



Government
Office for Science

 Foresight

THE FUTURE OF MANUFACTURING:

**A NEW ERA OF OPPORTUNITY
AND CHALLENGE FOR THE UK**

PROJECT REPORT

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THIS REPORT IS INTENDED FOR:

Policy-makers, legislators, a wide range of business people, and the professionals and researchers whose interests relate to the manufacturing sector. This Report focuses on manufacturing as a whole with a particular emphasis on the United Kingdom.

The Government Office for Science would like to thank the Project's Lead Expert Group who oversaw the technical aspects of the Project and were particularly involved in writing this Final Report. They were led by Sir Richard Lapthorne, and are Professor Nicholas Crafts, Professor Steve Evans, Professor Anne Green, Professor Richard Harris, Professor Alan Hughes, Professor Chris Lowe, Dr Hamid Mughal, and Professor Sir Michael Sterling.

Particular thanks are also due to the Project's High Level Stakeholder Group which was chaired by the Rt. Hon. Vince Cable MP (the Secretary of State for Business, Innovation and Skills) and the many officials, experts and stakeholders from the UK and around the world who contributed to the work of this Project, who reviewed the many Project reports and papers, and who generously provided advice and guidance.

The Foresight project team was led by Paul McCaffrey and also included Michael Andrea, Tomasz Ciuksza, Emily Eakins, Derek Flynn, Sejal Mahida, Lucy Martin, Chris Miles, Moh Shabier, Professor Sandy Thomas and Emma Tredgett.

The Foresight Programme in the UK Government Office for Science is under the direction of the Chief Scientific Adviser to HM Government. Foresight strengthens strategic policy-making in Government by embedding a futures approach.

The contents of this Report do not represent the views or policy of the UK or any other government.

A NEW VISION FOR UK MANUFACTURING

Manufacturing in 2050 will look very different from today, and will be virtually unrecognisable from that of 30 years ago. Successful firms will be capable of rapidly adapting their physical and intellectual infrastructures to exploit changes in technology as manufacturing becomes faster, more responsive to changing global markets and closer to customers.

Successful firms will also harness a wider skills base, with highly qualified leaders and managers whose expertise combines both commercial and technical acumen, typically in science, technology, engineering or mathematics.

Constant adaptability will pervade all aspects of manufacturing, from research and development to innovation, production processes, supplier and customer interdependencies, and lifetime product maintenance and repair. Products and processes will be sustainable, with built-in reuse, remanufacturing and recycling for products reaching the end of their useful lives. Closed loop systems will be used to eliminate energy and water waste and to recycle physical waste.

These developments will further emphasise the key role of physical production in unlocking innovative new revenue streams, particularly as firms embrace 'servitisation' and manufacturers make use of the increasing pervasiveness of 'Big Data' to enhance their competitiveness.

In the public sector, policy frameworks that affect the manufacturing sector directly and indirectly will need to recognise the extended nature of value creation and the new ways it is being developed. Public planning cycles should match the timescales of firms' own long term planning requirements. And it will be important that flows of highly skilled workers, patient capital, and support to promote critical mass in small and medium sized enterprises are all internationally competitive.

The implications for UK manufacturing firms and the UK Government are substantial. Some businesses are already adapting and are world class, but many are not positioned to succeed in a future world where

greater opportunities will be balanced by greater competition. The UK needs to radically change its approach to providing a constant and consistent framework within which all firms aspire to prosper.

A business-as-usual approach will not deliver that outcome. Other economies are already ahead, and catching up will require an adaptive capacity that the UK has not yet demonstrated. Achieving this is essential, as the future competitiveness and health of UK manufacturing will affect many other parts of the economy through its numerous linkages.

The key message is that there is no easy or immediate route to success, but action needs to start now to build on existing support, and to refocus and rebalance it for the future. Above all, policy design will need to address entire system effects. This Report sets out many areas where action is needed at both strategic and more detailed levels. However, the following should be particular priorities.

The quality and skills of the workforce will be a critical factor in capturing competitive advantage. It is essential that UK policy makers focus on the supply of skilled workers, including apprenticeship schemes, support for researchers, and the supply of skilled managers. Firms will need to pay much more attention to building multidisciplinary teams to develop increasingly complex products, and also innovative business models.

It will also be crucial to address the current image associated with manufacturing. Here government and industry should work together to further promote and market the opportunities for careers in manufacturing industries at all levels of education.

Financial challenges for the sector include a shortage of risk capital. This is particularly evident as a funding gap between research and early development and the funding for proof of concept that is usually required before the market steps in. There is also a shortage of funding for applied research and development in some areas such as the development of advanced green energy sources. So although there are excellent schemes for public support such as Knowledge

Transfer Partnerships, funding of the Technology Strategy Board, and public private partnerships such as the Energy Technologies Institute, these are much smaller than in competitor nations. Addressing this mismatch should be a priority.

Recent years have seen a resurgence in the development of industrial policies by governments in the UK and overseas. In the UK, industrial policies have been developed in 11 sectors, led in most cases by groups from the public and private sectors, with many of these encompassing manufacturing industries. One specific development has been the creation of the Catapult Centres. In particular, the High Value Manufacturing Catapult provides a strong base on which to build substantial further effort. It is recommended that its funding is substantially increased, and used in part to encourage the greater involvement of smaller firms in particular.

Whilst specific initiatives are essential in areas mentioned above, more is needed. Recognition that the UK's national infrastructure suffered from fragmented policy making led to the creation of Infrastructure UK (IUK). Manufacturing suffers from similar challenges and is no less strategic for the future strength and resilience of the UK economy. The Lead Expert Group of this Foresight Project considers that a similar office to the IUK is needed for Manufacturing. This would be responsible for helping Government to formulate long-term policies that would take into account the extended value chain associated with manufacturing industries.

It should be staffed by experts, preferably with substantial successful industry experience. They would consider all of the issues highlighted in this Report, and develop and assist Government with piloting new policies. A UK Office for Manufacturing would need to work closely with IUK, in view of the importance of infrastructure to manufacturing. It would also need to work closely with industry, particularly to improve skills and increase the ability of companies to innovate by working with relevant partners. Other countries including the United States and Australia have developed relevant offices from which the UK can learn.

In summary, manufacturing is too important to leave to its own devices. The Lead Expert Group for this project, comprising Academic and Industry leaders commend this Report to Government, together with its associated analysis and evidence underpinning its conclusions.



Sir Richard Laphorne
Chair, Project Lead Expert Group

A handwritten signature in white ink on a purple background, reading "Richard Laphorne".



Sir Mark Walport
Government Chief Scientific Adviser

A handwritten signature in white ink on a purple background, reading "Mark Walport".

PREFACE

It is surely unique in Europe, if not globally, for a Government to commission a strategic look at the future of manufacturing as far ahead as 2050.

This report – involving some 300 leading business people, experts and policy makers from 25 countries – sets out a vision of manufacturing that is very different to what we recognise today. Clearly, both industry and Government need to prepare for what will be considerable opportunities and challenges ahead.

The importance of manufacturing to the UK economy, as set out here, is incontrovertible. Manufacturing is no longer just about production, it is a much wider set of activities that create value for the UK and benefits for wider society. Manufacturing includes significant innovation. It creates jobs that are both highly skilled and well paid. It also contributes to the rebalancing of the economy, with its strong role on exports and import substitutions.

Through the Government's industrial strategy we are already working with business on long-range plans to strengthen advanced manufacturing sectors such as automobiles, aerospace, life sciences and energy supply chains. We are developing the UK's ability to commercialise new technology and expand our skills base.

There are many UK manufacturing firms that are world class. Indeed, manufacturing leads other sectors in many areas, including productivity, exports and research and development. There is no room for complacency, however.

The analysis and advice contained in this report will help Government to take its support for manufacturing to another level. My officials will be working with the project experts to work out next steps. I look forward to seeing how their conclusions help Government and industry to harness the full potential of UK manufacturing.



The Rt. Hon. Vince Cable MP
Secretary of State for Business, Innovation and Skills





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SUMMARY REPORT

1. MANUFACTURING MATTERS

Manufacturing is essential for long term economic growth and economic resilience. However, many of its characteristics are changing profoundly. Physical production processes are increasingly at the centre of much wider value chains.

A POWERFUL CONTRIBUTION TO THE UK ECONOMY

Manufacturing is and must continue to be an essential part of the UK economy. Its benefits include:

- **Absolute value:** The contribution of manufacturing to UK Gross Domestic Product (£139 billion in 2012) is still significant¹ and increasing over the long term².
- **Research and Development (R&D):** Manufacturing businesses are more likely to engage in R&D. 41% of manufacturing businesses with ten or more employees allocated resources to R&D in 2010 compared with an average of 23% of businesses in other sectors. Throughout 2000-2011, 72%-79% of total UK business R&D expenditure was associated with manufacturing³.
- **Innovation:** Manufacturers are more likely to innovate. In 2010, 26% of manufacturing businesses with ten or more employees carried out process innovation compared with less than 14% for non-manufacturers, and 44% undertook product innovation (less than 26% for non-manufacturers)⁴.
- **Productivity:** The growth in total factor productivity¹ for manufacturing has been 2.3% per year between 1980 and 2009, compared with 0.7% per year for the UK as a whole⁵.

¹Total Factor Productivity (TFP) is defined as the increase in output that is not due to an increase in the direct inputs used to produce goods and services (i.e. labour, physical capital and intermediate inputs). Rather it is the more efficient use of these inputs.

- **Exports:** Manufacturing businesses are more likely to engage in exporting. UK exports of goods produced by the manufacturing sector totalled £256 billion in 2012, accounting for around 53% of all UK exports⁶. In 2010, 60% of manufacturing businesses with ten or more employees exported products and services compared with 26% of non-manufacturers⁷.
- **Highly skilled jobs:** In 2011, remuneration in UK manufacturing was 10% higher in comparable occupations compared with the average across all industries⁸, reflecting the high levels of skills required in modern manufacturing roles.
- **Inter-industry linkages:** Manufacturing performance affects other sectors through its wide range of input-output and other linkages⁹.
- **Economic resilience:** Economies with strong, export-led manufacturing sectors typically recover from recessions faster than those without equivalent manufacturing sectors¹⁰.

A DIVERSE SECTOR WITH A CONTEXT OF HISTORICAL SHIFTS

The UK manufacturing sector is diverse, with activities ranging from aerospace, pharmaceuticals, chemicals and automotives to food and drink. It is characterised by a wide range of sizes of firm, with a disproportionate share of activity accounted for by a small number of large, often foreign owned multinational companies. Although most firms are small, with 87% of firms employing less than 20 employees in 2009, large firms generate most of the value added and dominate R&D expenditure. For example, firms with 250 or more employees created 88% of the total gross value in 2009¹¹ and the largest 10 R&D performers alone accounted for over a third of all manufacturing R&D.

However, in recent years, the relative share of manufacturing in the UK economy has declined more rapidly than in other developed economies (Figure 1¹²) while the service sector has grown at a faster rate. This growth of the service sector in the UK is consistent with growth in other developed economies¹³ including France and the US. This 'deindustrialisation' has also applied to UK manufacturing employment, with numbers reducing

at a faster rate than in other developed economies, from close to nine million people in 1966 to below three million in 2011¹⁴.

VARIABLE PERFORMANCE RELATIVE TO INTERNATIONAL COMPETITORS

UK manufacturing performance has been weak relative to international competitors in some key areas:

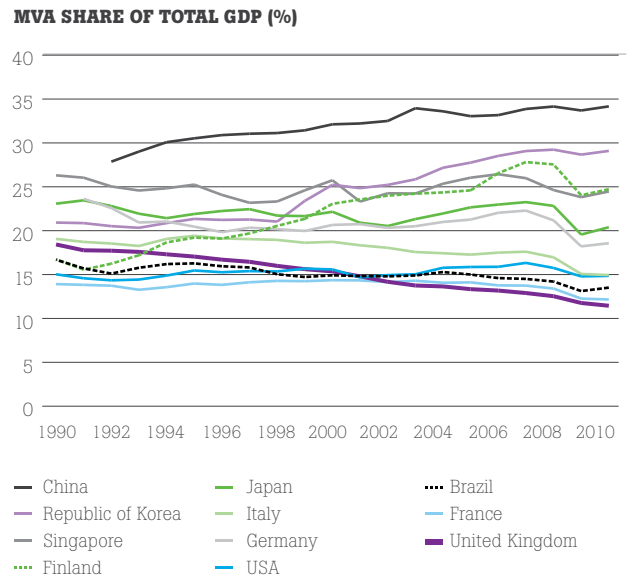
- Expenditure on manufacturing R&D has been low, especially with regard to new products.¹⁵
- The level of investment in capital equipment has been relatively low for many decades.¹⁶
- The UK's share of global manufacturing exports has fallen from 7.2% in 1980 to 2.9% in 2012¹⁷.

But there are also many outstanding individual firms, and some important areas of relatively strong performance for manufacturing as a whole:

- When total factor productivity is compared between the UK, the Netherlands, Spain, France, Italy and Germany, between 1980 and 2009, manufacturing performs best in the UK¹⁸.

- The fall in the UK's share of goods exports has been accompanied by an increase in export intensity (manufacturing exports as a proportion of manufacturing output), which rose from about 30% in 1991 to around 47% in 2011; which is similar to France and higher than the US¹⁹.

Figure 1: Manufacturing share of GDP 1990-2010



“ This study is unique within Europe both in terms of its scope and its time frame which looks out to the year 2050. It will help Nissan to tune its product offerings and production processes to better meet likely demographic and market trends. I am very encouraged by the efforts of the UK government to support manufacturing and this report builds on the excellent Automotive and Aerospace industrial strategies recently published by the Department for Business, Innovation and Skills.

John Martin

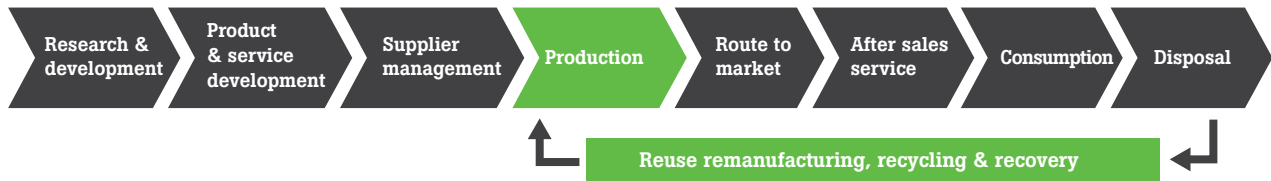
Senior Vice President – Manufacturing, Purchasing & Supply Chain Management
Nissan Motor Co. Ltd.

“ The Foresight report has done an excellent job of identifying what manufacturing brings to our economy and what it can contribute in the future. There are some clear messages for government on how it can ensure that UK manufacturing is well placed to take advantage of these opportunities, particularly in supporting the development of new technologies. It is also important that manufacturers use this report to look at how well prepared they are for the challenges facing them in the coming decades.

Terry Scuoler

Chief Executive, EEF

Figure 2: Simplified model of the manufacturing value chain



Note: Within this value chain some elements are repeated many times, for example as components come together to build a complex product. There are also feedback loops which may vary for different sub-sectors.

MANUFACTURING IS CHANGING PROFOUNDLY, CREATING MAJOR NEW SOURCES OF REVENUE AND VALUE BEYOND THE PRODUCTION AND SALE OF PRODUCTS

Manufacturing has traditionally been understood as the production process in which raw materials are transformed into physical products²⁰ through processes involving people and other resources. It is now clear that physical production is at the centre of a wider manufacturing value chain²¹. (Figure 2 and Box 1).

Manufacturers are increasingly using this wider value chain to generate new and additional revenue, with production playing a central role in allowing other value creating activities to occur. For example, 39% of UK manufacturers with more than 100 employees derived value from services related to their products in 2011, compared with 24% in 2007 (Figure 3)²⁵. This typically involves supporting or complementing products, and offering outcome or availability based contracts for products. Not all manufacturing firms report service revenue separately, and there is no requirement for them to do so. However, in 2009 Rolls Royce reported 49% of its revenue from services, and Arcelor Mittal reported 29%.

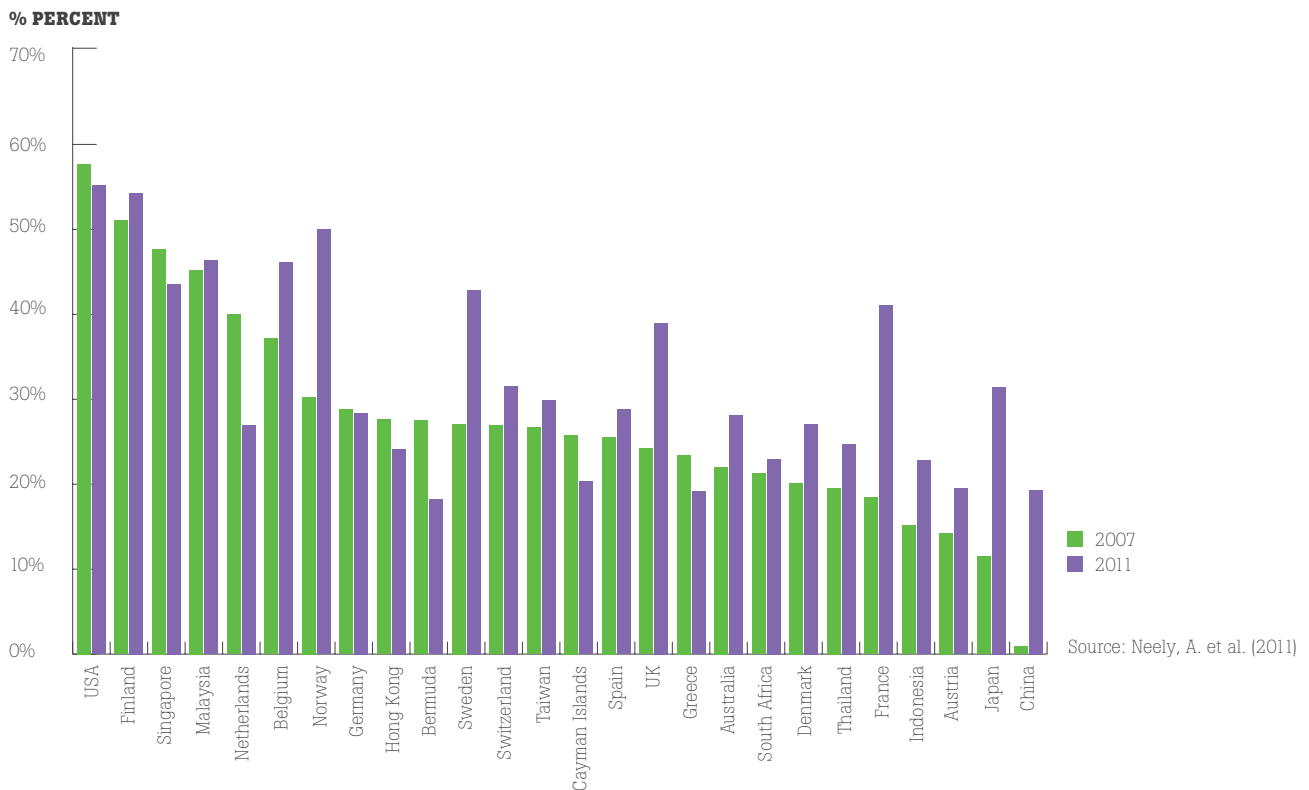
BOX 1: RECENT DEFINITIONS OF MANUFACTURING

'The new era of manufacturing will be marked by highly agile, networked enterprises that use information and analytics as skilfully as they employ talent and machinery to deliver products and services to diverse global markets' (McKinsey & Company, 2012)²².

'The application of leading-edge technical knowledge and expertise for the creation of products, production processes and associated services, which have strong potential to bring sustainable growth and high economic value to the UK. Activities may stretch from R&D at one end to recycling at the other' (Technology Strategy Board, 2012)²³.

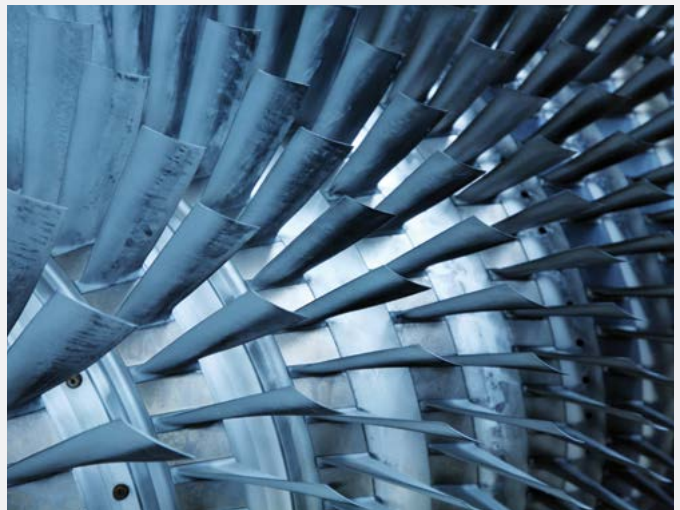
'The world is in the midst of a paradigm shift in the 21st century - one that integrates diverse sets of ideas, products and services globally through the lens of highly complex, integrated and self-morphing resource webs... Highly talented skilled people are necessary to effectively and consistently apply cutting edge science and technology, systems thinking, smart services and processes, and supply chain excellence' (Deloitte, 2013)²⁴.

Figure 3: Manufacturers offering services, 2007 & 2011 (100 or more employees)



New sources of revenue and of value creation will transform manufacturing business models over time. They will draw on new sources of knowledge and closer, long term relationships with customers. Future sources of revenue for manufacturers will include²⁶:

- Increasingly extensive packaging of services with products;
- New sources of information on how products are used, drawing on embedded sensors and open data;
- Becoming a 'factoryless goods producer', capturing value by selling technological knowledge and leaving production to others;
- Becoming a 'remanufacturer' with end of life products remanufactured and returned to original specifications or better;
- Targeting 'collaborative consumption', where no one customer owns a product outright;



- Creating value from new forms of (competitive) strategic alliance within and across sectors; and
- Exploiting new technologies more rapidly through greater operational capability coupled to entrepreneurial insight.

2. FOUR KEY FUTURE CHARACTERISTICS OF MANUFACTURING AND IMPLICATIONS FOR GOVERNMENT

Manufacturing is entering a dynamic new phase which will provide substantial opportunities for the UK. Looking ahead to 2050, this Foresight Project has identified four key future characteristics of manufacturing. They have significant implications for both Government and industry.

2.1. FASTER, MORE RESPONSIVE AND CLOSER TO CUSTOMERS

WHAT ARE THE LIKELY CHANGES?

Technology will play a central role in driving change. Some of the value being created in 2050 will derive from wholly unanticipated breakthroughs but many of the technologies that will transform manufacturing, such as additive manufacturing, are already established or clearly emerging. Table 1 summarises some of the most important pervasive and secondary technologies including ICT, sensors, advanced materials and robotics. When integrated into future products and networks, these will collectively facilitate fundamental shifts in how products are designed, made, offered and ultimately used by consumers.

Mass personalisation of low-cost products, on demand: The historic split between cheap mass-produced products creating value from economies of scale and more expensive customised products will be reduced across a wide range of product types. Technologies such as additive manufacturing, new materials, computer-controlled tools, biotechnology, and green chemistry will enable wholly new forms of personalisation. Direct customer input to design

will increasingly enable companies to produce customised products with the shorter cycle-times and lower costs associated with standardisation and mass production. The producer and the customer will share in the new value created. For example, research at the University of Loughborough shows that customers might be prepared to pay an additional 10% for some degree of personalisation²⁷. Customisation is a significant opportunity for UK manufacturers targeting both the domestic market and other developed economies.

Distributed production: We will see a transformation in the nature of production itself, driven by trends such as new forms of modelling and additive manufacturing through to nanotechnologies and advanced robotics. The factories of the future will be more varied, and more distributed than those of today (Figure 4). The production landscape will include capital intensive super factories producing complex products; reconfigurable units integrated with the fluid requirements of their supply chain partners; and local, mobile and domestic production sites for some products. Urban sites will become



Looking to the future, we recognise that transformational change is required and emerging technologies present an opportunity to create a paradigm shift, allowing us to manufacture medicines faster, greener and at a lower cost. Manufacturing has become increasingly critical in the pharmaceutical sector and will require more agility to respond to patient needs, more flexibility to bring production closer to customers, as well as increases in efficiency and sustainability. This will underpin high quality standards and ensure new medicines are affordable for patients around the world. The prize is significant and it is imperative that industry and Government work together to seize this opportunity and secure a leading position for the UK.

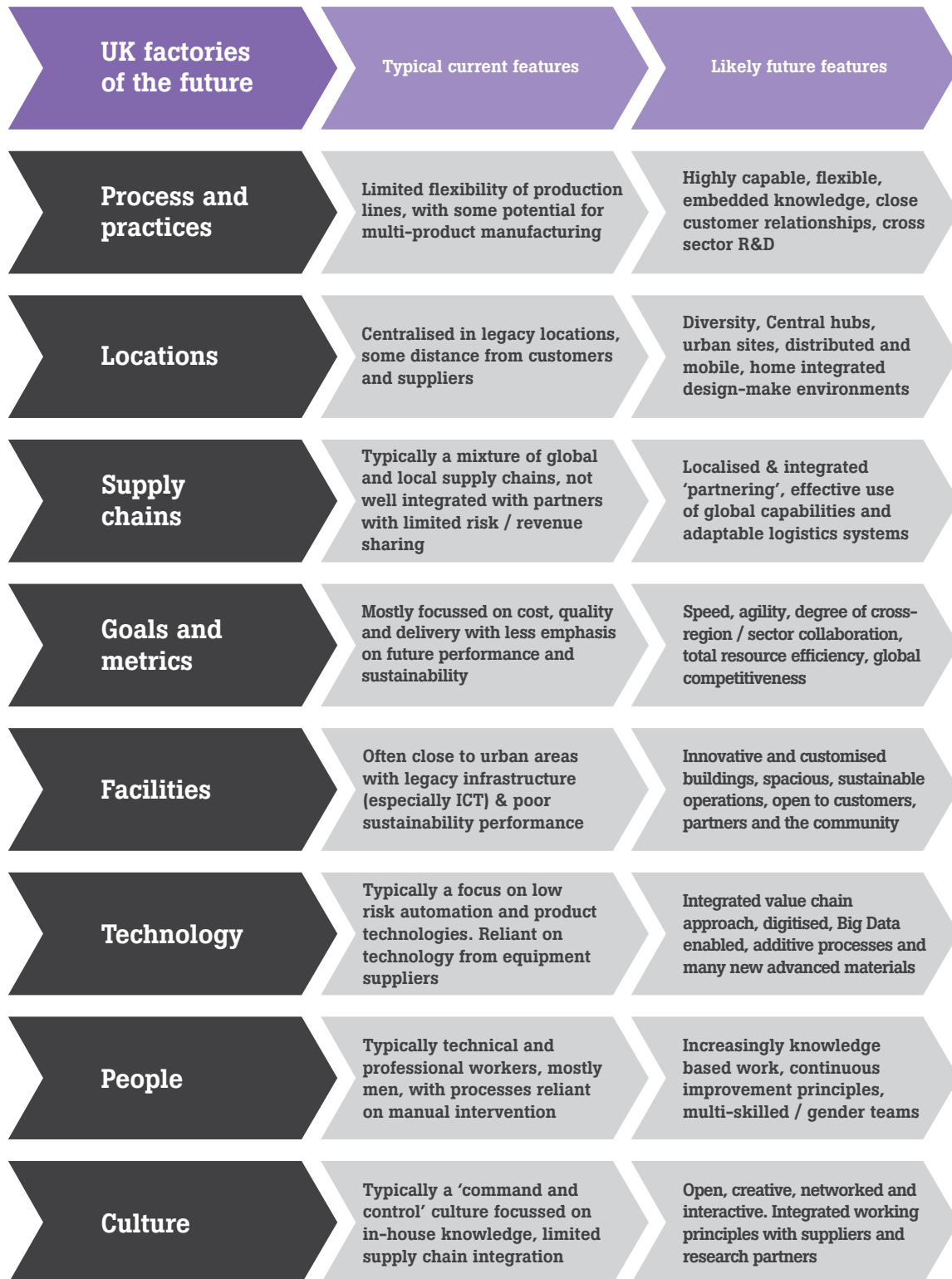
Roger Connor

President of Global Manufacturing and Supply, GlaxoSmithKline plc

Table 1: Important pervasive and secondary technologies for future manufacturing activities

PERVASIVE TECHNOLOGY	LIKELY FUTURE IMPACTS
Information and communications technology (ICT)	Modelling and simulation integrated into all design processes, together with virtual reality tools will allow complex products and processes to be assessed and optimised, with analysis of new data streams.
Sensors	The integration of sensors into networks of technology, such as products connected to the internet, will revolutionise manufacturing. New data streams from products will become available to support new services, enable self-checking inventories and products which self diagnose faults before failure, and reduced energy usage.
Advanced & functional materials	New materials, in which the UK has strong capabilities, will penetrate the mass market and will include reactive nanoparticles, lightweight composites, self-healing materials, carbon nanotubes, biomaterials and 'intelligent' materials providing user feedback.
Biotechnology	The range of biotechnology products is likely to increase, with greater use of fields of biology by industry. There is potential for new disease treatment strategies, bedside manufacturing of personalised drugs, personalised organ fabrication, wide availability of engineered leather and meat, and sustainable production of fuel and chemicals.
Sustainable / green technologies	These will be used to reduce the resources used in production including energy and water; produce clean energy technologies, and deliver improved environmental performance of products. Minimising the use of hazardous substances.
SECONDARY TECHNOLOGY	
Big data and knowledge based automation	These will be important in the on-going automation of many tasks that formerly required people. In addition, the volume and detail of information captured by businesses and the rise of multimedia, social media and the internet of things will fuel future increases in data, allowing firms to understand customer preferences and personalise products.
Internet of things	There is potential for major impacts in terms of business optimisation, resource management, energy minimisation, and remote healthcare. In factory and process environments, virtually everything is expected to be connected via central networks. Increasingly, new products will have embedded sensors and become autonomous.
Advanced and autonomous robotics	Advances are likely to make many routine manufacturing operations obsolete, including: healthcare and surgery, food preparation and cleaning activities. Autonomous and near-autonomous vehicles will boost the development of computer vision, sensors including radar and GPS, and remote control algorithms. 3D measurement and vision will be able to adapt to conditions, and track human gestures.
Additive manufacturing (also known as 3D printing)	This is expected to have a profound impact on the way manufacturers make almost any product. It will become an essential 'tool' allowing designs to be optimised to reduce waste; products to be made as light as possible; inventories of spare parts to be reduced; greater flexibility in the location of manufacturing; products to be personalised to consumers; consumers to make some of their own products; and products to be made with new graded composition and bespoke properties.
Cloud computing	Computerised manufacturing execution systems (MES) will work increasingly in real time to enable the control of multiple elements of the production process. Opportunities will be created for enhanced productivity, supply chain management, resource and material planning and customer relationship management.
Mobile internet	Smart phones and similar devices are positioned to become ubiquitous, general purpose tools for managing supply chains, assets, maintenance and production. They will allow functions such as directed advertising, remote healthcare and personalisation of products. Linked technologies include battery technology, low energy displays, user interfaces, nano-miniaturisation of electronics, and plastic electronics.

Figure 4: Likely features of factories of the future



common as factories reduce their environmental impacts²⁸. The factory of the future may be at the bedside, in the home, in the field in the office, and on the battlefield.

Digitised manufacturing value chains: Pervasive computing, advanced software and sensor technologies have much further to go in transforming value chains. They will improve customer relationship management, process control, product verification, logistics, product traceability and safety systems. They will enable greater design freedom through the uses of simulation, and they will create new ways to bring customers into design and suppliers into complex production processes.

WHAT ARE THE IMPLICATIONS FOR GOVERNMENT?

Improving the speed and co-ordination of the technology pipeline for UK manufacturing: Given the pace of change in technological developments and international competition, the UK needs to strengthen the extended system that identifies and supports new technologies and their applications. The UK's High Value Manufacturing (HVM) Catapult Centre, established in 2011, has a key role in the near term, and is an

example of a step that the Government has taken to develop a more systemic approach across research, innovation and industrial policy.

Immediate priorities should be to scale up funding for the HVM Catapult Centre, to promote much stronger involvement of small and medium enterprises in the member centres, and to enhance the role it plays in connecting academic expertise to industry. Longer term, there is potential for the Centre to support international collaboration between manufacturers, for example by establishing a presence in key emerging economies.

Greater leveraging of the UK's intellectual assets:

The UK's education system has considerable strengths relative to international competitors²⁹. However it files fewer patents than countries such as US, Japan and Germany³⁰. This suggests the UK is not leveraging its intellectual assets as much as it will need to in the future. For example, there needs to be a shift in the in balance of funding towards applied research and in its commercialisation. There also needs to be increased effort to identify key areas (such as sensors and additive manufacturing), to develop technology roadmaps, and to guide policy.



Protecting intellectual property, reducing counterfeiting and avoiding cyber-attacks: Digitisation increases the risks of objects being copied illegally. Technologies such as additive manufacturing may make it even harder to identify breaches²⁹. However, the same trends support innovation and new forms of value creation. Today's regulatory and policy frameworks need to be reappraised to ensure they achieve the best balance between openness and the rights and obligations of intellectual property ownership in this changing environment. They also need to consider what further action needs to be taken to address the threat of cyber-attack, which increasingly threatens information-rich products and services.

2.2. EXPOSED TO NEW MARKET OPPORTUNITIES

WHAT ARE THE LIKELY FUTURE TRENDS?

Patterns of global trade and investment will determine the relative importance of the countries to which the UK exports and from which it imports; the types of firms and sectors which will be involved in its trade; the future structure and performance of manufacturing within the overall Balance of Payments; the place of the UK in the global pattern of foreign direct investment (FDI) flows; and the conduct of R&D and investment in innovation.

