked in manufacturing industries

		Food, beverages & tobacco	Textiles, wearing apparel & leather	Wood & paper products, & printing	Chemicals, Pharmaceuticals	Rubber, plastics & non-metallic minerals	Basic metals & metal products	Computer products, Electrical equipment	Machinery & equipment	Transport equipment	Coke & refined petroleum, Other manufacturing
Divisions		10-12	13-15	16-18	20-21	22-23	24-25	26-27	28	29-30	19,31-33
Level (£)	2012	30.1	27.2	23.0	77.1	24.2	23.3	32.5	31.0	37.0	31.8
Index (2012=100)	2014	101.4	91.6	104.6	105.6	108.7	96.0	97.5	93.1	107.9	105.7
Percentage change	Q1 to Q2 2015	-0.8	-0.1	-3.9	1.8	-1.9	4.6	-1.5	-3.5	-1.1	-0.4

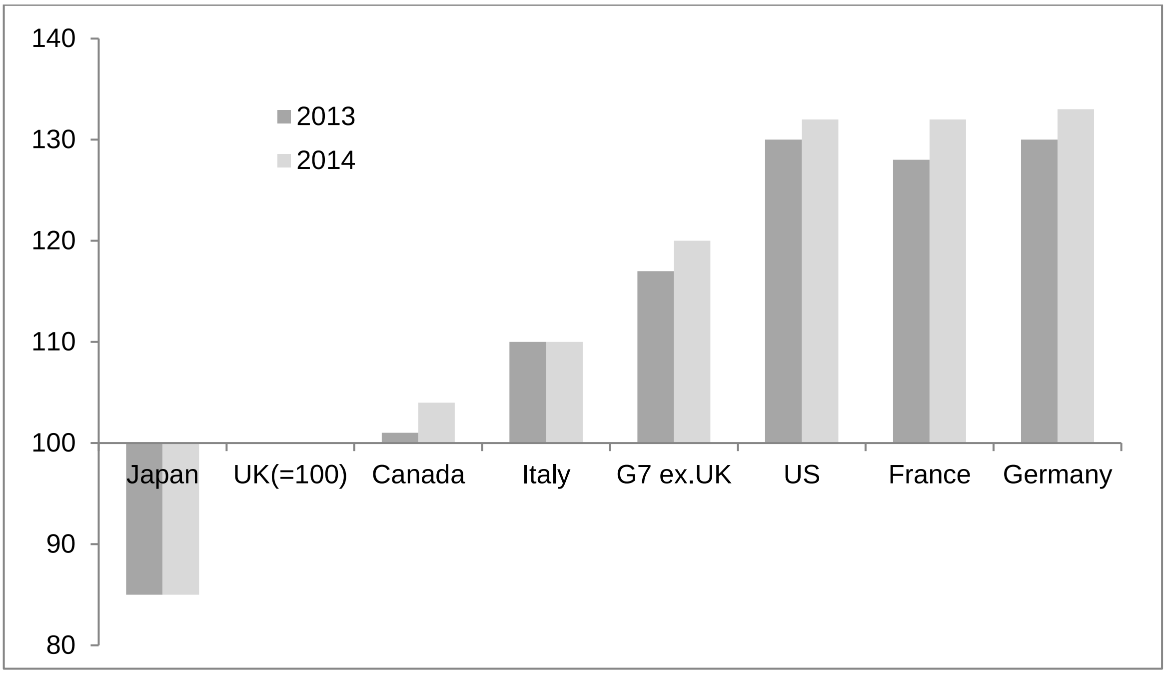
Source: ONS Productivity Statistics Q2 2015

[6] Clearly parts of the service sector have through the introduction of information and communication technologies been able to realise substantial labour productivity improvements over recent years.
[7] It is apparent from the ONS analysis that parts of the service sector have been able to realise these type of productivity gains too.

1.4 International productivity trends

Productivity needs to be seen from an international as well as domestic perspective. Figure 1.3 shows UK productivity per hour compared with G7 countries. Productivity compares relatively poorly with many G7 countries (lower than that of the rest of the G7 by 20 percentage points).

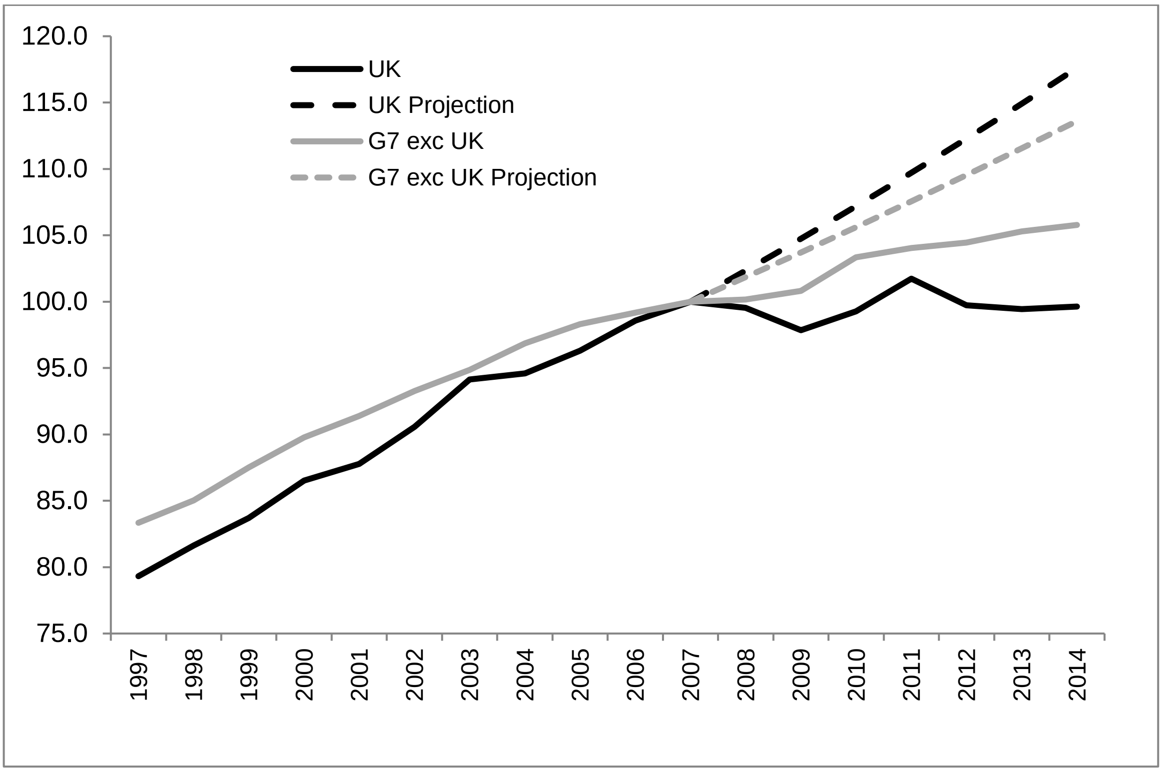
Figure 1.3 Productivity comparisons with selected G7 countries (UK = 100)



Source: ONS Productivity Statistics Q2 2015

Figure 1.4 provides a further comparison to show how productivity per hour has changed over time in selected countries. It also shows ONS's estimate of the gap between actual productivity and that projected had productivity continued to grow at is pre-recession level. As a result of relatively strong productivity growth in the period before 2007, the productivity gap is larger in the UK than in the G7 (18 per cent in the UK versus 8 per cent in the G7).

Figure 1.4 Constant price GDP per hour worked, actuals and projections (2007 = 100)



Source: ONS Productivity Statistics Q2 2015

1.5 Understanding the role of human capital in raising productivity levels

A particular focus of this report is on understanding the relationship human capital development can make to productivity improvements in the food and drink industry. Some consideration needs to be given to how the development of human capital can affect productivity and how that development can take place. If one accepts that the quality of human capital will have an impact on productivity, the question becomes one of identifying how employers can be persuaded to increase their investments in human capital.

The human capital model specifies that in relation to transferable skills, employers will not be willing to fund such training because they will not be able to recoup the costs of its provision. The wage paid to persons whilst training will need to be set a level which effectively compensates for the costs of their training and reduced productive capacity. If the employer amasses a net training cost at the end of the training period, there will be no way, in perfectly competitive labour market, of recouping that cost. To do so would require the employer to pay a wage below the marginal productivity of the employee (Hogarth and Gambin, 2016). Because the employer that had not provided training will be able to pay a wage equal to the marginal productivity of the employee, the employee in the training company will move to the non-training company where wages are higher.

The question then becomes one of identifying how the training employer can retain the employee who has been trained where there is a net cost to the employer at the end of the training period. It is known, for instance, that many companies that train engineers at Level 2 or Level 3 encounter a substantial net cost of training at the end of the formal training period. They are able to recoup that cost because they essentially develop a bond between employer and employee. Often it is the very fact that the employer has trained the employee that deepens the bond and allows the employer to recoup their training costs in a way that the human capital model does not explicitly acknowledge (Gambin and Hogarth, 2016; Gambin et al., 2010).

One of the ways in which the risk facing employers investing in training has been provided has been reduced is through the employer ownership of skills. By being able to increasingly tailor the provision of publicly funded training programmes to employer needs, the employer is better placed to ensure that the skills provided – be it those in the FE or HE sector – meet their needs. Employer routed funding will also provide employers will also ensure that training meets their needs too. This does not necessarily affect the propensity of the employer, other things being equal, of investing in transferable skills, but it does remove the potential barrier to training that arises where employers feel that existing provision does not match their needs (Hogarth et al., 2014). Hence and important issue for policy is to understand how employers are able to develop the bond between employer and employee that will allow employers to recoup their training investments, and how willing and able the employer is to take advantage of the flexibility afforded employers to tailor public training programmes to their needs.

1.6 Conclusion

This chapter has provided an overview of productivity performance in the UK based mainly on analysis of output per hour worked. The analysis illustrates the way in which long run productivity growth has stalled in the UK following the global financial crisis in 2007. In some respects, unfavourable comparisons with other countries – e.g. the gap between actual versus projected pre-2007 productivity growth - result from the relatively strong growth the UK experienced prior to 2007 which was sufficient to close much of the gap with competitor countries. It is apparent, however, that other countries have experienced stronger productivity growth since 2007.

The data also points to differences between industries within the UK. Much productivity growth has been driven by the service sector other than financial services. This report focuses on the manufacturing sector and a three-fold division therein outlined in Chapter 2.

2 The manufacturing sector in the UK

Chapter Summary

- The manufacturing sector is of strategic importance to the UK economy.
- Increasingly production is at the centre of a more complex manufacturing value chain, with more value than formerly derived from pre- and post-production processes.
- The manufacturing sector is diverse, characterised by different employment structures in high, medium and low technology / value industries.
- Output in manufacturing peaked in 2007 and has since remained below the pre-recession level.
- Manufacturing has seen ongoing employment decline but a marked shift in employment profile towards more highly-qualified workers.
- Medium technology / value industries are dominant in employment terms, accounting for over half of all manufacturing employment, with low value industries accounting for less than a third and high value industries for less than a tenth of employment in the sector.

2.1 Introduction

Manufacturing is a strategically important sector for the UK economy. Despite long-term decline in employment (see section 2.6) it accounts for nearly 70 per cent of R&D investment and 44 per cent of all UK exports (Rhodes, 2015). Productivity growth in the UK has historically been stronger in manufacturing than in most other sectors of the economy – due to the way it can benefit from advancements in technology. Hence manufacturing is a key driver of UK productivity growth.

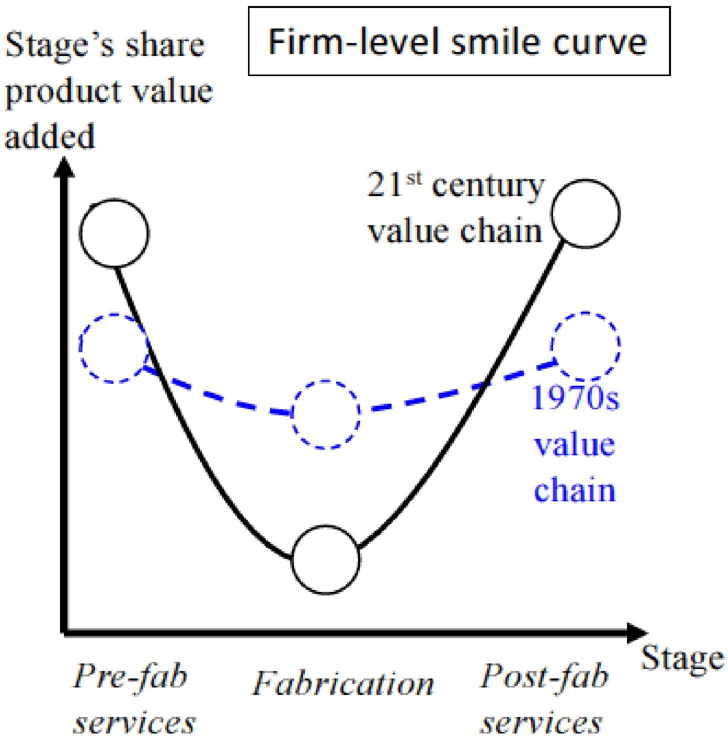
2.2 The changing nature of manufacturing

Manufacturing is traditionally understood as the production process in which raw materials are transformed into physical products. This is changing: production remains important but is now seen as being at the centre of a wider and more complex manufacturing value chain involving a range of activities prior to production and after production, as well as re-use of manufactured products back into the production process:

- R&D →
- Product & service development →
- Supplier management →
- Production →
- Route to market →
- After sales service →
- Consumption →
- Disposal → reuse remanufacturing, recycling & recovery → **Production**

Increasingly the value of manufacturing rests not so much in the production (i.e. the fabrication) process, but in pre- and post-production, as set out in Figure 2.1. Compared with the situation in the 1970s these pre- and post-manufacturing services have become more important, but production remains central.

Figure 2.1 The increasing importance of pre- and post-production services in manufacturing



Source: Baldwin and Evernett, 2012

2.3 The diversity of manufacturing

Manufacturing is a diverse sector. Activities covered include pharmaceuticals, manufacture of electronic products, manufacture of motor vehicles and other transport equipment, chemicals, textiles, wearing apparel and food and drink.

There are various possible ways of disaggregating the manufacturing sector. For the purpose of data presentation in this report a three-fold division of manufacturing is used (see Table 2.1), based on a EUROSTAT definition of the degree of technological intensity; (also referred to in subsequent graphs and tables as high value, medium value and low value). High technology industries are intensive in their use of capital and knowledge, as well as technology utilisation.

Table 2.1 Aggregation of manufacturing industries (2-digit) according to level of technological intensity (ordered by SIC code within levels)

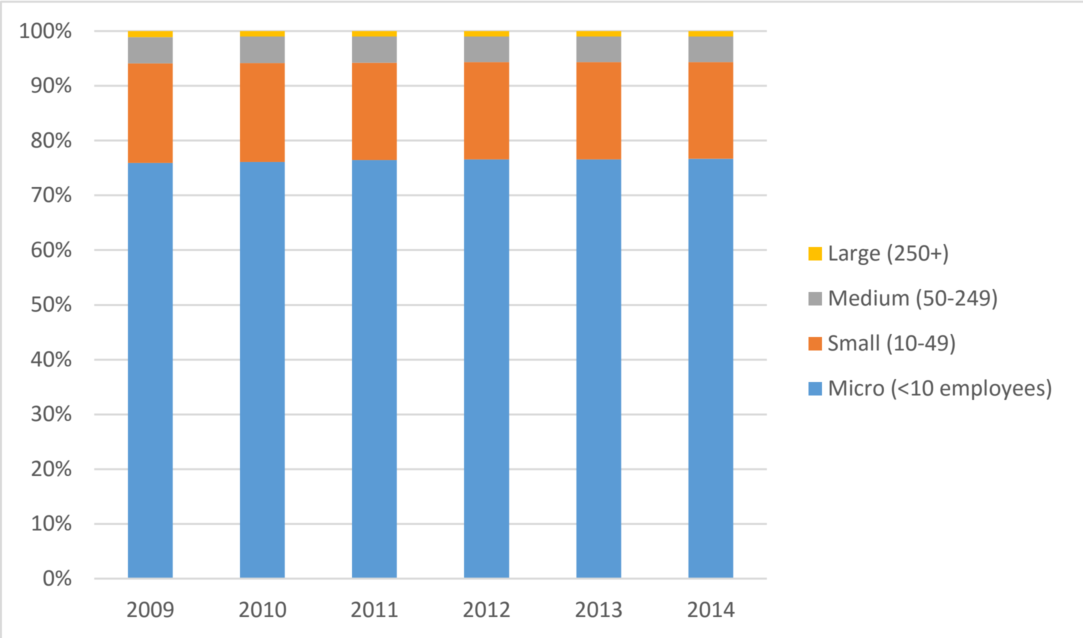
Level of technological intensity	SIC	Industry
High technology	21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
	26	Manufacture of computer, electronic and optical products
Medium technology	20	Manufacture of chemicals and chemical products
	27	Manufacture of electrical equipment
	28	Manufacture of machinery and equipment n.e.c.
	29	Manufacture of motor vehicles, trailers and semi-trailers
	30	Manufacture of other transport equipment
	19	Manufacture of coke and refined petroleum products
	22	Manufacture of rubber and plastic products
	23	Manufacture of other non-metallic mineral products
	24	Manufacture of basic metals
	25	Manufacture of fabricated metal products, except machinery and equipment
	33	Repair and installation of machinery and equipment
Low technology	10	Manufacture of food products
	11	Manufacture of beverages
	12	Manufacture of tobacco products
	13	Manufacture of textiles
	14	Manufacture of wearing apparel
	15	Manufacture of leather and related products
	16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
	17	Manufacture of paper and paper products
	18	Printing and reproduction of recorded media
	31	Manufacture of furniture
	32	Other manufacturing

Source: http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:High-tech_classification_of_manufacturing_industries

Note: Within the Medium technology category the ranking by SIC code distinguishes between 'medium-high' (i.e. SIC codes 20, 27, 28, 29, 30) and 'medium-low' (i.e. SIC codes 19, 22, 23, 24, 25, 33) sectors.

In 2014 just over three-quarters of businesses in manufacturing had less than 10 employees, around 18 per cent had between 10 and 49 employees, nearly 5 per cent had 50-249 employees and 1 per cent had 250 or more employees. Although micro businesses are dominant in manufacturing, they are less so than in many other sectors; the size structure of businesses in manufacturing is more skewed towards medium and larger size categories than for the economy as a whole. There was a slightly higher representation of medium and large businesses in medium value and high value manufacturing than in low value manufacturing.

Figure 2.2 Size profile of businesses in manufacturing in the UK

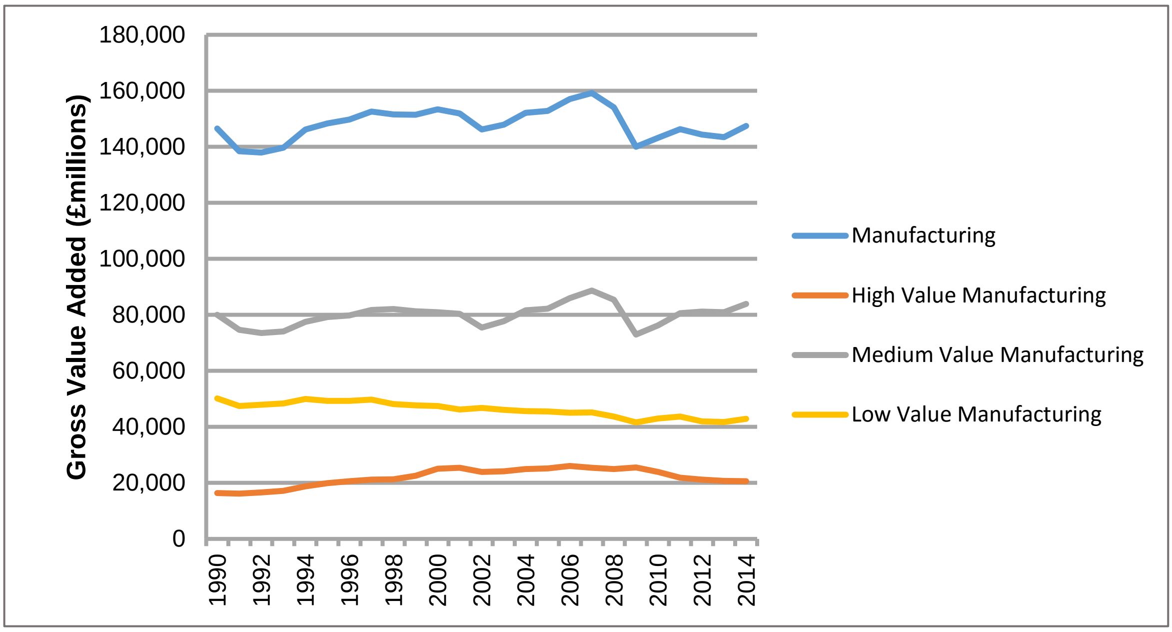


Sources: CE calculations based on ONS UK business: activity, size and location datasets.

2.4 Output in manufacturing

Gross value added (GVA) in manufacturing is estimated to be around £147 billion (in 2014). Medium value manufacturing is the largest component of the sector, with output of around £84 billion. Low value manufacturing (£43 billion) and high value manufacturing (£21 billion) account for smaller shares of total manufacturing output. Figure 2.3 shows the trend in output over time in constant prices. In 2014 manufacturing output was at a similar level to that in 1990, having increased by approximately 9 per cent to a peak of £159 billion in 2007, before declining in recession. The trend in medium-value manufacturing was similar, with a marked decline in output from 2007 to 2009. Output in low value manufacturing declined by around 14 per cent between 1990 and 2014, while over the same period output in high value manufacturing increased by 26 per cent, (albeit the trajectory was rather different here with a decline in output prior to the 2008-9 recession). It should be noted that high value manufacturing is a small category and the fact that less sign of recovery since the recession is evident here than in medium value manufacturing is likely to reflect industry-specific factors.

Figure 2.3 Gross value added in manufacturing, 1990-2014 (constant prices)



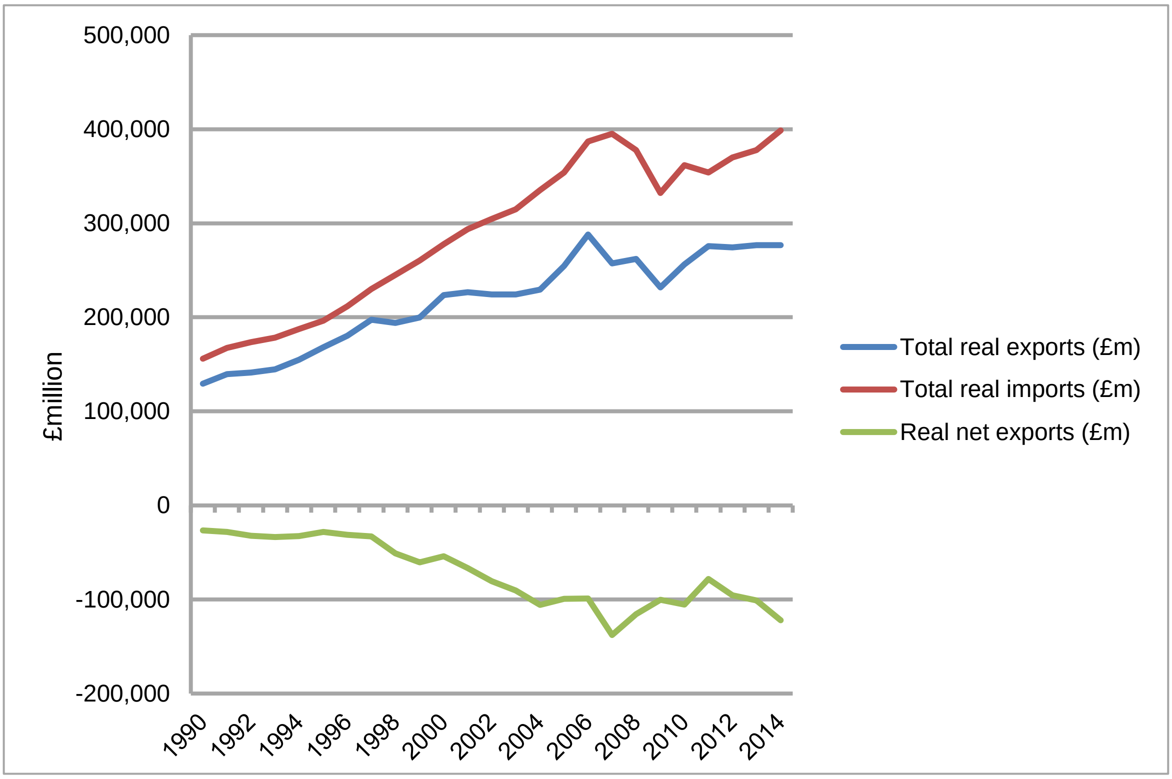
Sources: ONS and Cambridge Econometrics (MDM-E3 database).

2.5 Exports and imports

In the manufacturing sector, the value of both real exports and real imports increased over the period 1990 to 2014. Export growth did not keep up with the growth of imports and the level of net exports declined fairly steadily over the period (see Figure 2.4). The recession of 2008-9 acted as a brake on both exports and imports, with the level of imports declining more sharply than exports. The trend of imports resumed after 2010, returning to 2007 levels by 2014. However, the recovery of exports was more sluggish, and in 2014 real exports were still lower than in 2006. The trade deficit in manufactured goods was greatest in 2007. It stopped widening during the recession, but has been growing since 2011.

Real imports increased markedly on a steady basis over the period from 1990 until 2007 and then declined markedly in the period to 2009 before returning to an upward trajectory once again (Figure 2.4). Trends in real exports showed a similar temporal pattern, but since 2011 has shown a flat trajectory while real imports increased. As a result the net export position has become more unfavourable in recent years. This suggests that as manufacturing has become increasingly trade-driven, the comparative advantage of UK manufacturing has deteriorated somewhat, except in the period from 2007 to 2011.

Figure 2.4 Trends in real exports and imports in manufacturing, 1990-2014

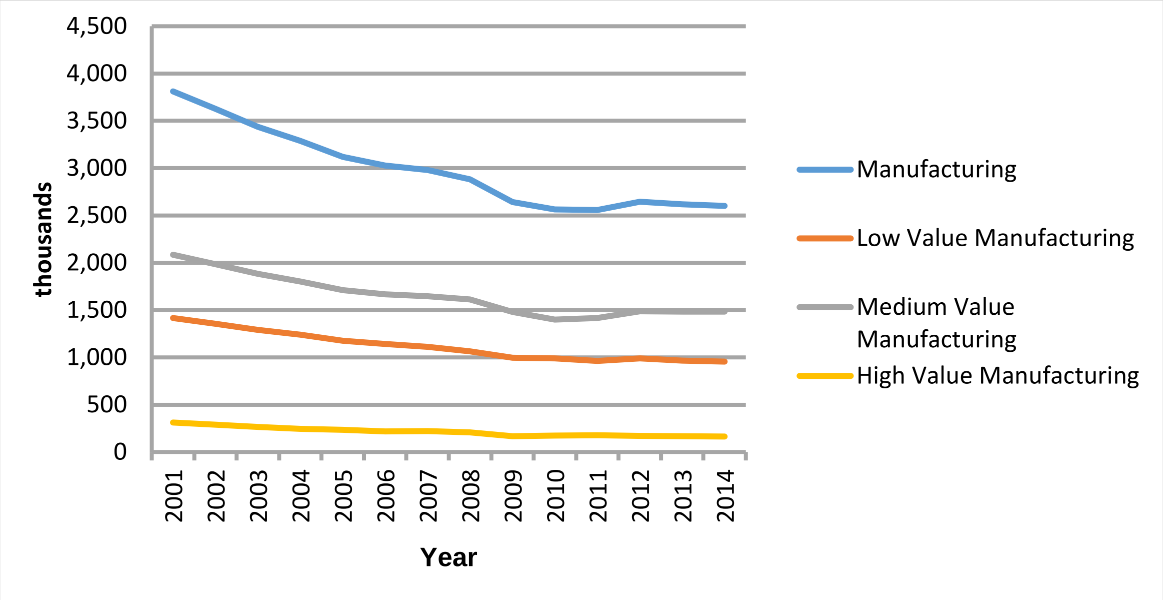


Sources: ONS and Cambridge Econometrics (MDM-E3 database).

2.6 Employment in manufacturing

Employment in manufacturing has seen a long-term decline (see Figure 2.5). The number of people working in the manufacturing sector as a whole has been in long-term decline for most of the recent past. UK manufacturing employment declined at an annual average rate of 2.8 per cent between 1990 and 2008, and 0.3 per cent between 2008 and 2014. However, the latter period saw a decline of 8.3 per cent for 2008-9, and a further decline of 3 per cent decline the next year, followed by a 3.4 per cent increase in 2011-12. Employment is projected to decline at an annual average rate of -0.9 per cent between 2015 and 2022.

Figure 2.5 Employment in manufacturing, 2001-2014



Source: Working Futures

Employment in low value manufacturing declined at a faster rate than in the sector as a whole between 1990 and 2014: at 3 per cent per annum between 1990 and 2008 and 0.8 per cent per annum between 2008 and 2015. Low value manufacturing is projected to lose employment at an annual average rate of 1 per cent between 2015 and 2022. Employment declined by 4.2 per cent 2007-9 and 6.4 per cent 2008-9. The most favourable year since then saw a 0.6 per cent fall in employment in the year 2009-10.