Emergence of BRIC economies and the 'Next-11': BRIC economies (Brazil, Russia, India and China) are likely to become larger than the US by 2015 and the G7 by 2032. In addition, the 'N-11' economiesⁱⁱ are likely to become larger than the US and almost twice the size of the Euro area by 2050³¹. By value, UK is low down the global list of exporters to China (24th) and India (21st). The UK is the world's 10th largest goods exporter, with a 2.9% share of global manufacturing exports in 2012. However its share of imports to countries forecast to be in the top 30 economies by 2050 is generally disappointing and below this level³². The UK's relatively poor current placement in these markets will make it harder for it to benefit from their future growth.

ⁱⁱ Bangladesh, Egypt, Indonesia, Iran, Korea, Mexico, Nigeria, Pakistan, Philippines, Turkey and Vietnam.

Continued importance of US and Europe for UK manufacturing exports: The UK exported to 226 different countries or territories in 2010. The US was the most important destination, accounting for 13% by value. In 2012, EU markets accounted for about 54% of total export value, with BRIC exports at 8%.

High-tech likely to remain an area of UK advantage: At 4.7%, the UK's share of global high technology manufacturing exports is relatively strong. Current high-tech sectoral strengths include pharmaceuticals, aerospace, chemicals, and the automotive sector.

Changing levels of personal wealth, including larger and older populations in major markets: The global population with annual per capita expenditure between US\$3,650 and US\$36,500 (2005 prices), is estimated to more than double in size from 2 billion in 2012 to 5 billion in 2030³³. Asia's share of the group will rise from 30% to 64%. There will be 3 billion more people in the world by 2050³⁴ with 97% of population growth taking place in developing regions³⁵. Populations in some major markets are growing significantly older, with the Asia-Pacific region having the oldest (Japan) and largest (China)³⁶.

Risks to Foreign Direct Investment into Europe may affect the UK: The UK has been a major recipient of inward FDI for manufacturing and remains in a good position to attract an above-average share of FDI coming into Europe. However, FDI flows into Europe, as a proportion of total available FDI, are likely to reduce due to competition from BRIC and other emerging economies³⁷.

“ The international, 'industrial systems' view of manufacturing set out in this report points the way to creating and capturing value in a dynamic global economy. Meeting the implied challenges will require radical new approaches which cross traditional disciplinary and institutional boundaries.

Professor Sir Mike Gregory
Head of the Institute for Manufacturing
University of Cambridge

Continued global fragmentation of the value chain:

Fragmentation includes the outsourcing of functions and offshoring. It is driven by factors such as the costs and quality of labour and transport, security of provision, the opportunities created by trade liberalisation; the availability of data and information; and the integration of suppliers into product development processes. Many manufacturing value chains are likely to continue to fragment, with the operation of supply chains playing a major role in determining future changes³⁸.

Some onshoring of production back to the UK:

Onshoring (or 'reshoring') is a recent trend typically involving the repatriation of production from low cost locations; investment in onshore production to enhance capability; and sourcing of components from onshore, rather than from overseas. This is typically in response to changing labour costs, higher transport costs, a need to be closer to the market, product quality concerns, and advantages of co-locating R&D and production³⁹. There is little robust evidence about the scale of this trend so far (see Box 2 for illustrations)⁴⁰. However, some underlying trends suggest it will become increasingly possible for the UK to compete with lower cost locations, on quality, delivery speed and customisation.

“ The quickest-acting and highest-octane fuel for growth in any economy, is a blisteringly strong export performance. The challenge for UK manufacturing is to recognise what things we're especially good at, embrace them and drive them forward, by investing time, money and skills in them. We should acknowledge our strengths, and play to them.

Sir Richard Olver
Chairman, BAE Systems plc

Increasing foreign ownership: If current trends continue, the foreign-owned manufacturing sector within the UK will account for a larger share of output (by 2020), GVA and employment (by 2015) than the UK-owned sector⁴¹. The presence of multinational corporations (MNCs) will continue to help improve the performance of the UK's largest firms, but the detail of the effects depends on the investment and production strategies of MNCs.

BOX 2: EXAMPLES OF UK ONSHORING

John Lewis plc: During July 2013⁴², the retailer emphasised its commitment to increasing sales of products manufactured in the UK by announcing a two-year 15 per cent growth target for all sales of goods in its shops that are made in the UK. In addition, it has increased its number of UK suppliers from 132 in 2012 to 207 in 2013.

Hornby plc: In November 2012⁴³ the UK model maker decided to return the production of 60% of its model paint brand, Humbrol, from China to the UK. This decision was taken to improve supply, and ensure high quality standards continue to be met, but from an easier location nearer to the Margate Head Office.

Laxtons Ltd: This spinning company, established in 1907, is now a design-driven yarn manufacturer. Like many British textile companies, production was offshored, but it has now returned to Yorkshire, reducing the firm's carbon footprint and lead times and increasing its control over quality and raw materials.

Bathrooms.com: In July 2013⁴⁴, the online bathroom specialist confirmed that it was handing 50% of the contracts currently held by Chinese manufacturers to UK businesses in the Midlands, to decrease the time taken from design through to production from four to six months to six weeks.

Marks & Spencer plc: In October 2013⁴⁵, the retailer launched its Best of British collection selling womenswear and menswear collections which emphasise British craftsmanship and quality, which feature a combination of British heritage, sourcing and production. This was part of a three-year deal with the British Fashion Council to support domestic talent and increase its sourcing from the UK.

WHAT ARE THE IMPLICATIONS FOR GOVERNMENT?

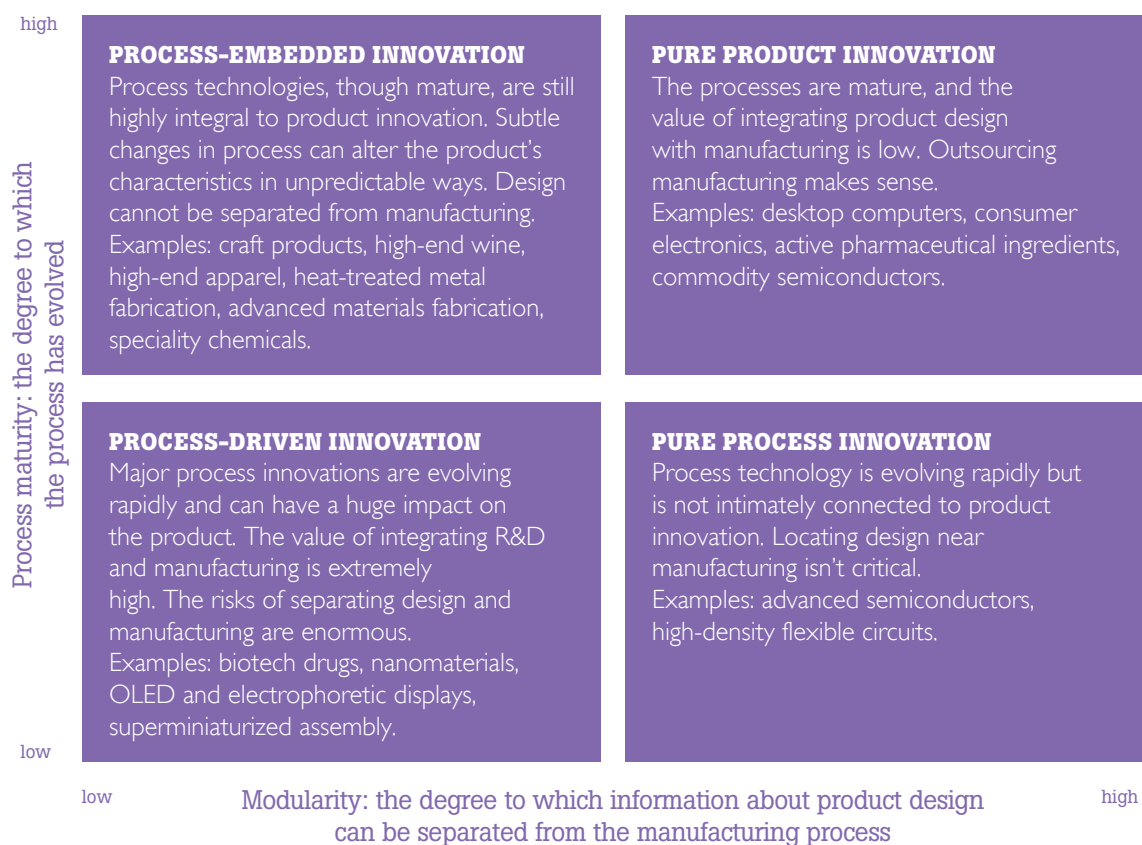
Enabling UK manufacturers to control global value chains: As manufacturing value chains continue to fragment globally, and new business models such as manufacturing services continue to develop, it will become increasingly important for manufacturers to create and operate value chains to maximise revenues⁴⁶. Government action in support of this needs to be agile and outward looking, and informed by a common view of developments which draws upon intelligence from BIS, Research Councils and the Technology Strategy Board. A recent example of such action is a funding competition launched by the Technology Strategy Board this year; this supports feasibility studies into new business models which in turn promote innovations in high value manufacturing⁴⁷.

Promoting co-location of R&D with production to maintain and build an 'industrial commons'ⁱⁱⁱ Products dependent on process-driven innovation, such as some drugs, nano-materials and some electronics applications benefit from the co-location of different parts of their production systems (Figure 5)⁴⁸. Government has a major role to play, nationally and locally, in encouraging greater agglomeration and clustering of particular activities, including encouraging co-location of production alongside research and development.

ⁱⁱⁱIndustrial commons: The embedded knowledge and technology framework that enhances the efficiency, effectiveness, and productivity of the proprietary capital and labour that use it.

Raising the UK's export performance, particularly to emerging economies: Products win export markets when they deliver value, rarity, and possess hard-to-imitate attributes⁴⁹. Most exporting is done by firms with relatively high levels of productivity, so

Figure 5: Product design/production and relationship to process maturity



Source: Pisano & Shih (2012)

measures to raise this, for example by improving the quality of leadership and management, will be key. The role of UK Trade and Investment (UKTI) will also continue to be important and should be strengthened in markets offering the best potential for export growth. This includes the provision of advice and market-based intelligence to companies seeking to increase their exports or enter new markets, and support to businesses once they are operating in a market, for example in areas of language and culture. Beyond these measures, there is a need to understand much better what prevents the UK from having more exporting 'superstars' - firms which export ten or more products to ten or more destinations.

Identifying 'phoenix' industries emerging from previous manufacturing activities: Established industrial regions typically possess important legacy assets such as specialised engineering skills, pre-existing personal networks, technical skills, and market knowledge⁵⁰. National and local policy-makers will need to develop new mechanisms to identify and exploit these legacies to support phoenix industries, such as small and medium-sized firms specialising in the production of high value sophisticated components for equipment manufacturers. Success will depend on strong

local alliances, such as those behind specialised training and research programmes run by Sheffield University⁵¹ and other universities.

Keeping the UK attractive to manufacturing FDI:

Three attributes that make the UK attractive to overseas investors include quality of life, culture and language; the stable political environment; and technology and infrastructure⁵². Priorities for attracting future FDI for manufacturing include the provision of high quality e-infrastructure and physical infrastructure (roads⁵³, in particular).

Ensuring a supply of patient capital: UK capital markets are characterised by an arms-length relationship between the providers and users of finance. An emphasis on short term returns by investors leads to management focus on short-term movements in stock market prices, and the threat of takeover, with long term investment in new capital equipment, skills and training and R&D spend inhibited. These effects are damaging for manufacturing, which requires relatively high long term investment in terms of new capital equipment, R&D and skills⁵⁴. The institutional architecture which encourages impatience in corporate governance and the capital market must be addressed to support future UK manufacturing competitiveness.



2.3 MORE SUSTAINABLE

WHAT ARE THE LIKELY FUTURE TRENDS?

Participants at the project's international workshops repeatedly emphasised the profound changes that environmental sustainability^{iv} will have on production processes over the next four decades. Figure 6 outlines these in three broad phases.

^{iv}The terms 'sustainable manufacturing' and the 'drive towards sustainability' are frequently used in the Foresight work. The definition of sustainability adopted here is that described in the widely cited Brundtland Report: 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.

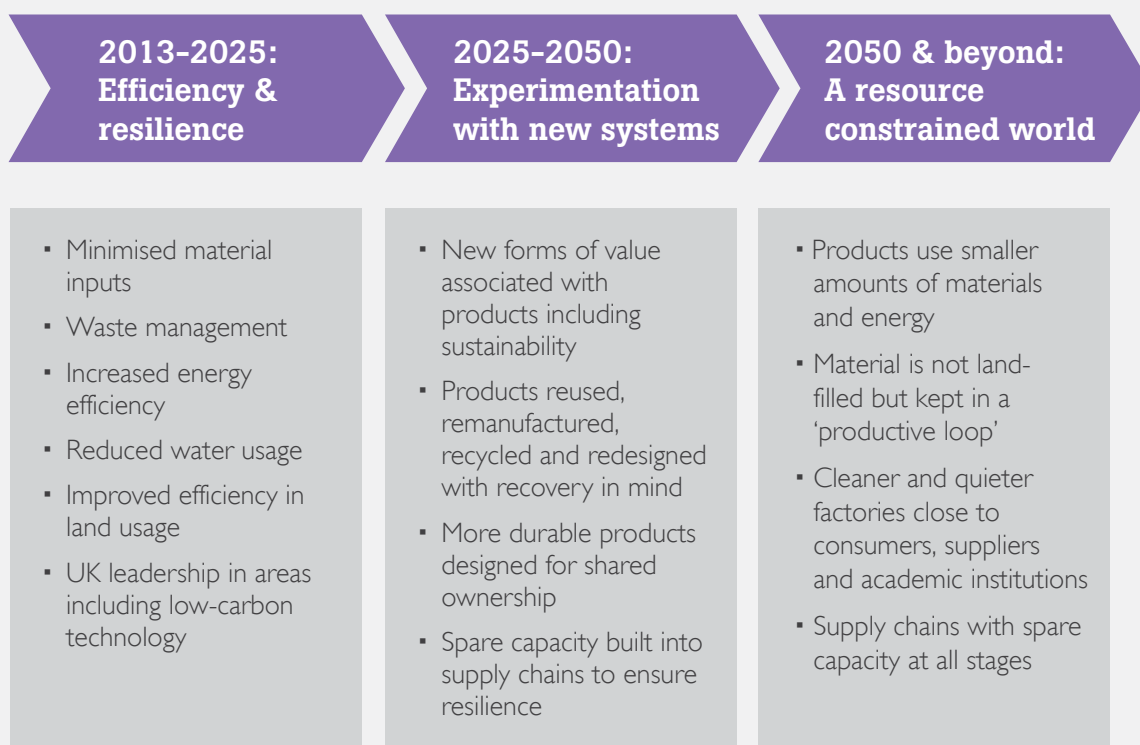
Volatility of supply: A growing global population and increased urbanisation (70% of the global population will live in urban areas in 2050)⁵⁵ will increase demand for materials, water, energy and land. As a result, resources will be subject to

greater competition, with potential disruptions in their supply. In most cases, prices will rise and they may also become more volatile. Those companies and nations that learn how to manufacture their products with less of these inputs will be more resilient to these effects.

Climate change and the increased vulnerability of global supply chains: Climate change will have a range of impacts including raising sea levels and extreme weather events⁵⁶. UK manufacturers will be affected by challenges such as the disruption of their international supply chains.

Greater use of regulation, potential 'pricing of the environment': Regulation is likely to focus increasingly on promoting resource productivity. For example, recent EU legislation aims to divert electrical equipment waste away from landfill. Over the period to 2050, national and international responses are likely to include tougher environmental standards for products and new ways to price natural resources and ecosystem services.

Figure 6: Three phases in the shift to sustainable manufacturing





Consumer pull for eco-products: Consumer demand for sustainable products which use less energy and fewer materials is growing⁵⁷, although it is not clear how far and fast demand will change. Unilever's pledge to double turnover without increasing greenhouse gas emissions⁵⁸ and Marks & Spencer's Plan A to go 'beyond compliance' on the environment⁵⁹ are examples of corporate responses.

Making robust products for 'collaborative consumption'⁶⁰: ICT-based systems are facilitating new business models based on shared use of assets. This shifts the business model from ownership to access, incentivises manufacturers to provide robust products, and allows the creation of new service based revenue streams.

Emergence of a 'circular economy' in which end of life products are reused, remanufactured and recycled: Resource scarcity and higher costs for energy and waste disposal will shift manufacturing value creation to new models (Figure 7 and Box 3)⁶¹:

- Reuse: Redeploying a product without the need for refurbishment;
- Remanufacturing: Returning a product to its original performance specification;
- Cascaded use: Using a product for a lower value purpose, for example turning used clothes into pillow stuffing or redeploying computers within a business for less demanding applications;
- Recycling: Extracting the raw materials and using them for new products;
- Recovery: Re-using materials for a low value purpose such as road base or combustion to produce heat⁶².

BOX 3: EXAMPLES OF FIRMS EMBRACING THE 'CIRCULAR ECONOMY'

Caterpillar Inc.: Caterpillar is a US manufacturer of construction and mining equipment, diesel and natural gas engines, industrial gas turbines and diesel-electric trains, with a strong UK presence. The business runs 'Cat Reman', a remanufacturing programme that returns products at the end of their lives to same-as-new condition, and seeks new ways to reduce, reuse, recycle, and reclaim materials which once would have gone into a landfill. During 2012, Cat Reman took back over 2.2 million end-of-life units for remanufacturing⁶³.

JC Bamford Excavators Ltd (JCB): JCB is one of the world's top three manufacturers of construction equipment, based in the UK. Through the JCB Service Exchange, the business helps plant users to reduce owning and operating costs, with a comprehensive range of remanufactured parts for all its machines. Around 1650 high quality parts, all remanufactured to Original Equipment Manufacturer standards and protected by the same warranty conditions as new parts, are offered. With typical savings against new of 40-50%, the remanufactured parts can restore machines to their optimum condition at a more affordable price. Furthermore, remanufactured parts are upgraded to incorporate the latest technology⁶⁴.

WHAT ARE THE IMPLICATIONS FOR GOVERNMENT?

Incentivising product and process efficiency:

Greater use should be made of well designed regulation, in particular drawing upon ideas from abroad. For example, effective energy reduction has been demonstrated by innovative schemes such as 'Top-Runner' in Japan⁶⁵ where future product standards are set so that all products manufactured at a specific point in the future must be at least as good as the best performance of today. The Government should consider developing top-runner schemes in the UK, for example relating to the energy usage of factories, and also procurement and waste policies.

Targeting R&D at improving resource efficiency and material substitution: The UK has world class capabilities in key areas of research in novel material design and development. Continued support for fundamental research should be complemented by programmes to develop

rapid recycling and recovery technologies, with non-destructive removal of high value parts and materials from complex end-of-life products.

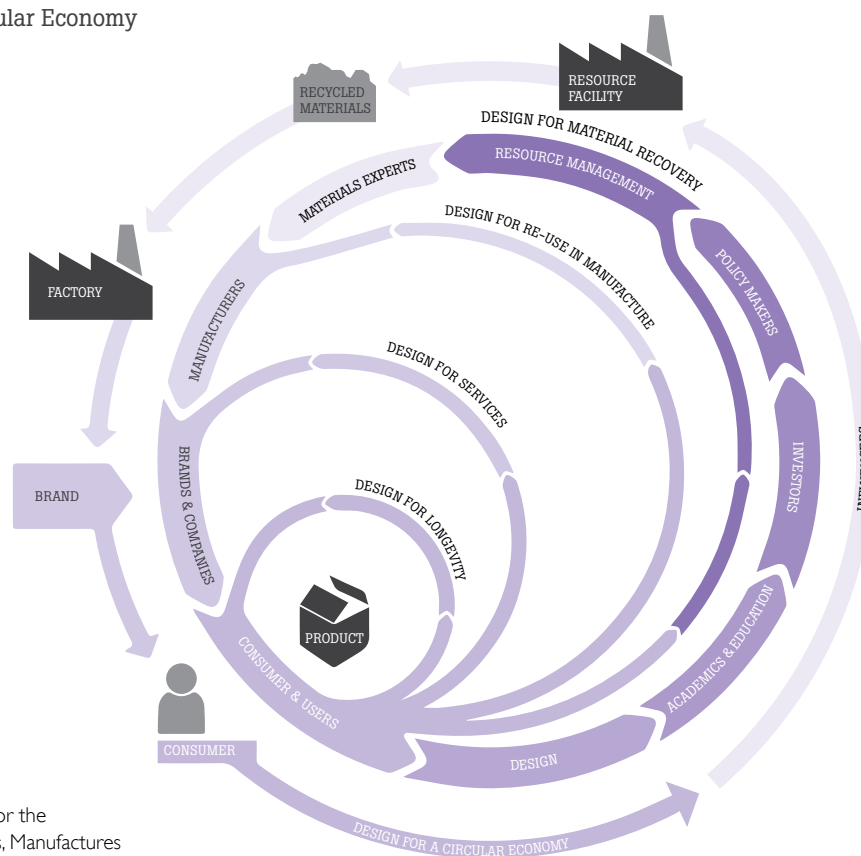
Supporting business models based on reuse remanufacturing and services:

Government should work with industry and others, for example in the UK such as the Royal Society for the encouragement of Arts, Manufactures and Commerce (RSA) and the Ellen MacArthur Foundation⁶⁶ to accelerate the development and roll out of the 'circular economy'. Lessons should also be drawn from overseas organisations such as the 2009 China 'Circular Economy Promotion Law'.

Quantifying domestic reserves of critical materials:

It is essential that the UK makes the most of any domestic supplies of key materials, where economically viable, such as sources of indium, widely used in the production of LCD displays and low-melting temperature alloys.

Figure 7: The Circular Economy



Source: Royal Society for the encouragement of Arts, Manufactures and Commerce (2013)

2.4. INCREASINGLY DEPENDENT ON HIGHLY SKILLED WORKERS

WHAT ARE THE LIKELY FUTURE TRENDS?

Sustained future demand for manufacturing workers: UK manufacturing employment has declined significantly in the past (from around 9 million people in 1966 compared with less than 3 million in 2011). Any future declines will be much smaller, with around 170,000 fewer people in the sector projected by 2020 compared with 2010. However, there will be around 800,000 jobs to fill in the years up to 2020, as people retire or leave manufacturing.

An ageing population and the need to accommodate more older workers: Over the period to 2050, the UK will have an ageing population, with the number of people aged 65 years and over (i.e. of 'traditional' retirement age) set to increase, while the numbers of 'traditional' working age people are set to decrease. By 2030, 17% of the UK population will be aged between 60-74. There will be a number of challenges in making manufacturing attractive to older workers, particularly in sub-sectors with the oldest age profiles including manufacturing of machinery and fabricated metal products.

Science, technology, engineering and maths (STEM) qualifications: By 2020 there are expected to be an additional 80,000 managerial, professional and associate professional and technical positions in manufacturing. Overall, many jobs will require apprentice, degree and technician level STEM qualifications, especially in product design and development. Future demand is currently likely to exceed supply especially as, at present, only around a quarter of engineering and technology graduates work in manufacturing six months after graduation.

Demand for technical specialism combined with commercial and problem solving abilities: The precise mix of skills in demand for the factories of the future will vary by sub-sector (see Table 2)⁶⁷, but new blends of skills will increase manufacturers' ability to exploit new opportunities. These blends

of high quality skills will allow developed economies such as the UK to increasingly compete in terms of the quality of their workforce.

A need to improve the perception of manufacturing amongst young people and women^{68,69} and to raise the quality of UK managers: Young people and women tend to have a negative perception of manufacturing, with 67% of girls aged 7-11 years indicated that they would not like a job in manufacturing compared with 44% of boys⁷⁰. In addition, the UK currently fares poorly on the quality of its managers⁷¹: average scores for management practices in surveys of manufacturing in different countries show that Great Britain scores below the US, Japan, Germany, Sweden, and Canada, but is on a par with Australia, Italy and France. Strong leadership teams and distributed leaders in key positions throughout manufacturing businesses will be essential in the future.

The potential for human enhancement: By 2050 patterns of employment will be influenced by new forms of human enhancement and augmented capabilities⁷². These may support mental performance and physical mobility, and help counter the effects of ageing.



WHAT ARE THE IMPLICATIONS FOR GOVERNMENT?

Increasing and diversifying the supply of manufacturing workers to avoid future shortfalls: There is a need to consistently reach out to young people in the education system to encourage them to study STEM subjects to keep their future options open; focusing on accessing and attracting international talent for example through 'science visas'; and building and maintaining existing workforce capability for example by encouraging continual vocational education and training.

Equipping future workers with high quality skills that manufacturers will need: potential workers will need to be as high quality and 'business ready' as possible, to meet the need for new skills sets driven by changing business models, technology and other factors. Higher level skills, vocational training, apprenticeships and STEM qualifications will be critical as the manufacturing workforce shifts to include a greater proportion of managerial, professional and technical roles. Government will need to increase the scale and ambition of its programme of current initiatives to meet these future requirements.

Ensuring that manufacturers utilise future workers effectively: this will involve raising employer demand for skills to stimulate a supply which meets future needs as closely as possible; and employers designing jobs that exploit new skills and capabilities for competitive advantage.

“ A common theme of all the future trends is the need for a highly talented, skilled and flexible workforce. We must do more to achieve a higher percentage of young people going into Science and Engineering and counter the current poor perception of Manufacturing industries. Manufacturing local to your consumers to deliver exceptional value is a trend we already see in the Food and Drink sector. Understanding the complete value chain (e.g. from farm to fork) will enable businesses to deliver increased value to customers and consumers.

Richard Martin

Chief Engineer, Nestle UK & Ireland



Table 2: Long term skill demands in selected manufacturing sub-sectors and technologies

SUB-SECTOR	MANAGEMENT SKILLS	PROFESSIONAL SKILLS	TECHNICAL SKILLS
Aerospace	Capacity to negotiate complex global markets	Mix of technical and business skills required to manage complex projects and international supply chains involved in design and R&D	Engineering (electrical and mechanical) / software (modelling and simulation); knowledge of advanced materials
Plastic and silicon electronics	Ability to bring new products to market and manage the transition from producing prototypes to higher volume production		Testing, prototyping and being able to implement new designs. Skills related to using plastic electronics
Biotechnology / Pharmaceuticals	Management of new product development	Need for scientists capable of working across boundaries of biology / genetics / chemistry / chemical engineering etc.	Technicians capable of working with the new production systems required to produce biotechnology products
New materials / composites	Skills related to the commercialisation of new materials	Scientists and technologists are required to develop new composites applicable to sectors such as automotive and aerospace	Technicians will need to acquire the skills required to work with new materials in their manufacture
Nanotechnology	As a new embryonic technology there is a need for managers and professionals (especially scientists) across the manufacturing sector to identify how nanotechnologies can be incorporated in to products and processes		Higher level skilled technicians will be required in relation to the handling and use of nanotechnologies

Source: Evidence Paper 36: Wilson, R. & Hogarth, T. (2013)

3. THREE SYSTEMIC AREAS FOR FUTURE GOVERNMENT FOCUS

As manufacturing evolves, policy makers will need new approaches which reflect the changing nature of manufacturing to ensure that the UK is a place where it thrives.

3.1. TAKING A MORE INTEGRATED VIEW OF VALUE CREATION IN THE MANUFACTURING SECTOR

Manufacturing is no longer just about 'production' - making a product and then selling it. Manufacturers are increasingly using a wider 'value chain' to generate new and additional revenue from pre and post production activities, with production playing a critical role in allowing these other activities to occur.

New metrics are needed to capture the new ways in which manufacturers are creating value, and to assess the scale and location of important changes within the sector. One way forward would be to

“ This report is very timely to prepare us for key opportunities and challenges and to ensure we use this changing manufacturing landscape to capture a larger share of global manufacturing than we currently enjoy in the UK.

Juergen Maier

Managing Director, Siemens UK and Ireland Industry Sector

pilot the development of new metrics focused on the value chain (Box 4). These will be critical in revealing key interconnections in the economy, understanding the important role of production in the manufacturing value chain, and helping to identify where in the value chain future policy intervention should focus to support manufacturers as they create and capture new and additional revenue streams. New metrics will also help in developing an understanding of how policies in other areas affect manufacturing.

BOX 4: NEW WAYS TO MEASURE MANUFACTURING?

The performance of the manufacturing sector is currently measured by classifying the output of manufacturing firms by the main type of economic activity in which they are engaged⁷³ with the Office for National Statistics using the Standard Industrial Classification (SIC) system. This provides a limited and incomplete picture since it captures neither the wider manufacturing value chain nor the incorporation within the firm of pre- and post-production services which are increasingly important in competitive business models for manufacturing firms.

The Office for National Statistics collects limited data relating to the type of goods and services bought-in by firms, and to which broad sectors goods and services are sold. This allows them to construct Supply-and-Use and Input-Output tables for the UK⁷⁴ which show in aggregate the flow of goods and services along the supply chain. However, it is not possible to use these data to measure which 'core' products also involve 'manufacturing-dependent' pre- and post-production goods and services.

Achieving this would require access to data relating to individual firm data, with information not only on what goods and services are bought-in and to whom output is sold but also on which plants and firms supply and purchase these goods and services. Such detailed information is not currently available. The ONS could lead a pilot looking at innovative ways to use existing and future potential data sources to develop finer grained models of activity in support of policy making.

3.2. TARGETING SPECIFIC STAGES OF THE MANUFACTURING VALUE CHAIN

TAKING A MORE TARGETED APPROACH TO SUPPORTING VALUE CREATION

Future industrial policies, informed by updated metrics (see above), will need to complement strategic approaches to individual sectors by allowing for a wider variety of types of targeted interventions. This provides an opportunity for developing the current Government approach to industrial strategy. New measures, tailored to specific requirements of manufacturing sub-sectors and the technologies upon which successful future business models will be built, should include, for example:

- Facilitating the emergence of challenger businesses. These exploit new business models and cross cutting approaches in technologies, across sub-sectors, to drive 'disruptive growth' in manufacturing. For example, support might focus on businesses with strong design capabilities specialising in additive manufacturing technology, which collaborate with others to work across manufacturing sub-sectors;
- Enhancing UK capabilities that cannot easily be relocated abroad. This is particularly important given the increasing ease with which manufacturing activities and the different elements of value chains can now be relocated around the world. Further promotion of R&D clusters and their co-location with production and the science base is one possible measure;
- Supporting the creation of new revenue streams from manufacturing services. For example this includes capitalising upon knowledge generated by sensors embedded in products;
- Helping manufacturers to expand their capabilities in remanufacturing and resource efficiency; and

Meeting these requirements will involve a move towards a coordinated systems based rationale for the design and delivery of the UK's industrial policy.

A SYSTEMS BASED APPROACH FOR THE FUTURE

Future approaches to policy depend strongly on recognising that manufacturing is part of an extended system, which requires a response from Government that cuts across policy departments.

This requires a 'systems based' approach that takes full account of the linkage between science, technology, innovation and industrial policies. The result is the need for more integrated coordination by government across policy domains and Government departments, that makes it easier to anticipate the potential unintended consequences of policies, and to identify where intervention would achieve the greatest impact. Such an approach should help to avoid the adoption of selective policies based on narrow objectives that might inadvertently hold back sustainable growth, and which are more a feature of the current approach which devolves policy-making to different government departments with different roles and agendas.

The evidence collected by this Project suggests that the greatest future need will be to remedy 'systems failures' that affect the rapid emergence and uptake of new, cross-cutting technologies. The future policy system must ensure that the most valuable new technologies are not missed, and needs to work with researchers, industry experts and policy-makers so that government initiatives collectively support them. In practice, this will mean developing new ways to support emerging technologies, including sophisticated use of roadmapping to identify what is needed to support technological change.

3.3. ENHANCING GOVERNMENT CAPABILITY IN EVALUATING AND COORDINATING POLICY OVER THE LONG TERM

It is essential that institutional structures within Government respond to changes in the manufacturing sector so that they can deliver the integrated systems approach which is advocated to enable more effective policy delivery and evaluation. This can be helped by promoting a better sharing of understanding and intelligence between the Department for Business Innovation and Skills and the Technology Strategy Board – in effect a shift in balance from sponsorship towards knowledge transfer.

A new institutional architecture can also help. A particular issue here is developing policy with a longer term perspective independent of the instabilities produced by the electoral cycle. Examples of where this has been achieved in other areas of policy include: an independent Bank of England to implement monetary policy, the National Institute for Health and Care Excellence (NICE) to advise the NHS on the take-up of new treatments, and the removal of ministerial discretion with regard to cases investigated by the Competition Commission. However, this has not generally been the case with regard to industrial policy.

In considering future industrial policy towards manufacturing and any related institutional reforms, it is recommended that close attention be paid to developments in other countries. These are consistent with the general arguments advanced in this Section. These examples are of the US Advance Manufacturing National Programme Office (AMNPO) (see Box 5), the Australian Productivity Commission (APC), and the UK Independent Commission for Aid Impact (ICAI).

Building on insights from these examples there is a clear need for future Government capability in evaluating and coordinating policy over the long term to be strengthened. The UK Government should create an 'Office for Manufacturing' which would:

- Regularly evaluate the effectiveness of industrial policies relevant to manufacturing;
- Identify relevant international best practice and highlight this to Government;
- Ensure the collation and effective use of the new best practice metrics for manufacturing (see above), also drawing in intelligence on manufacturing value chains from the wider public sector including Research Councils and the Technology Strategy Board; and
- Advise on where cross Government coordination can be strengthened and simplified.

BOX 5: ADVANCED MANUFACTURING NATIONAL PROGRAMME OFFICE, UNITED STATES

Charged with implementing a whole-of-government advanced manufacturing initiative, to facilitate collaboration across federal agencies and to convene private-public partnerships focused on manufacturing innovation. It is hosted by the National Institute of Standards and Technology, and is staffed by representatives from federal agencies with manufacturing-related missions and fellows from manufacturing businesses and universities. It was recommended by the Advanced Manufacturing Partnership Steering Committee and endorsed by the President's Council of Advisers on Science and Technology⁷⁵.

“

These are incredibly exciting times for manufacturing in the UK. I am delighted to be playing my part in this Foresight project and ensuring that manufacturing continues to be a key growth engine in the nation's economy for many years to come.

Nigel Stein

Chief Executive, GKN plc



4. CONCLUSIONS

PREPARING FOR THE FUTURE:

This Foresight Report looks out to 2050 and describes the transformation which will occur in the manufacturing sector and the environment in which it operates.

These changes will present major opportunities for the UK to develop competitive strengths in new and existing areas, but they will also present considerable challenges and threats, not least through increases in global competition. It will be essential for Government and industry to work together to forge new policy frameworks and develop measures so that manufacturing is able to fulfil its full potential for contributing to UK economic growth and prosperity, and in rebalancing the economy.

Together, the proposed measures put forward in this Report build on the current industrial and sector-specific strategies, emphasising that Government will need to significantly strengthen its future approach to ensuring a strong and resilient manufacturing sector:

GOVERNMENT NEEDS TO ACT IN THREE SYSTEMIC AREAS TO:

- exploit new forms of intelligence to gain sharper insights into the sector and where value is being created;
- take a more targeted approach to supporting manufacturers, based on a system-wide understanding of science, technology, innovation and industrial policies; and
- adapt and build innovative new institutional capability for the future.

POLICIES AND MEASURES ALSO NEED TO BE DEVELOPED TO SUPPORT MANUFACTURING AS IT BECOMES:

- faster, more responsive and closer to customers;
- exposed to new market opportunities;
- more sustainable; and
- increasingly dependent on highly skilled workers.

FURTHER WORK:

The work in preparing this report has revealed issues affecting not only manufacturing but industry in general in the UK. As immediate follow up, it is recommended the Government commissions detailed comparative studies into:

- the role of institutional infrastructures and systems in supporting industry;
- the need for increasing the availability and quality of long term (or patient) capital; and
- the role of a national belief in value creation in facilitating industrial success.

NEXT STEPS

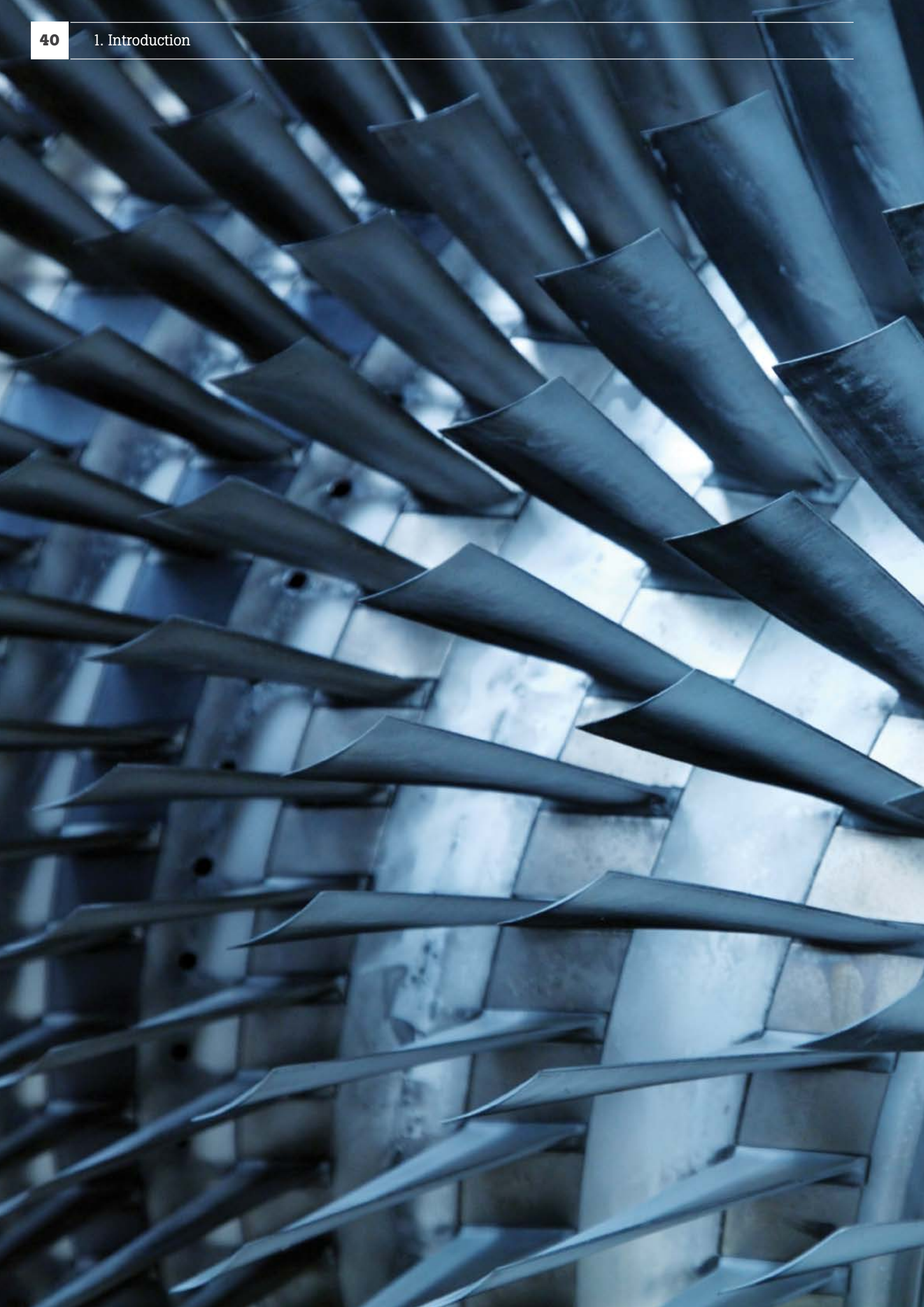
The Report and its supporting evidence propose a wide range of specific insights and potential actions for the public and private sectors to explore. These will need to be considered in the round, and the UK will need to adapt if it is to avoid being left behind. Many examples of new support initiatives and policy development have been identified in competitor countries.

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1. INTRODUCTION

This Chapter introduces the Project, and explain why it has been important to take a long-term and strategic look at the future of manufacturing at this particular time.

It sets out themes which have been explored, and the areas in which advice is provided.

1.1 AIMS OF THE PROJECT

The Project aim has been to take a strategic look at manufacturing out to 2050, in order to:

- Identify and analyse important drivers of change affecting the UK manufacturing sector;
- Identify the challenges and opportunities that lie ahead and which require action by Government and firms; and
- Advise how Government policy needs to evolve so that it is better positioned to support the growth and resilience of UK manufacturing over coming decades.

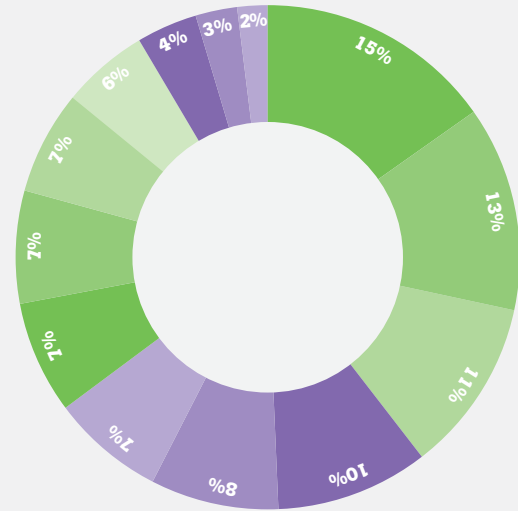
This report is primarily aimed at decision makers in Government. However, the Project, together with its underpinning evidence base¹ contains much that will be of direct interest to businesses. Individual firms will need to assess how changes in the decades ahead are likely to affect them and to act where needed. Importantly, those who do not act risk failure given the scale of the new challenges and increasing global competition.

1.2 WHY THE PROJECT WAS UNDERTAKEN AT THIS TIME

A diverse sector with a context of historical shifts

The UK manufacturing sector is diverse², with activities ranging from aerospace, pharmaceuticals, chemicals and automotives to food and drink (see Figure 1.1)³. Although most manufacturing firms are small (see Figure 1.2)⁴, with 87% of firms employing 1-19 employees in 2009, large and often foreign-owned firms generate most of the value-added and dominate research and development (R&D) expenditure. For example, firms with 250 or more

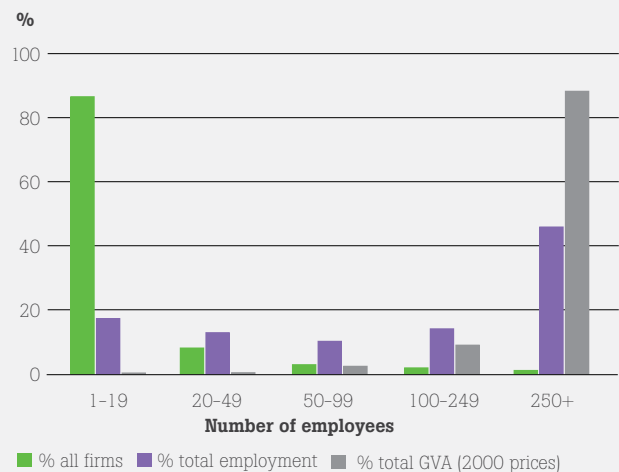
Figure 1.1: Gross Value Added (GVA) by manufacturing industries during 2012 (total £139 billion current prices)



KEY	%
1. Food products, beverages & tobacco	15
2. Transport equipment	13
3. Basic metals & metal products	11
4. Pharmaceutical Products & Pharmaceutical Preparations	10
5. Machinery & equipment	8
6. Rubber & plastics products	7
7. Manufacturing & repair	7
8. Wood and paper products, & printing	7
9. Computer, electronic & optical products	7
10. Chemicals & chemical products	6
11. Electrical equipment	4
12. Textiles, wearing apparel & leather products	3
13. Coke, & refined petroleum products	2

Source: Office for National Statistics (2013)

Figure 1.2: UK manufacturing GVA & employment by firm size, 2009



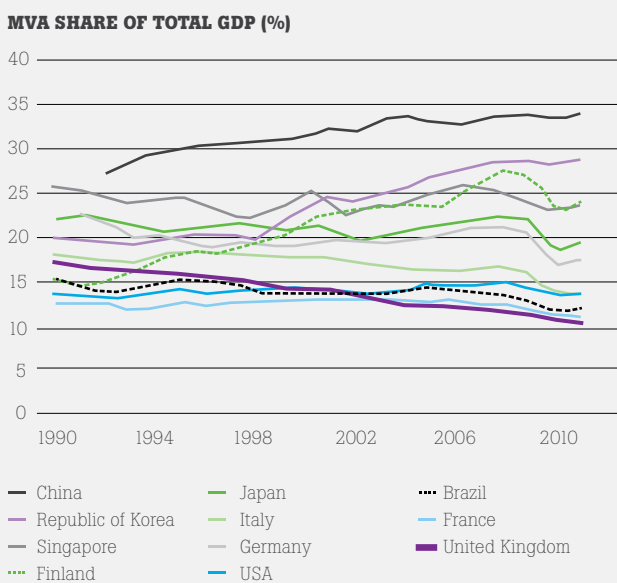
Source: ONS (2013)

¹ For full details of the 37 original evidence papers commissioned by the Project and a summary of the output from 3 international workshops, see: www.bis.gsi.gov.uk/foresight/our-work/projects/current-projects/future-of-manufacturing ² McKinsey & Company (2013a) ³ ONS 2013a ⁴ The figures produced here are based on the Annual Business Inquiry. This work contains statistical data from ONS which is Crown copyright and reproduced with the permission of the controller of HMSO and Queen's Printer for Scotland.

employees created 88% of the total gross value in 2009 and the largest 10 R&D performers alone accounted for over a third of all manufacturing R&D.

In recent years, the relative share of manufacturing in the UK economy has declined more rapidly than in other developed economies (Figure 1.3)⁵, from 30% in the early 1970s to 10% in 2011⁶, while the service sector has grown at a faster rate. This growth of the service sector in the UK is consistent with growth in other developed economies including France and the US⁷. This 'deindustrialisation' has also applied to UK manufacturing employment, with numbers reducing at a faster rate than in other developed economies, from close to nine million people in 1966 to below three million in 2011⁸.

Figure 1.3: Manufacturing share of GDP 1990-2010



Graph based on data from United Nations Industrial Development Organisation (UNIDO) (2013)

Variable performance relative to international competitors

UK manufacturing performance has been weak relative to international competitors in some key areas:

- Expenditure on manufacturing R&D has been low, especially with regard to new products⁹;

- The level of investment in capital equipment has been relatively low for many decades¹⁰; and
- The UK's share of global manufacturing exports has fallen from 7.2% in 1980 to 2.9% in 2012¹¹. There are also many outstanding individual firms, and some important areas of relatively strong performance for manufacturing as a whole:

When Total Factor Productivity (TFP) is compared between the UK, the Netherlands, Spain, France, Italy and Germany, from 1980 to 2009, manufacturing performs best in the UK¹²;

- The fall in the UK's share of goods exports has been accompanied by an increase in the export intensity (manufacturing exports as a proportion of manufacturing output), which rose from about 30% in 1991 to around 47% in 2011, similar to France and higher than the US¹³.

A powerful contribution to the UK economy

Whilst some of these figures are sometimes considered as clear indicators of the UK manufacturing sector being in inexorable decline, this is untrue. In assessing the role of manufacturing, it is important to go beyond its direct share of GVA and employment. Evidence shows a more complex picture, emphasising that manufacturing is and must continue to be an essential part of the UK economy, with diverse benefits including¹⁴:

- Absolute value: The contribution of manufacturing to UK GDP (£139 billion in 2012) is still significant¹⁵ and has been increasing over the long term¹⁶.
- Exports: Manufacturing businesses are more likely to engage in exporting. UK exports of goods produced by the manufacturing sector totalled £256 billion in 2012, accounting for around 53% of all UK exports¹⁷. In 2010, 60% of manufacturing businesses with ten or more employees exported products and services compared to 26% of non-manufacturers¹⁸.

⁵ UNIDO (2013) ⁶ Evidence Paper 14, Hay, G. et al. (2013) ⁷ World Bank (2009) ⁸ Evidence Paper 9: Fothergill, S. et al. (2013) ⁹ Evidence Paper 23: Moffat, J. (2013) ¹⁰ Evidence Paper 8: Driver, C. & Temple, P. (2013) ¹¹ World Trade Organisation (2013) ¹² Evidence Paper 14: Hay, G. et al. (2013) ¹³ Evidence Paper 17: Kneller, R. (2013) ¹⁴ A more detailed review of the role of manufacturing in creating value for the UK is provided in Chapter 2. ¹⁵ PricewaterhouseCoopers (2009) ¹⁶ ONS (2013a) ¹⁷ ONS (2012a) - the denominator to get the percentage is available from the total exports of goods and services found in: ONS (2012b). ¹⁸ See Harris, R. and J. Moffat (2013a)

- R&D: Manufacturing businesses with ten or more employees are more likely to engage in R&D. 41% of manufacturing businesses allocated resources to R&D in 2010 compared to an average of 23% of businesses in other sectors. Throughout 2000-2011, 72%-79% of total UK business R&D expenditure was associated with manufacturing¹⁹.
- Innovation: Manufacturers are more likely to innovate. In 2010, 26% of manufacturing businesses with ten or more employees carried out process innovation compared to less than 14% for non-manufacturers, and 44% undertook product innovation (less than 26% for non-manufacturers²⁰).
- Productivity: The growth in TFP²¹ for manufacturing has been 2.3% per year between 1980 and 2009, compared with 0.7% per year for the UK as a whole²².
- Highly skilled jobs: In 2011, remuneration in UK manufacturing was 10% higher in comparable occupations compared to the average across all industries, reflecting the high levels of skills required in modern manufacturing roles²³.
- Inter-industry linkages: Manufacturing performance affects other sectors through its wide range of input-output and other linkages²⁴.
- Economic resilience: Economies with strong, export-led manufacturing sectors typically recover from recessions faster than those without equivalent manufacturing sectors²⁵.
- The factories of the future will be more varied, and less spatially concentrated than those of today. The production landscape is likely to include capital-intensive super-factories producing complex products; reconfigurable units integrated with the fluid requirements of their supply chain partners; and local, mobile and domestic production sites for some products. Urban sites will become common as factories reduce their environmental impacts²⁷. The factory of the future may be at the bedside, in the home, in the field, in the office and in the battlefield.
- There will be significant changes globally in the levels of personal wealth, with larger and older populations in major markets. The 'global middle-class' with annual per capita expenditure between US\$3,650 and US\$36,500, is estimated to more than double in size from 2 billion in 2012 to 5 billion in 2030. Asia's share of the group will rise from 30% to 64%²⁸. There will be 3 billion more people in the world by 2050²⁹ with 97% of population growth by 2050 taking place in developing regions³⁰. Populations in some major markets are growing older, with the Asia-Pacific region having the oldest (Japan) and largest (China)³¹.
- Resource scarcity and higher costs for energy and waste disposal will shift manufacturing value creation to new models, with greater emphasis on reusing products and remanufacturing products to original performance specification.
- To be successful in high-value manufacturing, the UK and other developed economies will increasingly need to compete using the quality of their workforces. Demand for workers with new skill sets, including deep technical specialism combined with commercial and problem-solving abilities, will emerge, with the precise mix of skills in demand for the factories of the future varying by sub-sector.
- Shocks at local, regional and international scales will present particular challenges both for manufacturers in the UK, their overseas supply chains, and customer demand. For example, extreme weather events fuelled by climate change may disrupt vulnerable global supply chains, and future advanced and information-rich products may be particularly vulnerable to cyber-attack.

Manufacturing is entering a critical period

Manufacturing in the UK and the wider global manufacturing ecosystem will be faced with new or ongoing changes in a number of areas over the decades ahead. These changes (see Chapters 2-6), will combine to create major opportunities, and challenges, for manufacturers. For example:

- Manufacturing is evolving beyond simply making a product and then selling it. Manufacturers are increasingly using a wider value chain²⁶ to embrace new sources of revenue, which will transform business models over time.

¹⁹ ONS (2010) ²⁰ Department for Business, Innovation and Skills (BIS) (2012c) ²¹ TFP is defined as the increase in output that is not due to an increase in the direct inputs used to produce goods and services (i.e. labour, physical capital and intermediate inputs). Rather it is the more efficient use of these inputs. ²² Timmer, M. et al. (2010) ²³ ONS (2012c) ²⁴ ONS (2011) ²⁵ Evidence Paper 28: Pike, A. et al. (2013) ²⁶ Marsh, P. (2012) ²⁷ Evidence Paper 1: Foresight & Arup (2013) ²⁸ Rohde, D. (2012) ²⁹ United Nations (2013) ³⁰ Bloom, D. (2011) ³¹ Evidence paper 22: McNairs, S. et al. (2013)

A key message is that over coming decades, diverse changes will play out in a world that will be increasingly wealthy, urban and interconnected. The result will be unprecedented opportunities, as well as significant threats to manufacturing businesses. Businesses will need to rise to these challenges or fail. However, the threats should not be overstated. The strengths in UK manufacturing activities provide a broad foundation on which to build resilience and ultimately success.

1.3 HOW THE WORK HAS BEEN STRUCTURED

The past, the present, and a modern lens:

The starting point for this Project has been to review the changing nature of UK manufacturing activities and their role in creating value. This provides important insights into how manufacturing is currently understood and measured, and how this might need to change in the future (Chapter 2).

Four key future characteristics of manufacturing and implications for Government: The Report has investigated key changes affecting UK manufacturing – out to 2050 where possible – to provide a comprehensive perspective on long-term change. Individually, these drivers point to significant shifts and uncertainties in the future landscape in which manufacturing will operate. International workshops involving senior industry and academic experts in Europe, the United States, and Asia have been used to test these results³². The evidence is presented as four future characteristics of manufacturing, and is accompanied by discussion of the implications for Government:

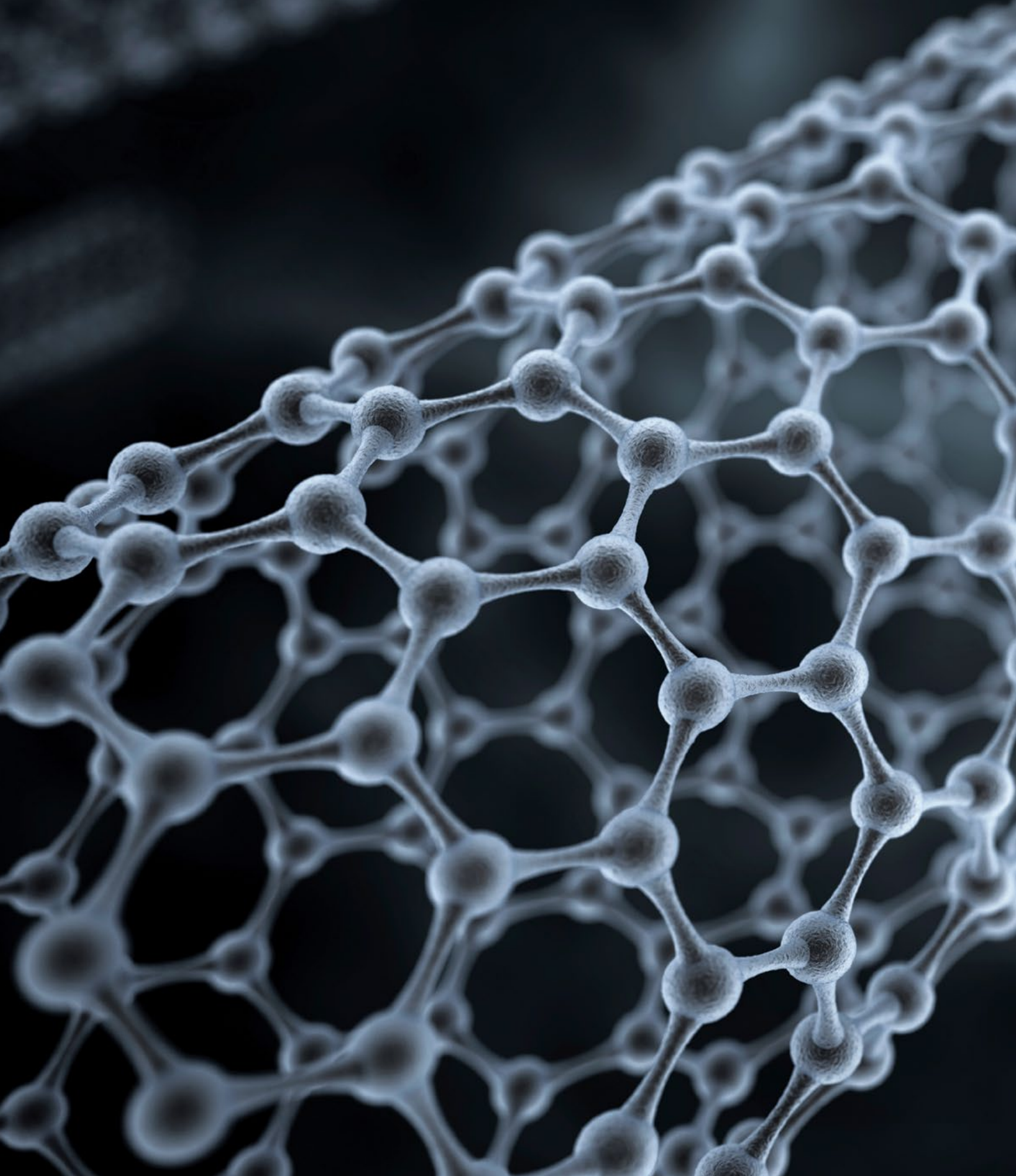
- Faster, more responsive and closer to customers (Chapter 3);
- Exposed to new market opportunities (Chapter 4);
- More sustainable (Chapter 5); and
- Increasingly dependent on highly skilled workers (Chapter 6).

Three systemic areas for future Government focus:

As manufacturing evolves, policy makers will need new approaches to ensure that the UK is a place where it also increasingly thrives. The Report analysis argues the need for Government to (Chapter 7):

- Obtain more rigorous information about how manufacturing is changing and how it is creating value;
- Take a more targeted approach to supporting manufacturing, by adopting a systems based approach to science, technology, innovation and industrial policy; and
- Adapt and build institutional capacity, potentially in the form of an Office for Manufacturing.

It is important to emphasise that this Report discusses policy measures likely to be effective in the future, given the areas of change and uncertainty identified. It does not, therefore, seek to evaluate the performance of past and present policies. However, in places, the advice provided by this Report takes existing plans, priorities and initiatives as a starting point. Additionally, the project builds on previous Foresight work in this area looking out to 2020 as a backdrop to developing an understanding of manufacturing in the decades ahead out to 2050^{33 34}.



2. THE PAST, THE PRESENT, AND A MODERN LENS

This Chapter looks at how manufacturing is currently understood and how it might change in the future. This includes discussion of the manufacturing value chain and factors which will drive changes including innovation in business models and technology, and the role of manufacturing in the wider business environment (Section 2.1).

The Chapter also examines the significant contributions manufacturing makes to the UK economy, particularly in terms of innovation, productivity, trade, and high quality jobs (Section 2.2).

These factors are used to argue the need to adopt a more integrated view of manufacturing for the 21st century, and the strategic importance of 'new manufacturing' for the future economy.

2.1 A MODERN LENS FOR MANUFACTURING – REAPPRAISING ITS PLACE IN THE ECONOMY

KEY MESSAGES:

Manufacturing is no longer just about making a product and selling it

Manufacturers are increasingly using a wider 'value chain' to generate new and additional revenue from pre- and post-production activities, with production playing a fundamental role in allowing these other activities to occur. Capturing value from manufacturing is therefore increasingly about capturing value throughout the lifecycle of products¹. For example, 39% of UK manufacturers with 100 or more employees derived value from 'manufacturing services' related to their products in 2011².

Manufacturing will continue evolving in the future, with new ways of doing business placing greater importance on using new sources of knowledge and information, and establishing much closer, long-term relationships with customers. Future sources of new and additional revenue for manufacturers are likely to include the following³:

- Selling services in combination with products much more extensively;
- Using products to generate new information about consumers and the usage of products;
- Becoming 'factoryless goods producers', capturing value by selling technological knowledge and leaving production to someone else;
- Shifting to a 'circular economy' way of doing business, with end of life products remanufactured and returned to original specifications or better;
- Making use of changes in product ownership, by providing more robust products for 'collaborative consumption' as opposed to outright ownership of a product;

- Forming strategic alliances with manufacturers across sub-sectors, resulting in collaborative communities which may become more significant than networks dominated by lead firms; and
- Using operational capabilities combined with greater entrepreneurial insight to respond rapidly to technological developments.

An integrated view of manufacturing is needed

The current metrics used to measure the performance of the manufacturing sector by the Office for National Statistics (ONS), the 2007 Standard Industrial Classification (SIC) system, captures data relating to the production output of manufacturing firms.

New metrics are needed to assess the scale and location of important changes within the sector. These will be critical in revealing key interconnections in the economy, clarifying the important role of production in the manufacturing value chain, and helping to identify where in the value chain policy intervention should focus to support manufacturers as they create new and additional revenue streams.

2.1.1 MANUFACTURING TODAY

Manufacturing has traditionally been understood as the production process in which raw materials are transformed into physical products⁴, involving people and other resources (Figure 2.1).

This production-focussed perspective has been used to make the argument that developed economies have entered a post-industrial age, with production declining in importance and deindustrialisation now the norm⁵. However, recent thinking considers production as a critical part of a much wider manufacturing 'value chain'⁶ (Figure 2.2), which includes complementary pre-production and post-production activities.

There is broad agreement emerging on the rapidly evolving nature of the manufacturing value chain, as emphasised in Box 2.1. A recent report by the US Advanced Manufacturing Partnership also referred to manufacturers' ability to respond to customer needs⁷, which places manufacturing within a wider business context.

Today, manufacturing embraces diverse commercial activities operating across integrated global supply chains, financial networks and trade frameworks⁸. Two particular developments have fuelled increases in complexity in recent decades: the growth of manufacturing services, and the demand for bespoke products requiring manufacturers to increasingly take a 'make to order' approach, tailoring products to meet specific needs⁹.

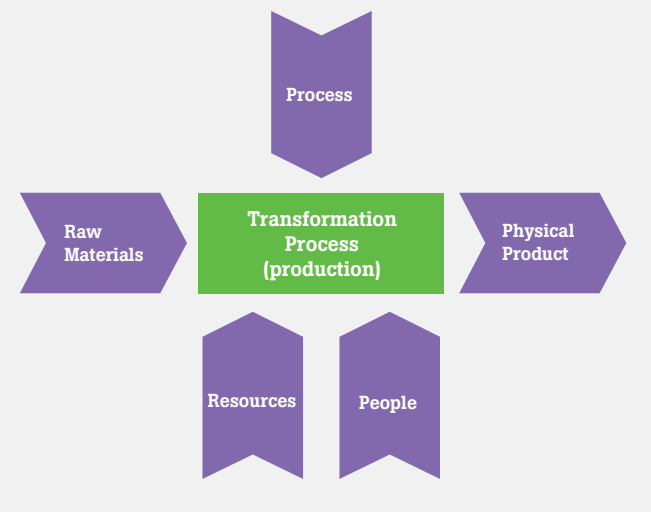
BOX 2.1: RECENT DEFINITIONS OF MANUFACTURING

'The application of leading-edge technical knowledge and expertise for the creation of products, production processes and associated services, which have strong potential to bring sustainable growth and high economic value to the UK. Activities may stretch from R&D at one end to recycling at the other' (Technology Strategy Board, 2012)¹⁰.

'The new era of manufacturing will be marked by highly agile, networked enterprises that use information and analytics as skilfully as they employ talent and machinery to deliver products and services to diverse global markets' (McKinsey & Company, 2012)¹¹.

'The world is in the midst of a paradigm shift in the 21st century – one that integrates diverse sets of ideas, products and services globally through the lens of highly complex, integrated and self-morphing resource webs... Highly talented skilled people are necessary to effectively and consistently apply cutting edge science and technology, systems thinking, smart services and processes, and supply chain excellence' (Deloitte, 2013)¹².

Figure 2.1: Traditional view of manufacturing



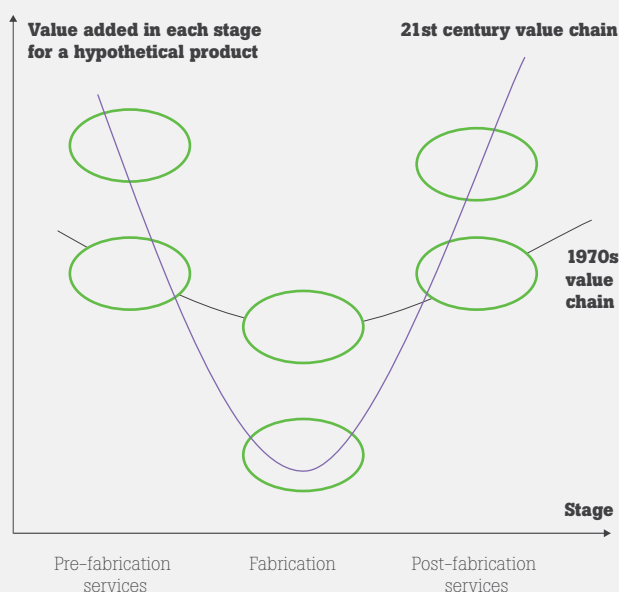
This growth in complexity of the manufacturing value chain has, for many sub-sectors, led to an increased contribution to overall final value from pre- and post-production or fabrication services (Figure 2.3)¹³. However, production in the manufacturing value chain remains of central importance in allowing these other activities to occur. It is the production of a product, such as a Rolls-Royce engine, that 'drives' the value chain, providing the capabilities, including technological expertise needed to create revenue from pre- and post-production activities.

Figure 2.2: Simplified model of the manufacturing value chain



Note: Within this value chain some elements are repeated many times, for example as components come together to build a complex product. There are also feedback loops which may vary for different sub-sectors.

Figure 2.3: The 'smile curve' representation of the manufacturing value chain



Source: Baldwin and Evenett (2012)

Manufacturing firms are increasingly adjusting how they do business to create new and additional revenue streams. Servitisation, personalisation, the circular economy and rental models are all examples of current trends in the innovation of business models, discussed shortly. These will become important in most sub-sectors in future decades as technological, economic, environmental and social trends force manufacturing firms in these directions. For example, technological developments such as the integration of sensors into products, and advances in information communication technology will enable products to be increasingly 'personalised'.

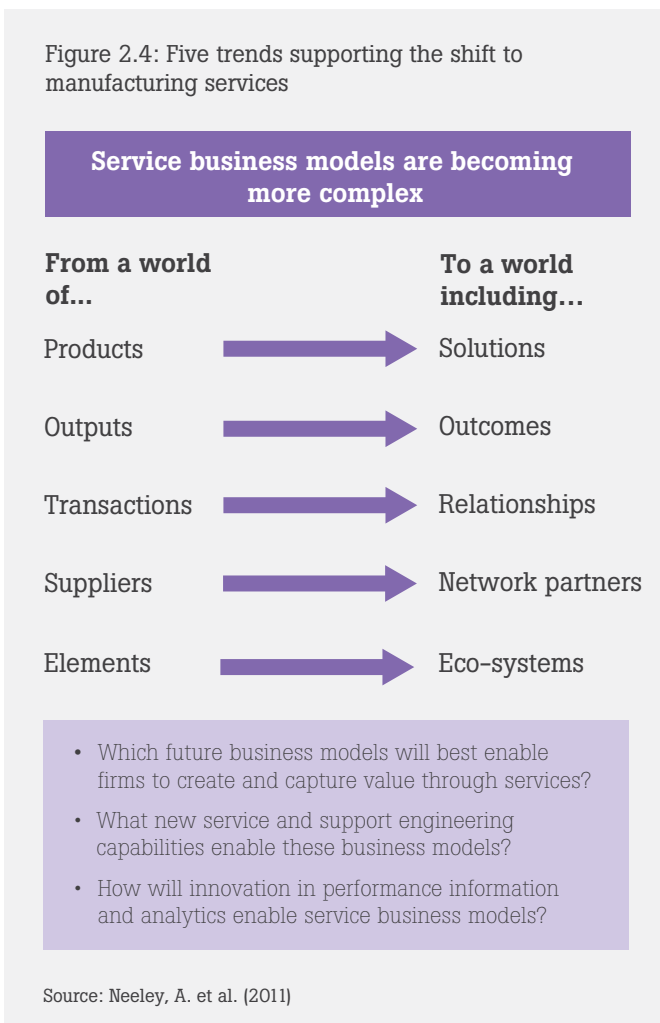
Servitisation

Servitisation is the provision of services to clients by manufacturing firms¹⁵, with services typically supporting or complementing products and helping manufacturers to establish long-term relationships with consumers (see Figure 2.4)¹⁶. This is likely to be an important trend for manufacturers to embrace, by exploiting complementarities that can arise when offering both products and services.