Employment in medium value manufacturing declined at a slightly slower rate than the sector as a whole between 1990 and 2008: 2.6 per cent per annum. Employment fell by 8.3 per cent between 2008 and 2009 and then by 5.4 per cent between 2009 and 2010, but this was followed by a rebound with employment growing by 1.3 per cent between 2010 and 2011 and 5 per cent between 2011 and 2012. Employment is projected to decline at a rate of 0.9 per cent per annum between 2015 and 2022.

The annual average rate of decline in employment for high value manufacturing, at 3.4 per cent, was faster than for the sector as a whole between 1990 and 2008. Employment continued to decline between 2008 and 2014, at an annual average rate of 0.5 per cent. Employment is projected to decline at an annual average rate of 0.9 per cent between 2015 and 2022. Employment in high value manufacturing was affected both earlier and more severely than average by the recession, with employment declining by 6.8 per cent 2007-8 and 19.0 per cent 2008-9. However, it also bounced back faster, with employment growth of 3.5 in 2009-10 and 2.9 per cent in 2010-11. Since 2011, employment decline has resumed, with a loss of 4.6 per cent of employment in 2011-12. A priori It would be expected that high value manufacturing would be more competitive than average in international markets, but also more susceptible to productivity increases.

The manufacturing workforce has become more qualified over the period from 2000 to 2014, as the proportion of those employed with a qualification at degree level or above has increased from one in five to one in three. This is significant given that workforce skills have been shown to be a key factor boosting productivity in the UK and that the contribution of high-level academic skills to aggregate growth is rising (Rincon Aznar et al., 2015). Over the same period the share of those in high value manufacturing with a qualification at degree level or above has increased from one in two to three in five. In low value manufacturing the qualification profile is biased more to low level qualifications than across the sector as a whole. Indeed, in comparison with the qualification profile across the economy as a whole, manufacturing has a smaller share of high qualified workers and greater than average proportions with medium and low level qualifications.

Table 2.2 Qualification profile of the workforce in manufacturing, 2000 and 2014

Qualification level	Year	Manufacturing	Low value	Medium value	High value
High (QCF4 and above)	2000	21.3	18.4	21.5	50.1
	2014	32.9	29.7	33.6	61.5
Medium (QCF2 and QCF3)	2000	43.4	41.1	45.7	42.8
	2014	45.1	43.4	46.8	30.7
Low (QCF1 and below)	2000	35.3	40.5	32.8	7.1
	2014	22.0	26.9	19.7	7.8

Source: Working Futures 5.

2.7 Conclusion

Value from manufacturing comes increasingly from both the pre- and post-production ends of the value chain, rather than from the production process itself. However, manufacturing is a diverse sector, which can be disaggregated in a number of different ways, including via technological intensity / value. In manufacturing as a whole output peaked in 2007 and in 2014 output remains below the pre-recession level. Real exports and real imports grew over the period from 1990 to 2014, with the deficit in net real exports increasing since 2011. Although all parts of manufacturing share in employment decline, there has been a shift towards more highly qualified workers – which is particularly apparent in high value manufacturing. This is significant given the positive role played by skills in driving productivity.

3 Key drivers of change in manufacturing

Chapter Summary

- Social, technological, economic, environmental and political drivers will all have implications for the changing nature of manufacturing.
- In the medium-/long-term manufacturing will need to become more responsive and closer to customers.
- Developments in emerging economies and changing levels of personal wealth offer potential new markets for manufacturing.
- Technological developments – particularly the 'internet of things' (Industry 4.0) - offer opportunities for new products and processes.
- A further key driver of change in manufacturing is increased sustainability.

3.1 Introduction to drivers of change

Drivers of change may be grouped using the so-called 'STEEP' framework into those that are social, technological, economic, environmental and political (i.e. STEEP) in nature. The following sections draw on a synthesis by Arup (2013) of international workshops undertaken as part of the Foresight (2013) study on the Future of Manufacturing, with particular reference to the findings from an international workshop in which stakeholders in Europe considered global drivers.

3.2 Social drivers of change

Four social drivers of change are:

- Social attitudes towards consumption: Social attitudes are an important driver in shaping future demand for manufactured goods in future. For example, a greater demand from consumers for eco-transparency implies that manufacturers will need to be more transparent about the ecological footprint of their products and operations.

- Urbanisation: On a global scale there is a growth in population in urban areas. Technological change means that urban production (see section 3.3) presents an important opportunity: in future, specialist micro-manufacturing facilities may be located in or near urban centres in order to benefit from closer proximity to the workforce and to the end consumer, as well as to access to educational institutions. Urban manufacturing help mitigate supply chain risk and could also help tackle unemployment, given concentrations of unemployment in urban areas.
- Access to information and technology: Wider access to information via the internet is likely to lead to new social and customer attitudes and behaviour. Additive manufacturing techniques (such as 3D printing) mean that consumers can become producers.
- Changing demographics: An ageing population alters the nature of the workforce and also creates new markets (e.g. for medical technology devices used by older people in their own homes). It also has implications for the nature of the workforce, as people have longer working lives. This has implications for (re)training of the existing workforce and also for recruits to manufacturing from various age groups in order to ensure that skills are maintained and developed. Even though employment in manufacturing is projected to decline overall, replacement demand is positive and so the talent pool (at various skills levels) in manufacturing will need to be increased and then replenished on an ongoing basis. This has implications for workers of all ages. Specifically for older workers, workplaces need to be made suitable for older employees.

3.3 Technological drivers of change

Given the centrality of the production process in manufacturing, technology will always be an important driver of change. Key drivers under this heading include:

- R&D: Investment in research and development is a key driver of competitive advantage. While the onus is on manufacturing employers to make such investments, there is a role for public policy in incentivising R&D spending in fields such as technology, energy and material science. Educational institutions can support manufacturers through research in subject areas such as clean energy, resource efficiency, material science innovation and technological advancement.

- New materials: Over time innovative use of new materials has driven demand and future productivity gains. There is scope here for better government-industry partnerships to help ensure these gains occur.
- Urban production: As set out in section 3.2, changes in technology mean that there is potential to shift production to urban areas, enabled by additive manufacturing techniques such as 3D printing, and emergent niche micro-manufacturing capabilities. A move to urban areas may help foster greater collaboration (through greater spatial proximity) to suppliers, consumers, competitors and academic institutions.
- Mass customisation: With developments in technology, big data and a shift to urban production, there is potential to move further from mass production to mass customisation. This has implications for the nature of the value chain in manufacturing and also for productivity gains.
- Big data: Greater availability and use of big data, and the advanced analytics and capabilities that can be expected as software and computing power further develops, underlies many of the technological developments outlined above. Many organisations are already using analytics to manage a growing wealth of data encompassing everything from supply chains and manufacturing processes, to consumer behaviour. However, there is huge potential for harnessing the power of Big Data as these become yet more sophisticated.

The developments in computing and big data underlie 'the internet of things' (so-called Industry 4.0), which is about connecting devices over the internet, letting them talk to suppliers, producers, consumers, applications, and each other, as discussed in broader context in section 3.4.

3.4 The internet of things: Industry 4.0

In historical context, Industry 4.0 can be thought of as the fourth industrial revolution since the end of the 18th century:

- Industry 1.0: 1st Industrial Revolution at the end of the 18th century – heralded the introduction of mechanical production facilities with the help of water and steam power.

- Industry 2.0: 2nd Industrial Revolution at the beginning of 20th century – marked the introduction of mass production with the help of electrical energy.
- Industry 3.0: 3rd Industrial Revolution at the beginning of 1970s – brought the application of electronics and IT to further automate production.
- Industry 4.0: 4th Industrial Revolution at the current time involves the merging of real and virtual worlds on the basis of cyber-physical production systems (CPPS). At the heart of Industry 4.0 are smart machines, which continually share information about current stock levels, problems or faults, and changes in orders or demand levels. Hence, processes and deadlines can be co-ordinated with the aim of boosting efficiency and optimising throughput times, capacity utilisation and quality in development, production, marketing and purchasing. CPPSs network smart machines with each other and also create a smart network of machines, properties, ICT systems, smart products and individuals across the entire value chain and the full product life cycle. Sensors and control elements enable machines to be linked to plants, fleets, networks and human beings. Smart networks underpin smart factories – which underpin industry 4.0.

Each successive Industrial Revolution is characterised by increasing complexity. The significance of Industry 4.0 for manufacturing is that it is occurring now. Four key characteristics of Industry 4.0 (Deloitte, 2015) are:

- The vertical networking of smart production systems, such as smart factories and smart products, and the networking of smart logistics, production and marketing of smart services, with a strong needs-oriented, individualised and customer-specific production operation. This underscores the integration of supply and service elements into the manufacturing value chain.
- Horizontal integration by means of a new generation of global value-creation networks, including integration of business partners and customers, and new business and co-operation models across countries and continents. This highlights the geographical reach of manufacturing, and also emphasises how in Industry 4.0 issues of IP protection are increasingly important.

- Through-engineering throughout the entire value chain, taking in not only the production process but also the end product. This emphasises the nature of the so-called 'circular economy', in which resources are kept in use for as long as possible, maximum value is extracted from them whilst in use, and then materials and products are recovered and regenerated at the end of their life (see section 3.6).
- Acceleration through exponential technologies[8] that, while not necessarily new, are now capable of mass-market application as their cost and size have come down (e.g. sensor technology) and their computing power has risen massively. Hence, exponential technologies are an accelerant or catalyst allowing individualised solutions, flexibility and cost savings in industrial processes

Industry 4.0 offers potential to enhance competitiveness. Appropriate skills (in STEM subjects, including software design and computer science) and IT infrastructure need to be in place to maximise potential.

A global benchmarking study on 'preparedness' for Industry 4.0 based on a study of 433 industrial manufacturing executives in China, the USA, the UK, Germany and France, from sectors such as aerospace, automotive and electronics, etc., who were asked about implementation and plans for implementation of asset management technologies (maintenance, operational, information and energy management), found that the UK ranked alongside the USA and Germany in the middle of the table, behind China but ahead of France (Infosys, 2015). 8 per cent of UK companies reported having systematically implemented and 39 per cent said that they had partly implemented such technologies, and 37 per cent indicated that they had recognised the potential of such technologies. 16 per cent reported not having implemented them.

3.5 Economic drivers of change

From an economic perspective key drivers of change in manufacturing include:

[8] Examples are Biotech, Neuotech, Nanotech, ICT and mobile technology, Sensoring, 3D printing, Artificial Intelligence, Robotics and Drones.

- Human capital: The sourcing, training, development and retention of workers with required skills in manufacturing will be an important driver of change. Deficiencies in human capital mean that the ability to take advantage of the developments outlined in other sections and associated productivity gains will not be realised. Manufacturing has a particular need for workers with STEM skills. There is also a need to ensure that these skills are used effectively within the workplace to achieve productivity gains.
- Services: The manufacturing sector is increasingly reliant on service providers (e.g. telecommunications, software provision, etc.) to make connections to suppliers and customers in global production networks. Many services are required to support automation such as logistics management, plant maintenance and marketing.
- Collaboration and coopetition: As products become more complex technically manufacturers will likely need to collaborate more with each other and with those outside manufacturing. Digitised[1]manufacturing value chains, with digital connections between customers, manufacturers and suppliers are increasing the scope for collaboration.
- New markets and competitors: As outlined in section 3.2, population growth and differential economic growth around the world creates new markets, but also new competitors for UK manufacturing.
- Circular economy: Advances in resource efficiency and cutting use of materials and energy mean that economic models underlying current manufacturing processes may need to change.

3.6 Environmental drivers of change

Key environmental drivers of change include:

- Climate change: Regulatory pressures to reduce greenhouse gas emissions will be a key driver of change in manufacturing, with particular implications for energy-intensive sectors.
- Environmental efficiency and effectiveness: In the long-term it is likely that manufacturers will need to do more with fewer material resources. This helps to give rise to the ‘circular economy

- Consumer environmental pull: As highlighted in section 3.2, consumer pressures are likely to pull in the direction of increasing concerns about environmental provenance, etc.

3.7 Political drivers of change

Political drivers of change can operate at various scales from the global to the local, and include:

- Resource conflicts: In context of population increase, rising consumption, energy resource depletion, access to resources is important. Geopolitical instability in certain parts of the world remains a concern also.
- Global governance regulations: Government intervention in market deregulation and/or fiscal policy can have a high impact on manufacturers. Foreign currency fluctuations can impact on the competitiveness of manufacturers in export markets.
- Smart specialisation: Sub-regional and local government can foster and develop collaboration at local level through ensuring the necessary physical infrastructure is in place and also by providing arenas for local collaboration in developing new products.
- Education: Ensuring the requisite supply of skills is in place is fundamental to future of manufacturing. Governments can play a key role in encouraging take-up of STEM subjects at degree and apprenticeship levels.

3.8 Conclusions: key future characteristics for manufacturing

The mass personalisation of low-cost products, distributed production and digitised manufacturing value chains mean that manufacturers will need to be able to *move fast and become more responsive and closer to customers*. This means that it will be necessary to improve the speed and co-ordination of technology pipeline, leverage intellectual assets more effectively, protect IP and avoid cyber-attacks (Foresight, 2013).

The emergence of Asian and Latin American economies and changing levels of personal wealth means *new market opportunities* for UK manufacturing on the one hand, but risks to foreign direct investment (FDI) to UK and of global fragmentation of value chain. It will be important to keep the UK attractive to FDI. Promoting co-location of R&D with production is important also (especially for SMEs [Wright, 2014]), so maintaining and building an 'industrial commons' (i.e. the embedded knowledge and technology framework that enhances the efficiency, effectiveness, and productivity of the proprietary capital and labour that use it). Government has a major role to play, nationally and locally, in encouraging greater agglomeration and clustering of particular activities.

In the environmental sphere pressure on resources and the emergence of the 'circular economy' and consumer preference for eco-products means that future manufacturing will need to be *more sustainable*. This means it is necessary to target R&D at improving resource efficiency and material substitution, support business models based on reuse remanufacturing and services, and incentivise product and process efficiency.

Despite projected employment decline, replacement demand means that there will be a sustained demand for manufacturing workers, especially (but not exclusively) with high level technical skills. The ageing of the population means that there will be a need to accommodate more older workers. The talent pool for employers to draw on will need to be increased and replenished – with a particular focus on STEM and problem solving skills, and employers will need to ensure that skills are utilised effectively.