2.1.2 THE IMPORTANCE OF CHANGING BUSINESS MODELS

Business models describe how organisations create, deliver and capture value. In the case of manufacturing firms, business models are typically considered in terms of the technologies involved, what is being sold, and the wider network a manufacturer is dependent upon. The UK manufacturing sector typically adopts a 'linear' business model, based on the production and sale of products¹⁴. But this is changing.

Figure 2.4: Five trends supporting the shift to manufacturing services



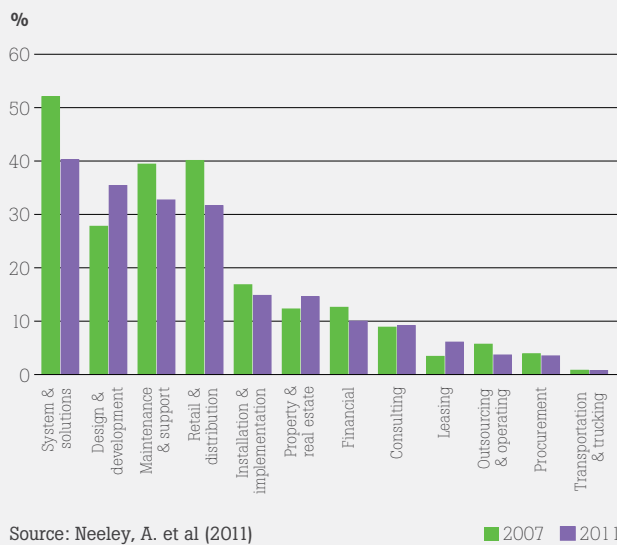
Official statistics shed little light on servitisation, as discussed in the following section on measuring manufacturing, however survey evidence reveals that 39% of UK manufacturing firms with over 100 employees derived revenue from services in 2011, compared to 24% in 2007¹⁷. Other surveys conclude that 80% of manufacturing firms are likely to have derived revenue from services in 2008¹⁸. In reality, it is more likely that almost all manufacturers provide some degree of services, with the extent of provision depending on various factors including the sophistication of the product, with more complex and expensive products likely to have a wider range of relevant services available. There is therefore a distinction to be made between 'service enhanced' and 'service oriented' manufacturers¹⁹. Little evidence is available on specific sub-sectors.

Estimates of revenues from services are limited to manufacturing firms which report service revenue separately. There is no obligation on manufacturers to do this. In 2009, the following manufacturers generated substantial proportions of revenue from services: Rolls Royce (49%); ST-Ericsson (38%); Atlas Copco Group (43%); Tyco (40%); Alstom (26%); Arcelor Mittal (29%)²⁰. Specific examples of manufacturing services include the well known 'Power-by-the-Hour' Rolls Royce offering, using capital equipment on an access basis. This service has required new process and technology to capture usage data. Similarly, Alstom Group is a multi-specialist product and service provider offering transport, transmission and clean power solutions as well as technical training for the railway sector²¹.

Despite growth in the numbers of firms offering manufacturing services, most manufacturers still focus on products and largely ignore services²², with only 15% of firms typically deriving 25% or more of their revenue from services²³. This is especially the case for smaller firms and firms in 'upstream' sectors such as materials, as opposed to firms in 'downstream' finished product sectors²⁴. There is also evidence that small extensions into services are worse than none at all, with firm value only rising once service revenue constitutes about 30% of total revenue²⁵. This emphasises the importance of not entering into service provision half-heartedly. Clarity about the different forms of manufacturing services, associated business models, and measures necessary to develop them is needed if this source of value creation is to be exploited.

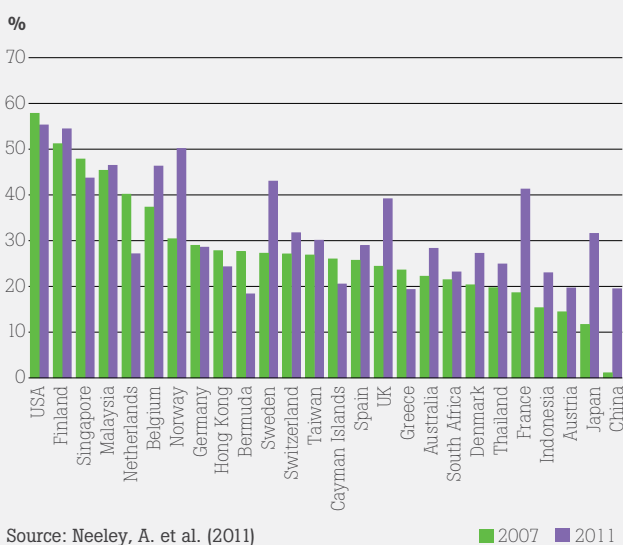
Systems and solutions, which encapsulate a range of services sold in support of products, were the most common form of services offered in 2011, followed by design and development, and maintenance and support. These services have remained dominant since 2007 (Figure 2.5)²⁶. Of the countries shown in Figure 2.6²⁷, the US had the greatest proportion of manufacturing firms offering services in 2011 (56%), and the UK had the ninth-highest level.

Figure 2.5: Manufacturing services being offered globally



Source: Neeley, A. et al (2011)

Figure 2.6: Manufacturers offering services, 2007 & 2011



Source: Neeley, A. et al. (2011)

Between 2007-2011, the extent of servitisation also rose significantly in other countries including Sweden, Norway and France, as well as in China, from 1% to almost 20%²⁸. Evidence suggests that services are added to generate extra revenue and to 'lock-in' customers^{29,30}. They can also make products and their maintenance more accessible, enable customer-specific uses and linkage to other products and provide the benefits of a product without exchange of ownership.

2.1.3 TRENDS IN FUTURE BUSINESS MODEL INNOVATION

A number of other business models are likely to become more common in the decades ahead, as manufacturers seek to create new and additional revenue streams. These are grouped as trends (see Table 2.1), which are also highlighted throughout the report.

2.1.4 MEASURING MANUFACTURING

The performance of the manufacturing sector has, since 1948, been measured by focussing on the production output of manufacturing firms using a system of Standard Industrial Classification (SIC), which classifies businesses by the type of economic activity in which they are engaged³¹. Manufacturing classifications focus on the production process, as opposed to the wider manufacturing value chain. The latest SICs used by the Office for National Statistics were last revised in 2007.

As the pace of change in manufacturing accelerates, these metrics are increasingly likely to misrepresent the performance of the sector, providing limited insight into important and innovative connections across the economy, and the central role of production in the manufacturing value chain. This is primarily due to the current metrics failing to capture:

- The inter-relatedness and complexity of the manufacturing value chain, with various activities and firms dependent on the production of a manufactured product. In the past, these activities would generally have been undertaken mostly at one location, however they now tend to be separated out or fragmented into separate businesses classified outside of manufacturing³².
- Activities such as the production of goods that would be classed to manufacturing but are done through service-type activities, such as wholesaling. For example, 'factoryless goods producers' (see Table 2.1) heavily involved in activities relating to the production of manufactured goods in the future are not currently likely to be classified as manufacturers. A study³³ of the US manufacturing sector indicates that reclassifying factoryless goods producers to the manufacturing sector instead of the wholesale sector would have shifted at as many as 1,934,000 workers from wholesale to manufacturing sectors in 2007, and increased reported manufacturing output by US\$895 billion (16.8%), indicating how extensive these activities are.

New measures of manufacturing performance need to rise to the increasing challenge of attributing to manufacturing 'production-dependent' goods and services. This would enhance understanding of value creation in the sector; and ensure that the critical role of production is not underestimated. The measurement of manufacturing, and implications for Government, is discussed more fully in Chapter 7.

³² Up until the early 1980s manufacturing was, relatively speaking, simpler and often located in a small number of large plants, with a greater range of activities classified as manufacturing including financial and HR services undertaken in the plant. Between 1984 – 1990 manufacturing underwent a period of outsourcing and fragmentation (Chapter 4.2), with some 'non-core' activities reclassified as non-manufacturing activities. This helps to partly explain why manufacturing accounts for a smaller share of overall GDP. See Evidence Paper 23: Moffat, J. (2013) ³³ Bernard, A. & Fort, T. (2013)

Table 2.1: Summary of future manufacturing business model trends

FUTURE BUSINESS MODEL TRENDS	DRIVERS OF CHANGE	SUB-SECTORS AFFECTED BY TRENDS	POTENTIAL IMPACTS (SOME ALREADY BEING SEEN)
<p>The circular economy (involves products being re-used, 're-purposed', repaired, re-manufactured) and collaborative consumption (products or services are shared, rather than individual ownership)</p>	<ul style="list-style-type: none"> ▪ Desire for greater financial predictability of costs/revenue for customer/manufacturer. ▪ Customers not wanting the financial and environmental burden of product ownership. ▪ Material scarcity, oil prices, and extreme weather events ▪ See Chapter 5 for details on environmental trends and sustainability. 	<p>The wider manufacturing sector; particularly sub-sectors involving large capital goods such as transportation equipment where manufacturers retain ownership of the asset and carry out maintenance, and customers pay for use.</p>	<ul style="list-style-type: none"> ▪ Incentives shifted: as manufacturers bear costs of maintenance and repair; they are more likely to design products to reduce those costs. ▪ Business models based on temporary or shared/collaborative ownership, with shifts from a linear to a circular economy, i.e. where products are re-used, 're-purposed', repaired, re-manufactured and recycled, rather than being used and discarded^{34, 35}. ▪ Re-manufacturing, whereby high-value or high-use parts of (typically) capital equipment are returned, repaired and re-sold. Already seen in aerospace, commercial vehicles, passenger cars and medical equipment. ▪ Re-manufacturing being used as a market-entry mechanism in emerging markets, for example by Volvo in India, where re-manufactured engines are 65% of the price of new engines. ▪ Re-manufacturing institutionalised through standards, with more products designed from the outset with re-manufacturing in mind.
<p>Personalisation of products (technological advances enable products and services to be designed with much greater customer-specificity)</p>	<ul style="list-style-type: none"> ▪ Technology and ICT, including sensors, making it possible to identify and characterise individual people, places, organisations and things. ▪ Information enhanced or 'Informed' products are likely. ▪ See Chapter 3 for details on technological trends and implications. 	<p>The wider manufacturing sector; with specific examples of personalised medicine, and the tracing of safety critical components in products.</p>	<ul style="list-style-type: none"> ▪ New connections between products, individuals, institutions and information become possible. As this occurs, new sources of value are created, and new business models are likely. ▪ Increased ability to connect a physical artefact to information, for example through measuring usage and linking to the identity of a user; makes it feasible to operate non-ownership-based business models. ▪ Information-enhanced products and the wider ecosystems in which they exist offer opportunities for additional value creation. ▪ It will be important to understand the rights of those who create information, to protect ownership, and to safeguard the privacy of those to whom information relates. ▪ Personalised medicine aimed at individuals or segments of the population become established as prognostic and diagnostic information on patients becomes available.

FUTURE BUSINESS MODEL TRENDS	DRIVERS OF CHANGE	SUB-SECTORS AFFECTED BY TRENDS	POTENTIAL IMPACTS (SOME ALREADY BEING SEEN)
<p>‘Factoryless goods producers’ also known as fabless or virtual manufacturers (design and sale of products, typically hardware devices, with outsourcing of production)</p>	<ul style="list-style-type: none"> ▪ Typical manufacturing business models capture value created in development and design by the sale of products. ▪ ‘Fabless’ manufacturing captures value by selling a ‘kernel’ of technological knowledge, leaving production to someone else. 	<p>Dependent on the nature of the product being made and the extent to which design and development knowledge can be separated from production.</p>	<ul style="list-style-type: none"> ▪ Represents a major opportunity for manufacturers whose capability in production is made less distinctive as manufacturers in emerging economies gain these capabilities. ▪ These manufacturers will have to shift their reliance on recouping expenditure on R&D through selling products, to selling the design and development in its own right. ▪ This requires a major effort in designing the product, and doing so in concert with the business models of relevant partners in the value chain³⁶. ▪ ARM Holdings is a good example of this business model trend.
<p>Value through environmental sustainability and provenance</p>	<ul style="list-style-type: none"> ▪ Environmental sustainability emerging as an important component of product value. ▪ Growing consumer awareness of the environmental and social impacts of manufacturing and increased environmental regulation³⁷. ▪ See Chapter 5 for details on environmental trends and sustainability. 	<p>The wider manufacturing sector:</p>	<ul style="list-style-type: none"> ▪ Environmental sustainability will become an increasingly important component of product differentiation and value-creation. ▪ Empirical evidence shows that environmental sustainability can reduce costs, with sustainable management of supply chains resulting in improved financial performance of a firm³⁸. ▪ Environmental sustainability is likely to come to be measured and managed in order to provide clear information for consumers. This will be part of the mechanism for capturing value from sustainability. ▪ There are several challenges, with sustainability issues difficult to identify and quantify within design, production and distribution. ▪ The National Physical Laboratory (NPL) and the Environmental Materials Information Technology Consortium are developing tools to allow the calculation of a product’s CO₂ footprint and energy usage³⁹. ▪ In the US, Walmart are developing a sustainability metric which may become widely used across retailing in the US and beyond⁴⁰.

³⁶ Spring, M. & Araujo, L. (2013) ³⁷ Evidence Paper 33: Spring, M. (2013) ³⁸ Golcic, S. L & Smith, C. (2013) ³⁹ National Physical Laboratory (2013) ⁴⁰ The Sustainability Consortium (2012)

Table 2.1: Summary of future manufacturing business model trends

FUTURE BUSINESS MODEL TRENDS	DRIVERS OF CHANGE	SUB-SECTORS AFFECTED BY TRENDS	POTENTIAL IMPACTS (SOME ALREADY BEING SEEN)
<p>Business models that take advantage of 'infinite bandwidth/zero latency'</p>	<ul style="list-style-type: none"> Advances in IT are expected to have profound implications for manufacturing business models, given it is a core technology within many products, affecting how products or services can be made available. 	<p>The wider manufacturing sector:</p>	<ul style="list-style-type: none"> Given the advances already seen in the data-carrying capacity of the internet, emerging practices are probably poor indicators of longer-term implications of IT. Current developments include cloud computing, and wireless networks make it possible for organisations to connect with products embedded with sensors and other technology. 'Infinite bandwidth/zero latency' (IBZL)⁴¹ would potentially remove obstacles to working across firm boundaries and distances, making data-transfer-intensive processes requiring telepresence more feasible. An illustrative instance of this is remote surgery, whereby a surgeon is able to operate via a robot which is able to provide real-time sensory feedback. Telepresence will affect development and production processes of manufacturing, as well as create opportunities for new types of services.
<p>Business models that take advantage of new general-purpose technologies (GPTs) (technologies affecting an entire economy, for example the internet)</p>	<ul style="list-style-type: none"> General-purpose technologies create new opportunities for value creation through new properties. 	<p>The wider manufacturing sector:</p>	<ul style="list-style-type: none"> GPTs provide a basis for value creation, but the business model achieves value creation and value capture. Value creation depends on the ability to use GPTs to generate 'novel applications'. This goes beyond finding products in which new technology can be inserted as a replacement. The most valuable future economic activity in biotechnology and nanotechnology is likely to not be in the manufacture of input materials, but in the application of these technologies.
<p>Increasing interaction between firms to gain access to indirect capabilities</p>	<ul style="list-style-type: none"> IT is making it easier for activities to be organised between firms. Increased collaboration causing sectoral fragmentation. 	<p>The wider manufacturing sector:</p>	<ul style="list-style-type: none"> The ability of firms to coordinate activity through collaborative, inter-organisational connections is likely to continue to increase as IT makes it easier to access the capabilities and resources of others. The ability of firms to collaborate and access others' capabilities will become critical. 'Co-production' between firms is likely to occur as collaborative communities of firms emerge, which may become more significant than tight networks dominated by a few lead firms.

41 Bell, S. & Walker, S. (2011)

2.1.5 MANUFACTURING IN THE CONTEXT OF THE WIDER BUSINESS AND THE EXTERNAL ENVIRONMENT

Strength in the manufacturing value chain is important in driving product innovation and success in the marketplace⁴². This is reflected in the 'Big M' concept of manufacturing⁴³ which emphasises that many factors within the business and wider external environment influence the manufacturing value chain. The eight 'Big M' groupings listed below are supported by the Deloitte Global Manufacturing Competiveness Index 2013⁴⁴ and the US Advanced Manufacturing Partnership on Capturing Competitive Advantage in Advanced Manufacturing⁴⁵.

- Supply: Interfaces with suppliers of materials, parts, energy and services.
- Network: Physical and virtual networks enabling businesses to operate in a global economy.
- People: People required to define, develop, execute and improve the value chain.
- Regulatory: Deployment of standards, legislation and regulation.

- Market: The output of a physical product or product-based service to customers.
- Technology: Underlying product and process technologies incorporated in product design.
- Skills: Competencies required to support value chain activities.
- Financial: Investment in research and development and associated industrial infrastructure.

The areas of UK value generated by the manufacturing sector are diverse, and set out in Section 2.2. The influence of the manufacturing landscape extends beyond immediate and obvious areas, creating further value, not always exclusive to manufacturing, which include economic, intellectual, social, natural and human capital. These aspects of value were all emphasised at the Project's international workshops⁴⁶.

Value in some other areas is less tangible. For example, proximity to manufacturing creates innovation spillovers across industries, supporting the next generation of products and processes⁴⁷. Even less tangibly, manufacturing creates a sense of identity and civic pride⁴⁸ in the workforce and wider population through the power of brands and awareness that products are 'made in my country', while products and services improve the quality of life of customers and users. Figure 2.7 provides an illustration of the how the manufacturing system sits within wider society and the economy. It builds on the 'Big M' concept by emphasising that the manufacturing value chain should be viewed in the context of wider business activities, external business environment, and elements of value.

2.1.6 IMPLICATIONS FOR POLICY MAKERS

Today, manufacturing is no longer just about a production process in which raw materials are transformed into a physical product. Emphasis is now on making use of a wider and interconnected manufacturing value chain, including production processes which remain of central importance. The manufacturing sector is likely to continue evolving, with value created in increasingly diverse ways. Changes in business models and other areas will result in a more interconnected manufacturing system, with production at its heart.

Figure 2.7: The manufacturing value chain, its wider context, and the diverse areas where it creates and stimulates value



Source: Dr Hamid Mughal (2013)

Given the wider manufacturing system which is emerging, new metrics are needed to assess the scale and location of changes within the sector. These will be critical in revealing key interconnections in the economy; understanding the significant role of production in the manufacturing value chain; and helping to identify where in the value chain future policy intervention should focus to support manufacturers (see Chapter 7) as they create new and additional revenue streams.

2.2 THE VALUE OF MANUFACTURING IN THE UK ECONOMY – PAST AND PRESENT

KEY MESSAGES

In assessing the role of manufacturing, it is important to go beyond its direct share of output and employment. Manufacturing continues to be highly interconnected to other sectors, making it important to future economic growth, exports and high value jobs. The value of manufacturing to the economy is set out in this section through discussion of:

- **Productivity:** Manufacturing plays a powerful role in driving economic productivity. Between 1980 and 2009, UK total factor productivity (TFP) growth was an average of 0.7% per annum, with manufacturing growth an average of 2.3%.
- **Exports:** Manufacturing businesses are more likely to engage in exporting, with 60% of manufacturing businesses with ten or more employees exporting products and services in 2010 compared to 26% of non-manufacturers. UK exports of goods produced by the manufacturing sector totalled £256 billion in 2012, accounting for around 53% of all UK exports⁴⁹.
- **Research and Development (R&D):** Manufacturing businesses are more likely to undertake R&D. 40.7% of manufacturing businesses with ten or more employees

allocated resources to R&D in 2010 compared to an average of 23.4% of businesses in other sectors. Manufacturers also accounted for 72-79% of total UK expenditure on R&D throughout 2000-2011.

- **Innovation:** Manufacturers are more likely to innovate, with 26% of manufacturing businesses with ten or more employees undertaking process innovation (less than 14% for non-manufacturers) and 44% undertaking product innovation (less than 26% for non-manufacturers) in 2010.
- **Inter-industry linkages:** Manufacturing 'dominates' other industries through the strength of its linkages to other industries when inputs and outputs are measured.
- **Scales of production:** Manufacturing plants have experienced significant returns to scale of production over 1997-2006 which will be important in raising productivity and driving economic growth in the future.
- **Highly skilled jobs:** In 2011, employee remuneration in manufacturing was some 10% higher when compared to the average for comparable occupations across all industries, reflecting the high levels of skills required in modern manufacturing roles.

Overall, manufacturing performs well above what might be expected given its relative contribution to areas crucial to long-run economic growth. To this extent, it has high levels of additionality in the economy. This evidence, when combined with the wider view of the manufacturing sector described in Section 2.1, makes the case for the critical importance of manufacturing to the UK economy today and in the future⁵⁰.

This Section reviews recent data to establish a baseline of manufacturing's changing contribution to the UK economy, and its performance compared with international competitors. As the current Standard Industrial Classification (SIC) metrics relating to manufacturing are somewhat narrow in scope⁵¹, as discussed in the previous section, the available data paint a limited picture but provide important insights.

⁴⁹ ONS (2012a) – the denominator to get the percentage is available from the total exports of goods and services found in: ONS (2012b). ⁵⁰ Davis, E. (2011) ⁵¹ The SIC is based on the main good(s) and/or service(s) supplied by a plant or firm. Thus, it does not take account of linkages across the value chain, and how plants/firms combine different elements from this chain when producing manufacturing value-added.

2.2.1 PRODUCTIVITY – MANUFACTURING AS AN ENGINE FOR CREATING WEALTH AND INCOME

Productivity, and especially the productivity of both labour and capital inputs into the production process, i.e. total factor productivity (TFP) is widely recognised as a key driver of long-run economic growth. As Paul Krugman⁵² noted '...Productivity isn't everything, but in the long run it is almost everything'. William Baumol similarly states that, 'without exaggeration, in the long run probably nothing is as important for economic welfare as the rate of productivity growth'⁵³.

TFP is typically defined as the increase in output that is not due to an increase in the direct inputs

used to produce goods and services⁵⁴ (i.e. more efficient use of labour and physical capital and/or the development of new products). Country and industry studies confirm the importance of TFP and its dominance in explaining differences in output growth across economies⁵⁵.

This emphasis on productivity is linked with the concept of self-reliant economic growth, which stresses the importance of growing industries or sectors that are likely to be self-reliant. A self-sufficient industry⁵⁶ is not dependent upon local demand alone, has a high ability to innovate, is highly interconnected to other industries, and encourages wider growth by its expansion.

Growth in UK total factor productivity for 1980-2009 was 0.7% per annum. TFP growth in manufacturing was three times higher at 2.3% p.a. over the same period (see Table 2.2)⁵⁷. Of the top 10 performing sectors, manufacturing industries account for eight (telecommunications, and

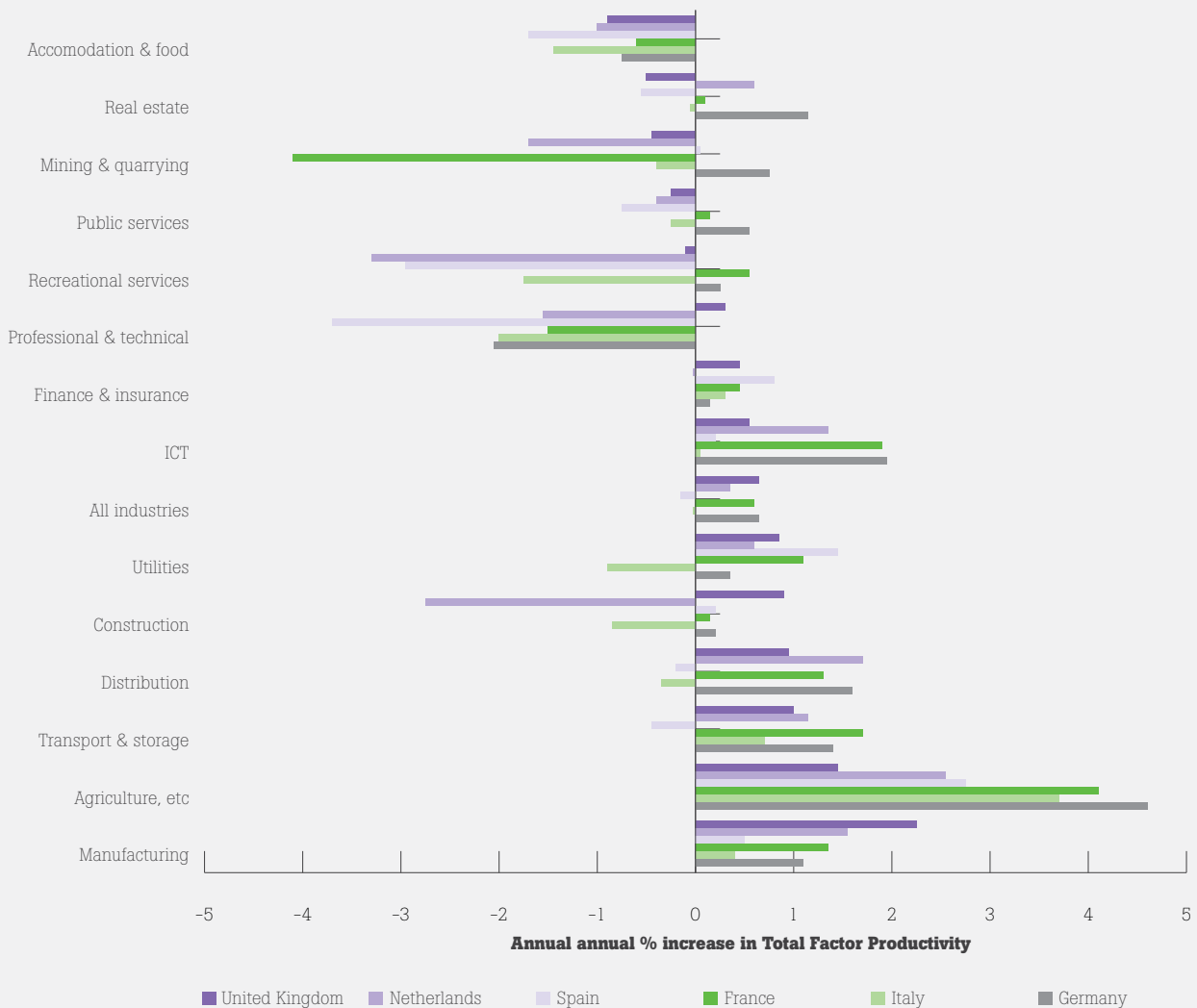
Table 2.2: Growth in UK total factor productivity 1980-2009 for top ten sectors (% p.a.)

Note: Manufacturing industries in italics; sectors ranked (highest-to-lowest) on the basis of data in column 1	1980-2009	1980-1990	1990-2000	2000-2008
TOTAL INDUSTRIES	0.7	0.8	1.0	0.6
<i>Chemicals and chemical products</i>	4.6	5.2	3.9	4.7
Telecommunications	4.0	-0.3	7.2	5.6
<i>Electrical and optical equipment</i>	3.4	4.9	3.0	1.9
<i>Transport equipment</i>	3.3	5.1	2.3	3.3
<i>Basic metals, fabricated metal products, except machinery and equipment</i>	2.6	5.6	1.1	2.6
TOTAL MANUFACTURING	2.3	3.4	1.1	2.8
<i>Rubber and plastics products, and other non-metallic mineral products</i>	2.0	2.5	1.1	3.0
<i>Textiles, wearing apparel, leather and related products</i>	1.8	1.9	-0.2	4.8
<i>Machinery and equipment</i>	1.7	1.6	0.4	4.4
<i>Wood and paper products; printing and reproduction of recorded media</i>	1.7	2.8	-0.3	2.4
Agriculture, fishing & forestry	1.5	2.4	1.8	2.0

Source: EUKLEMS database

52 Krugman, P. (1997) 53 Baumol, W. (1984) 54 Harris, R. (2005) 55 OECD (2003) See also: Department for Business, Enterprise and Regulatory Reform (2008). Also: O'Mahony, M. & Timmer, M. (2009). Also: Mourre, G. (2009) 56 Harris, R. (1987) 57 O'Mahony, M. & Timmer, M. (2009) and Timmer, M. Inklaar, R. O'Mahony, M. & van Ark, B. (2010)

Figure 2.8: Growth in productivity across sectors 1980–2009



Source: EUKLEMS database

agriculture, fishing and forestry are the others). Although manufacturing contributed higher levels of TFP growth, its relatively small(er) share of the economy means that the lower performance of other sectors dominate total UK productivity growth⁵⁸. When TFP is compared across the UK and five EU member states between 1980-2009 (see Figure 2.8)⁵⁹, manufacturing performs best, in comparison to other sectors, only in the UK. In the five other countries, agriculture, fishing and forestry had the highest TFP growth in this period. Nevertheless, in every country, manufacturing is above the industry average and every sub-period covered.

2.2.2 EXPORTS

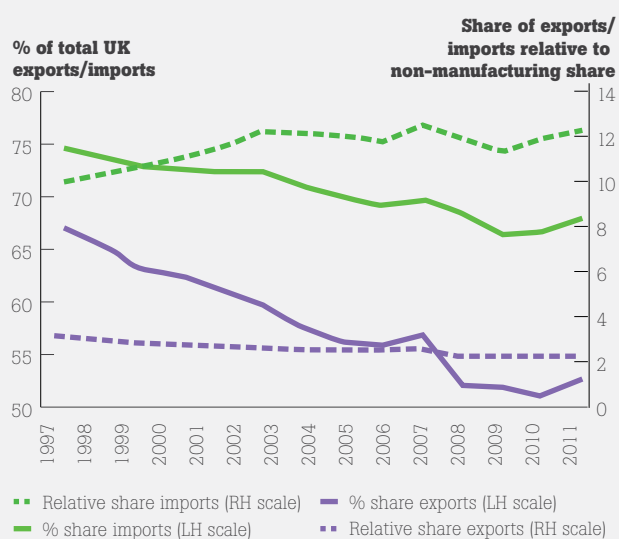
Manufacturing is critical for the exporting of goods and services. As world demand for exports grows alongside globalisation, exporting produces additional income for the UK economy. UK exports of goods produced by the manufacturing sector totalled £256 billion in 2012, accounting for around 53% of all UK exports⁶⁰.

On the supply side, exporting is recognised as leading to higher productivity⁶¹. This is because businesses that export typically have to become

⁵⁸ According to the EUKLEMS database, which is used here, in 1980 manufacturing accounted for 24.3% of total UK value-added; by 2010 it accounted for 10.0%. ⁵⁹ Evidence Paper 14: Hay, G. et al. (2013) ⁶⁰ ONS (2012a) – the denominator to get the percentage is available from the total exports of goods and services found in: ONS (2012b). ⁶¹ Salomon, R. and Shaver, J. (2005)

more productive to break down 'barriers-to-exporting' which are mostly linked to higher levels of competition in international markets. Firms that operate in more competitive export markets have access to and knowledge of better technologies and/or higher quality products. They can obtain an additional current and future productivity benefit if they can utilise this. Direct information on technical and product development is often provided by customers and suppliers which can stimulate a firm's own innovation outputs^{62 63}.

Figure 2.9: UK manufacturing's share of international trade (goods & services), 1997–2010



Source: UK SUTS (ONS)

Some argue that economic growth is determined by the growth of exports, with non-export sector growth depending upon the export base. With the manufacturing sector as the major source of exports, growth of national output is dependent upon growth of the manufacturing sector. Certainly, manufacturing products (Figure 2.9)⁶⁴ are the largest contributor to exports relative to the sector's share of total industry value-added. The manufacturing share of total final demand⁶⁵ is more than twice the average of all other industries⁶⁶, although this has fallen from 3.1 to 2.2 between 1997 and 2010⁶⁷.

Manufacturing accounts for an even larger share of imports relative to its size, which explains why manufacturing net exports have been negative in recent years. Also, this negative contribution to the balance of trade has been increasing. Negative net exports suggest two interrelated factors are at play. First, UK exports have been losing their share of world exports through a lack of competitiveness. Secondly, fragmentation of manufacturing production since the mid-1980s through the spatial fragmentation of production has led to outsourcing of intermediate goods and services to overseas locations with attractive production costs⁶⁸. Firms in manufacturing are also much more likely to engage in exporting. In 2010, 60% of manufacturing firms were engaged in exporting while in non-manufacturing the figure was only 26%⁶⁹ (Table 2.3)⁷⁰.

Table 2.3: Distribution of establishments in 2010 by exporting and R&D activities (Figures are percentages of the totals reported).

	DO NOT EXPORT	EXPORT	ALL
Manufacturing			
No R&D	30.7	28.6	59.3
Undertake R&D	9.2	31.5	40.7
Total	39.9	60.1	100
Non-manufacturing			
No R&D	60.3	16.3	76.6
Undertake R&D	13.6	9.8	23.4
Total	73.9	26.1	100

Source: weighted data from Community Innovation Survey (CIS) 2010

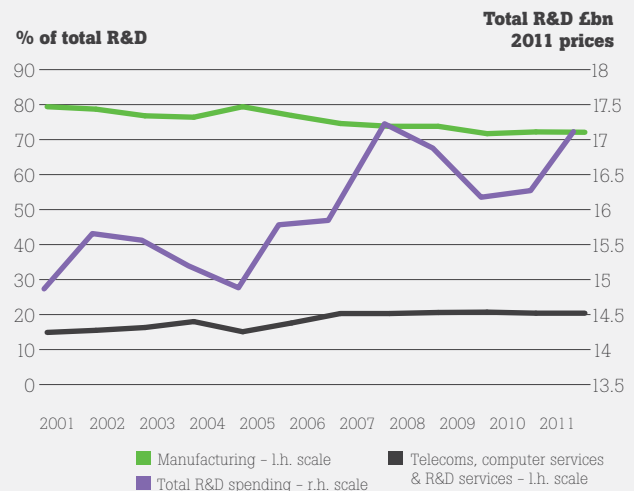
62 Aw, B., Roberts, M. & Xu, D. (2011) 63 Greenaway, D. & Kneller, R. (2007) 64 ONS (2011) 65 Total final demand in the economy equals the sum of spending on consumption (UK household and government sectors), fixed investment (by UK business and government sectors), stockbuilding (a small component of final demand), and exports (spending by overseas purchasers on UK goods & services). 66 The relative shares in Figure 2 are computed as $(\text{exports} + \text{total final demand})_m \div (\text{exports} + \text{total final demand})_{nm}$, where m = manufacturing and nm = rest of the economy. 67 The top 20 product subgroups (out of a total of 110 subgroups identified in the UK supply-and-use tables) for exports in 2010 accounted for 67.8% of UK exports of goods and services. Of these 8 were non-manufacturing, providing 27.5% of total UK exports (there were: Financial intermediation – 6.0%; office & business support services – 4.8%; auxiliary support to financial services – 4.3%; oil and gas extraction – 4.1%; insurance & pension services – 3.0%; other professional & technical services – 2.0%; water transport services – 2.0%; and scientific R&D services – 1.4%). 68 Baldwin, R. (2006) 69 Data based on 2004, 2006 and 2008 (comparable to Table 2.3) produces very similar results. 70 Harris, R. & Moffat, J. (2013a)

2.2.3 INNOVATION

Spending on R&D has an impact on Total Factor Productivity (TFP) in two ways. Most obviously, R&D may generate process innovations which allow existing products to be produced with greater efficiency, through lower costs. It may also generate product innovations, which will improve TFP if the new products are produced with greater efficiency or by use of better technology than existing products⁷¹. The second way is through the development of 'absorptive capacity'^{72,73}, which relates to a firm's ability to recognise the value of new internal and external information, absorb it, and exploit it⁷⁴ to compete and grow in markets.

Manufacturers are also more likely to undertake R&D than firms in other sectors (see Table 2.3). In 2010, some 40.7% of manufacturers allocated resources to R&D while on average only 23.4% in other sectors did so. Nearly one third of manufacturers neither undertook R&D or exporting, compared to nearly two thirds of non-manufacturers. The comparison is starker when the percentages that undertook both activities are compared: over 31% of manufacturers exported and undertook R&D (BERD) while less than 10% in non-manufacturing did both. Figures from the business enterprise R&D survey show that throughout 2000-2011, relatively constant (real) spending on R&D in manufacturing⁷⁵ amounted to 72-79% of total UK R&D expenditure (see Figure 2.10)⁷⁶, with much of the remainder being attributable to telecoms, computer services and R&D services⁷⁷.

Figure 2.10: Expenditure on research & development by UK businesses between 2000 & 2011



Source: BERD 2011 (ONS)

R&D is one source of intangible assets which improve productivity, for example through innovations and/or greater efficiency. Figure 2.11^{78,79,80} shows the incidence of spending on these assets is generally higher in manufacturing (investing in software is the exception) with manufacturing firms also tending to spend more on average.

Figure 2.11: Average spending on intangible assets by broad sector in the UK



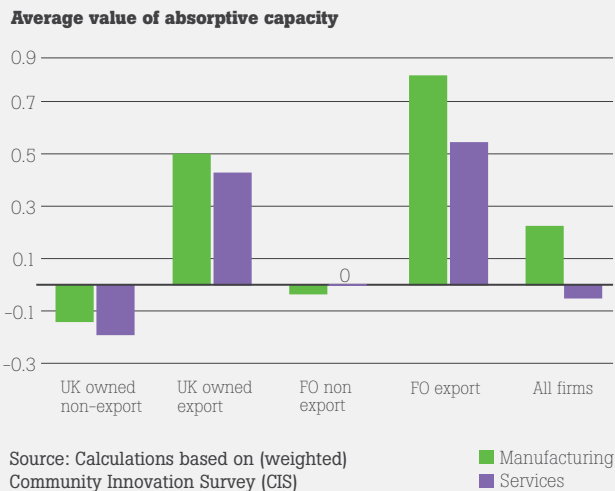
Source: ONS, 2010; NESTA, 2010

Note: Spending values relate to those who engaged in positive spending; incidence shows the percentage who undertook spending.

71 Innovation is defined here in using the traditional approach (i.e., product and process innovations). Note, we do make use of a much wider concept ('absorptive capacity') (see Harris, R. and Li, Q.C. (2009) 72 Cohen, W. and Levinthal, D. (1989) 73 Zahra, S. A. & George, G. (2002) 74 Zahra, S. A. & George, G. (2002) Note, absorptive capacity was developed by Cohen and Levinthal (1989) 75 In 2011 prices, spending in manufacturing was between £11.7b to £12.7b throughout this period. 76 ONS (2012d) 77 Evidence paper 14 Hay G. et al. (2013, Table 15) shows that manufacturing dominates total business R&D spending in France, Germany, Japan and the U.S. during 1997-2007. 78 The diagram shows the average spend per firm by sector (note manufacturing comprises the overwhelming majority of the production sector data produced here) for those undertaking spending, while the figures along the top of the diagram indicate the percentages of firms that undertook each activity. 79 Awano, G., Franklin, M. Haskel, J., & Kastrinaki, Z. (2010) 80 Nesta (2010)

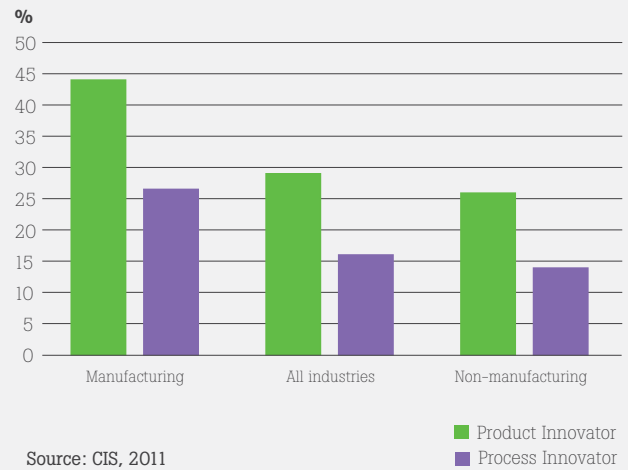
UK-owned manufacturing firms involved in exporting tend to have higher absorptive capacity than those not involved in exporting (Figure 2.12)⁸¹, with foreign-owned subsidiaries engaged in exporting having the highest levels of absorptive capacity.

Figure 2.12: Absorptive capacity 2004–2010 in UK by ownership & sector



The UK manufacturing sector demonstrates a stronger rate of product and process innovation (44% for 2010) than non-manufacturing sectors (26%) (see Figure 2.13)⁸². Product innovation was particularly strong in the development of medical and other precision instruments, electrical machinery, chemicals, and rubber & plastics, but strong too in computing and R&D services. Over 26% of manufacturers in 2010 undertook process innovation compared to under 14% of non-manufacturers.

Figure 2.13: Percentage of UK firms innovating by industry, 2010



2.2.4 INTER-INDUSTRY LINKAGES

For an industry to make a major contribution to long-run growth, it should have strong purchases and sales known as input-output (demand and supply) linkages with other industries that it dominates, and therefore have a high capacity for transmitting growth⁸³. To determine which industries 'dominate' others requires examination of the strength of such 'forward' and 'backwards' inter-industry linkages⁸⁴. Using the UK input-output tables for 2005, the latest data available, the linkage indices given in Table 2.4⁸⁵ show that manufacturing and transport and communication are the most propulsive industries, as they are the only sectors with both linkages at or above one.

⁸¹ Harris, R. and Li, Q.C. (2009) Note: We use a single overall AC index here, which by construction has a mean of 0 and a standard deviation of 1 across establishments who provide the data used to measure AC. ⁸² Figure based on calculations by Lead Expert Group using CIS 2011 data. ⁸³ Lasuen, (1971) ⁸⁴ Backward linkages, denoting purchases of intermediate inputs from suppliers, show the impact on other industries when the demand for industry j rises by one unit; i.e., the addition output resulting through j's purchases of intermediate inputs from other interlinked industries. Forward linkages, denoting sales of intermediate inputs to customers, shows the output generated in industry i when (final) demand in each interconnect industry j is increased by one unit; i.e., the additional intermediate sales made by industry i to meet the extra demand from other interlinked industries. Key industries are defined as those for which both indices are greater than one, since these industries dominate through their forward and backward linkages. ⁸⁵ ONS (2011)

Table 2.4: Product (relative) linkages in the UK, 2005

SIC (SIC2003)	FORWARD	BACKWARD
Agriculture, etc.(1-5)	0.6	1.1
Mining and quarrying (10-14)	0.8	0.8
Manufacturing (15-37)	1.6	1.0
Electricity, gas and water supply (40-41)	0.8	1.2
Construction (45)	0.9	1.2
Wholesale & retail trade (50-55)	0.8	0.9
Transport and communication (60-64)	1.1	1.0
Business services (65-74)	2.3	0.9
Public administration (75)	0.5	1.1
Education, health and social work (80-85)	0.7	0.9
Other services (90-95)	0.9	0.9

Source: ONS, 2005

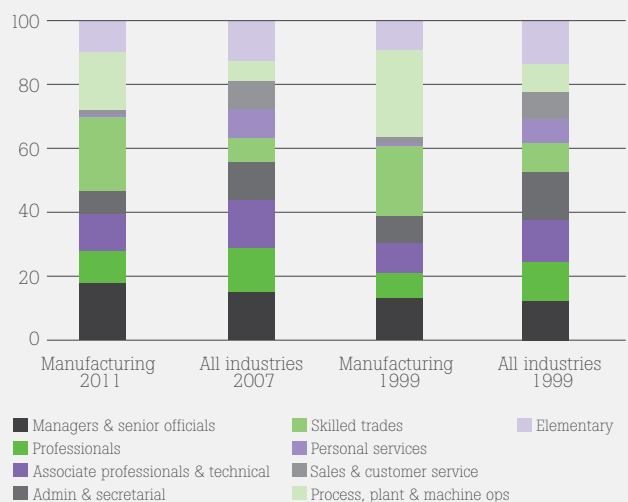
2.2.5 SCALES OF PRODUCTION

Increasing returns to scale⁸⁶, i.e. output more than doubles when capital and labour inputs are doubled, result from internal, external and agglomeration economies⁸⁷. Evidence shows that increasing returns to scale enable some firms to produce more cheaply by concentrating production in a smaller number of potentially geographically co-located plants⁸⁸. Increasing returns will lead to greater productivity, and economic growth. Evidence for the UK, based on data for 1997-2006⁸⁹, shows that manufacturing plants generally experience greater increasing returns to scale, while in non-manufacturing constant or decreasing returns are more common.

2.2.6 HIGHLY SKILLED JOBS

Some argue that manufacturing is over-dependent on manual skill occupations which pay lower wages. Manufacturing has relatively more employees in process, plant and machine operatives, skilled trades, and managers & senior officials. It has fewer in all other occupational groups (Figure 2.14)⁹⁰. Over time, the sector has increased its reliance on managers & senior officials, professional, associate professionals & technical occupations, and decreased its reliance on manual 'shop-floor' occupations.

Figure 2.14: Composition of the workforce by occupations (manufacturing & all industries)



Source: Annual survey of hours & earnings

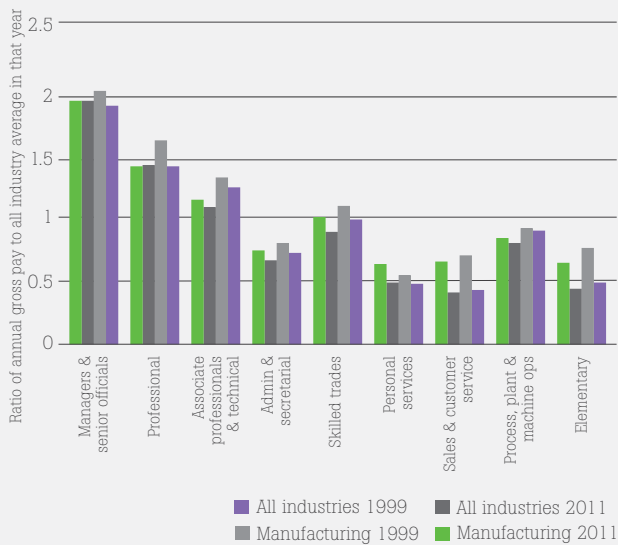
Employee remuneration was some 10% higher in manufacturing than the average across all industries in 2011 (see Figure 2.15)⁹¹. Those working in manufacturing were generally paid more than in comparable occupations across all sectors.

⁸⁶ The importance of returns to scale in 'cumulative causation' models is explained in: Kaldor, N. (1985); Krugman, P. (1991); and Krugman, P. (1980).

⁸⁷ Harris, R. & Moffat, J. (2011) ⁸⁸ Baldwin, R., Forslid, R., Martin R., Ottaviano, G.I. & Robert-Nicoud, F. (2003) ⁸⁹ Awano, G., Franklin, M., Haskel, J. & Kastrinaki, Z. (2010) ⁹⁰ ONS (2012c) ⁹¹ ONS (2012c)

If pay is an indication of skill levels linked to the productivity of human capital, then the data suggests that manufacturing performs significantly better than the average across all industries. Further evidence relating to the role of people in manufacturing is provided in Chapter 6.

Figure 2.15: Relative UK annual gross pay by occupations (manufacturing & all industries)



Source: Annual survey of hours & earnings



3. FASTER, MORE RESPONSIVE AND CLOSER TO CUSTOMERS

Technology will play a central role in driving change in manufacturing. Some of the value being created in 2050 will derive from wholly unanticipated breakthroughs, but many of the technologies that will transform manufacturing, such as additive manufacturing, are already established or clearly emerging.

This Chapter examines important long-term changes expected in technology and innovation, and the shape of the potential factories of the future, setting out fundamental shifts in how products are designed, made, offered and ultimately used by consumers.

The Chapter concludes by outlining a range of implications for Government, and relevant advice where needed, that will need to be addressed as manufacturing becomes faster, more responsive and closer to customers.

3.1 TECHNOLOGY AND INNOVATION

KEY MESSAGES

Technology plays a central role in the competitiveness of UK manufacturing, supporting innovation, driving product development and providing impetus for improvements in manufacturing performance. The UK has attributes that if suitably focused, could better exploit maturing technologies to capture a larger proportion of future global markets.

Primary or underpinning technologies such as information and communications technology (ICT), sensors, advanced and functional materials, biotechnology and sustainable or green technologies are likely to become increasingly pervasive in products and processes.

Secondary or contingent technologies such as mobile internet, big data, the internet of things, robotics, additive manufacturing and cloud computing will make use of these underpinning technologies to collectively facilitate:

- Mass personalisation of low-cost products, on demand;
- A much more distributed local and global production base, with manufacturing done much closer to the customer and a greater diversity in the factories of the future (see Section 3.2);
- ‘Digitised’¹ manufacturing value chains, with digital connections between customers, manufacturers and suppliers increasing the speed and efficiency of manufacturing, and enhancing opportunities for international collaboration;
- Greater freedom of design;
- Delivery of innovative new products;
- Higher performance and more flexible manufacturing systems delivering better quality and cost performance; and
- Better customisation of products and services (called ‘customerisation’).

The pace of technological change means that it is not always possible to exactly predict the consequences of developments, or when they will occur. However, technological developments will ultimately lead to new ways of doing business, for example using new sources of data to make products more tailored or personalised, or to sell complementary services. It will also bring new challenges in the protection of intellectual property, skills requirements and cyber- and biosecurity.

The secondary or underpinning technologies discussed in this section are relevant to the ‘eight great technologies’ (big data, space, robotics and autonomous systems, synthetic biology, regenerative medicine, agri-science, advanced materials and energy) receiving current Government investment².

3.1.1 INTRODUCTION

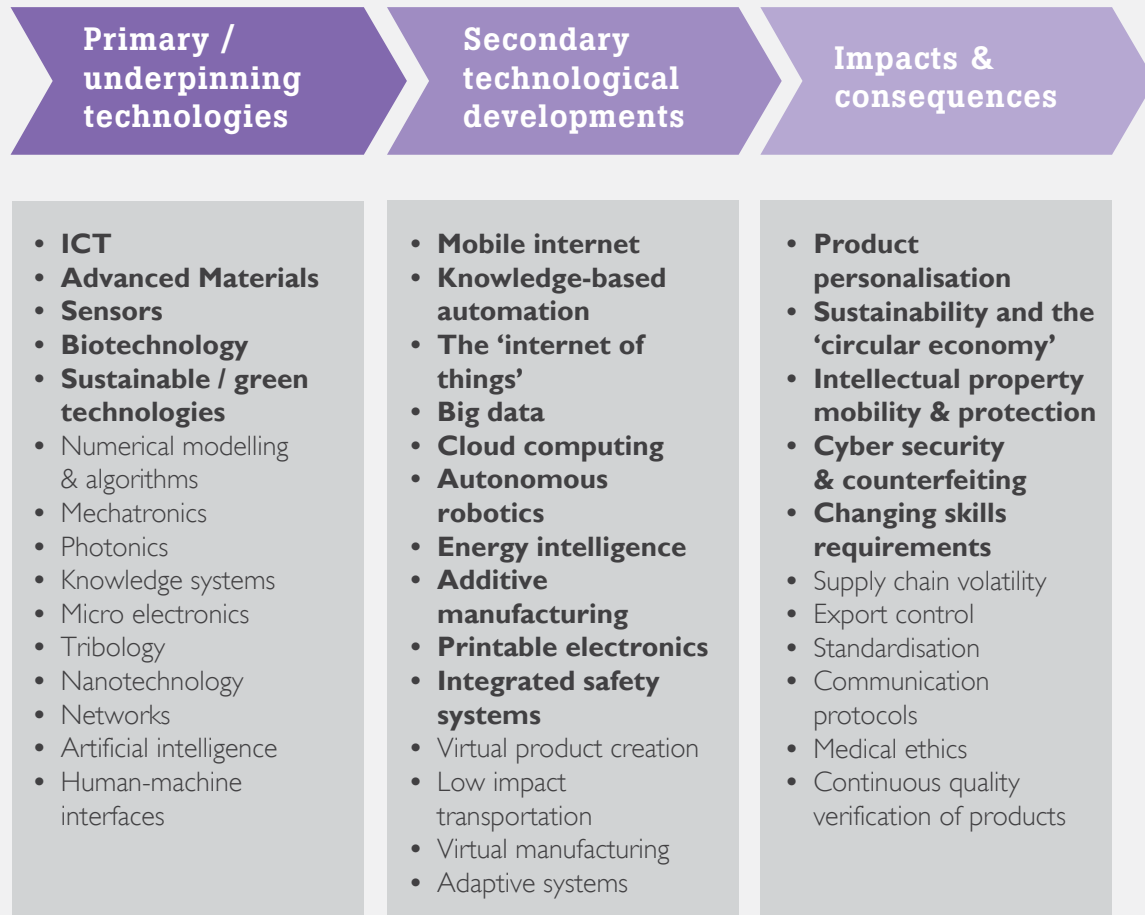
Modern manufacturing technologies, including automation and robotics, and practices such as ‘lean’ which focus on removing non-value-adding activities³, are now used throughout the world following progress in communication and transport technologies, and the globalisation of supply chains. The UK’s competitiveness in low-, mid- and high-end technologies⁴ is increasingly being put to the test by manufacturers in emerging economies, which are building, or have already built, national research and development (R&D) bases and state-of-the-art manufacturing facilities. This is likely, eventually, to level, or even invert, differences in technological development between different regions of the world.

In these evolving conditions, those who innovate most effectively will succeed in capturing and dominating global markets. This will include creating products using low energy and low resource input; responding to customer needs for high quality, customisation and personalisation; decreasing time to market and product delivery time; and maximising complementary services. Significant competitive advantage can be achieved by establishing

¹ The Economist (2012) ² For further details see: <https://www.gov.uk/government/news/600-million-investment-in-the-eight-great-technologies>

³ Evidence Paper 21: McLaughlin, P. (2013) ⁴ Evidence Paper 6: Dickens, P. et al. (2013)

Figure 3.1: Primary/underpinning & secondary technological trends & the consequences for how products are designed, manufactured, used & recycled



Note: Examples highlighted in bold are discussed in this section

high performing and technologically advanced manufacturing capabilities, through the creation and/or acquisition of technologies that fully exploit an integrated approach to design, R&D and knowledge.

The importance of securing competitive advantage through key technologies has been emphasised by a recent study⁵ which estimated that the potential global economic impact of twelve key technologies, including advanced robotics and energy storage, could reach US\$14-33 trillion by 2025. This figure relates to new revenue that companies will generate and the value individuals will personally derive from an innovation they do not need to pay for.

This Section examines likely future developments in two areas, and considers their likely impacts and consequences for UK manufacturing in the decades ahead (Figure 3.1):

- **Primary or underpinning technologies:** These fundamental underpinning capabilities are pervasive and often integrated within higher level systems with the potential to influence almost every aspect of human life, wellbeing, leisure, business and the global economy.
- **Secondary or contingent technologies:** These make use of underpinning or basic technologies to create secondary technologies with higher functionality, from very broad and highly configurable 'systems', through to narrow and deep, highly targeted, high performance capabilities.

Developments in these technologies are likely to be either derivative (including advances in technologies already in place); novel (immediately offering new capabilities, for example medical biotechnology and additive manufacturing); or disruptive (currently unknown and highly innovative technologies that offer unpredictable implications, with the potential to revolutionise an industry)⁶.

3.1.2 PRIMARY OR UNDERPINNING TECHNOLOGIES

Information and communications technology

ICT stresses the role of integrated telecommunications and computers, and enables users to access, store, transmit, and manipulate information. Few aspects of modern life are untouched by ICT following its 5-7% annual growth since its origins in the 1960s⁷. The total worldwide investment in ICT has been estimated as US\$3.5 trillion, and is currently doubling every 15 years⁸. Manufacturing is no exception, with investments in automation alone expected to comprise some 8% of global ICT expenditure by 2020⁶.

Used initially to automate human processes, ICT is now applied to enable integration of data across functions including the management of customer relationships, process control, product verification, manufacturing simulation, logistics, product traceability and safety systems. More recently, the capacity for storage (estimated at 295 billion gigabytes in 2007⁹ but now significantly larger¹⁰) and global inter-connectivity has led to the development of 'big data'¹¹ 'cloud computing'¹² and the 'Internet of Things'¹³.

Over the next 20 years, modelling and simulation is expected to become integrated into all design processes as the cost of computing continues to fall and specialised tools for virtual reality are

developed. This will allow increasingly complex simulations to optimise and check the safety of new products, designs and production systems, new process concepts, factory design, and supply chains¹⁴. In addition, simulation capabilities will become embedded within processes to provide intelligent, adaptive, real time control, revolutionising quality performance and options for product complexity. Firms will need to adapt their underlying systems architectures and processes to cope with large amounts of data, incorporating new data streams such as smart sensor or social media feeds if they are to take advantage of new business opportunities¹⁵. Furthermore, the so-called 'knowledge economy' and the more recent 'innovation economy' are both dependent on the inexorable rise of the world-wide web and associated ICT technologies where systemised knowledge becomes a critical commodity.

Advanced and functional materials

Materials are integral to every manufactured product in the global economy, and in many applications, a specific property or properties of a material will provide competitive advantage¹⁶. However, new materials rarely have intrinsic value in themselves. They provide value through integration into new systems or components to enable improved performance or new designs. It is therefore difficult to disentangle materials development from manufacturing innovations, which drive each other in a spiral of improvement¹⁷.

It is usually the case that new materials create new production challenges, requiring major advances in manufacturing process technologies that in turn can be used for other applications. The added value of materials will expand as new materials such as graphene, carbon nanotubes, diamond-like carbon, composites (ceramic, metallic and organic) with shape memory and self-healing properties, and copolymers are used more widely in applications including energy storage, computer and smart phone displays, enhanced chemicals and catalysts, consumer electronics, pharmaceuticals, aerospace, and many other types of manufacturing.

⁶ Bower, J. L. & Christensen, C. M. (1995) ⁷ Evidence Paper 6: Dickens, P. et al. (2013) ⁸ Operations Management Technology Consulting (2013) ⁹ Hilbert, M. and López, P. (2011) ¹⁰ McKinsey & Co. (2011a) ¹¹ Defined here as datasets whose size is beyond the ability of typical database software tools to capture, store, manage and analyse. ¹² Defined here as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. ¹³ Defined here as the next revolution towards massively distributed information, where any real world object can participate in the internet and thus be globally discovered and queried. ¹⁴ Evidence Paper 6: Dickens, P. et al. (2013) ¹⁵ Economist Intelligence Unit (2012) ¹⁶ Evidence Paper 6: Dickens, P. et al. (2013) ¹⁷ Evidence Paper 10: Grant, P & Mason, T (2013)

In the past, the key driver for new materials has been to achieve superior performance at high cost for the most elite applications, with some developments focused on low-cost applications. While this is expected to continue, other drivers, including global resource scarcity and environmental concerns¹⁸ will promote the use of sustainable materials and processes. For example, renewable inputs in the chemical industry are increasingly being used globally, with significant research programmes dedicated to the transition from petrochemicals to biomass¹⁹. Scarce materials, or those subject to fluctuations in supply, for example rare earth elements used in renewable energy technologies²⁰, consumer electronics and aerospace, are also being substituted with alternative materials, reflecting growing realisation of the limits to non-renewable primary mineral resources²¹.

A number of new materials, in which the UK has strong capabilities, are currently in development and are expected to penetrate the mass market in the near future. These include:

- Highly reactive nanoparticles, which have potential for a wide range of applications and could lead to manufacture at nanoscale, or 'atomically precise manufacturing'²².
- Lightweight materials including composites²³, which combine ceramic, metallic and organic materials with design optimisation to reduce inputs. Also, research into multifunctional materials, where combinations of properties are used to achieve two or more functions²⁴. The maturation of additive technologies will significantly expand the ability to create hybrid, tailored and graded structures, further enhancing the use of capabilities for design optimisation.
- Biomaterials, or substances which interact with biological systems (discussed in a following section), will continue to penetrate the consumer goods sector.
- Intelligent materials which have been designed to provide feedback into a larger system, for example feedback via chemical signals, with feedback dependent on material composition.

Sensors

Sensors are miniaturised devices which measure a physical, chemical or biological variable and convert it, usually into an electronic signal. In modern products and production processes, sensors are usually an integrated and vital part of the system, providing information about variables such as position, temperature, stress, chemical environment, product concentration, and number of uses. The global market for sensors was estimated to be about US\$56 billion in 2010²⁵.

Sensors are ubiquitous across the manufacturing sector and provide data about the progress, quality or condition of manufacturing systems. Modern cars have sensors to measure the performance of vital components in real-time, for example tyre pressure, oil temperature and fuel injection. Aircraft would be unable to operate without sensors providing real-time feedback on all aspects of the airframe and engine status even from the most inhospitable environments within the hot areas of the gas turbine engine. Future development of nano-electro-mechanical systems is likely to support sensing and control of very small systems, for example in consumer electronics.

The digital integration of sensors has developed alongside computer-integrated manufacturing (CIM) to allow automated real-time control of production processes. Internet connectivity allows the sensing and controlling of products in the field. For example, Rockwell Automation, a US business with several sites in the UK, manages the availability of machine tools remotely across client factories using real time data, improving the availability of equipment. Olympus Automation, a UK based business, is also a notable example of a business specialising in process and automation technologies for the food and drink, and pharmaceutical sectors.

Developments in sensing technology performance will continue. But it is the integration of sensors into networks of technology that is expected to revolutionise manufacturing, especially when coupled to simulation and adaptive capabilities, providing increasing levels of process autonomy. New applications, for example where products

are connected to the internet, will become commonplace. Likely developments include autonomous vehicle navigation in city centres, more widespread use of data in new business models as firms seek to create new revenue streams by complementing their products with services, and remote management of automated equipment.

As sensing infrastructure becomes more commonplace and confidence grows in its reliability, applications such as medical monitoring for the elderly also become viable. In the manufacturing sector, information will be increasingly machine-generated, leading to self-checking inventories, smart containers that detect and monitor the status of their contents, automatic reconfiguring of production lines to alter a product mix, and condition monitoring where machines are able to self-diagnose and predict faults before failure²⁶.

Sensors will become very important for the future competitiveness of UK manufacturing over the medium and long-term²⁷. They will be critical for developing competitive products and for achieving continued improvements in manufacturing performance which lead to competitive advantage in cost, quality and delivery. However, sensors rely on networks to transmit the data and on computing ability to store, analyse and use it intelligently. Manufacturers must develop their ability to transform this explosion of data into useful knowledge and value.

Biotechnology

Biotechnology²⁸ is used to describe any technology that exploits or enhances biological products. The global market for biotechnology products was valued at US\$216.5 billion in 2011 and is expected to reach \$414.5 billion in 2017²⁹. This section highlights key future developments in biotechnology, focusing on where the UK has competitive advantage and capability:

- Industrial biotechnology is already exploited in plant and animal breeding, food ingredients, bulk chemicals, energy generation and materials. Products include genetically modified plants, biopharmaceuticals, biofuels, bio-based bulk,

fine and speciality chemicals, and bioplastics (see Box 3.1). Biopharmaceuticals have dominated the sector, but food biotechnology is an emerging area where microorganisms and microalgae are being used to synthesise a range of food supplements. In addition, traditional production of leather and meat is already starting to be supplemented with engineered products, however on a small scale at present. The barriers restricting the development of biotechnology products are cost, complexity of scale-up, consumer acceptance and regulatory hurdles³⁰.

BOX 3.1: NEW BIOTECHNOLOGY PRODUCTS

- Sorona, an 'eco-fibre for carpet, apparel and automotive' developed by DuPont is a bio-derived brand of poly-trimethylene terephthalate obtained by fermentation from corn-derived glucose and is expected to be the first billion-dollar product made through industrial biotechnology which is not a pharmaceutical.
- Bioplastics derived from renewable biomass sources, for example vegetable fats and oils, offer the advantages of novel functional properties and relatively low greenhouse gas emissions during manufacture³¹.
- Synthetic biology offers the capability to 'rewire' biological systems and capitalises on advances in DNA synthesis. Rapid progress is being made globally on engineering organisms at the level of the genome by introducing targeted modifications, multi-site genome engineering or by synthesis of whole genomes³². These approaches are being applied to the industrial production of amino acids and polyketides and are expected to be applied to the manufacture of bio-fuels.
- The regenerative medicine market³³, which includes tissue engineering, biomaterials and biomolecules (scaffolds, growth factors) and stem cell therapies, exceeded US\$3 billion in 2010 and is expected to reach \$4.5 billion by 2014 and over \$35 billion by 2019. This rapidly expanding market will include products such as tissue-engineered skin, cartilage and bone. Novel manufacturing processes that can replicate

²⁶ Evidence Paper 6: Dickens, P et al (2013) ²⁷ Evidence Paper 6: Dickens, P et al (2013) ²⁸ Defined here as 'the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services; ²⁹ Transparency Market Research (2013) ³⁰ Evidence Paper 6: Dickens, P et al (2013) ³¹ Barker, M & Safford, R. (2009) ³² Alper, H. & Weber, W. (2012) ³³ Trimark Publications (2013)

in vivo physiology and which could lay the groundwork for personalised organ fabrication³⁴, point-of-care diagnostics and bedside manufacturing of drugs in the hospital ward may become possible.

- Chemical synthesis from waste streams by mixed microbial communities (microbiomes) is being extended beyond anaerobic digestion in the UK to produce chemicals from waste organic material or CO₂. Traditional chemical markets are increasingly using products derived from bioprocesses or hybrid chemical-biocatalytic reactions³⁵.

Over the next two decades, the range of biotechnology products is set to expand, with revenues expected to grow to US \$600 billion by 2020³⁶. There will be a widespread adoption of 'omics', or the increased use of various fields of biology, by industry. The longer term promise is that if the interactions between molecules, macromolecules and cells are more fully understood, it will be possible to better interpret, predict, control and redirect complex cell systems. This would become an important platform for future UK competitive advantage, building on existing competencies. For example, biological data will provide new insights into the molecular mechanisms of complex diseases, allowing the identification of novel treatments, and the development of novel factories for the sustainable production of fuels, chemicals and materials³⁷.

Medical and industrial biotechnology holds significant potential for UK manufacturing in the short, medium and long term, given the UK's strengths in these fields, particularly in research and development³⁸. Maintaining national capability in critical underpinning technologies and avoiding over-reliance on the selection of single applications will however be crucial³⁹ if the UK is to compete in what are expected to be substantial global markets.

Sustainable or green technologies

Sustainable technology comprises technologies that reduce material or energy use to levels considered sustainable in the longer term. It encompasses a broad range of technologies from those that provide clean energy to everyday products with improved environmental performance, for example paint booths which use less water for cleaning. The importance of shifting to sustainable manufacturing was strongly emphasised at the three international workshops undertaken by the Project⁴⁰.

Future production processes are likely to compete on minimising energy and use of non-renewable materials, whilst simultaneously shifting to renewable sources as they become available and economically viable^{41, 42, 43, 44}. This shift will benefit manufacturing activities, as businesses become more resilient to shocks on the supply and price of energy and materials. Firms will increasingly favour resilient supply chains, with built-in redundancy which allows adaptation to disturbances with minimal financial impact⁴⁵, despite higher transaction costs and reduced efficiency⁴⁶. More resilient supply chains are likely to be shorter with fewer links, and include more local suppliers with shorter transport routes. Firms will embrace the benefits of co-location in 'industrial ecology'⁴⁷ systems, taking advantage of reduced reliance on raw materials by using 'circular economy' waste cycles as end-of-life products are re-used⁴⁸ (see Chapter 5 for details).

All sub-sectors will need to adapt to embrace sustainable technologies if they are to remain competitive. For example, in the UK chemical sector, research and engineering practices are likely to change fundamentally, as 'green chemistry'^{49, 50}, where products and processes are designed to minimise the use and generation of hazardous substances, becomes widely adopted. Similarly, in industrial biotechnology, biological catalysts are increasingly likely to replace chemical catalysts.