4 Labour productivity performance in manufacturing

Chapter Summary

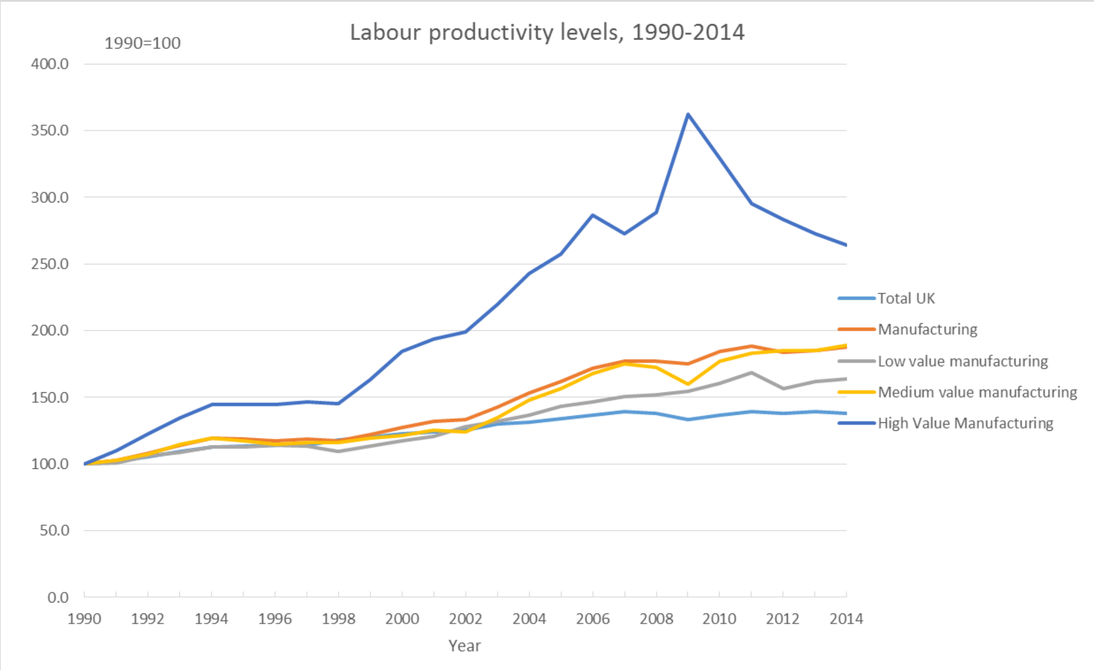
- Labour productivity is higher in manufacturing than the UK average across all sectors.
- Labour productivity increased over the long-term from 1990 to 2014, in a context of employment decline.
- Productivity fell markedly during the recession and has not recovered to pre-recession levels.
- There is considerable heterogeneity in experience within the manufacturing sector, with high value manufacturing displaying highest productivity, but also marked volatility over time.
- The UK's labour productivity performance is relatively strong vis-à-vis EU competitors, but lags behind that in the US. However, the UK has been slower than other key EU economies to see recovery in productivity following recession.

4.1 Labour productivity in UK manufacturing

In 2013 labour productivity in manufacturing was 32 per cent higher than the UK average. This disguises considerable heterogeneity within manufacturing. Labour productivity in low value manufacturing was only 3 per cent higher than the UK average, whereas in medium value manufacturing it was 34 per cent higher and in high value manufacturing it was 170% higher.

The trend over the period from 1991 to 2013 is shown in Figure 4.1. For much of the period shown – and particularly the latter part of the period – labour productivity is higher in manufacturing than in the economy as a whole, in a context of employment decline in manufacturing. The trend in medium value manufacturing is similar to that in manufacturing in aggregate, with low value manufacturing following a similar trajectory, but at a lower level. High value manufacturing is distinctive in terms of its high levels of labour productivity, but also in terms of a downward trend following recession; (this reflects the position of pharmaceuticals).

Figure 4.1 Index of labour productivity levels in manufacturing, 1990-2104 (1990=100)



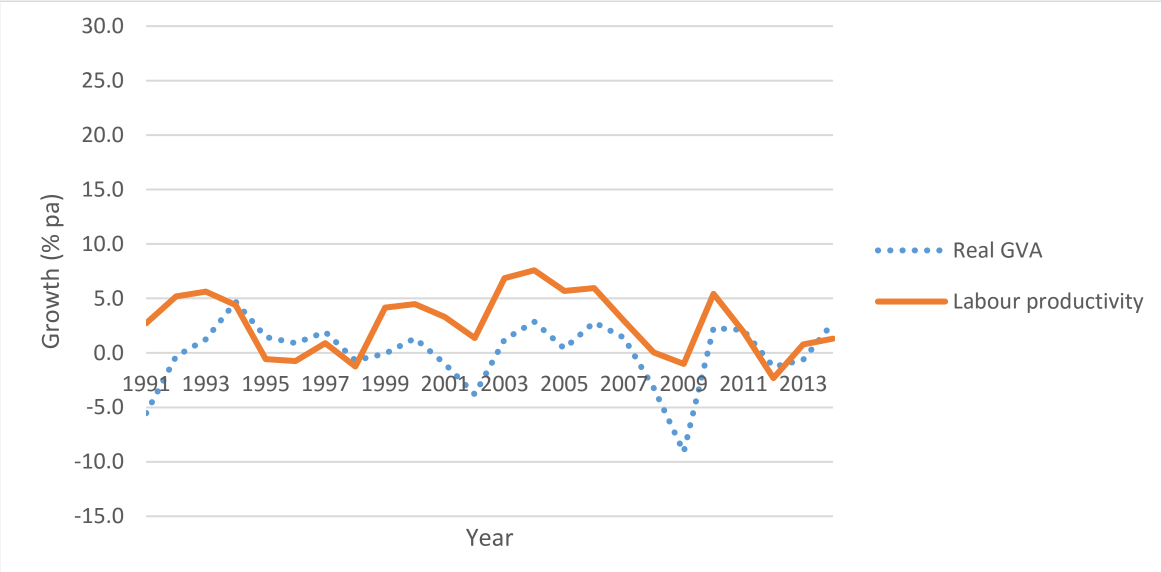
Sources: ONS and Cambridge Econometrics (MDM-E3 database).

In greater detail, labour productivity (real GVA per job) increased fairly steadily between 1990 and 2014 in the manufacturing sector, albeit with some dip in the recession. However, the growth of labour productivity lagged behind the sector average in low value manufacturing industries, being only 60 per cent higher in 2014 (increasing from 27 thousand in 1990 to 44 thousand in 2014). In contrast, labour productivity in high value manufacturing industries increased by 160 per cent, from £42 thousand to £111 thousand over this period. However, there was a fall in productivity of 1.0 per cent for the sector as a whole and of 7.1 per cent for medium value manufacturing in 2008-9, which was not experienced by low value manufacturing. These industries saw a fall of productivity of 7.1 per cent between 2011 and 2013. In contrast, labour productivity in high value manufacturing increased by 5.6 per cent in 2007-8 and 25.6 per cent in 2008-9. It has fallen in each subsequent year, but the annual rate of decline is falling. It would appear that a key factor here has been weak output per hour in pharmaceuticals for several years, but this sector’s contribution to manufacturing output per hour turned positive in 2014 (ONS, 2015b).

4.2 Changing labour productivity on an annual basis

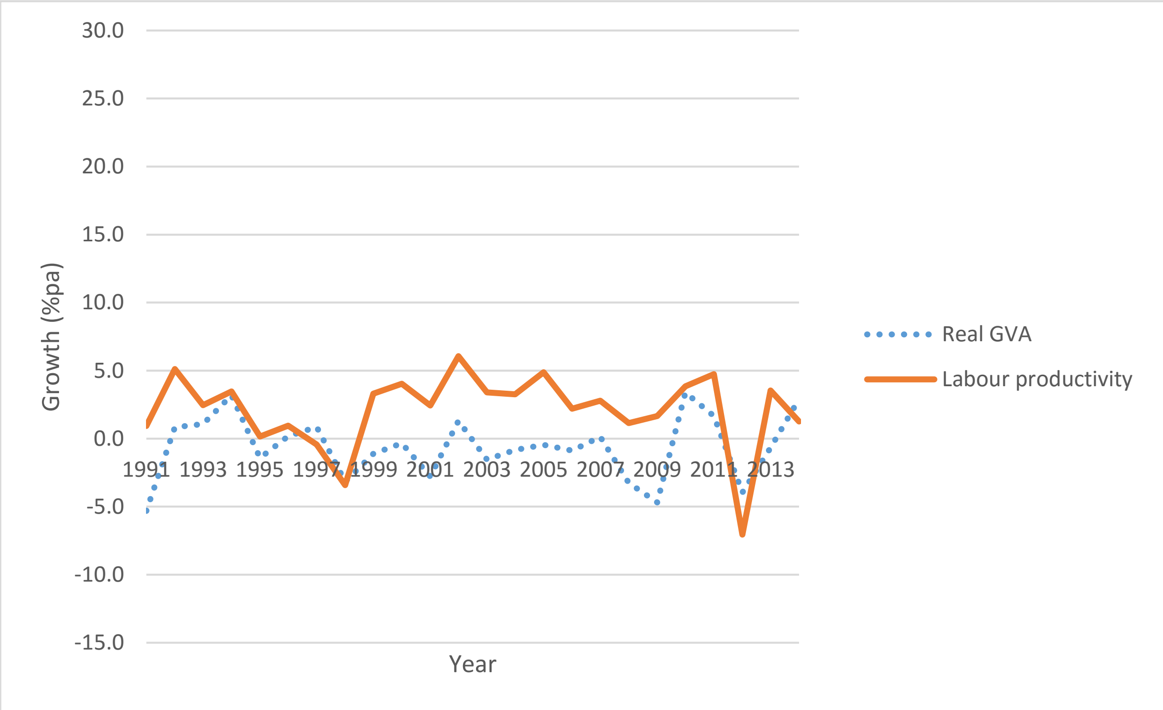
There is no clear trend in changing labour productivity on an annual basis over the period from 1991 to 2014. Figure 4.2 shows the trend for the manufacturing sector, while Figures 4.3, 4.4 and 4.5 show changes for low value, medium value and high value productivity, respectively. Volatility is greatest for high value manufacturing (which is the smallest category and so most susceptible to volatility in trends).

Figure 4.2 Growth in labour productivity and GVA, manufacturing



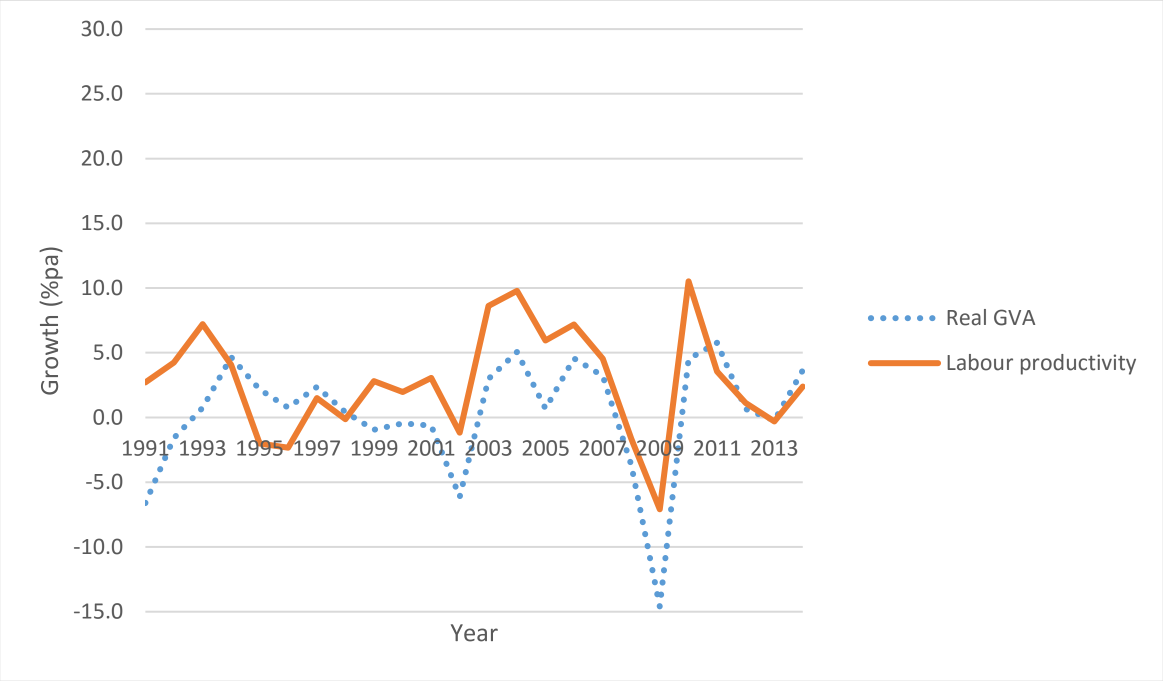
Sources: ONS and Cambridge Econometrics (MDM-E3 database).

Figure 4.3 Growth in labour productivity and GVA, low value manufacturing



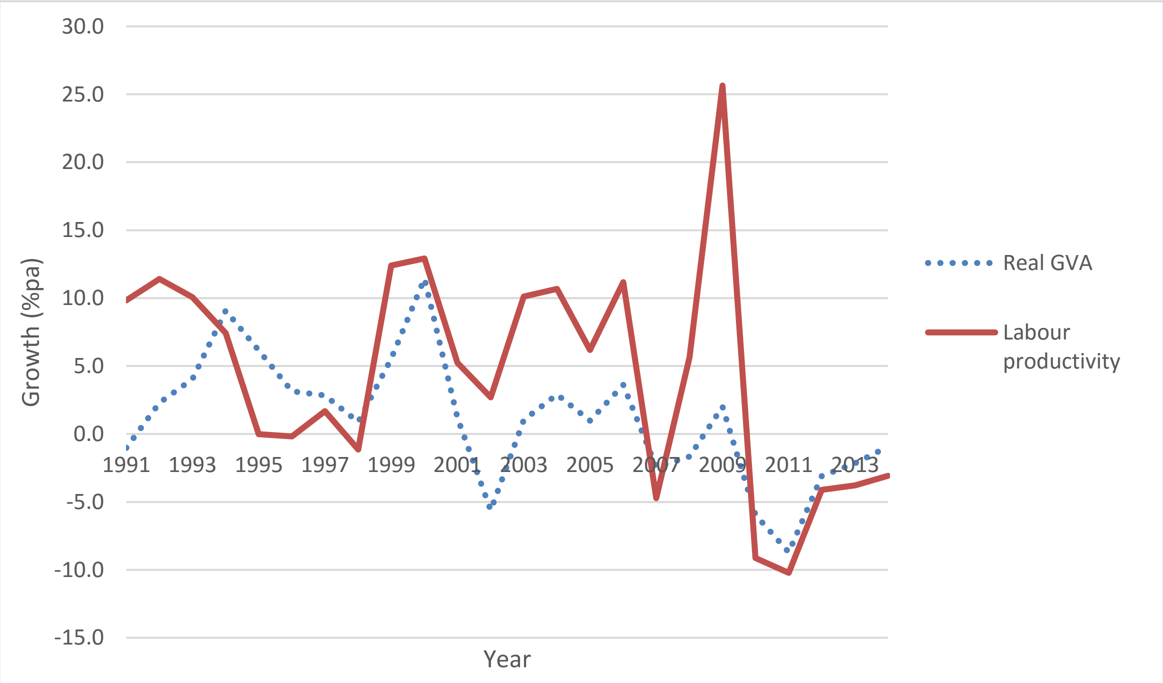
Sources: ONS and Cambridge Econometrics (MDM-E3 database).