³⁴ Evidence Paper 6: Dickens, P. et al (2013) ³⁵ Schmid, A., Hollman, F., Byung Park, J. & Bühler, B. (2002) ³⁶ Evidence Paper 6: Dickens, P. et al (2013) ³⁷ Nielsen, J. & Yip Lee, S. (2012) ³⁸ Evidence Paper 6: Dickens, P. et al (2013) ³⁹ World Economic Forum (2013) ⁴⁰ Evidence Paper 1: Foresight and Arup (2013) ⁴¹ Evidence Paper 6: Dickens, P. et al (2013) ⁴² Evidence Paper 35: Tennant, M. (2013) ⁴³ Evidence Paper 10: Grant, P. & Mason, T. (2013) ⁴⁴ Technology Strategy Board (2012b) ⁴⁵ Deloitte (2013) ⁴⁶ Evidence Paper 35: Tennant, M. (2013) ⁴⁷ Industrial ecology involves the study of the 'flows' of materials and energy through socio-economic systems with a view to optimising their use. See: <http://www.roionline.org/what-is-industrial-ecology.htm> ⁴⁸ Evidence Paper 35: Tennant, M. (2013) ⁴⁹ United States Environmental Protection Agency (2013) ⁵⁰ Anastas, P.T. & Warner, J. C. (1998)

The UK is currently considered an average performer in the development of clean technology in support of sustainable manufacturing⁵¹, with significant barriers including a lack of support for R&D activities⁵². However in the future, achieving sustainability presents major opportunities for the UK manufacturing sector⁵³, with significant potential economic, social and environmental benefits⁵⁴. For example, the world market for energy efficiency-related products has been estimated to be US \$1.2 trillion by 2020, which the UK could exploit using its existing competitive advantage in some areas of low-carbon technology⁵⁵. As the UK is competing directly with other countries who are also targeting the rapidly growing market for sustainable technology, policies will need to encourage innovation (for example, with higher landfill taxes) without stifling growth by making UK firms uncompetitive or unattractive to foreign direct investment.

3.1.3 SECONDARY TECHNOLOGICAL DEVELOPMENTS

Secondary technologies make use of underpinning or basic technologies to bolster secondary or contingent technological developments. For example, the 'Internet of Things' could not evolve without sensors, which themselves are dependent on the development of new materials, ICT and techniques for data analysis.

Mobile internet^{56, 57}

The influence of the mobile internet extends far beyond the provision of access to a browser from smartphones, tablets or laptops, and has the potential to bring significant opportunities to the manufacturing sector. It encompasses a range of functions relating to service delivery, worker productivity, remote and mobile healthcare, personalisation, and directed advertising.

The use of built-in GPS and the possibilities of adding radio frequency identification (RFID), near-field communication (NFC), bar code, quick response (QR) code and magnetic stripe capabilities, will mean that smartphones are positioned to become ubiquitous, general purpose tools for the management of supply chains, assets, maintenance, and production.

Technologies whose future is inextricably linked with mobile internet include battery technology, advanced and low energy displays, new user interface designs, nano-miniaturisation of electronics and optoelectronics, plastic electronics, wireless techniques and sophisticated encryption technologies.

Knowledge-based automation and big data⁵⁸

An integration of artificial intelligence (AI), natural user interfaces (NUI), more intuitive computing and new techniques for the analysis of large data sets (big data) will allow continued automation of many tasks that formerly required people. The amount of data collected and stored worldwide⁵⁹ is already increasing at a rapid rate, and its analysis will become a key aspect of competitiveness, underpinning new cycles of growth in productivity and innovation. The expanding volume and detail of information captured by businesses and the rise of multimedia, social media and the 'Internet of Things' will fuel a continued massive increase in data in the decades ahead⁶⁰.

Big data can create significant value by making information much more accessible, transparent and usable at much higher frequency. The collection of more accurate and detailed data can expose variability in customer preferences and the usage of products, and be used to boost product performance and personalise products or services. It can also improve decision making through sophisticated analytical algorithms and assist in the design and development of next generation products, manufacturing processes and services. There is clearly an opportunity here for UK manufacturers to rise to the challenge of making better use of data in the future. For example, in the US estimates indicate that if the healthcare sector

51 Evidence Paper 6: Dickens, P. et al (2013) 52 Evidence Paper 35: Tennant, M. (2013) 53 Evidence Paper 6: Dickens, P. et al (2013) 54 Elkington, J. (2013) 55 HSBC. The Climate Group (2011) 56 McKinsey Global Institute (2013b) 57 MIT (2013) 58 McKinsey Global Institute (2013b) 59 Hilbert, M. & Lopez, P. (2011). 60 McKinsey Global Institute (2013b)

were to utilise big data to drive efficiency and quality, it would create more than US\$300 billion in value annually and reduce overall expenditure by about 8%⁶¹. However, several issues concerning privacy, security, intellectual property, and skills shortages will have to be addressed if the full potential of big data is to be realised.

The 'Internet of Things'^{62, 63}

Physical, chemical and biological sensors embedded in devices, equipment, clothing, machinery and people, and linked via wireless and near-field communications, are likely to be able to 'talk to' intranets and the rest of the internet within the next couple of decades. There will be major impacts for UK manufacturers in the optimisation of business processes, and management of natural resources, energy delivery and minimisation, and remote and mobile healthcare. In the factory and process control environment, virtually everything is expected to be connected via central networks and the Internet. Industrial products will become more autonomous in functionality, with systems which may incorporate millions of sensors.

Within the next few decades, software that oversees how, when and where devices embedded with sensors function will be critical. These developments, when combined with smartphones, will allow a multitude of tasks on the factory floor to be improved, including the control and programming of robotic and automation systems, and troubleshooting of quality issues. It may also be possible to combine touch, and gesture or motion with voice interfaces to direct artificial intelligence (AI) assistants, which have access to search engines, databases and cloud computing systems.

Cloud computing⁶⁴

Cloud technology can provide centralised computing facilities to serve company intranets, suppliers or service providers. In the future, more efficient and effective use of computing and software resources may enable manufacturers to access resources more economically than by building their own systems and architectures. Cloud storage and processing can offer tools for enhancing productivity which were previously unaffordable for

small and medium enterprises (SMEs), to strengthen the management of supply chains, requirements for resources and materials, and customer relationships.

Manufacturing execution systems (MES) are likely to become more important. These are computerised systems used to show the manufacturing decision maker how conditions on the factory floor can be optimised to improve production output. MES work in real time to enable the control of multiple elements of the production process such as inputs, personnel, machines and support services. Over the next decade, cloud-based software will move from specialist applications towards the shop floor.

Advanced and autonomous robotics⁶⁵

In the next three decades, the development of powered exoskeletons (a wearable robotics suit), artificial and enhanced visual, aural and touch sensations, remote control and operation and artificial intelligence will make a number of routine operations within manufacturing, healthcare and surgery, food preparation, cleaning and consumer activities obsolete, and provide a wealth of opportunities for manufacturers.

Autonomous and near-autonomous vehicles such as cars, drones, trains and ships will boost the development of computer vision, sensors including radar and GPS, communication with networks, and remote control algorithms. Current systems for machine vision are widely used for sorting, inspection and quality control. However, 3D vision and measurement systems are now becoming more commonplace, allowing control systems not only to distinguish between components but also to adapt conditions based on identified variation. On the human front, 3D vision will be able to track gestures, body motion, gaze and recognise faces, creating the potential for new products and applications as well as supporting robot and human co-working in the same operating space.

Energy intelligence⁶⁶

It is crucial, particularly for energy-intensive process industries, to understand a process plant's energy needs and eliminate wasteful consumption by

collecting energy information from sensors, plant automation systems and sub-meters. As energy prices fluctuate in the future⁶⁷, manufacturers will rely increasingly on energy intelligence to monitor and control energy consumption in their manufacturing operations. The growing trends in industry to improve corporate sustainability and implement energy and carbon reduction targets are expected to continue.

Energy storage is a limiting factor in many technologies including consumer electronics, mobile computing, vehicles, remote mechanical systems and alternative energy production. If new ways to store energy at high density could be found through novel approaches to battery technology, nanoscience and advanced materials, multiple new applications and potential for new manufactured products would be achievable.

Alternative energy resources are also expanding in commercial scope, facilitated by advances in technology, although petroleum and gas retain their importance in many manufacturing processes as critical components. New techniques such as hydraulic fracturing of shale rocks or 'fracking', horizontal drilling and microseismic monitoring will be important in the extraction of shale gas, light oil and coal-based methane. In addition, the requirement to mitigate climate change and conserve finite petroleum reserves is prompting the exploitation of solar, geothermal, wind, wave, hydroelectric and various forms of biofuels to assist in generating and distributing energy. This has implications for UK manufacturers in terms of the opportunities in providing and using new products.

Additive manufacturing (AM)^{68,69}

Additive manufacturing (or 3D printing) developed from advances in rapid prototyping technology. It produces parts by adding layers of material, rather than removing material, i.e. subtractive manufacturing, to build an object. It is expected to lead to profound changes in the way businesses make almost any product over the coming decades, becoming an essential tool allowing for:

- A diverse range of products to be fully personalised to individual customer requirements, for example medical implants;
- Products to be made as lightweight as possible;
- Designs to be optimised to reduce waste;
- Inventories of spare parts to be reduced, with data stored instead;
- Value chains being managed more effectively, reducing the need for complex operation sequences, raw materials, inventory buffers and extended supply chains;
- Greater flexibility in the location of manufacturing;
- Customers being able to make their own products;
- Potential for creating compatible tissues and organs for transplantation;
- Products to be made with new graded composition and bespoke properties; and
- Reduced dependence on moulds and product assembly.

Additive manufacturing has strong potential for being adopted in a range of industries, including aerospace, medical devices and implants, power generation, automotive, and the creative industries⁷⁰. Research is now underway to produce parts in multiple materials, to accelerate production, to produce larger areas of material, and to integrate electro-mechanical systems into AM products⁷¹. The market for products made using additive manufacturing techniques is growing rapidly and will provide significant and transformative opportunities for UK manufacturers. For example, between 2010-2012, the global market for AM products rose from US\$1.3 billion to \$1.9 billion⁷², with estimates for future market growth reaching \$100 billion by 2020⁷³.

Printable electronics⁷⁴

The technologies underpinning printable electronics, for example 'e-ink' materials, and intelligent bar code systems such as RFIDs, have the potential to drive down the costs of digital displays, to compete with bar code printing. RFID tags in particular could disrupt many current ways of doing business in manufacturing by offering the prospect of low-cost object and asset tracking, with sensors and computing integrated into products. An RFID tag on a manufactured product with integrated sensors could potentially detect physical, heat or moisture damage during storage or transit and subsequently provide a warning on an e-ink display. This is a rapidly developing area of technology with many potential opportunities for UK manufacturers.

Integrated safety systems⁷⁵

Many manufacturers have taken advantage of global safety standards to integrate rapidly advancing safety and plant automation systems. In doing so they have maintained their safety record without sacrificing productivity. Inter-communication between safety and quality control systems provides manufacturers with greater intelligence on the reasons for, and frequency of, adverse events and how best to identify them from massive amounts of complex safety data. Advanced process monitoring sensors and systems can create a process fingerprint and eliminate process anomalies, which are especially useful for ultra-high integrity products. Future adoption of these systems will rise as more UK manufacturers realise the benefits.

3.1.4 FUTURE IMPACTS AND CONSEQUENCES OF TECHNOLOGY ADVANCES

The development and maturation of new technologies often delivers the opportunities and implications envisaged at the time of inception. However, they can also have unintended impacts and consequences which were not anticipated. This section reviews some of the opportunities and challenges that the new technologies discussed above are likely to present.

Product personalisation

The prospect of mass product personalisation over the coming decades in the UK will challenge the traditionally held view that a steep trade-off exists between cheap mass-produced 'one-size-fits-all' products using economies of scale, and those tailored to individuals at substantially higher costs. This concept can be expressed as 'make-to-stock' versus 'make-to-order' and will be driven by advances in additive manufacturing, new materials, computer-controlled tools, biotechnology, and green chemistry. In addition, direct customer input at the design stage will enable companies to produce customised, affordable, high quality goods and services with shorter cycle-times and lower costs associated with standardisation and mass production.

Personalisation currently represents a small part of the global economy, although research suggests⁷⁶ that customers in developed economies are already prepared to pay a premium of 10% for some degree of personalisation. This is a significant opportunity for UK manufacturers, and innovative technologies are already making this option more feasible. Examples of personalised products include Nike trainers, Levi Strauss's Original Spin, Swatch and Dulux colour combinations, made-to-order Dell computers and many durable goods such as cars.

Sustainability and the circular economy

A key driver of future manufacturing is likely to be a shift to more sustainable manufacturing, which uses less material, energy and other inputs, and a shift to a 'circular economy' way of doing business, with end-of-life products reused as inputs. This shift in thinking is likely to generate real competitive advantage and differentiation compared to the largely incremental changes in efficiency currently being considered in manufacturing practice.

Manufacturing has, in recent decades, focused on production and consumption in which goods are manufactured from raw materials, sold, used and then discarded. This 'linear economy' approach is material and energy intensive, relies on economies of scale and uses complex and international supply chains. In the current system, approximately 80% of these materials finish their life in incinerators, landfill or wastewater. Estimates indicate that the total material value of consumer goods is US\$3.2 trillion, with approximately 20% being recovered through decomposition, recycling, returning nutrients to the soil and cascading through adjacent supply chains. The circular economy offers an alternative pattern of resource deployment by creating more value from each unit of resource by recovering and regenerating products at the end of their service lives⁷⁷.

Designing and using durable and consumer goods such as cars, vans, white goods, mobile phones, food, beverages, textiles and packaging using circular principles could be worth up to US\$700 billion per annum if fully adopted worldwide⁷⁸. In the consumer goods sector, opportunities exist throughout the value chain in manufacturing (food and beverages), distribution and consumption (textiles and packaging) and disposal (food waste). For example, single-use biodegradable packaging can support the return of bio-based materials such as food to the soil when no other viable end-of-life options exist. These examples of the circular economy are inherently more productive than the traditional business models because they extract value from otherwise defunct resources.

In a fiercely competitive world of rising demand from consumers and dwindling natural resources, market forces will favour business models which create the most value per unit or resource. 'Circular' business models will be promoted further by resource scarcity and tighter environmental standards, urbanisation that concentrates flows of consumer goods and wastes, developments in track-and-trace ICT, new packaging systems and discrete shifts in consumer behaviour, where access is preferred over ownership⁷⁹. However, re-use and recycling requires different manufacturing capabilities and operational models, and will need new technologies to deliver globally competitive manufacturers. Chapter 5 discusses this in further detail.

Intellectual property (IP) protection and new technologies⁸⁰

The use of formal protection mechanisms for intellectual property rights (IPR), including patents, trademarks and industrial design rights, has increased in global importance over past decades as the knowledge economy established. Evidence suggests that IP ownership is positively related to the performance of enterprises⁸¹, although it is difficult to ascertain whether it is the IP protection or the underlying tangible assets which drives value.

As manufacturing changes, businesses are paying more attention to their intellectual assets and devising new ways of managing their portfolios. For example, strategic patenting, when firms leverage complementarities between patents to obtain a strategic or defensive advantage over technological rivals, thereby creating patent 'thickets', is one such option. However, this can lead to low patent quality which barely satisfies the usual criteria of novelty and non-obviousness. Similarly, worldwide litigation over IP infringement has increased in proportion to the rise in patent filings and this trend is likely to continue unless firms can cross-license, create patent pools and resolve issues around royalty 'stacking'⁸².

The introduction of new technologies such as wireless communication, additive manufacturing and biotechnology raise a new set of IP issues and challenges for manufacturers involving consumers, legislators, regulators and other stakeholders. One such example concerns the interaction of the 'Internet of Things' with the current IP and regulatory environment for wireless communication⁸³. Embedded devices linked via wireless and near-field communications which communicate with intranets and the rest of the internet would require businesses to run their own networks for security reasons. However, in doing so they would encounter regulatory barriers regarding the use of private intellectual property. Similarly, customer-specific additive manufacturing may encounter infringement claims from third parties concerning their freedom to operate. These issues may also arise when this technology is used to repair or refurbish a patented product where there is a fine line between part-by-part replacement and reconstruction of the object in its entirety. Equivalent arguments could be presented in the case of cell-based therapies and 3D tissue construction.

Cyber security⁸⁴ and counterfeiting

The closed nature of conventional automation networks appeared, until recently, to be relatively immune from external security threats. However, the pervasiveness of the internet and mobile communications has allowed equipment and systems to be connected and controlled in a seamless fashion, with every connected asset now a vulnerability for its owners or users. Most leading manufacturers are implementing multiple levels of security to ensure that entire networks are not able to succumb to security breaches.

Biosecurity, which encompasses preventative measures designed to reduce the risk of transmission of infectious diseases, invasive alien species, quarantined pests, genetically modified organisms and bioterrorist agents⁸⁵, will require systems put in place to prevent the introduction and spread of pathogens in natural and managed ecosystems. In the future, biosecurity, like cyber

security will require the cooperation of scientists, technicians, security engineers, law enforcement officials and policy-makers to combat real viruses rather than cyber viruses.

Advanced 3D measurement, digital modelling and rapid prototyping technologies enable improved product and process development. However, they also facilitate reverse engineering, cloning and the production of counterfeit products. Security technologies including digital traceability must stay ahead of illegal operations to protect legitimate businesses and minimise risks of product safety.

Advanced technologies and changing skills requirements

It will be critical for the future workforce to be highly skilled and flexible enough to allow manufacturers to embrace new technologies (see Chapter 6). For example, a supply of skilled workers and managers to manage big data will be essential, with the US already forecasting potential shortages of managers and analysts with the requisite skills by 2018⁸⁶. In addition, in a future age of distributed assets and an increasingly mobile workforce, management will need to be mobile to drive asset efficiency and overall business profitability. Simulation technologies will play a greater role in training the work force before they set foot on the shop floor.

The nature of the workplace is also likely to alter substantially in most developed economies, including the UK, over the next four decades. Working practices and environments will change, the workforce will age and the requirement for mental rather than physical agility will grow. Human enhancement technology⁸⁷ could contribute to improved workplace efficiency by increasing participation among those who might be disadvantaged or lifting the productivity of all employees beyond the current limits of human endurance (see Chapter 6).

3.2 FACTORIES OF THE FUTURE

KEY MESSAGES

Factories in developed economies and some emerging economies have undergone a transformation in recent decades as manufacturers have focused on labour and resource efficiency, adapted to new technologies including robotics and automation, and responded to opportunities in emerging economies. As a result, there is already a high level of diversity in the focus, scale and location of factories.

The factories of the future will vary, depending on specific sub-sectors and products. But the majority will be influenced by common trends driving change in processes and practices, locations, supply chains, goals and metrics, facilities, technology, people and culture (Figure 3.2).

It is likely that the factories of the future will be increasingly diverse, with multiple models of operation increasingly adopted by individual businesses, resulting in:

- Capital intensive 'super factories' producing complex products
- Reconfigurable units integrated with the requirements of their supply chain partners
- Localised and even home manufacturing for some products
- Mobile manufacturing, potentially at the bedside and in the battlefield
- More urban locations as the factory increasingly becomes a 'good neighbour'⁸⁸ in terms of its environmental impact

These changes will be facilitated by an increase in standardised processes which can be rapidly configured utilising digital technology, to replicate proven production capabilities. New process technologies, allied with data-dependent mechanisation of production processes, will shift

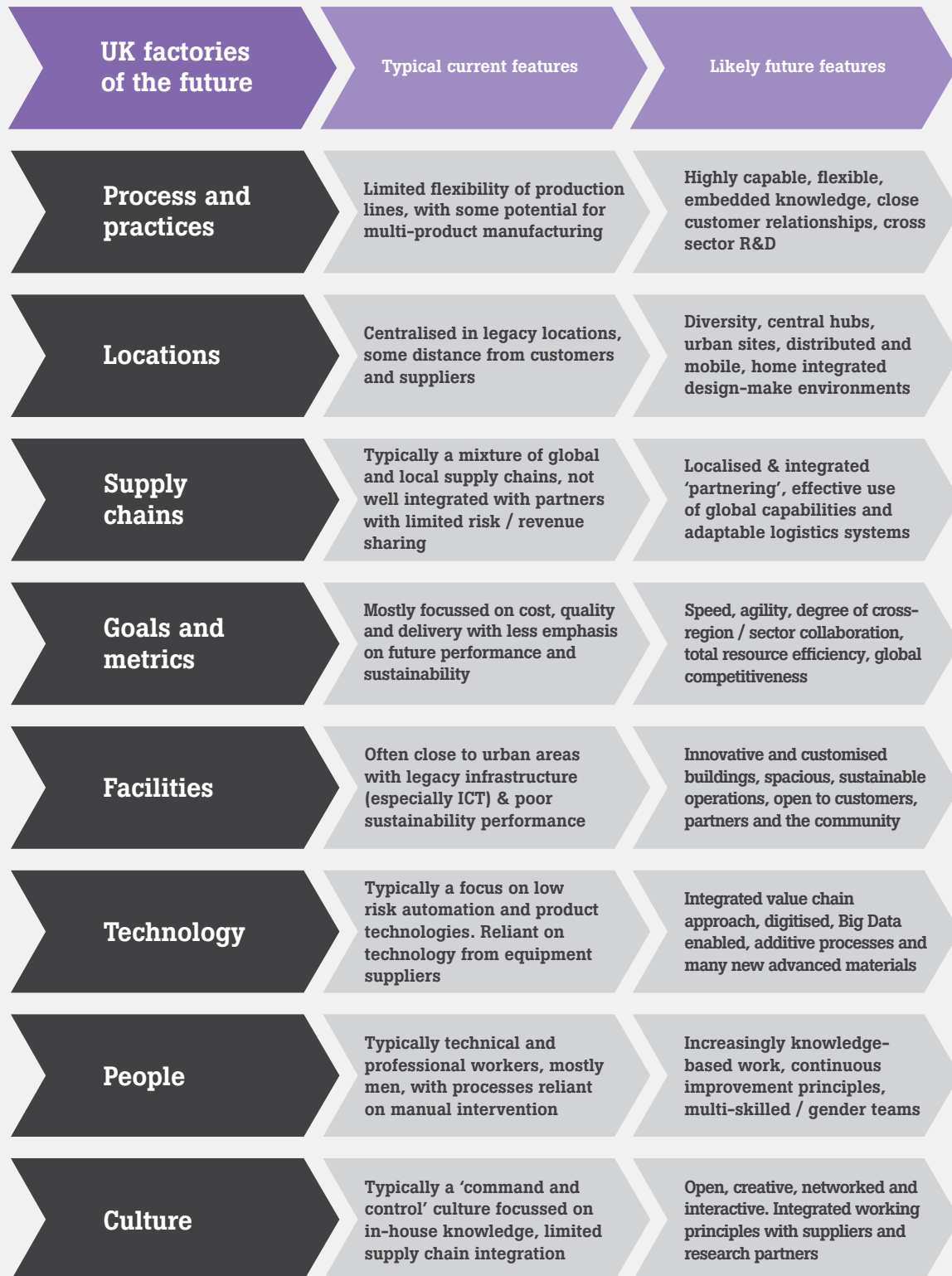
key competences away from traditional production engineering and operational management to information processing and digital control.

Information-production-engineers are likely to design the factories of the future, re-configure them, remotely schedule and then assess the quality of production. They will design products to be made by 'listening' to customers using sensors embedded in products, as well as guiding their use and repair.

Factories of the future are also likely to need to adapt to a range of other changes:

- Becoming more agile to respond quickly and flexibly to customer demands, and volatility in external factors, including access to resources.
- Becoming more open to support stronger manufacturer-customer relationships,
- Adapting to new product technologies as customer demands make products more challenging to manufacture with ever decreasing introduction times for new products.
- Embracing new manufacturing technologies as the value chain becomes digitised, with markets becoming more competitive and sustainability accelerating the rate of change.
- Harnessing the knowledge of skilled workers who may no longer be on the shop floor but working remotely, and developing new skills to adapt to advances in technology.
- Further blurring the boundaries between research, design, production and services.
- Establishing new more integrated working relationships through the value chain and across the product life cycle,

Figure 3.2: Likely features of factories of the future



3.2.1 INTRODUCTION

Like much infrastructure, given the investment required, factories are generally built for the longer term. Despite this, factories in the UK have undergone a transformation in recent decades as manufacturers have focused on labour and resource efficiency, adapted to new technologies including robotics and automation, and responded to opportunities in emerging economies. Significant economic, technological and environmental trends will influence factories of the future, and the value chains that they are part of. Proximity to the customer whether real or virtual, massive quantities of data, and new technologies that enable a change in the logic of scale will transform today's factories into very different enterprises.

3.2.2 WHAT ARE THE FUTURE TRENDS?

While it is not possible to forecast how factories in specific manufacturing sub-sectors will evolve over the next 40 years, a reliable strategic assessment of broad trends can be made. These are summarised in Figure 3.2, with a number of examples provided in Boxes 3.2 to 3.6 of factories moving in this direction, with further discussion below.

- Technological developments: Advances in additive manufacturing and other technologies will allow factories on a micro scale to become much more common, to the point where some people undertake manufacturing at home. Factories will become more agile and able to respond quickly and flexibly to customer demands due to their flexible machinery, staff and infrastructure, enabling the 'reconfigurable factory'⁹⁰. Factors such as fast progression from manual to automated manufacturing through greater process control are expected to play a growing role in the factory of the future. Factories will become more open to customers, supporting closer manufacturer-customer relationships.
- New process technologies: When allied with data-rich, mechanised production processes, these technologies will shift the key competences away from traditional production engineering and operational management to information processing and digital control. The role of the computer in managing complex and adaptable manufacturing systems, to support decisions concerning what is made where, and to feedback data from use, will change operational decision-making. The huge increase in data fed back from users, combined with the increased competence of computer simulations to accurately model production processes and value chains, will allow manufacturers to model factory designs and alternative strategies before initial commitment, during implementation, and subsequent evaluation.
- 'Information-production engineers': Manufacturers will compete on their ability to create value through the smart use of ICT. Employees will be hired for knowledge-based roles related to production, instead of those based on manual work. Information-production-engineers will design factories, re-configure them as required, and remotely assess output quality. They will design products to be made by 'listening' to customers as well as guiding their use and repair in the field. Workers with technical capability and a breadth of other skills including commercial competence and problem solving abilities will be in demand (see Chapter 6).
- Spatial changes: These will be at the heart of future developments. Factory locations are likely to become increasingly diverse and nearer to the customer's home. Facilities will include smaller, centralised hubs and more urban locations as the factory increasingly becomes a 'good neighbour'⁸⁹ in terms of its environmental impact. Factories are also likely to be more distributed and more mobile, resulting in developments such as manufacturing at the bedside and in the battlefield. For complex products, some manufacturing activities will migrate to larger, more capital intensive 'super factories' while others will become reconfigurable units co-located and integrated with associated supply chain partners.

- **Data and digital technologies:** Firms will need to embrace new digital technologies to make sense of the proliferation of data, which will be important in remaining up to date with customer demand. The best manufacturers will use data directly captured from customers to offer a superior service. Consumers recognise this today in the surprising 'intelligence' with which loyalty cards target special offers. Out to 2050, second-by-second data on usage will allow manufacturers to alter products while in use (for example through the sending of a signal to stop the use of a phone which requires repair, or altering the software in a bicycle to provide feedback on training techniques appropriate to the customer's riding style). Firms will also take advantage of flexible automation and robotics which adapt processes in response to feedback.
- **People and culture:** Factories of the future are likely to be centres of creativity and innovation, operating in networks of relationships, for example with suppliers and universities, where skilled people use world-class technologies and processes to create new ways of adding value, often working remotely. The 'command and control' approach to management used by professional and technical workers will become outdated.

It is critical that UK factories continue evolving, particularly as the pace of technological development continues, to seize new opportunities and ensure that manufacturers are able to compete internationally and leverage additional and new value⁹¹. However, as factories are typically built for the long term, there is a chance that emerging markets could become the destinations of choice for some of the newest approaches to manufacturing⁹².

Mobile factory sites which can move closer to target markets and remanufacturing sites are already operating in countries such as India. Brandix India Apparel City is an integrated supply chain city located in Andhra Pradesh is one example (see Box 3.6). This growing challenge creates an even greater need for effective government policy to stimulate and support UK manufacturers to invest and change in order to ensure they get ahead of the game. This is particularly in terms of supporting collaboration between firms and sharing of best practice, and using industrial policies to enable the next generation of factories to develop (Chapter 7).

BOX 3.2: THE CUSTOMER EXPERIENCE (VW AUTOSTADT, THE CITY OF CARS)⁹³

The Autostadt complex in Wolfsburg, Germany, offers 'an enjoyable experience for the whole family'. Here the customer can specify his or her new car, watch the car being made and see it come off the production line. Inside the complex, there are a variety of driving and car-related attractions (from educational and historical displays, art exhibitions, driving experiences on all-terrain tracks, and a children's driving school). There are restaurants, shops and even hotels so that customers can stay for a few days.

The car distribution centre offers a staged process for car collection in which car-buying customers are given vouchers to use in restaurants and other parts of the complex as the car buying and preparation process commences. Combining museum, entertainment and vehicle purchase, the Autostadt is an example of growing interaction between previously distant factories and consumers.

BOX 3.3: FAST AND FLEXIBLE (LOADHOG IN SHEFFIELD)⁹⁴

Loadhog manufactures innovative handling and logistics products including re-usable pallets and storage devices. It is a good example of features such as fast progression from manual through semi-automated to automated manufacture, and greater process control.

Loadhog have successfully improved the characterisation of their production processes by through use of simulation and modelling. They use this knowledge to accelerate through the slower, manual production to faster, automated production. Achieving this 'ramp-up' faster than their competitors and at reduced capital cost (by replacing expensive hard tooling with computer controlled automation) is a critical competence in medium-volume, customisable product manufacture. The firm uses sophisticated computer aided design (CAD) software to design prototypes which avoids commitment to hard automation or tooling.

There is a dedicated 'ideas and innovation' centre, made up of 10 designers and engineers, an extensive engineering workshop, CAD and rapid prototyping facilities. The majority of prototypes are developed on-site with an exceptionally rapid turn-around of ideas. The most successful projects have been carried out in close collaboration with customers.

BOX 3.4: FOCUS ON DESIGN (VITSOE – 'AGAINST OBSOLESCE')⁹⁵

Unlike most furniture designers who design new products that change with fashion, Vitsoe is based in London and has focuses on creating furniture that can last for generations. Customers are asked to photograph their living space so that Vitsoe can design a specific solution. Over the product's life time the customer is encouraged to return for help in adapting the product to their changing needs. Great care is taken to ensure that maximum customer value is not just delivered at point-of-sale but throughout the product's life.

The products created by Vitsoe do not become obsolete. For example, new parts required for a Vitsoe shelving unit bought 50 years ago can be purchased today. Many aspects of Vitsoe's approach are directed towards sustainability: encouraging less wastage by consumers, using the least amount of materials to create the product and emitting minimal pollution during the production and life-time of the product.

BOX 3.5: A GOOD NEIGHBOUR (CATERPILLAR RE-MANUFACTURING SERVICES)⁹⁶

Caterpillar has been providing re-manufacturing services for over 20 years and has a European re-manufacturing site located in Shrewsbury, UK. A leader in re-manufacturing technologies and processes, 'Cat Reman' returns products at the end of their lives (called 'core') to same-as-new condition and helps reduce owning and operating costs by providing customers same-as-new quality at a fraction of the cost of a new part. Cat Reman operations are sustainable, with a goal of zero waste going to landfills.

Once a returned core arrives at a Reman facility, it is disassembled down to the smallest part, losing its original identity. Each element goes through a cleaning process and is inspected against strict engineering specifications to determine if it can be effectively salvaged. Accepted 'worn out' components are converted into production-ready material through salvage techniques. The process of re-manufacturing requires 85-95% less energy and material than manufacture of the same, new component.

BOX 3.6: NEW BUSINESS MODELS (BRANDIX INDIA APPAREL CITY (BIAC))

BIAC is a unique city based on an integrated apparel supply chain for fabrics, threads, buttons and hangers which is being developed in Visakhapatnam, Andhra Pradesh, India. A 'Fibre to Store' concept has been created by siting a vertically integrated value chain in one location, which included R&D and branding activities.

BIAC offers the convenience of an industrial city with modern infrastructure including 'plug and play' facilities for immediate production. All business partners are provided with rapid access to facilities to meet all their requirements from sourcing to transportation. Greater efficiency in distribution is ensured through the single location of all value chain partners and a centralised logistics unit. BIAC enjoys financial benefits from the government of India which is extended to all partners who invest and set up in BIAC.

3.3 IMPLICATIONS FOR GOVERNMENT

KEY MESSAGES

Technology will become increasingly important to the UK's manufacturing competitiveness in the decades ahead, particularly in the context of wider changes and uncertainties in the world. It will play a key role in facilitating the development of new business models.

As a variety of cross-sector areas of technology develop, they are likely to make manufacturing faster, more responsive and closer to consumers. This will lead to a revolution in designing, making, offering, using and recycling products.

These technologies, including pervasive ICT, embedded sensors, big data, additive manufacturing, and advanced materials will rapidly become available to boost the capability of UK manufacturers. It is therefore reasonable to anticipate the need for strong future technological competence in UK manufacturing.

Government must continue to increase its efforts in supporting the successful development, commercialisation and utilisation of future ideas and technology for the UK manufacturing sector, with specific future focus on:

- Improving the speed, protection and co-ordination of the UK technology pipe-line in areas relevant to UK manufacturing. This includes spotting high potential technologies which are relevant across the manufacturing sector, to improve competitiveness;
- Greater leveraging of the UK's intellectual assets for technology directed at driving competitiveness;
- Using technology to keep the UK a world leader in manufacturing services;
- Supporting competence in design, simulation, personalisation and 'information-dense' products;
- Encouraging factories to pre-empt future volume sensitivity and become reconfigurable;
- Using advanced technology to reduce energy, water and raw materials in manufacturing; and
- Anticipating potential intellectual property, cyber and bio-security issues.

This section discusses seven areas, listed above, which Government will need to address to ensure that the UK benefits from a likely revolution in designing, making, offering, using and recycling products.

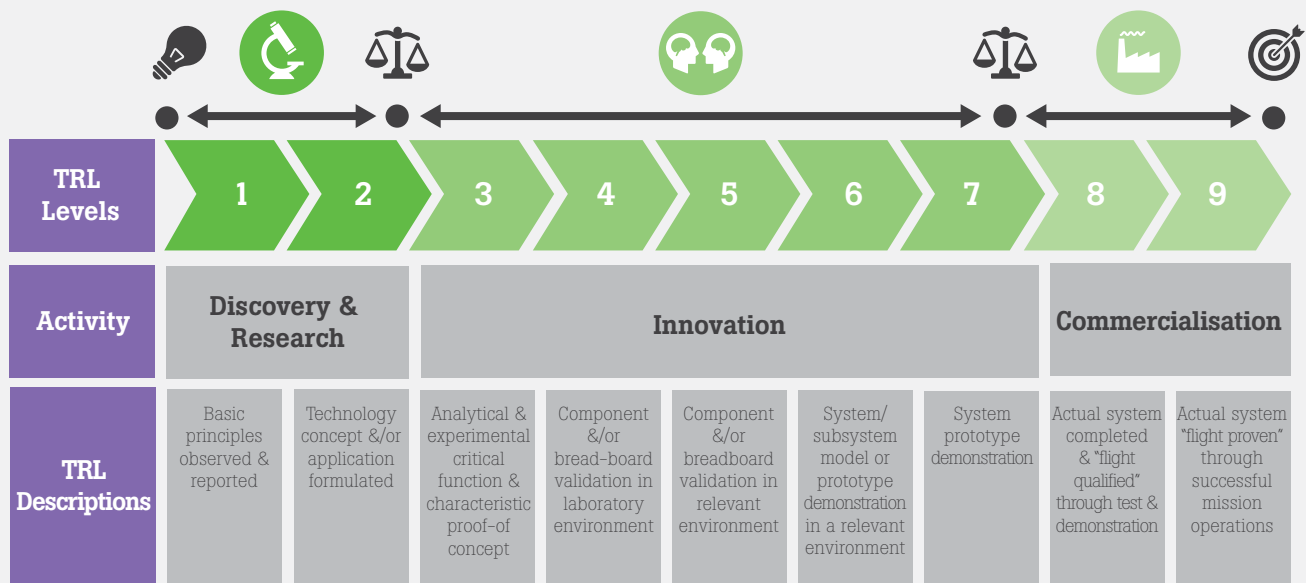
3.3.1 IMPROVING THE SPEED, PROTECTION AND COORDINATION OF THE UK TECHNOLOGY PIPE-LINE IN AREAS RELEVANT TO UK MANUFACTURING

The development of a number of pervasive primary (underpinning) and secondary (contingent) technologies are being driven by advances in specific areas of technology, and other non-technological changes. These include older and wealthier populations creating demand for new products, pressure on resources (see Chapter 5), and international competition driving manufacturers to increase their productivity (see Chapter 4).

Global technology development can be described as a 'pipeline' of new technologies becoming available from discovery and research activities, through to commercialisation. Many of the technologies detailed earlier in this Chapter are being developed in the UK. The pipe-line model (see Figure 3.3) sets out the way in which technologies and related intellectual property move through Technology Readiness Levels (TRLs)⁹⁷. It is also possible to make this pipe-line more specific to the manufacturing sector, where the assessment and validation needed before a technology becomes suitable for production are emphasised (see Figure 3.4).

Some of the technologies moving through the technology readiness levels that are likely to be of future significance to manufacturing are already well known. However, the consequences of some of the technologies will be radical, bringing new performance in value delivery over the next few decades. Biotechnology, for example, will affect not only the products of manufacturing, but also the way in which manufacturing processes are performed. For example, it is already possible to envisage personalised medicines being made in close proximity to a patient. It is less easy to predict the impact of technologies that are yet to appear or be commercialised.

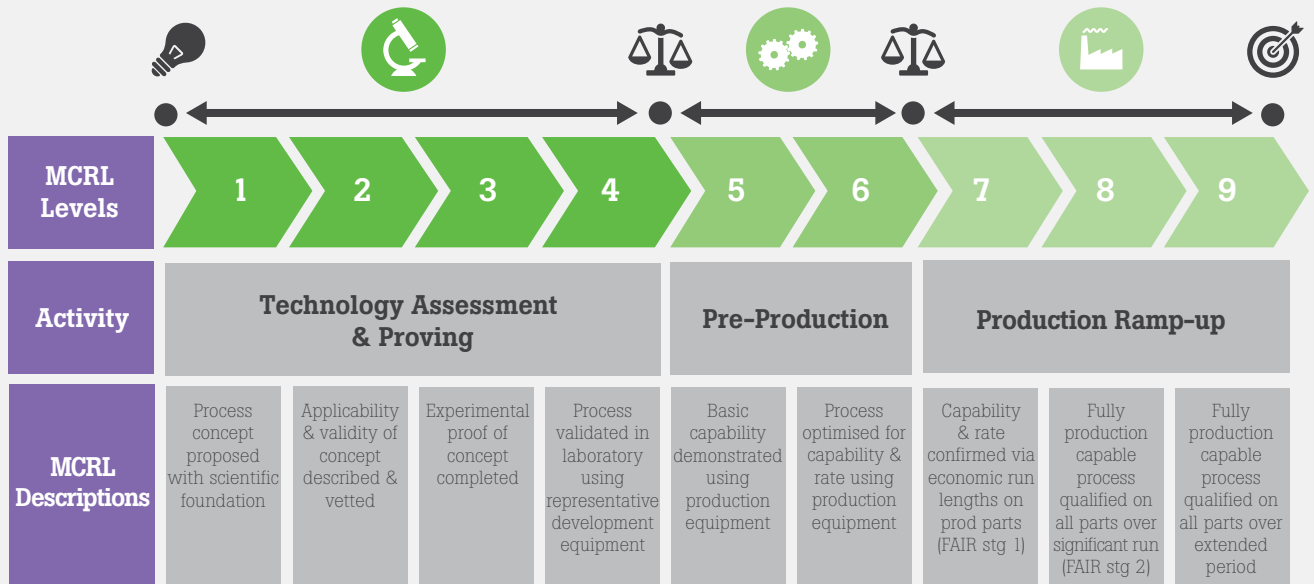
Figure 3.3: The NASA developed Technology Readiness (TRL) Level model



Source: Rolls-Royce plc

⁹⁷TRLs are a technology management tool, originally developed by NASA which provide a measurement to assess the maturity of evolving technology.

Figure 3.4: Manufacturing Capability Readiness Levels (MCRLs)



Source: Rolls-Royce plc

The already substantial impact of enabling technologies on the manufacturing sector, such as ICT, is expected to continue⁹⁸. Technologies will become increasingly pervasive and will re-shape global manufacturing activities, enabling new business models and opportunities for market offerings through increased speed, proximity and depth of relationship with customers⁹⁹. The aspiration to create goods that are 'circular by design' and 'green' will encourage higher rates of technological development, and improved materials, labour and energy efficiency with correspondingly greater opportunities for wealth creation. These technologies, including ICT, biotechnology, sensors, new materials and green chemistry, will be equally available to UK manufacturers and competitors. The ability to utilise them effectively will help determine which firms remain as manufacturers and which become actors in a supply network dominated by those organisations able to muster technologies to deliver the greatest value.

The UK currently has a high level of expertise in many areas of technological development including biotechnology, additive manufacturing, hybrid materials, and some areas of green chemistry¹⁰⁰. It also has important competencies in high-tech aerospace and biopharmaceutical products, and

is likely to be well positioned, for example, in the market for human enhancement technologies which is set to grow as the ageing population increases¹⁰¹. There is good potential for the use of this expertise in the UK to develop new forms of manufacturing with strong export potential, for example precision agriculture and on-farm processing.

As some of the new technologies with applications in manufacturing such as ICT, biotechnology and sensors may be owned and made outside of the UK, the greatest advantage will go to those companies that experiment and learn the most rapidly, scaling up the technology and exploiting it to the greatest extent possible. These generic competences can help maximise the value from each of these technological shifts. This will enable the UK to experiment with emerging technologies and gain advantage from early use of the technology, whether home-grown or not.

The UK's technology pipeline has in recent years been recognised as faltering between invention and exploitation, at the stage known as the 'valley of death'¹⁰². The UK's TRL system is currently based on research funded by the UK Research Councils, which focuses on early stage research, progressing into innovation and commercialisation-focused

activity supported by the Technology Strategy Board (TSB). A typical TSB project will move a technology by one or two TRLs¹⁰³ in the 3-5 range. However, academic experts that lead early research (levels 1-3) generally do not necessarily have the same inclination or motivation to follow up their work at later levels. There have been some steps to remedy any disconnect, such as a joint partnership in high value manufacturing between the Engineering and Physical Sciences Research Council and the TSB¹⁰⁴, and the introduction of the High Value Manufacturing Catapult Centre (HVM Catapult). However, greater investment is needed to ensure seamless transitions between the various TRL levels and to motivate academics to contribute to all TRL levels.

Given the pace of change likely to occur in technological developments and international competition, the speed and coordination of a comprehensive technology pipeline will be critical in enhancing UK capability and maximising export potential.

ADVICE FOR POLICY MAKERS:

Greater support for technologies at technology readiness levels three to five

There is a need for more partnering of academics in different institutions, potentially via the High Value Manufacturing Catapult Centre, to support experimentation with new technologies to encourage early development, to identify and start to target 'routes to market' and to eventually support work at higher technology readiness levels.

There is also a need to overcome financing weaknesses in the current system for these technology readiness levels. Financing must be made more risk-competent to bridge the 'valley of death', through the role of procurement, risk-sharing fiscal instruments, and encouragement of SME R&D.

Government procurement can play a critical part in enabling innovation and technology commercialisation. The innovative model of 'forward commitment procurement' could stimulate UK

manufacturing by purchasing ultimate outcomes rather than focusing on immediate needs, and risk-reducing the investment plans of manufacturers. International policies such as the current EU rules limiting direct buying from UK suppliers are current barriers to these initiatives¹⁰⁵.

Strengthening the role of the UK's High Value Manufacturing Catapult Centre¹⁰⁶

Since its launch in October 2011, the HVM Catapult, including its seven member centres, has worked with industry and academic partners to focus on accelerating the commercialisation of new and emerging manufacturing technologies¹⁰⁷.

In the 2012-13 financial year, the Centre leveraged £2 of private sector investment for every £1 of core public funding, a strong performance given that member centres are still developing. The TSB, which funds the Centre, typically achieves a return of £6.71 for the economy for every £1.00 invested in collaborative research and development projects¹⁰⁸, with an annual budget of around £440 million. The direct translation of newly delivered technology into improvements in manufacturing performance, competitive advantage and jobs is a major benefit of HVM Catapult associated activities.

An immediate priority should be to increase the scale of funding for the HVM Catapult Centre, to ensure that the legacy membership models of some of the member centres do not restrict the future involvement of small and medium enterprises. Longer term, there is potential for the Centre to support international collaboration between manufacturers, for example by establishing a presence in key developing economies.

In addition, analysis should also consider how comparable international research technology organisations are funded, sponsored and led, including the network of 66 Fraunhofer centres in Germany and the U.S. Defense Advanced Research Projects Agency.

¹⁰³ Evidence Paper 6: Dickens, P. et al. (2013) ¹⁰⁴ Engineering and Physical Science Research Council (2013) ¹⁰⁵ Evidence Paper 24: Morton, B. et al. (2013) ¹⁰⁶ For further information please see: <https://www.innovateuk.org/high-value-manufacturing> ¹⁰⁷ The Centre has delivered against £86m in grant funding, with a further £79m allocated to major projects including The National Biologics Industry Innovation Centre; the expansion of the National Composites Centre; and the UK Energy Storage R&D Centre. By March 2013, it had secured access to an asset base of around £250million hi-tech equipment and infrastructure operated by over 900 staff (increase of over 150 in 6 months). There has also been a significant increase in SME engagement, with the Centre enabling SMEs to partner in ca. £45m of collaborative R&D project value. ¹⁰⁸ Public and Corporate Economic Consultants (2011)

3.3.2 GREATER LEVERAGING OF THE UK'S INTELLECTUAL ASSETS

The UK is well regarded internationally for the quality of its education system¹⁰⁹ and the high quality of its universities¹¹⁰, with the 2012 Academic Ranking of World Universities placing two UK universities in the top 10. In country rankings of its university sector, the UK is second to the US and well ahead of its nearest competitors of Japan, Germany and France¹¹¹. Of the BRIC nations, only Russia has any university in the top 100, whilst China has only 7 ranked in the top 200, compared to 14 in Germany, 19 in the UK and 85 in the US.

However, US universities not only dominate the list of the top research-intensive universities in the world, but they are also foremost in the creation of intellectual property. The UK, on the other hand, is a less prolific patent filer. In 2011, the US led the top 15 countries in filing international patent applications, followed by Japan and Germany, which collectively accounted for 58% of the world's output, with China, South Korea, France, the UK, Switzerland, Holland and Sweden filling the remaining top 10 places¹¹². However, among the top filing countries, patent applications from China (33.4%), Japan (21%), Canada (8.3%), South Korea (8%) and the US (8%) saw the fastest growth in 2011.

There is a case for greater future leveraging of the intellectual assets of the UK for the benefit of the manufacturing sector and the wider economy¹¹³. This would entail a thorough analysis of the invention-innovation-exploitation trail and where the bottlenecks to smooth passage occur. Issues that might be addressed include the creation of resources to encourage patenting and maintain new inventions within the higher education sector and the widespread adoption of the 'Patent Box' concept. This leveraging might include, for example, a concerted approach to technology support involving NHS procurement, the TSB, Research Councils,

universities, and manufacturers working together on personalised medicine targeted at an ageing society. This is clearly a growing global market where the UK has broad competence¹¹⁴. Another option would be to identify a small number of 'National Investment Projects' in high value manufacturing such as the next generation single aisle aircraft which, if supported at sufficient scale could see the UK playing a leading role in one of the biggest future job and wealth creation opportunities available.

ADVICE FOR POLICY MAKERS:

Placing greater emphasis on the importance of applied research and commercialisation

- Government will need to work more closely with research councils, universities and learned societies to encourage academics to undertake research programmes that strike a balance between pure, applied and challenge-led research. One potential option might be to put in place incentives to commercialise applied research.
- The UK's poor performance in total R&D expenditure is due to both its weak public and industry R&D spending relative to other countries. For example, UK government funding for R&D was 0.57% of GDP in 2011 while industry support was 1.2% of GDP. By comparison, during the same year, US government expenditure was 0.92% and industry R&D support was 1.84% of GDP (see Chapter 4). UK Government needs to not only increase its own R&D spend, but to encourage and support industry to do the same.

Taking a joined-up approach to exploiting technologies for the manufacturing sector

- A number of the technological developments in this chapter need to be given greater strategic oversight to identify and implement strategies for their exploitation for the benefit of the UK manufacturing sector, and beyond. For example, a TSB Special Interest Group has recently considered how the UK can best exploit additive Manufacturing technology¹¹⁵. This work demonstrates there is much to be done to identify the most effective routes to implement additive manufacturing in the UK manufacturing

sector, with a need to strengthen engagement between the UK supply chain, end-users and the research base.

- There is a need to support, potentially via the High Value Manufacturing Catapult Centre, the development of industry-academia-government technology roadmaps that can spot relevant developments, particularly those which operate across sub-sectors, and guide policy. This might then produce action plans for the wider co-ordination of technology road-mapping across government, business and academia.
- This roadmap approach, along with a more aggressive investment plan supporting large scale demonstrator infrastructure and applications development, could see the UK becoming a world leader in technology, especially if 'keystone' IP can be secured by UK based companies. This work could also build on the evidence underpinning the government's recent £600 million investment in 'Eight Great Technologies'¹¹⁶.

3.3.3 USING TECHNOLOGY TO KEEP THE UK A WORLD LEADER IN MANUFACTURING SERVICES

Given its history in developing high technology products, the UK has strong capability in the integration of ICT and sensors with tacit knowledge to deliver value-adding services, and even integrating them into full 'function-delivery' services. In the decades ahead, it is likely that leaders such as Rolls-Royce plc will be joined by other manufacturers using their knowledge of products and technology to sell services globally. It is now relatively easy to offer technical advice across great distance. However this approach will increasingly rely on sensors which travel with the product, combined with ubiquitous computing capacity and tacit knowledge.

In addition to manufacturing services, this general strategy offers the potential to turn know-how

and product operational data (big data) into revenue through the development of new business models embracing trends including personalisation of products. ICT is rapidly assuming a pivotal position in manufacturing and often commences with defining customer needs, design and representation of products by Computer Aided Design (CAD), production planning and scheduling, Computer Aided Manufacturing (CAM), sales and distribution online, and performance feedback through embedded sensors¹¹⁷. The manufacture of advanced information-dense products will require highly specialised design methodologies and tools, and sophisticated supply chain management and customers.

The new manufacturing services business models that will become mainstream out to 2050 will involve customers increasingly purchasing life-time care along with their product, or purely buying a function rather than the product, for example, paying per copy rather than buying a photocopier. Manufacturers will need to take greater care of the long term performance of their products, to the point of monitoring and sending out engineers to the customer. These new business models, enabled by technologies described earlier, are already changing the way that manufacturers design, make and service products globally. Given the potential value creation these new business models support, there is an important role for government, as discussed in Chapter 4.

3.3.4 SUPPORTING COMPETENCE IN DESIGN, SIMULATION, PERSONALISATION AND 'INFORMATION-DENSE' PRODUCTS

As consumers increasingly seek, and pay for, products and services that match individual needs more closely, technologies that enable precise requirements to be met (for example personalised clothing, newsletters, consumer goods and medicine)¹¹⁸ are beginning to emerge.

However, true mass personalisation of other consumer products at low cost is within sight. A combination of improvements in ICT, consumer-input, automation and additive manufacturing will increase the potential for offering individually tailored products under conditions that traditionally were seen as unfeasible¹¹⁹. Like manufacturing services, personalisation implies a high competence in a base technology plus a sophisticated aggregation of information. Those manufacturers who can deliver this shift in value are likely to realise higher margins, high quality jobs and product leadership.

The UK is well positioned to lead the potential paradigm shift to personalised manufacturing, given its competence in areas including design and additive manufacturing, with a potential first step being the building of further competence in semi-customised products, possibly via more extensive use of consumer-designed and requested options. To exploit opportunities presented by mass personalisation, understanding consumer needs combined with strong design skills will be required to adapt products to rapidly shifting consumer tastes and trends. Similarly, modelling and simulation are expected to play an increasingly important part in manufacturing at the stage of design and optimisation¹²⁰.

Products are also likely to become increasingly 'information-dense' or 'informed' enabling not only the personalisation and services mentioned above, but also explaining the provenance and 'green' credentials of products as consumers seek easy access to data about what they eat, wear and buy. These products will also potentially, via sensors, be able to feedback usage data to designers to improve the next generation of the product, and to offer advice or comment to the user to optimise pleasurable use. However, these types of advances would have consequences for open data exchange, cyber security issues, the protection of intellectual property¹²¹, and open trade agreements.

3.3.5 ENCOURAGING FACTORIES TO PRE-EMPT FUTURE VOLUME SENSITIVITY AND BECOME RECONFIGURABLE

One potential consequence of combining future technologies is a shift in the volume sensitivity of many manufacturing products, driven by for example distributed models of manufacturing, and collaborative consumption. The latter refers to economic arrangements in which participants share access to products or services, rather than have individual ownership. This likely trend implies that the scale of many factories will get smaller over the next decades for many sectors.

For some product categories, distributed or even home manufacturing will be undertaken by consumers sharing data and using technologies, including additive manufacturing. This sharing of data, potentially in the form of product designs, would have a range of consequences for the protection of intellectual property¹²², and could bring about radical new business models relating to the ownership of products, with data and designs becoming more valuable than the product. The evolution of these products is likely to occur in different ways depending on the manufacturing sub-sectors, and factors including safety, regulatory and quality requirements.

Another factor likely to have an unpredictable impact on the volume sensitivity of factories are potential changes in the ownership of products, with the rise in collaborative consumption, which encompasses old world behaviours such as lending, exchange, swapping and bartering that are now able to operate at scale and across geographic boundaries, enabled by technology. This phenomenon could have a significant impact on the demand for products and the length of their life cycles. It may become established first in developed

¹¹⁹ Personalised medicine is a medical practice that uses an individual's genetic profile, ascertained via whole genome sequencing or a companion diagnostic, to guide decisions made in regard to the prevention, diagnosis and treatment of disease. ¹²⁰ Hart, C. (1995) ¹²⁰ Evidence Paper 6: Dickens, P. et al (2013) ¹²¹ Evidence Paper 12: Hall, B. (2013) ¹²² Evidence Paper 12: Hall, B. (2013)

economies as technology and human ingenuity combine to develop new ways of sharing, lending and exchanging time, skills and resources¹²³, although such changes will also occur in highly creative emerging economies.

Factories are therefore likely to move closer to customers, build more localised products, and use more local materials, which will change the shape of the supply chain and lead to possible collaborative supply networks. For example, in cell-based therapies, particularly those exploiting the patient's own or autologous cells, treatments are likely to be conducted at the point-of-care, i.e. the bedside, care centre or hospital, in which case, the 'factory' becomes a device or instrument located adjacent, or in close proximity, to the 'customer'. These cell-based 'factories' and other consumer goods factories are likely to be supported remotely with sensors informing experts about the state of equipment and the flow of energy and materials, as well as the quality of products and staff. The factory of the future will be able to re-configure itself rapidly to make a variety of products¹²⁴ using ICT hardware, simulation modelling and biotechnology.

Bringing these potential developments together, a future challenge for manufacturing firms will be to coordinate an efficient value creation process in the factories of the future. These factories will be required to deliver more value, often in collaboration with others, be more connected globally and locally, and offer services integrated with physical outputs¹²⁵.

ADVICE FOR POLICY MAKERS:

Helping factories, as they diversify in form and function, to become reconfigurable

Factories of the future are likely to include more urban locations as the factory increasingly becomes a 'good neighbour'¹²⁶ in terms of its environmental impact. Planning regulations will need to accommodate potential changes in land use, particularly as these factories are likely to undertake a range of activities.

The Research Councils, the TSB and the High Value Manufacturing Catapult Centre should work with industry to develop enhanced technical expertise

relating to the design of agile, reconfigurable factories and extended enterprises. This enhanced expertise could then be used to provide future support factories becoming reconfigurable.

3.3.6 USING ADVANCED TECHNOLOGY TO REDUCE ENERGY, WATER AND RAW MATERIALS IN MANUFACTURING

As products increasingly become 'informed' with information relating to their use and provenance, a large material component to the value exchange with customers will remain. This will be influenced by growing environmental and social forces.

Resources such as energy, materials, land and water are likely to become scarcer, with availability increasingly volatile in the coming decades¹²⁷ (see Chapter 5). Manufacturing activities currently rely on these resources, so scarcity due to either global shortages or lack of access caused by geopolitical factors, is likely to be a key challenge for the entire sector in the UK¹²⁸. Manufacturers who learn how to make their products with less energy, water and raw materials than their competitors will be more resilient during likely periods of disruption. A major part of this shift to produce products with fewer resources will be the movement towards the circular economy, with end of life products re-entering the manufacturing value chain as they are re-used, re-manufactured or recycled.

The market for technologies and knowledge that enable resource-efficient production will grow quickly, with a potential role for government procurement in 'nudging' and stimulating developments, whilst avoiding unintended consequences. The emergence of technologies that will help manufacturers use less resource to deliver value, for example lightweight materials and products, are likely to become more widely available over the next two decades. UK manufacturing activities must continue to adapt to best practice,

particularly in the light of resource pressures. It is expected that future best practice will include fast response to market, product service systems and greater operational agility¹²⁹. Evidence suggests there is no reason that the UK cannot match, or better, management practices from overseas¹³⁰.

The technologies that develop can be considered enablers of a revolutionary change in the relationship between producer and consumer, with new business models likely to be used to ensure that the customer receives the maximum value for the minimum of material, water, and energy input. For example, business models might be based on cooperation between competitors with shared concerns about resources, or might include selling services to customers and retaining ownership of hard-won molecular properties so that their value can be re-gained after end of first use. These developments are discussed further in Chapter 5.

3.3.7 ANTICIPATING POTENTIAL INTELLECTUAL PROPERTY, CYBER AND BIO-SECURITY ISSUES

New paradigms for innovation (involving ICT, the internet of things, mobile and cloud computing, additive manufacturing and biotechnology) raise a new set of requirements for intellectual property, business models, cyber and bio-security, and skills, which will have to be met by the combined efforts of consumers, legislators, regulators and other stakeholders.

The most important industry in terms of copyright protection in the manufacturing sector is currently considered the 'publishing, printing, and reproduction of recorded media industry'¹³¹. However, it is likely that this industry will be challenged in the future by growth in the ICT sector, facilitated by developments in technology. Greater availability of information is likely to support the development of additive manufacturing, with likely increases in

copying of a patented object for personal use, which may go largely undetected¹³².

The ease of copying created by additive manufacturing is also likely to reduce any returns to operating manufacturing at scale, which implies that preventing imitation through a minimum efficient scale requirement becomes less feasible. This may increase the importance of using legal means to prevent imitation, alongside agile strategies that keep companies ahead of 'home makers'. At the same time, the opportunity to customise and build upon another's design may lead to innovation and new business opportunities. Strict patent enforcement may hinder this activity¹³³.

Of particular concern is the potential vulnerability of future advanced, information-rich products and services to external cyber attack. In addition, bio-security, like the more traditional cyber security, will require the cooperation of scientists, technicians, security engineers, law enforcement officials and policy makers to combat the disabling or theft of valuable and easily transportable bio-assets.

ADVICE FOR POLICY MAKERS:

Protecting intellectual property without inhibiting innovation

There is a clear need to strike a balance between protecting intellectual property, as technologies including additive manufacturing increase the ease of copying products, and supporting innovation as product designs are developed and enhanced. Any future approach taken to the protection of intellectual property will need to be both flexible and pragmatic.

Protecting sensitive data potentially vulnerable to cyber attack

It is important that the UK places systems and practices into effect to prevent intrusions and theft of sensitive data and knowledge. Similar policies may need to be adopted for the protection of novel assets of enormous value in the bio-economy.



4. EXPOSED TO NEW MARKET OPPORTUNITIES

Demand for new products will increase from emerging economies, creating strong market opportunities. International 'fragmentation' of manufacturing value chains will continue to be driven by advances in ICT and other areas. Smaller but important shifts such as onshoring of production back to the UK, driven by factors including changing labour costs, will influence the geography of manufacturing.

This Chapter examines important long-term changes expected in global trade and investment. It also examines the changing spatial distribution of manufacturing, and trends including deindustrialisation and reindustrialisation.

The Chapter concludes by outlining a range of implications for Government, and relevant advice where needed, that will need to be addressed as manufacturing becomes exposed to new market opportunities.

4.1 GLOBAL TRADE AND INVESTMENT

KEY MESSAGES

The UK has significant strengths in exporting manufactured goods.

- UK exports of goods produced by the manufacturing sector totalled £256 billion in 2012, accounting for around 53% of all UK exports¹.
- The UK is the 10th largest exporter of manufactured goods globally, accounting for about 2.9% of total world exports of goods in 2012, with pharmaceuticals, aerospace, chemicals, the automotive sector, beverages and spirits, boilers and machinery displaying strong performance. Export intensity increased from 30% of output in 1991 to 47% in 2011.
- The UK's share of global manufacturing exports has fallen from 7.2% in 1980 to 2.9% in 2012.
- 'Superstar exporters' (exporting 10 or more products to 10 or more markets) are dominant in export performance, accounting for 76% of the total value of UK manufacturing exports.
- The UK share of global, high technology, manufacturing exports of 4.7% indicates that high-tech manufacturing exports may be a continuing area of comparative advantage for the UK.
- The 2012 Budget ambition to double UK exports to £1 trillion by 2020² implies export growth of 9% per annum. If UK manufacturing exports doubled by 2020, this would suggest exporting 78% of all UK manufacturing output. Germany currently exports 57%. On current trends, manufacturing exports would not double before 2032.

As the global economy changes and future markets emerge, EU and US markets will continue to be important for the UK in the medium to long term.

- The UK exported to 226 different countries/territories in 2010, with the US the most important destination accounting for 13% of

the value of exports. EU markets accounted for about 54% of the total value of UK exports in 2012, while BRIC exports were only 8%.

- The BRIC economies are likely to become larger than the US by 2015, and the G7 by 2032. The UK is low down the global list of exporters to China (24th) and India (21st) in terms of the value of exports, with the UK's current share of imports to countries forecast to be in the top 30 economies by 2050 generally disappointing, given its 2.9% share of total world exports in 2012. As the UK is currently poorly placed in these markets, it is not expected to benefit significantly from their future growth.

Policies for strengthening the balance of payments must assign a role to manufacturing.

- The UK's overall current balance of payments, including investment income, was -3.7% of gross domestic product (GDP) in 2012. A baseline scenario for 2022 indicates if trends continue, with sustained economic recovery, a current account deficit equal to 3% of GDP may be reached by 2022. The pessimistic scenario would be a cause for alarm, with a potential deficit of 5.2% of GDP.

UK expenditure on manufacturing research and development (R&D) and capital investment rank poorly when compared internationally, indicating a reluctance to invest for long term growth and innovation.

- R&D is concentrated in a few UK manufacturing sectors and is dominated by a few large firms. For manufacturing as a whole, expenditure on R&D in the UK has been weak, with the UK ranking poorly compared to key competitors. The ratio of manufacturing R&D to GDP has fallen consistently since 1999.
- UK manufacturing has underperformed in comparison to key competitors on levels of capital investment. This implies that higher growth in total factor productivity (TFP) was dependent on efficiency gains, rather than on quality enhancing improvements, for example in technology.

¹ ONS (2012a) – the denominator to get the percentage is available from the total exports of goods and services found in: ONS (2012b) ² HM Treasury (2012)

The UK's above-average share of Foreign Direct Investment (FDI) coming into Europe is at risk.

- The UK has been a major recipient of inward FDI and remains in a good position to attract an above-average share of FDI flowing into Europe. However, as competition from BRIC and emerging economies increases, future FDI into Europe is likely to be a smaller share of global FDI flows. A decline in the share of manufacturing as a proportion of total inward FDI is likely.

Foreign-owned manufacturers in the UK will continue to increase.

- If trends continue, the foreign-owned manufacturing sector within the UK will account for a larger share of output (by 2020), gross value added (GVA), and employment (by 2015) than the UK-owned sector. A larger presence of multi-national corporations (MNCs) could be associated with an improvement of the competitive and potential export performance of the UK's largest firms, depending upon investment and production strategies of MNCs and their global value chains.

China will continue to be a global force in manufacturing.

- China's growth in the recent past has been close to 10% per year, with Chinese GDP forecast to overtake the US between 2017 and 2026. The world has not seen rapid growth based on a hybrid of communism and a market economy before, and history suggests that Chinese catch-up may stall before 2050.

4.1.1 INTRODUCTION

This section examines potential changes and uncertainties in global trade and investment which are relevant to how UK manufacturing will create and capture value in the future. Seven important areas are discussed in this section (see Figure 4.1). Changes in each, individually and collectively, will determine the relative importance of:

- The countries the UK exports products to, and imports products and other inputs from;
- The types of firms and sectors which will be involved in UK manufacturing trade;
- The future structure and performance of manufacturing within the overall balance of payments;
- The place of the UK in the global pattern of foreign direct investment flows; and
- The conduct of R&D and investment in innovation relating to trade competitiveness.

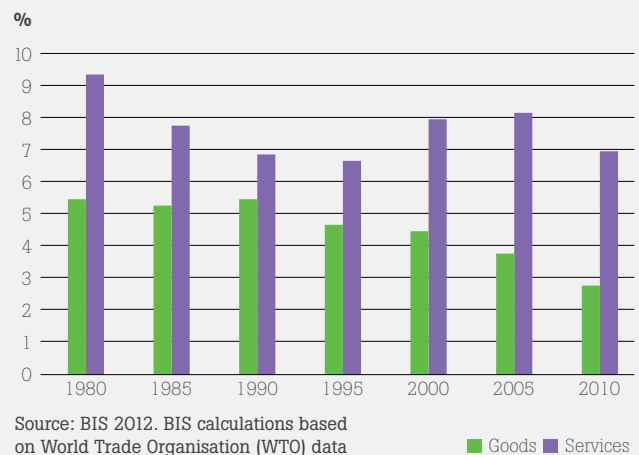
Figure 4.1: Changes in global trade and investment with implications for manufacturing



4.1.2 UK MANUFACTURING EXPORTS

UK exports of goods produced by the manufacturing sector totalled £256 billion in 2012, accounting for around 53% of all UK exports³. The UK is a major exporter of manufactured goods, and accounted for 2.7% of total global exports of goods in 2010 (see Figure 4.2). This is about half the share of goods that were exported in 1980⁴. The UK's share of global exports of services was higher than its share of goods exports throughout the period 1980-2010. Although this share of services declined during this period, it was the second highest globally in 2011⁵.

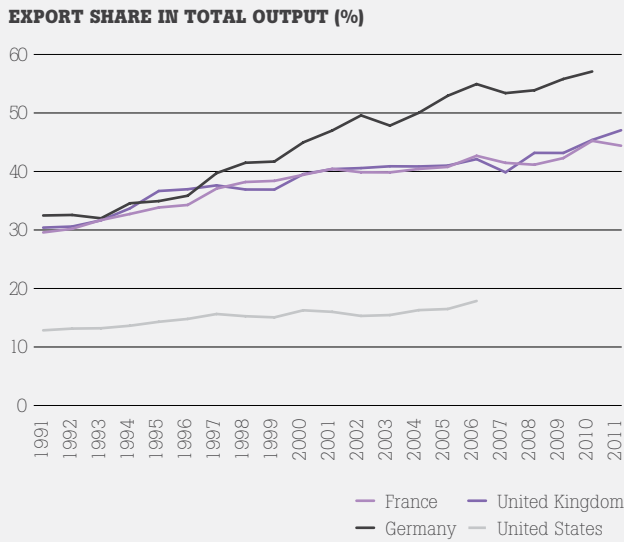
Figure 4.2: UK share of global exports



The fall in the UK's share of goods exports has, nevertheless, been accompanied by an increase in the export intensity of the manufacturing sector. This is expressed as manufacturing exports as a proportion of manufacturing output (Figure 4.3)⁶. The share of exports, which rose from about 30% in 1991 to about 47% in 2011, was similar to France, less than Germany and higher than the US⁷.