Figure 4.4 Growth in labour productivity and GVA, medium value manufacturing



Sources: ONS and Cambridge Econometrics (MDM-E3 database).

Figure 4.5 Growth in labour productivity and GVA, high value manufacturing

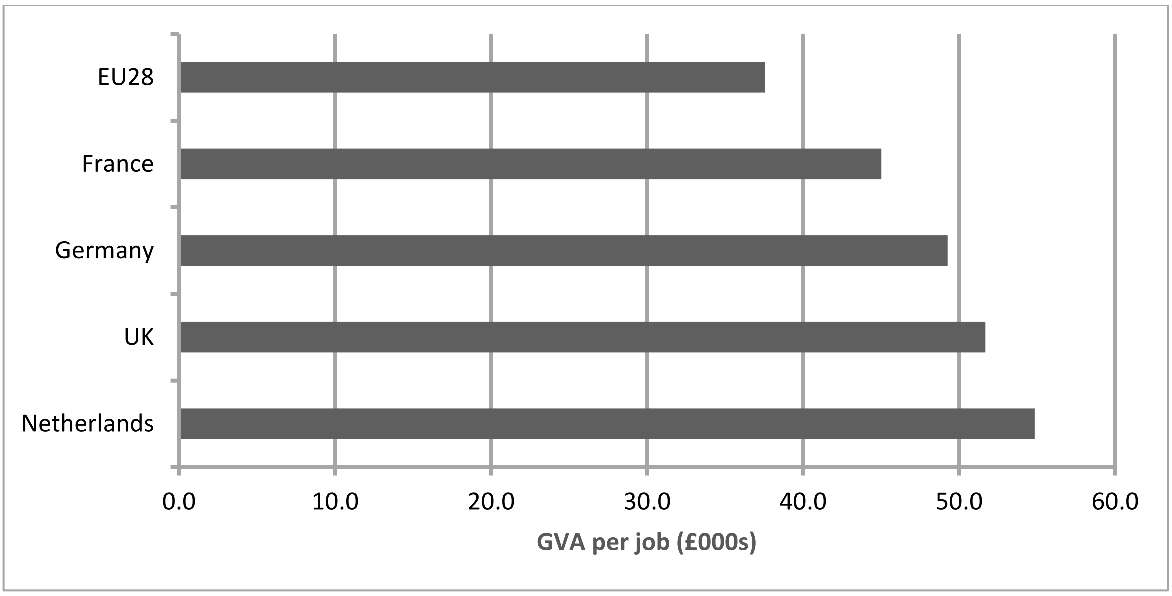


Sources: ONS and Cambridge Econometrics (MDM-E3 database).

4.3 Labour productivity growth in the UK compared with selected high productivity countries

Figure 4.6 provides a snapshot of the UK's relative productivity position in manufacturing compared with the average situation in the European Union (EU28) and selected relatively high productivity EU countries (France, Germany and the Netherlands). It shows that the UK compares relatively well. Analyses indicate that some of the UK's advantage is accounted for by investments in skills which appears to have been a particularly strong driver of productivity growth in the 1990s, and relatively strong total factor productivity (TFP) performance during the 2000s (Mason et al., 2014). TFP is the productivity gain once that from capital and labour have been accounted for.

Figure 4.6 Gross value added per job in selected EU countries, 2013



Source: Cambridge Econometrics

Over the medium-term the general trend in labour productivity growth in the UK has been broadly similar to that in selected high productivity countries (Germany, France and the Netherlands) and the EU average. The UK displayed slower productivity growth than the other three countries during the 1990s, faster growth in the first years of the 21st century and a smaller fall in productivity (and hence smaller recovery) during the 2008-9 recession. In contrast to the other three countries, the rate of increase in labour productivity fell to a smaller extent but for longer between 2010 and 2013.

4.4 Conclusion

The UK manufacturing sector has seen productivity growth – particularly as a result of employment decline. However, productivity fell markedly during the recession, and has not recovered to pre-recession levels. This suggests an overall decline in efficiency in the sector. Over the medium-term labour productivity levels in manufacturing are relatively favourable compared with European competitors.

5 Factors facilitating and inhibiting productivity growth

Chapter Summary

- Investment in manufacturing fell markedly in the recession in comparison with the economy as a whole, albeit investment is now on an upward trajectory.
- Manufacturing accounts for a relatively high level of business expenditure on R&D but there remain longstanding concerns about ground to be made up vis-à-vis international competitors in linking research and innovation to commercial products.
- Best practice in manufacturing is most prevalent in foreign-owned and multi-national companies with UK sites, and in large establishments. It is particularly apparent in the aerospace and automotive sectors.
- The UK fares relatively poorly on an international comparative basis in terms of the quality of management. This has implications for best practice.
- Compared with the UK economy as a whole, manufacturing is characterised by a greater incidence of high or very high product market strategies, but a below average incidence of establishments using high performance working practices.
- Manufacturing has a higher proportion of skill-shortage vacancies than average, especially in professional and skilled trades occupations. This is likely to inhibit productivity growth.
- Training spend in manufacturing is slightly lower than the UK average, and manufacturing scores worse than average on a range of training activity indicators, although labour productivity is higher.

5.1 Introduction

Productivity gains will be realised in the workplace, so there is a need to understand how productivity might be considered from a workplace perspective.

Starting with the product then one is trying to assess the value-added (or gross margin in management accounts) generated by a particular product and, in aggregate the overall operating surplus generated in the workplace. To some extent the margin will be determined by the nature of the product (some products are inherently high value), the extent to which other manufacturers are producing the same or similar products, and the extent to which producers can extract a relatively high rent from their product (e.g. from adept marketing and product placement). Being able to have one's product market stand out in the market in order to generate a relatively high margin is dependent upon innovation in both product development and being able to effectively market that product in order to realise a relatively high margin. It is also dependent upon having production facilities in place that will allow production costs to be minimised.

In looking at productivity in manufacturing, there is also a need to consider forward and backward linkages of an industry. This can reveal much about who appropriates the gains to be obtained from increasing productivity. The forward and backward linkages can become blurred where there are high levels of vertical integration, spanning the pre- and post-fabrication process, as set out in Chapter 2.

In aggregate, the way in which productivity gains take place will correspond with a firm's product market strategy. Key to successfully developing the product market strategy is that of possessing the skills, in the first instance, to develop the strategy in a way which will yield a relatively high margin, and ensuring that all of the requisite skills are in place to realise the product market strategy in practice. This needs to be considered dynamically where new products and processes are constantly being developed or modified over time in order to maintain competitiveness.

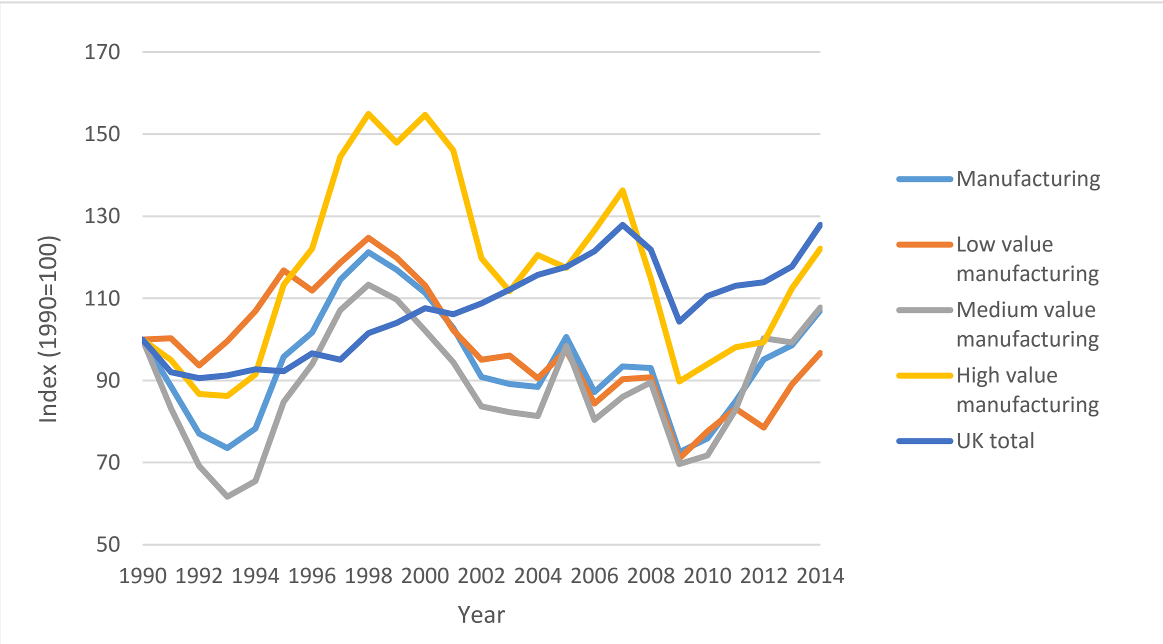
5.2 Investment

One key issue often discussed in relation to productivity in manufacturing is investment – which is often interpreted as covering investment in R&D, IT and technology, capital equipment, machinery, etc. (Song et al., 2014).

Gross fixed capital formation (GFCF) is a measure of investment. Figure 5.1 shows GCFC levels over the period from 1990 to 2014.

In the UK economy as a whole, GFCF was low in the early 1990s, but grew steadily until 2007, fell sharply in the subsequent recession and grew again after 2009, reaching 2007 levels by 2014. GFCF has been highest in the high value manufacturing sector for most of the period since 1990. Levels were lowest during the recession of the early 1990s, highest around the millennium, fell sharply afterwards, briefly recovered, then fell dramatically in 2008-9, but have started to recover since 2011. The trends for medium-value manufacturing and the manufacturing sector as a whole follow each other closely, with a trough in the mid-1990s, a peak around the millennium, followed by decline, stagnation, further decline in the 2008-9 recession and then strong recovery. The level of GFCF in low-value manufacturing was higher than for other parts of the manufacturing sector in the early 1990s and remained higher than for medium-value and all manufacturing around the millennium. However, the relative level of GFCF declined from then on. The recovery in GFCF since the 2008-9 recession has not been as strong as for other parts of the manufacturing sector.

Figure 5.1 Gross fixed capital formation levels, 1990-2014

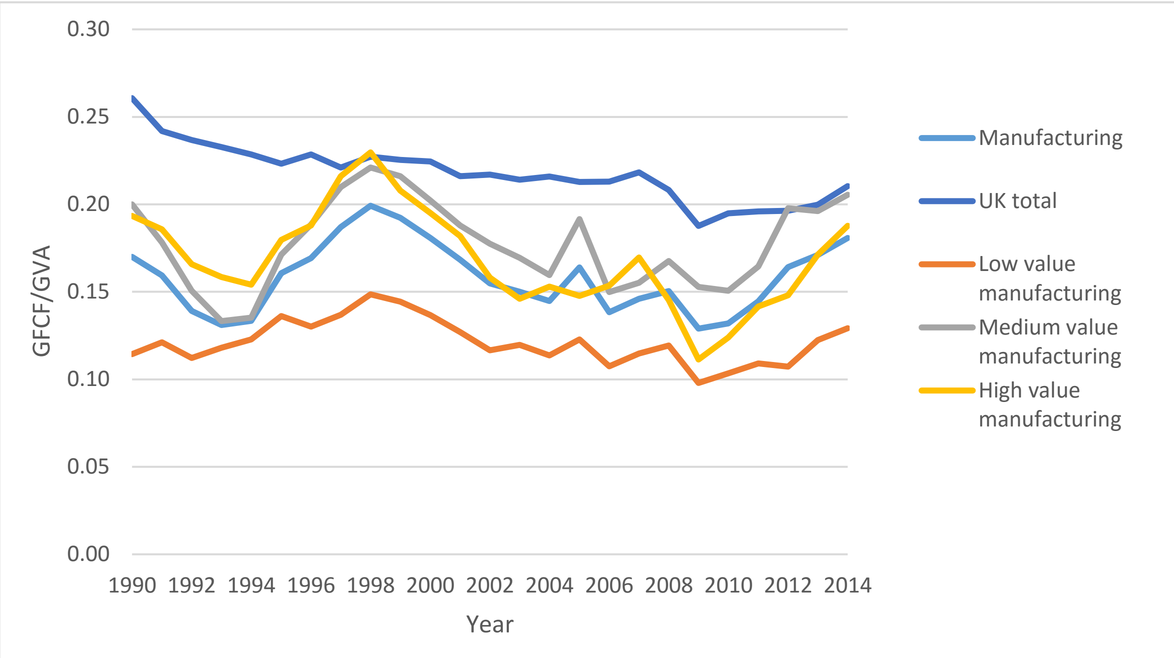


Sources: ONS and Cambridge Econometrics (MDM-E3 database).

Figure 5.2 shows GFCF as a share of GVA has declined continuously in the UK since the early 1990s, with an acceleration during the 2008-9 recession, and only a weak subsequent recovery. For the manufacturing sector as a whole, this percentage decreased in the early 1990s, reached a peak of about 20 per cent in 1998, declined steadily until 2008, then fell more sharply during the 2008-9 recession, afterwards recovering somewhat. The pattern shows that investment is at relatively low levels compared with the economy as a whole.

This pattern was followed in a slightly exaggerated form in high-value and medium-value manufacturing industries. This percentage was higher for high-value manufacturing than medium-value manufacturing industries until 1998, but has been higher for medium-value manufacturing industries since then. GFCF as a percentage of GVA has been lowest for low-value manufacturing industries throughout this period, and the degree of variation in this percentage has been much less for this part of manufacturing. Low investment levels would be expected to be translated into relatively poor productivity performance. Medium-value manufacturing is the only section of the manufacturing sector in which this measure had returned to being close to the 1998 level by 2014.

Figure 5.2 Investment levels in manufacturing, 1990-2014



Sources: ONS and Cambridge Econometrics (MDM-E3 database).

Another measure of investment is the amount of spending (whether by firms or from government) on R&D and on linking research with business innovation. While the manufacturing sector represented around 11 per cent of total UK economic output, it accounted for around 72 per cent of business expenditure on R&D in the UK in 2011 (EEF, 2014). Large firms account for a large majority of R&D activity: those with 250 or more employees were responsible for 80 per cent of business R&D in 2011. Wright (2014) highlights that in comparison with Germany, the UK has a good deal of ground to make up with regard to linking research and innovation – especially in turning basic research - into commercial products. In 2013, for instance, £440 million was invested in the UK in the Technology Strategy Board, by comparison with £1.6 billion invested in Fruanhofer Institutes in Germany.

5.3 Manufacturing best practice and productivity

Companies with 'best practice' generally perform better than others. 'Practices' may be defined as established processes which a company has put in place to support the way in which business operates. Here management matters, and adoption and utilisation of best practice is closely linked to productivity. Examples of current and potential future areas of best practice are detailed in Table 5.1.

Table 5.1 Best practice examples

Time period	Example
Current	agile and lean manufacturing
	six sigma: a process in which 99.99966% of products manufactured are expected to be free of defects
	new product development
	ISO 9000 and ISO 14000: quality management and environmental management systems
	process analysis and simulation
	quality function deployment
	supply chain management
	statistical quality control
	statistical process control
Future	supply chain agility and clustering
	application of new technologies
	engagement with universities
	education of manufacturing personnel
	new product development and innovation management
	knowledge management
	data analytics
	leadership practices and change management
	productivity in product-service systems

Source: McLaughlin (2013)

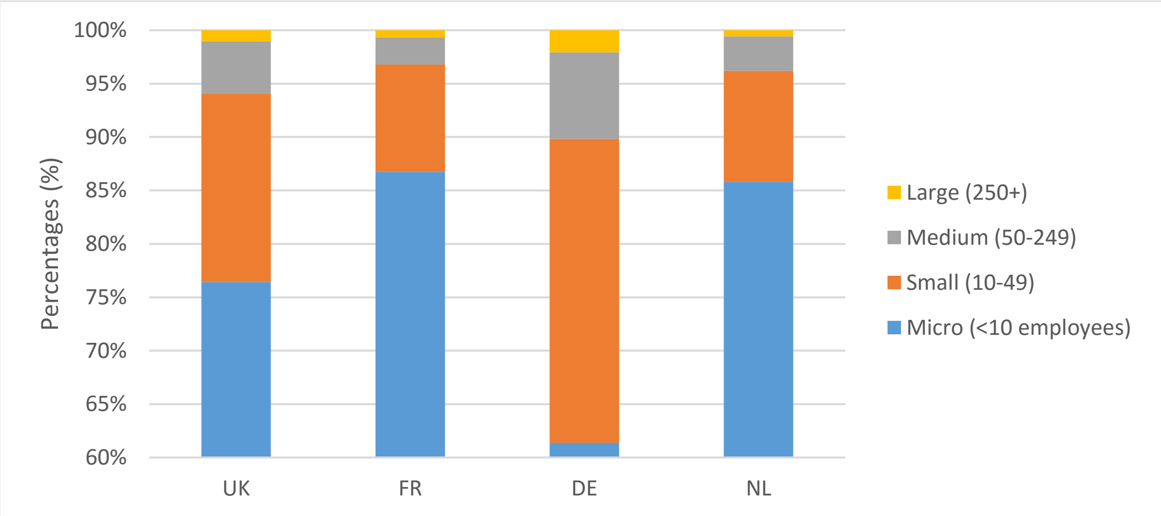
Best practice activity needs to be appropriate for the business and deliver competitive advantage. In UK manufacturing best practice tends to be most evident / prevalent in:

- Automotive and aerospace industries.
- Foreign-owned and multinational businesses with UK sites than in domestic companies.
- Companies valuing and promoting education for their employees – successful implementation depends on strategic commitment, top management and workforce engagement, effective communication and appropriate skills.
- Larger rather than smaller companies: there is a positive association with organisation size.

5.4 Business size in manufacturing

Figure 5.3 shows the size distribution of manufacturing business in the UK vis-à-vis selected international competitors. As highlighted above, business size appears to play an important role in adoption of best practice. Micro and small businesses often need help to support innovation and to secure new business / penetrate new markets. Likewise they can feel pressures in bringing staff up to requisite skill levels.

Figure 5.3 Business sizes for manufacturing in selected countries, 2013



Source: Eurostat (Structural Business Statistics).

France and the Netherlands had the largest percentage of micro businesses (less than 10 persons employed) in 2013, in each case representing more than 85 per cent of the total. Just over three-fifths of German and just over three-quarters of UK businesses had fewer than 10 employees. In contrast, small businesses (10 to 49 employees) represented the largest share (over a third) of all businesses in Germany. Just under a fifth of UK businesses and around a tenth of French and Dutch businesses fell into this size category.

Germany is distinctive in terms of its relatively large share of medium-sized businesses (around 8 per cent of the total): the Mittelstand hailed as the backbone of the German economy. The UK comes next (with about 5 per cent), and smallest in France. Germany also had the largest percentage (about 2 per cent) of large businesses (with 250 or more employees)

Research on mid-market companies in the UK shows that although they hold more patents than large and small companies combined, and 66 per cent reported process innovations and 50 per cent report product innovations, such UK companies are less productive than their mid-market counterparts in France, Germany and Italy (Roper and Malshe, 2012). UK mid-market companies reported more difficulties finding / retaining skilled employees and spent less on R&D than those in France, Germany and Italy. They were also more grounded in local markets – i.e. not as 'global' or as 'European' as their international comparators in this study.

Roper and Malshe (2012) suggest that a short-term focus may be contributing to the problems of mid-sized companies in the UK. In turn, this may be attributed to shortcomings in management and leadership (as discussed below).

5.5 Management and leadership

The UK fares poorly when compared internationally on the quality of managers as measured by qualifications: 42 per cent of managers in UK manufacturing have degrees compared with at least 60 per cent in India, Japan, Germany, USA and France. The quality of managers may have implications for management vision and practices, which in turn may have implications for productivity.

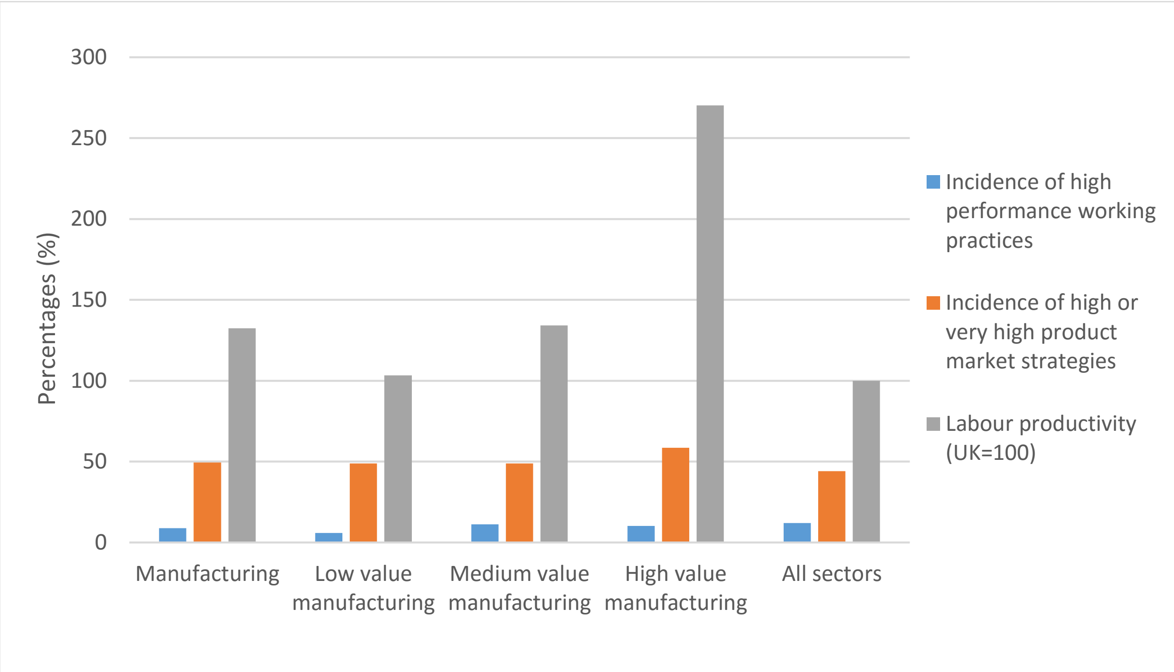
There is a good deal of emphasis in manufacturing, and in other sectors, on improving management and leadership. Homkes (2014) suggests that key barriers to doing so include:

- A lack of up to date models of leadership and development systems and training.
- A tendency to consider leadership and management within a short term view - especially for smaller or resource-constrained firms.
- Underestimating the need to improve or enhance leadership and management capabilities and the related practices and processes.

This is a matter of concern since strong leadership teams and distributed leaders in key positions throughout manufacturing businesses are likely to be more critical in future. Key elements in enhancing leadership and management include future focus, attention to context, leadership and management development training, and performance and talent management systems. Other research on comparing management practices internationally suggests that new managers may be better than incumbent managers in creating changes in management practices; in international terms the UK suffers from a scarcity of managers with the right skills and knowledge over what management practices to introduce (Bloom et al., 2011). These shortcomings are less evident in larger than in smaller firms.

Relative to the UK average, however, manufacturing is characterised by a higher than average incidence of high or very high product market strategies (see Figure 5.4). High value manufacturing is distinctive in this regard (with little difference among other parts of the manufacturing sector). High value manufacturing also has higher labour productivity than medium value and low value manufacturing.

Figure 5.4 Management and training indicators



Source: UKCES (Employer Skills Survey, 2013).

The percentage of establishments using high performance working practices is lowest in low value manufacturing, but is still below the average for all sectors in medium and high value manufacturing industries.

Research by Thomas et al. (2012), based on a detailed survey by the Wales Manufacturing Advisory Service of one hundred manufacturing employers (of varying sizes) from the Aerospace, Automotive, Medical and Electronics sectors found that respondents in these high value sectors were aware of, and knowledgeable about, the following future challenges:

- rapid and consistent delivery of new products by developing responsive design and engineering capabilities based around new and sophisticated manufacturing technologies and techniques
- development, enhancement and extension of human and technical capabilities to move from 'manufacturing only' to manufacturing of high value added products *and* relevant services to a global marketplace
- development of responsive knowledge management and business intelligence systems to aid better decision making
- minimisation of environmental damage and development of highly responsive and energy efficient local supply chains and logistics systems
- the ability to rapidly reconfigure manufacturing capabilities *plus* the supply chain *plus* logistics
- development of innovative products, processes and services by driving down product lifecycle times and continuously developing and enhancing new product development and introduction systems
- development of better collaborations with HE – including the development of improved collaborative design, research and manufacturing environments
- development / enhancement of digital networks
- development of new manufacturing management paradigms, to create more flexible / adaptive organisations supported by better change management and leadership

However, on the basis of the detailed survey results, Thomas et al. (2012) concluded that they were less familiar with key developmental areas and systems needed to address those challenges. It could well be the case that manufacturing employers in lower value sectors would display lower levels of knowledge and awareness than reported here.

Indeed, while the above is a relatively small survey focusing on a subset of manufacturing sectors, other research also points to an awareness of challenges faced, but a shortfall in actions to address them. For example, a survey of 286 business leaders and decision makers in UK manufacturing in 2012 (The Royal Bank of Scotland, 2012) showed that:

- 98 per cent agreed that R&D is crucial to growth but only 10 per cent plan to increase their R&D spend in the short term

- 74 per cent were worried that skill shortages would risk future growth and competitiveness, but only 12 per cent were investing in new apprenticeship schemes
- 78 per cent felt that their business was equipped to face medium-term challenges but 88 per cent were not planning to invest in key growth strategies (e. g. improving supply chain or investing in staff)

This suggests that at least in some spheres policy needs to play a stronger role in levering decisions that might lead to enhanced productivity. For example, a report on the shift towards sustainable manufacturing (i.e. using less material and energy input) – which could help increase multi-factor productivity – indicates that the lack of leadership is a key factor in stopping firms implementing 'green' initiatives that would raise company profits (Moore and Folkerson, 2015). Short-termism in decision-making and in innovation funding was also identified as a key constraint.

5.6 Skills: availability and utilisation

Improving productivity requires improving skills and putting them to better use in the workplace (UK Commission for Employment and Skills, 2015; Mayhew and Keep, 2014). The 2013 Employer Skills Survey (Winterbotham et al., 2015) shows that:

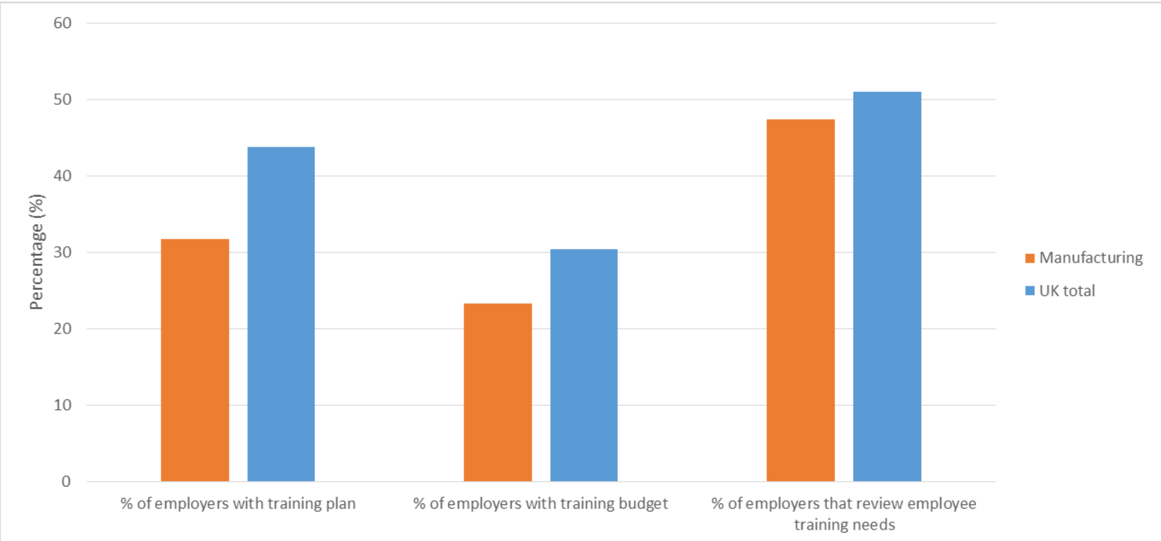
- Skill shortages in high level skills jobs are prevalent in the area of STEM professionals and the manufacturing sector most acutely affected: the shortage of mechanical engineers is ranked highest.
- High level skills shortages are disproportionately concentrated in larger firms.
- Higher skilled roles are difficult to fill because of a lack of experience rather than formal qualifications; a lack of technical, practical or job specific skills, including advanced IT or software skills or strategic management skills.
- Many skills shortages and skills gaps in middle-skills jobs are concentrated in manufacturing.

In manufacturing skill-shortage vacancies accounted for 30 per cent of all vacancies in 2013 (up from 24 per cent in 2011), a higher proportion than in any other sector in aggregate. In professional occupations skill-shortage vacancies accounted for 55 per cent of all vacancies (again a higher proportion than for any other sector). This shortage has tended to be persistent over time. In skilled trades occupations 41 per cent of all vacancies in manufacturing were skill-shortage vacancies. The occupations in manufacturing with the next highest skill-shortage vacancy densities were associate professionals and technical occupations (28 per cent) and managers and senior officials (26 per cent).

The percentage of staff reported as having skills gaps in the manufacturing sector was 5.8 per cent in 2013 (compared with 5.8 per cent across all sectors), down from 6.0 per cent in 2011. 18 per cent of manufacturing employers reported skills gaps in 2013 (compared with 15 per cent across all sectors), down from 20 per cent in 2011. This reduction was similar to that across all sectors.

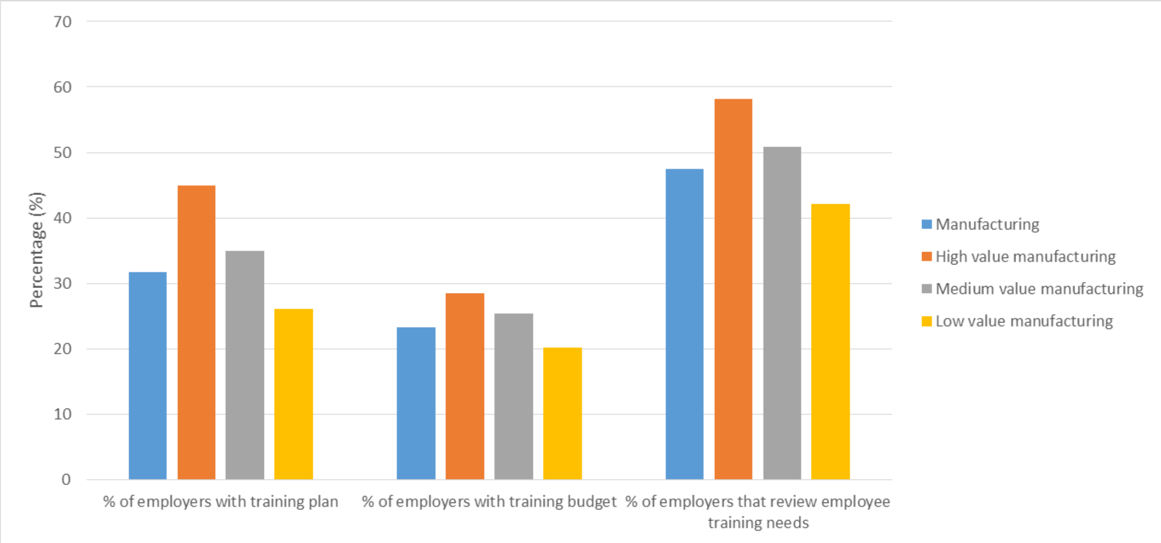
Figures 5.5 and 5.6 present a range of other indicators of training practice in manufacturing and compares them with the average for the UK economy as a whole. Figure 5.5 shows that the manufacturing sector has lower scores than the all sector average on the percentage of employers with a training plan (31.7 per cent compared with an all sector average of 43.8 per cent), the percentage of employers with a training budget (23.3 per cent in manufacturing compared with an all sector average of 30.5 per cent) and the percentage of employers that review training needs (47.4 per cent in manufacturing compared with an all sector average of 51.1 per cent). Figure 5.6 shows that within manufacturing there are clear differentials between high value, medium value and low value sectors, with the former exhibiting higher scores than the latter.

Figure 5.5 Training practice in manufacturing compared with the whole UK economy, 2013



Source: UKCES (Employer Skills Survey, 2013).

Figure 5.6 Training practice in manufacturing by sector, 2013

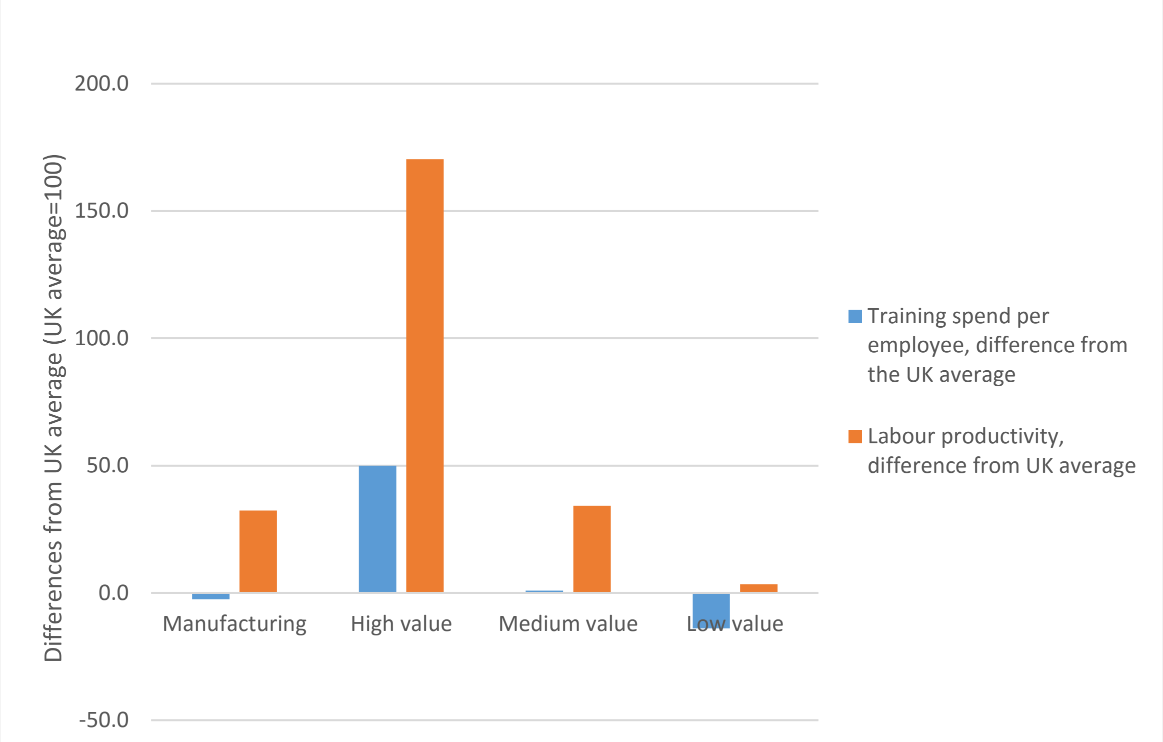


Source: UKCES (Employer Skills Survey, 2013).

50.3 per cent of employees in manufacturing received training, compared with 62.3 per cent across all sectors. The percentage of employees trained displays relatively little variation across high value, medium value and low value manufacturing. The mean number of days training in manufacturing is 5.5 days compared with 6.9 days across the whole economy. The mean number of days training per employee is slightly greater in medium value (5.7 days) and low value manufacturing (5.6 days) than in high value manufacturing (4.5 days). It is possible that this reflects higher initial qualification levels, on average, of employees in high value manufacturing.

Figure 5.7 shows differences in training spend per employee alongside labour productivity in manufacturing vis-à-vis the UK average. Training spend per employee is 2.5 per cent lower in manufacturing than the UK average. This is a function of a 14 per cent lower than UK average training spend in low-technology manufacturing, whereas in medium-technology manufacturing training spend is 1 per cent higher than the UK average and in high-technology manufacturing training spend is 50 per cent higher than the UK average. These differences in training spend per employee are likely to be associated with variations in occupational structure within these different manufacturing sectors, given that training spend varies by occupation.

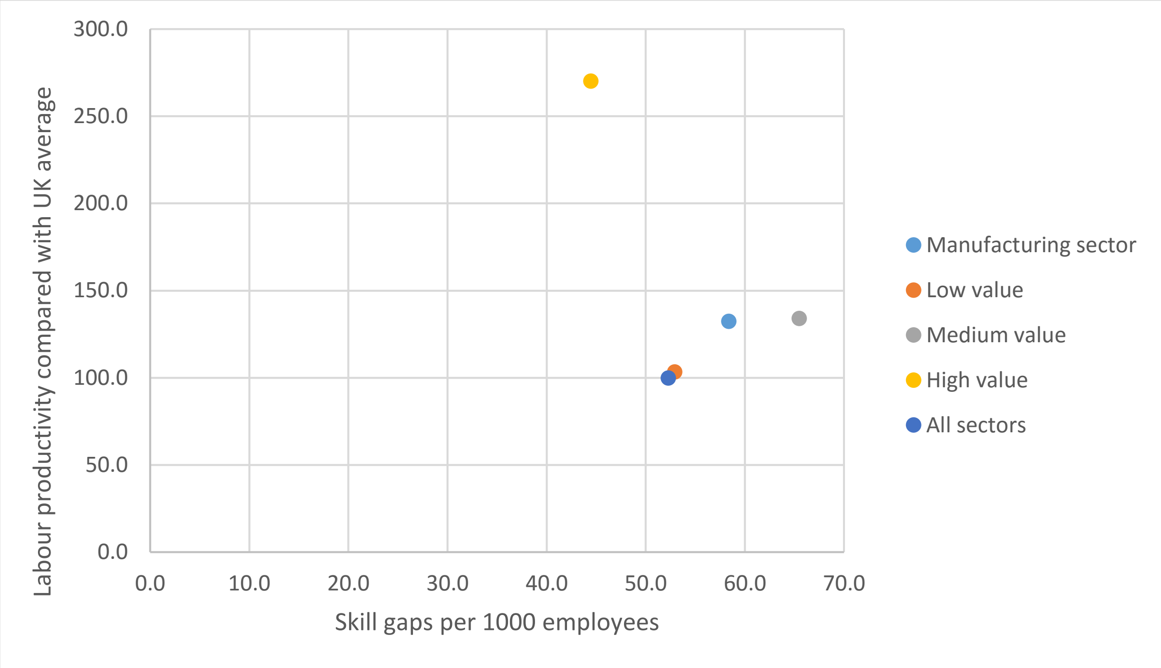
Figure 5.7 Training spend per employee and labour productivity, as differences from the UK average, 2013



Sources: UKCES (Employer Skills Survey, 2013).

There is a greater incidence of skills gaps in manufacturing (58.4 per thousand in employment) compared with the UK average (52.3 per thousand in employment) (see also Figure 5.8). The incidence of skills gaps is highest in medium-technology manufacturing (65.5 per thousand in employment), compared with 52.9 per thousand in employment in low-technology manufacturing (i.e. similar to the UK average). By contrast at 44.5 per thousand in employment the incidence of skills gaps in high-technology manufacturing is lower than the UK economy average. This could reflect a situation in which high value manufacturing companies employ highly qualified workers who are less likely to have skills gaps, or deploy workers in such a way that skills gaps are less apparent. Skills gaps might be more apparent at intermediate and low qualification levels, but the extent to which workers' deficiencies translate into skills gaps depends also on the roles to which workers are deployed and the tasks they are asked to undertake. The percentage of employers with skills gaps is higher in manufacturing (17.6 per cent) than the UK average (15.4 per cent).

Figure 5.8 Labour productivity versus skills gaps per 1000 employees



Source: UKCES (Employer Skills Survey, 2013), ONS and Cambridge Econometrics (MDM-E3 database).

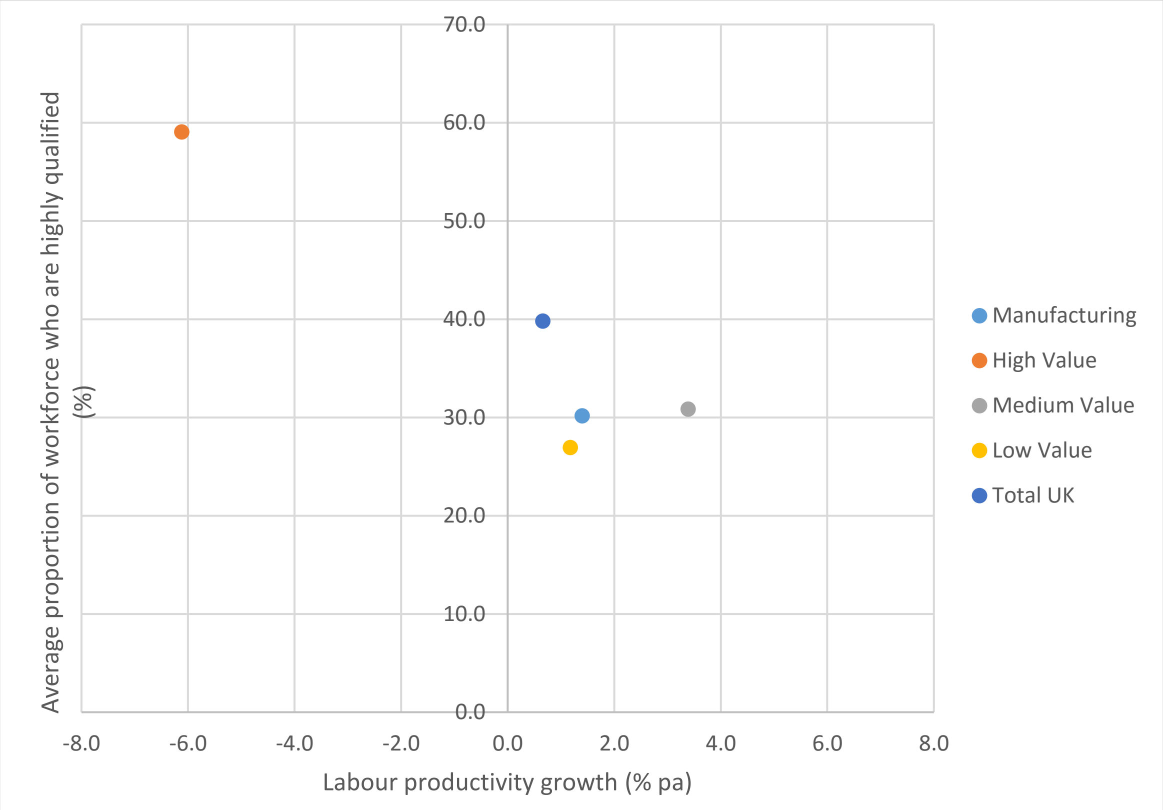
There is a higher incidence of apprenticeships in manufacturing than the UK average. In 2013 14.5 per cent of employers in manufacturing had staff currently on apprenticeships, compared with a UK average of 10.4 per cent. The share of employers with apprenticeships was highest in high-technology manufacturing (17.6 per cent and medium-technology manufacturing (17.2 per cent).

A slightly smaller share of manufacturing establishments reported that HE / school / college leavers were poorly prepared for work (1.3 per cent) than the UK average (1.6 per cent). Establishments in high-technology manufacturing were most likely to report HE / school / college leavers as being poorly prepared for work (2.1%).

Skill shortage vacancies were considerably more prevalent in high value manufacturing (11.1 per thousand in employment) than in manufacturing (4.8 per thousand in employment). Although productivity is higher in high value manufacturing than in medium value and low value manufacturing, it seems reasonable to expect that in the absence of skill shortages the productivity gap would be even greater, in that it is reasonable to expect that the constraint on productivity imposed by skill shortages would be greatest in high value manufacturing and lowest in low value manufacturing.

High value manufacturing aside (where productivity growth has been negative in the period 2009-2014, as outlined above), Figure 5.9 indicates that low value and medium value manufacturing have achieved productivity growth at levels similar to the economy as a whole, with a workforce that is slightly less well qualified. However, it should be borne in mind that it is the mix of skills – both higher academic qualifications and vocational skills, and how that mix aligns with a company's business strategy, that is of particular importance for productivity (Rincon Aznar et al., 2015).

Figure 5.9 Proportion of workforce who are highly qualified versus labour productivity growth, 2009-2014



Source: UKCES (Working Futures 5), ONS and Cambridge Econometrics (MDM-E3 database).

5.7 Conclusion

This chapter has provided an outline of various trends in the manufacturing sector that are relevant to productivity. There is a concern that investment has taken time to recover since the recession and also that skill shortages in certain professional and skilled trades occupations are longstanding. Training spend per employee is slightly lower than across the economy as a whole, although high value and medium value establishments are more likely than the UK average to have staff on apprenticeships. The evidence also suggests that shortcomings in management and leadership act as a brake on productivity. Manufacturing has lower scores on a range of training activity indicators compared with the UK economy average.

6 Conclusion: what can employers and public policy do?

Chapter Summary

- Leadership, management and development of skills aligned with product market strategies are essential to move up the value chain and to reap productivity enhancements.
- Employers' growth ambitions shape prospects for productivity increases.
- Industry 4.0 brings new challenges and opportunities for UK manufacturing, and highlights the importance of ICT skills.
- Employers need to invest in recruitment and retention of a broad mix of skills – not only those that are production-specific.
- But technical skills at high and intermediate levels remain important.
- Supportive public policy can help foster an environment conducive for fostering innovation and productivity increases.

6.1 The importance of manufacturing for innovation and productivity

Manufacturing is a key driver of UK productivity growth. It has been characterised by increasing productivity over the long-term, although growth stalled during the recession. The manufacturing sector is a major investor in R&D - with large firms and foreign firms playing a particularly important role.

Relative to other sectors, manufacturing has particular scope for increasing labour productivity by taking advantage of technology and substituting labour with machinery and by outsourcing low value elements of the production process. While production remains crucially important, developments in the nature of manufacturing mean than production is now a smaller component of a more complex chain, in which pre- and post-production activities have become more important. This means that, as in other sectors of the economy, process innovations, relating to deployment of resources within and across different elements of the value chain, are important also.

Manufacturing is diverse, encompassing a range of sub-sectors, of which three (defined in terms of technology intensity) have been considered here. There are variations within and between these sub-sectors. High technology intensive manufacturing and parts of medium technology intensive manufacturing in the UK shows what can be achieved – by aligning investment in training and skills development with high / very high product market strategies. But the UK has a 'long tail' of low value manufacturing establishments – especially in small and medium-size categories.

As outlined below, management, leadership and development of skills aligned with product market strategies are essential to move up the value chain. It is also important that UK manufacturing takes advantage of developments associated with Industry 4.0. Public policy can play a supportive role here.

6.2 The significance of product markets and of leadership and management

Product market strategies are of key importance in understanding the investment decisions and behaviour of firms and in shaping how productivity gains take place. To succeed employers need to adapt their product strategies according to the segment of the market in which they operate.

In manufacturing large employers engaged in mass production have typically used automated production processes that lend them substantial economies of scale. By contrast small employers may have production processes and/or niche products which are less conducive to large scale mass production, and/or which are geared to local markets. Some employers in the latter category have managed to achieve productivity improvements by limiting labour costs (i.e. relying on cheap labour), whereas others have invested in further development of niche products and/or extending markets for them.

Given the diversity of manufacturing these examples are necessarily overly simplistic, but they underline the importance of employers' growth ambitions for innovation and internationalisation, and so for productivity gains. They also indicate that leadership and management has a key role to play in upgrading productivity performance in manufacturing. The evidence presented in previous sections has suggested that shortcomings in leadership and management contribute to underperformance – particularly in mid-sized companies.

6.3 The changing nature of manufacturing: positioning to take advantage of Industry 4.0 developments

Industry 4.0 (sometimes known as 'The Internet of Things') marks an important change in the nature of manufacturing. In essence Industry 4.0 is about digital facilitation of communication between suppliers, producers, consumers and applications. It highlights the importance of vertical networking, horizontal integration (enabling greater geographical reach), through engineering of inputs and outputs in a circular economy, and the catalytic role of exponential technologies in enabling greater customisation. Together these developments can enhance competitiveness.

Taking advantage of Industry 4.0 developments means reaping productivity gains of big data and smart utilisation of supplier and customer data.

6.4 What this means for employers' investment in and utilisation of skills

The developments outlined above have a range of implications for skills:

- more complex value chains – in which pre- and post-production activities are ever more important – means that the manufacturing sector needs to draw on a broader mix of skills than formerly
- yet because production remains the central element in the value chain there is an ongoing need for manufacturing, engineering and STEM skills – at higher and intermediate levels
- individuals with STEM skills are in demand from other sectors as well as manufacturing, so this suggests that employers need to make an ongoing commitment to STEM initiatives and to attract recruits to manufacturing from schools, colleges, universities and other sectors, including through developing links with these educational institutions and through careers service providers
- employers need to invest in their workers and find ways of retaining them (this might mean investing in the development and promotion of career pathways and/or job redesign and/or changing workplace practices)

- although high value and medium value manufacturing employers have higher than average proportions of staff currently on apprenticeships they need to maintain and grow their commitment to apprenticeships (as and where appropriate) and to invest in development of routeways from apprenticeships to higher level qualifications
- digitisation and Industry 4.0 developments highlight the importance of a blend of technical, engineering, manufacturing, ICT, software development, data analytics, creative, design and management skills in manufacturing, and so this means not only employers needing to reach out to a wider labour pool, but also to find means of developing the hybrid skills required internally and through co-design of training courses with education and training providers
- investment in leadership and management skills is crucial, particularly given that strong leadership teams and distributed leaders in key positions throughout manufacturing companies are likely to become more important in future
- to maximise productivity increases manufacturing firms need to learn how (better) to optimise their workplaces and processes to take best advantage of highly skilled and highly productive workers; managers need to demonstrate agility in mixing and utilising skills of workers as appropriate to meet strategic needs - a stronger focus on workplace / employment relations might be helpful here in enabling inputs from a bottom-up approach to increasing productivity.

6.5 Supportive public policies

Alongside actions that employers can take there is space for public policy to play a stronger role in levering decisions that might lead to higher productivity. Foresight (2013) highlighted the importance of 'industrial commons' (i.e. the embedded knowledge and technology framework that enhances the efficiency, effectiveness and productivity of the proprietary capital and labour that use it). Examples include:

- investment in Catapult Centres set up to promote R&D, innovation through business led collaboration between scientists, engineers and market opportunities
- ensuring the availability of local arenas for local collaboration to develop new products

- Industrial Partnerships – bring together employers across an industrial sectors to lead development of skills with emphasis on growth and competitiveness.

More generically public policy (see OECD, 2015) can play a role through fostering:

- experimentation with *new* knowledge and technologies – through national innovation policies (including investment in basic and applied research, R&D fiscal incentives), international co-ordination of innovation policy, and framework policies (e.g. on product market regulation)
- diffusion of *existing* knowledge and technologies – through and framework policies (e.g. on product market regulation) and R&D policies between firms and universities
- efficient resource allocation (capital, labour, skills) and supply of skills – through channelling resources to the most productive and innovative firms (e.g. higher returns to commercialisation and implementation of new ideas, lowering the cost of business failure and encouraging risk taking), and housing policies (to help lower geographical skill mismatch).

The foregoing discussion points to the variety of means in place to develop skills in the manufacturing sector. It remains the case that the development of many key skill sets are costly to produce – for either the individual (foregone earnings whilst training) and the employer (where the cost of training far exceeds the productive capacity of the trainee or apprentice). So long as some skill sets remain costly to produce, and where the employer is concerned about appropriating the returns on the training investment to produce those skills, then skills demand will tend to exceed supply. This can quickly become a vicious circle. Programmes such as employer ownership of skills and employer routed funding have the capacity to reduce the risk associated with employers making investments in skills. It remains the case that employers need to be centrally involved in the production of the skills they need. In some sectors, especially in the high and medium value segments of manufacturing, the pace at which skill development takes place is such that the supply side is constantly trying to keep up. Hence the relatively high levels of skill shortages that high performers experience. Without involvement of the employer then the likelihood is that skills supply will not adequately meet current skill demand.

6.6 Conclusion

Leadership, management and development of skills aligned with ambitious product market strategies are essential to move up the value chain and to reap productivity enhancements. Industry 4.0 brings new challenges and opportunities for UK manufacturing. In particular, it highlights the importance of ICT skills and investment in the IT and telecommunications infrastructure. To enable them to further develop their current strategic objectives and develop new strategies, ambitious employers need to invest in recruitment, retention and replenishment of a broad mix of skills – not only those that are production-specific – albeit technical skills at high and intermediate levels remain centrally important. More generically, supportive public policy can help foster an environment conducive for fostering innovation and productivity increases.

Bibliography

Arup (2013) 'The future of manufacturing: international perspectives - workshop report', *Future of Manufacturing Project: Evidence Paper 1*, Foresight, Government Office for Science, London.

Baldwin R. and Evenett S. (2012) 'Value Creation and Trade in 21st Century Manufacturing: What Policies for UK Manufacturing?' in Greenaway D. (ed), *The UK in a Global World: How can the UK focus on steps in global value chains that really add value?*, CEPR, London

Barnett A., Batten S., Chiu A., Franklin J. and Sebastiá-Barriel M. (2014). 'The UK productivity puzzle', *Bank of England Quarterly Bulletin*, 54 (2).

Baumol W.J. and Bowen W.G. (1966), *Performing Arts: The Economic Dilemma*, The Twentieth Century Fund: New York.

Bloom N., Van Reenan J., Lemos R., Sadun R. and Qi M. (2011) 'Constraints on developing UK management practices', *BIS Research Paper* 58.

Deloitte (2014) *Industry 4.0 – Challenges and solutions for the digital transformation and use of exponential technologies* - http://www2.deloitte.com/content/dam/Deloitte/ch/Documents/manufacturing/ch-en-manufacturing-industry-4-0-24102014.pdf

Dolphin T. and Hatfield I. (2015) *Missing Pieces: Solving the Productivity Puzzle.* IPPR, London.

EEF (2014) *Developing innovation support for the success of manufacturing and its supply chain*, EEF, London.

Eichengreen B. (2014) *Secular stagnation: A review of the issues*. Centre for Economic Policy Research, London.

Foresight (2013) The Future of Manufacturing: A new era of opportunity and challenge for the UK Project Report. The Government Office for Science, London.

Gambin L., C. Hasluck and Hogarth T. (2010) 'Recouping the costs of apprenticeship training: employer case study evidence from England', Empirical Research in Vocational Education and Training, Vol. 2,No.r 2, pp. 127-146(20)

Gambin L. and Hogarth T. (2016) *Employer Investment in Intermediate Level STEM skills: how employers manage the investment and risk associated with Apprenticeships*, Gatsby Foundation, London.

Gordon R. (2012), "Is US Economic Growth Over? Faltering Innovation Confronts the Six Headwinds", NBER Working Paper No. 18315.

Hogarth T., Adams L., Gambin L., Garnett E., and Winterbotham M. (2014) 'Employer Routed Funding: Employer Responses to Funding Reform', *BIS Research Paper* 161, Department for Business, Innovation and Skills, London.

Homkes R. (2014) 'What role will leadership play in driving the future of UK manufacturing?', *Future of Manufacturing Project: Evidence Paper* 15, Foresight, Government Office for Science, London.

Infosys (2015) *Industry 4.0 The State of Nations,* Infosys Ltd, Bangalore, India.

Mason G., Holland D., Liadze I., O'Mahoney M., Riley R. and Rincon-Aznar A. (2014) 'Macroeconomic benefits of vocational education and training', *Cedefop Research Paper* 40.

Mayhew K. and Keep E. (2014) *Industrial strategy and the future of skills policy – the high road to sustainable growth,* CIPD, London.

McLaughlin P. (2013) 'Manufacturing best practice and productivity', *Future of Manufacturing Project: Evidence Paper 21*, Foresight, Government Office for Science, London.

Mokyr J (2014). 'The Next Age of Invention: Technology's Future is Brighter than Pessimists Allow', *City Journal* (Winter): 12-20.

Moore T. and Folkerson M. (2105) *Industrial Evolution: Making British manufacturing sustainable,* Manufacturing Commission, London.

OECD (2015). *The Future of Productivity*, OECD Publishing, Paris.

ONS (2015a). *Labour Productivity: Q2 2015*. London: Office of National Statistic, London.

ONS (2015b). *Labour Productivity: Q4 2014*. Office of National Statistics, London.

Rhodes C. (2015) 'Manufacturing: statistics and policy', *House of Commons Briefing Paper* 01942. , www.parliament.uk.

Rincon Aznar A., Forth J., Mason G., O'Mahoney M. and Bernini M. (2015) 'UK skills and productivity in an international context', *BIS Research Paper* 262.

Roper S. and Malshe A. (2012) *Leading from the Middle: The Untold Story of British Business*, GE Capital, London.

Song B., Kouka M., Gautum P.K., Hussain S.M.F. (2014) *Analysis of UK Manufacturing: Productivity,* University of Cranfield, Cranfield.

Summers L. (2014), 'U.S. Economic Prospects: Secular Stagnation, Hysteresis, and the Zero Lower Bound', *Business Economics*, 49(2).

The Royal Bank of Scotland (2012) *The future of UK high value engineering.* http://www.rbs.co.uk/corporate/insight/g4/future-hve.ashx

Thomas A.J., Byard P. and Evans R. (2012) 'Identifying the UK's manufacturing challenges as a benchmark for future growth', *Journal of Manufacturing Technology Management* 23(2), 142-156.

UK Commission for Employment and Skills (2015) *Growth through people: evidence and analysis,* UK Commission for Employment and Skills, Wath-upon-Dearne.

Winterbotham M., Vivian D., Shury J. and Davies B. (2014) 'UK Commission's Employer Skills Survey 2013: UK Results', *Evidence Report* 81*,* UK Commission for Employment and Skills, Wath-upon-Dearne.

Wright M. (2014) *Making the UK a globally competitive investment environment. The Wright Review of advanced manufacturing in the UK and its supply chain.* www.thewrightreport.net