³ Office for National Statistics (ONS) (2012a) – the denominator to get the percentage is available from the total exports of goods and services found in: ONS (2012b). ⁴ Department for Business, Innovation and Skills (2012d) ⁵ Evidence Paper 25: Peng, M. & Meyer, C. (2013) ⁶ Evidence Paper 17: Kneller, R. (2013) (Author's calculations from OECD STAN data) ⁷ Note the United States has a substantial domestic market for output, affecting the proportion of exports.

Figure 4.3: Export intensity (manufacturing exports as a proportion of manufacturing output)

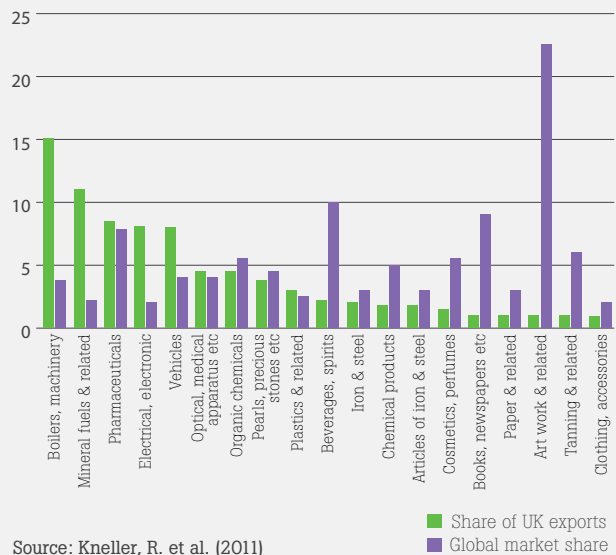


Source: Kneller, R. (2013)

To help disentangle factors affecting the falling share of UK manufacturing exports in global manufacturing exports and the rise in export intensity it is useful to consider which firms export, what they export and where they export to. Value of exports can be broken down into 'firm margin' (number of firms and export intensity); 'firm-product margin' (number of products each firm sells and average export value); and 'firm-product-destination margin' (number of destinations in which a firm sells and average export value).

As a measure of the product margin, the UK share of world exports is relatively large for pharmaceuticals, chemicals, beverages and spirits, boilers and machinery, and the automotive sector (see Figure 4.4)⁸. A small number of products account for a large proportion of the value of UK manufacturing exports, with 10 products out of a total of around 4,500 accounting for over a quarter of the total (see Table 4.1)⁹. The top ten export products in Germany accounted for 17% of the total export value, compared to 20% for France and 15% for the US in 2011. UK exports are therefore specialised in a small number of products. Data for Germany and France shows that motor vehicles and aeroplane manufacturing are also prominent¹⁰

Figure 4.4: Share of manufacturing in UK exports & world market share 2010



Source: Kneller, R. et al. (2011)

Table 4.1: Top ten UK export products in 2011

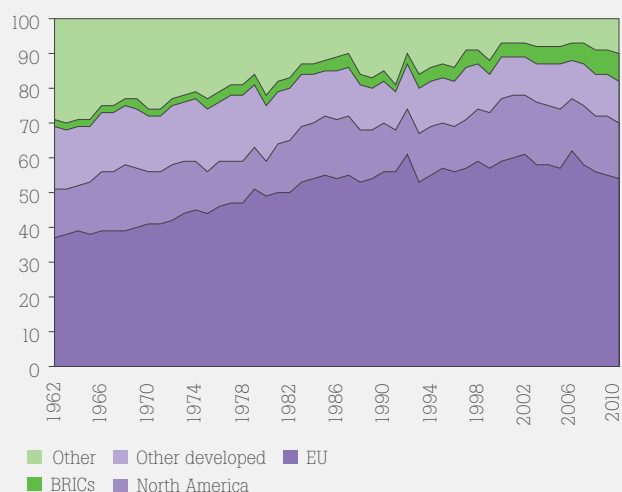
RANK	DESCRIPTION	EXPORTS US\$ BN	SHARE OF TOTAL UK EXPORTS
1	Petroleum oils and oils obtained from bituminous minerals, crude	27.3	5.8%
2	Medicaments consisting of mixed/unmixed products for therapeutic/prophylactic uses	18.4	3.9%
3	Petroleum oils & oils obtained from bituminous minerals (other than crude) & preparations not elsewhere specified	15.6	3.3%
4	Light petroleum oils & preparations	13.3	2.8%
5	Vehicles principally designed for the transport of persons with spark-ignition internal combustion reciprocating piston engine, of a cylinder capacity >1500cc but not >3000cc	10.0	2.1%
6	Vehicles principally designed for the transport of persons with spark-ignition internal combustion reciprocating piston engine, of a cylinder capacity >3000cc	9.4	2.0%
7	Parts of the turbo-jets/turbo-propellers	8.7	1.8%
8	Turbo-jets, of a thrust >25 kN	7.1	1.5%
9	Diamonds, non-industrial, unworked/simplely sawn/cleaved/bruted	7.0	1.5%
10	Whiskies	6.9	1.5%

Source: Kneller, R. (2013)

Manufactured exports can be grouped according to the levels of technology that they embody. UK high and medium-high technology exports increased from about US\$100 billion in 1990 to US\$250 billion (out of a total of US\$400 billion for all UK manufactured exports) in 2008¹¹. The UK share of global high technology manufacturing exports is lower than Germany (4.7% compared to 7.9%)¹² but exceeds the UK average global share across all sectors of 2.7%. Within the EU, only Germany and France have a greater global share. High-tech manufacturing exports appear to be an area of comparative advantage for the UK.

As a measure of the destination margin, the UK exported to 226 different countries or territories in 2010, comparable to France (224), Germany (227), the United States (221) and China (208). The most frequent destinations have changed little over time. After the EU, taken as a whole, the next most important destination for the UK is the US, which accounts for 13% of the value of exports (Figure 4.5)¹³, while the top 10 individual country markets account for 60% of exports.

Figure 4.5: UK exports by destination

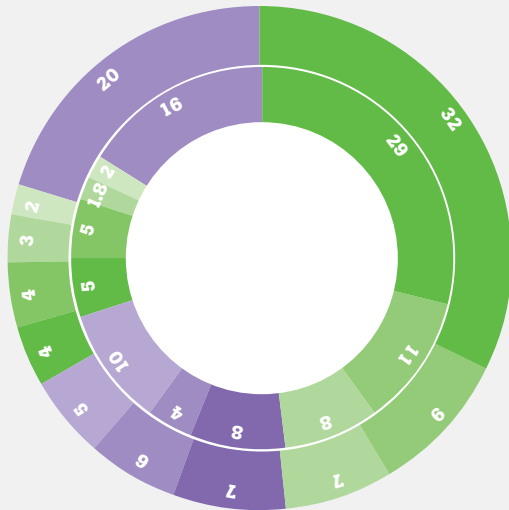


Source: Kneller, R. (2013)

Growth in UK manufacturing exports has come from EU countries which, taken together, accounted for about 54% of the total value of UK exports in 2012, compared to only for 8% for the BRIC

economies (Brazil, Russia, India and China)¹⁴. For France and Germany, the patterns are different. The growth of trade to the EU started from a higher level and manufacturing exports are less oriented towards North America, and more to China and other BRIC economies (Figure 4.6)¹⁵.

Figure 4.6: EU manufacturing exports to China (inner circle=2000, outer circle=2011)



KEY %	2000	2011
1. Germany	29	32
2. Italy	11	9
3. France	8	7
4. Netherlands	8	7
5. Poland	4	6
6. Finland	10	5
7. United Kingdom	5	4
8. Belgium	5	4
9. Czech Republic	1.8	3
10. Austria	2	2
11. Other	16	20

Source: Peng, M. & Meyer, C. (2013)

With regard to the firm margin, the percentage of manufacturers exporting in the UK, France and Germany is about 60%, with exports accounting for about 30% of sales¹⁶. But as France and Germany have more manufacturing firms than the UK, their overall outputs and export shares are higher. The proportion of very small through to medium-sized enterprises¹⁷ (SMEs) that export is higher in the UK than France, and higher than Germany for the smallest firms (10-19 employees) (see Table 4.2)¹⁸.

In contrast, UK manufacturing firms with 250 or more employees are less likely to export compared to similar firms in France and Germany.

Export intensity in each SME size class is slightly higher in the UK than in France, and for the lowest SME size class it is higher than in Germany (see Table 4.3)¹⁹. In contrast, UK firms with 250 or more employees are less export intensive, especially when compared to France. The UK export market is thus over-represented by small firms in terms of the number of exporters and the proportion of output they export. The size composition of UK exporting firms and, in particular, the under-performance of large firms is a likely explanation of why the UK lags behind Germany in terms of the overall share of manufacturing output that is exported.

Table 4.2: Percentage of manufacturing firms who export (firm extensive margin) 2010

SIZE CLASS	FRANCE	GERMANY	UK
10-19	44.7	45.7	54.9
20-49	59.1	65.4	62.8
50-249	75.4	78.2	76.8
250+	87.6	84.0	80.7
Total	57.9	63.4	64.0

Source: Kneller, R. (2013)

Table 4.3: Percentage of output exported by exporting firms (firm intensive margin) 2010

SIZE CLASS	FRANCE	GERMANY	UK
10-19	23.0	25.9	26.2
20-49	27.0	28.1	27.8
50-249	33.0	33.9	33.2
250+	41.2	37.8	34.2
Total	28.5	30.0	29.1

Source: Adapted from Kneller, R. (2013)

¹⁴ Evidence Paper 25: Peng, M. & Meyer, C. (2013) ¹⁵ Evidence Paper 25: Peng, M. & Meyer, C. (2013) ¹⁶ Evidence Paper 17: Kneller, R. (2013)

¹⁷ The SMEs covered in these tables are those firms with between 10 and 249 employees. Data on SMEs with less than 10 employees is not available on a comparable basis. ¹⁸ Evidence Paper 17: Kneller, R. (2013) ¹⁹ Evidence Paper 17: Kneller, R. (2013)

For firm-product-destination margin, most UK firms export a small number of products to a small number of markets. 59% of exporters export between 1-4 products to between 1-4 markets. Only 14% of all exporters export 10 or more products to 10 or more markets, but they account for 76% of the total value of exports (see Table 4.4)²⁰. 'Superstar' exports are the dominant force in export performance in the UK. In contrast, German firms are more likely to export more products and to more countries than firms in France or the UK²¹. They are larger, in the aggregate, than the UK because the large firms export more products to more markets in greater volumes.

Developing a better understanding why larger UK firms are less likely to export compared to German firms and achieve fewer and smaller export orders when they do is central to understanding the UK's current relative performance and how it can be improved in the future.

Table 4.4: Distribution of UK exports over products and markets

SHARE OF UK EXPORTERS IN 2010 (TOTAL NUMBER OF EXPORTERS 77,774)				
NUMBER OF COUNTRIES				
No of products	1 to 4	5 to 9	10+	Total
1 to 4	58.6	3.1	1.4	63.2
5 to 9	7.5	5.2	3.3	16.0
10+	3.3	4.1	13.5	20.9
Total	69.4	12.4	18.2	100

SHARE OF UK EXPORTS IN 2010 (TOTAL EXPORTS: £255BN)				
NUMBER OF COUNTRIES				
No of products	1 to 4	5 to 9	10+	Total
1 to 4	3.6	1.8	6.9	12.3
5 to 9	1.1	1.5	5.9	8.5
10+	1.3	2.3	75.6	79.2
Total	6.0	5.5	88.5	100

Source: Kneller, R. (2013)

Forecasts for UK manufacturing exports

Most forecasts for world GDP growth are about 4% per year over the next decade²², although for the BRICs GDP is forecast to grow between 7% -10% per year. UK exports are likely to increase at a similar rate of 3-4% over the next decade. As exports to BRIC countries are dwarfed by exports to the EU (8% and 54% respectively in 2011²³), a modest growth in demand across the EU and US would have a larger impact on UK exports than growth in BRICS in the near future.

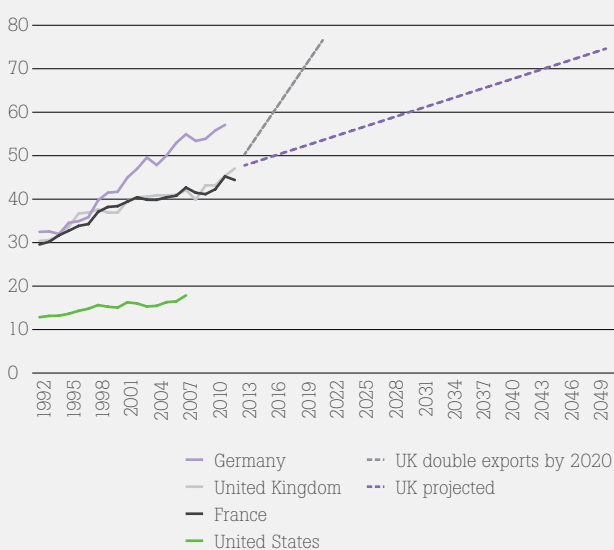
The composition of exports may also change. For example, the UK's comparative advantage in high-technology sectors will be a source of export growth in the future. However, export volumes in these sectors are sensitive to increases

in income and it is important to note that the UK underperforms Germany in absolute terms in the sense that they have bigger world export shares. The UK's performance is relatively weaker in low-tech sectors²⁴.

The 2012 Budget outlined an ambition to double UK exports to £1 trillion by 2020, from £493 billion in 2011²⁵. The projected rate of growth of exports necessary to double manufacturing exports is significantly faster than the growth of manufacturing output that has been achieved over the last few decades. If UK manufacturing exports were to double by 2020 whilst output growth followed recent trends, the export to output ratio would rise to over 78% (see Figure 4.7²⁶, orange line). Germany currently exports 57% of manufacturing output, which makes the UK target to double exports, appear challenging.

Over the last 20 years, the ratio of exports to manufacturing output has on average increased by around 0.7% per year. Projecting this forward would imply an export to output ratio of 54% by 2020 and an export value of £310 billion. Manufacturing exports would not double until 2032, some 12 years after the upper-bound forecasts, and would reach £800 billion by 2050 (see Figure 4.7, green line).

Figure 4.7: Forecasts for the share of UK manufacturing exports to total output



Source: Kneller, R. (2013)

4.1.3 GLOBAL ECONOMIC GROWTH AND FUTURE MARKETS

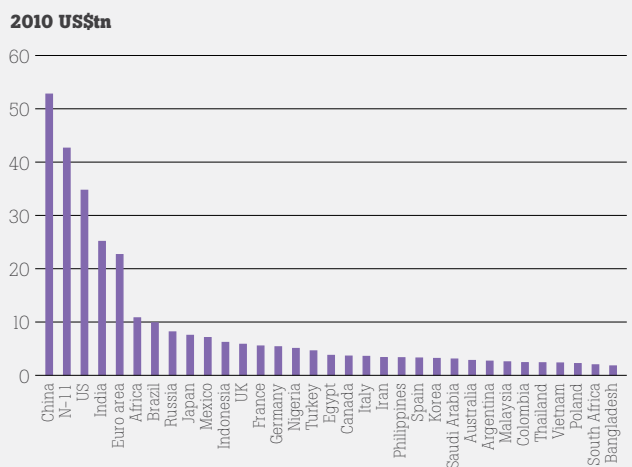
How global economic growth performs over the next four decades will shape future markets worldwide. This section uses two scenarios to help assess the long-term impact of emerging economies on UK manufacturing exports, and the creation of future markets.

SCENARIO 1: CONTINUED GLOBALISATION

This scenario envisions a path of growth that is perhaps more volatile than that of the past 20 years, but ultimately leads to higher levels of economic integration and higher levels of income in countries currently designated as emerging economies. Under this scenario:

China, the US, India, Brazil, and Russia become the largest economies by 2050 (Figure 4.8)²⁷: BRIC countries may contribute nearly half of the growth of global GDP over the next two decades, overtaking the US by 2015 and the G7 by 2032. China may overtake the US by 2026 or 2017²⁸.

Figure 4.8: Scenario where BRICs and the US become the largest economies by 2050

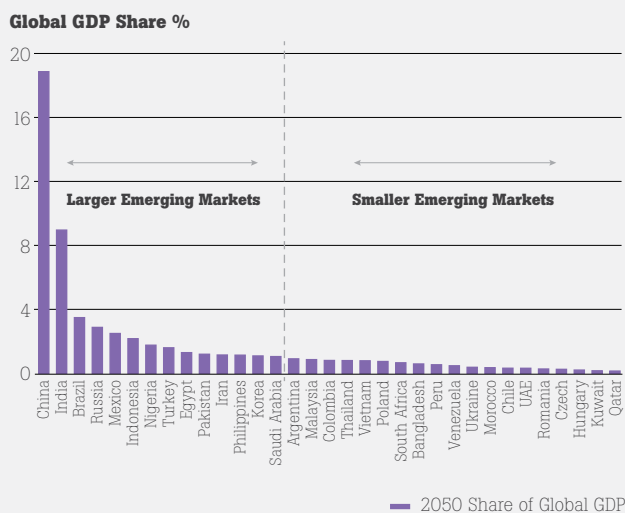


Source: Goldman Sachs (2012)

24 Evidence Paper 17: Kneller, R. (2013) 25 HM Treasury (2012) 26 Evidence Paper 17: Kneller, R. (2013) 27 Goldman Sachs (2012) 28 For estimates suggesting overtaking by 2026 see Goldman Sachs (2012) p3. and for estimates suggesting overtaking by 2017 see OECD (2012b).

The 'Next Eleven' or 'N-11' countries²⁹ (N-11) become significantly larger than the US and almost twice the size of the Euro area by 2050 (Figure 4.9)³⁰: While BRIC growth rates will slow down, emerging economies as a group, consisting of BRIC, N-11, and other 'larger' and 'smaller' emerging markets, will continue to drive global growth.

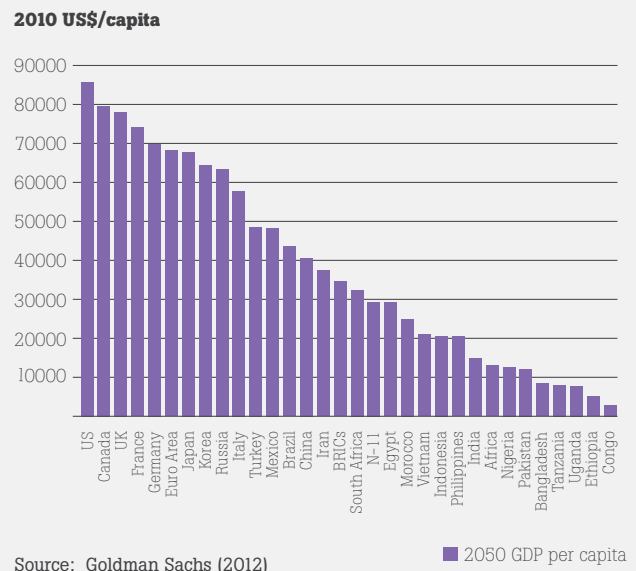
Figure 4.9: Larger (>1% global GDP) & smaller (<1% global GDP) emerging markets by 2050.



Source: Adapted from Goldman Sachs (2012).

By 2050, the G7 countries will still be the wealthiest (Figure 4.10)³¹: At about US\$78,000³² the UK will enjoy the third highest per capita income, behind the US and Canada but ahead of France, Germany, and Japan. Russia may top the BRIC group, with China and India lagging behind developed economies. These forecasts are supported by studies from HSBC (2011)³³ and the Organisation for Economic Co-operation and Development (OECD) (2012)³⁴. For example, the OECD forecast that by 2060, Chinese and Indian per capita income would reach 59% and 27% of the US level, respectively, and that the combined GDP of China and India will be larger than that of the entire OECD area.

Figure 4.10: Rankings of per capita income will remain relatively unchanged by 2050



Source: Goldman Sachs (2012)

A number of assumptions underpin this scenario, including emerging economies as a group will maintain strong (albeit with gradually reduced) growth; geopolitical events and natural disasters will not create significant disruption; and regional and international institutions continue to function.

SCENARIO 2: DE-GLOBALISATION

The second scenario³⁵ is characterised by a number of powerful global factors, including prolonged recession, high unemployment, climate shocks, conflicts over resources, public unrest, protectionist policies, and the unravelling of certain established institutions such as the EU.

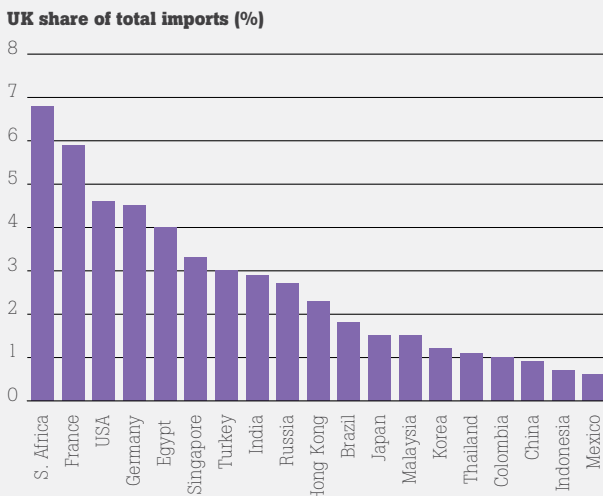
The consequences of this scenario would be weak economic growth around the world. While global de-integration would harm economies worldwide, regional de-integration would harm European countries. BRICs may also fail to reach their much-hyped potential³⁶. For example, in the late 1960s, Burma (now Myanmar), the Philippines, and Sri Lanka were widely anticipated to become the next Asian tigers, only to falter.

²⁹ Bangladesh, Egypt, Indonesia, Iran, Korea, Mexico, Nigeria, Pakistan, Philippines, Turkey, and Vietnam. ³⁰ In the original publication, 'larger emerging markets' are labelled 'growth markets' and 'smaller emerging markets' are labelled 'emerging markets'. To avoid confusion, all of them are labelled 'emerging markets' and are differentiated by size. ³¹ Goldman Sachs (2012) ³² All dollar amounts quoted in this paragraph refer to 2011 USD. ³³ HSBC Business (2011) ³⁴ OECD (2012b) ³⁵ Government Office for Science (2009) ³⁶ Sharma, R. (2012)

How are UK manufacturing exports positioned in the fast growing markets?

Both scenarios envisage that emerging economies will grow faster than today's mature economies and that competition for manufacturing exports will increase. UK exports to China and India of goods and of services have been growing rapidly, albeit from a low base. Between 2001-2011, UK exports of goods and services to China (including Hong Kong) and India grew at an annual average rate of 12.7%, compared to 4.4% to the existing EU³⁷. However given that the UK is the world's 11th largest goods exporter (with a 2.9% world share), the UK's export performance in China, and India in 2012 (Figure 4.11)³⁸ remains disappointing. The UK needs to do better to win emerging markets for manufacturing exports, in these and other rapidly growing countries such as Russia, Brazil, Indonesia, and Mexico.

Figure 4.11: UK share of total manufacturing imports into key markets (2010)

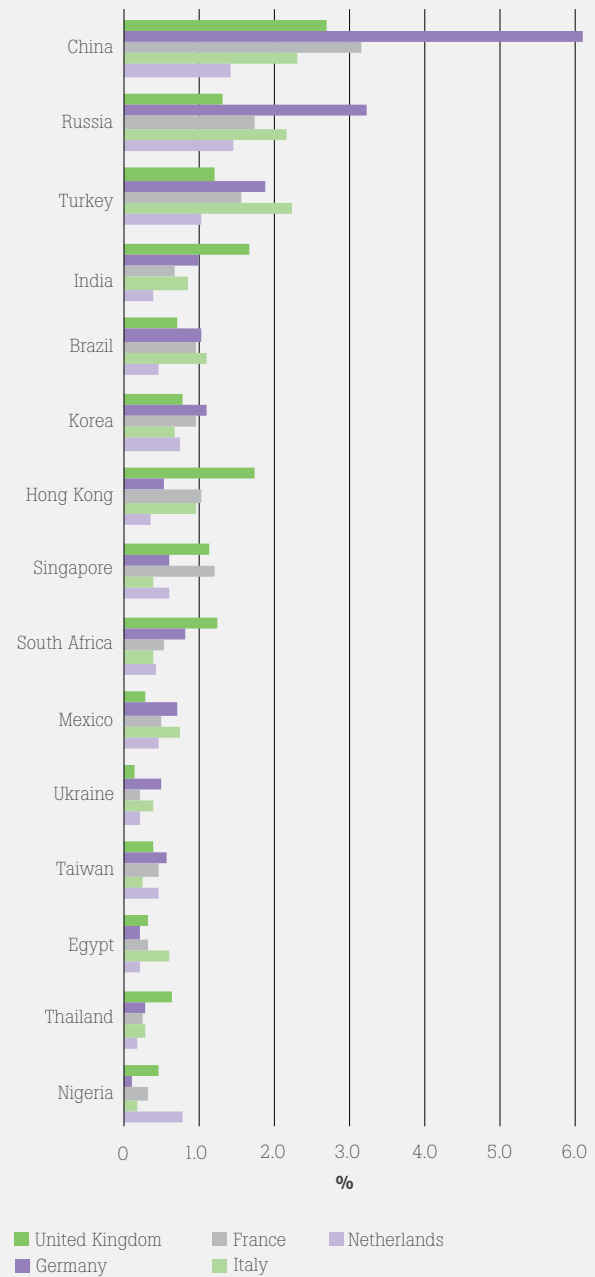


Source: Adapted from BIS (2012)

Emerging economies play an increasing, but still small, role for most EU countries including the UK (see Figure 4.12)^{39,40}. Among emerging economies, the biggest EU export destinations, by size, are Turkey, India and Brazil. On average, during 2011, EU countries sent 3.1% of their exports to China and 2.5% to Russia. The UK trails behind Germany

in the majority of these fast-growing markets, with the exception of India, Hong Kong, Singapore, South Africa, and Thailand, which buy a higher percentage of imports from the UK than from Germany, evidently due to historical ties.

Figure 4.12: Exports to emerging economies (% of all exports) for selected countries, 2011



Source: Calculations based on the Eurostat international trade database

4.1.4 EXPORTS, IMPORTS AND THE BALANCE OF TRADE

The relative movement of both exports and imports is important. A divergence between these two aggregates will influence the balance of payments, and levels of wider economic activity. Between 1985-2011, manufacturing expenditure and output both increased in the UK with the former exceeding the latter. As a result, the UK trade balance deteriorated, as export performance was outstripped by growth in manufacturing imports, leading to a trade deficit of -4.1% of GDP in 2011. This pattern occurred in the United States, but not in East Asia or the Eurozone⁴¹.

It is important to consider manufacturing within the overall balance of payments, to understand the order or magnitude involved. The overall payments position of a country is normally measured by the current account. In addition to manufactured goods, this account includes 'other visibles', such as food, fuels and raw materials, together with 'invisibles', such as services, income from overseas investments, migrants' remittances and inter-governmental transfers.

The trade balance in manufactures has been on a downward trend for several decades and there is now a large deficit on this item. After a period of stability, the balance on 'other visibles' has deteriorated recently due to a combination of higher commodity prices and lower domestic oil and gas production. However, for most of the time these negative trends have been largely offset by improvements on the invisible side of the account, so the overall current account deficit has mostly been quite small for most of the time. The overall improvement in invisibles conceals some widely divergent trends, including growth in receipts from knowledge-based services, for example finance,

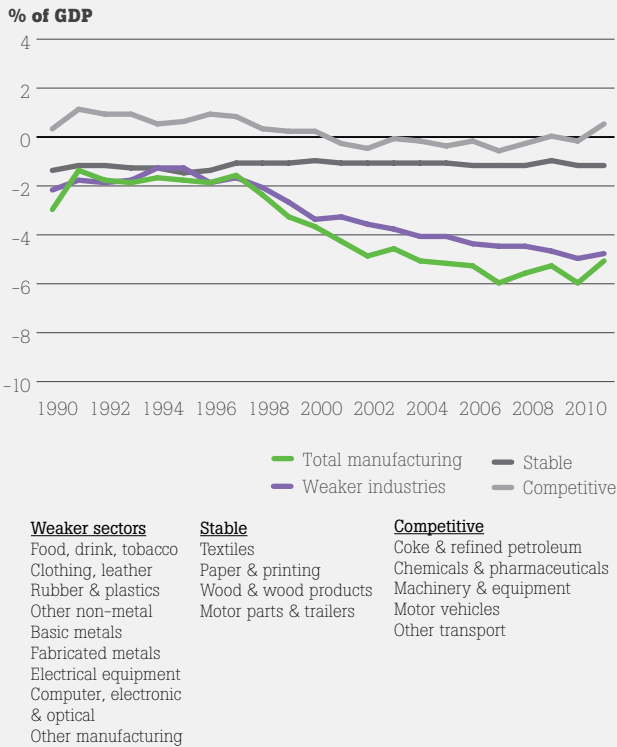
insurance, consultancy and other business services. In 1991, knowledge-based services including finance and services generated a net income for the UK equal to 1.3% of GDP. By 2012, this had risen to 5.1% of GDP. This compares to net income from manufacturers being -0.6% of GDP in 1991 and -4.2% of GDP in 2012⁴².

It is useful to probe beyond manufacturing, taken as a whole, to identify relatively weak and strong performing industries within manufacturing in terms of the trade balance. Figure 4.13⁴³ classifies manufacturing industries into three groups:

- Weaker industries are defined as those that have a negative and worsening trade balance. This large grouping includes clothing and leather where domestic producers are suffering severe competition from low wage imports. It also, however, includes electrical equipment, computer, electronic and optical products⁴⁴.
- Competitive industries have a positive or an improving trade balance. This includes coke and refined petroleum products, chemicals & pharmaceuticals, machinery and equipment, motor vehicles and other transport (aerospace and weapons)⁴⁵. This corresponds closely to the list of top performing export sectors identified earlier.
- Stable industries are in trade balance deficit but with no trend deterioration and include for example textiles and motor parts.

⁴¹ Evidence Paper 30: Rowthorn, B. & Coutts, K. (2013) ⁴² Evidence Paper 30: Rowthorn, B. & Coutts, K. (2013) ⁴³ Evidence Paper 30: Rowthorn, B. & Coutts, K. (2013) ⁴⁴ Some of the weaker industries' decline may reflect the success of competition from low wage countries where firms have invested in technology transfer to close the gap in the frontier of technology with advanced economies (see Aghion and Howitt (2009)). For other sectors the weakness in trade performance may reflect lack of R&D investment to compete with other advanced countries.

Figure 4.13: UK trade performance of manufacturing sectors 1990–2011 (current prices): UK exports by destination



Source: Coutts, K. and Rowthorn, R. (2013)

In most UK manufacturing sub-sectors, imports and exports are increasing simultaneously, both absolutely and in relation to national production. In some cases, total exports are increasing, but they are being outstripped by rapidly expanding imports. This is most obvious in computer, electronic and optical products where exports rose by 80% between 1995–2001, but imports grew by 270%. The fact that exports are increasing in such apparently weak industries indicates that they retain competitive product subgroups. Equally, it shows the limitations of focusing on movements of exports alone in identifying comparative advantages.

Predicting long run movements in the balance of payments is hazardous. This balance is the difference between two very large quantities (exports and imports) and small proportionate changes can cause the balance to swing sharply from surplus to deficit or vice-versa. One way to consider future prospects is to use projections which forecast what would happen under certain assumptions about government policy and the behaviour of economic variables, for example the price of oil or the growth of world trade. Different assumptions yield different forecasts. Projections rely on assessment, based mainly on past relationships, of the main macroeconomic factors such as income and relative prices that influence long-term trends in the balance of payments. Analysis starts from a base projection which assumes no change in government policy and embodies a set of assumptions about broad economic trends that seem reasonable in the light of existing evidence. It then examines how varying some of the assumptions would affect projected outcomes. Such an exercise helps to indicate the potential importance of various policy interventions to strengthen the balance of payments.

The projections used here have a ten year horizon. As a starting point for the projections, the main items in the current account in 2012 are listed in Table 4.5⁴⁵. The category 'other knowledge-intensive' services covers a variety of services for example communications, construction, computer and information services, royalties and license fees, consultancy, legal services, and audio-visual services. It excludes financial services and insurance.

⁴⁵ Motor vehicles have been separated from other activities within its sector and put it into the competitive group because it has substantially reduced its deficit over the past decade. The remaining component consisting of vehicle parts, trailers etc. is put into the stable group. ⁴⁶ Evidence Paper 30: Rowthorn, B. & Coutts, K. (2013)

Table 4.5: Main items in the UK current account balance of payments 2012 (£ millions)

	CREDITS	DEBITS	BALANCE	%GDP
Surplus Items				
Financial services & insurance	57,532	12,646	44,886	2.9
Other knowledge-intensive services	81,742	47,802	33,940	2.2
Investment income*	161,915	160,353	1562	0.1
Deficit Items				
Manufactures	225,864	290,354	-64,490	-4.2
Energy (oil, coal, electricity & gas)	44,023	65,289	-21,266	-1.4
Food, beverages and tobacco	17,818	36,552	-18,734	-1.2
Basic materials	8,486	10,820	-2,334	-0.2
Transport and travel	46,426	53,329	-6,903	-0.4
Government services	2,272	4,006	-1734	-0.1
Current transfers	16,512	39,599	-23,087	-1.5
Goods not elsewhere specified	4,265	3,784	481	0.0
Current Account	666,855	724,534	-57,679	-3.7

Source: Coutts, K. and Rowthorn, R. (2013), Tables 1.2, 2.1, 3.1 in UK Balance of Payments Pink Book 2012. ONS; tables 1.2, 2.1, 3.1.

*Includes earnings of employees.

Base projection and alternative projections for 2022

The base projection presents an informed picture of what may occur over the next decade if trends continue and a strong economic recovery is sustained. The main assumptions underlying the base projection for the principal components of the balance of payments are shown in Table 4.6⁴⁷.

Table 4.6: Base projection main assumptions (annual percentage growth rates)

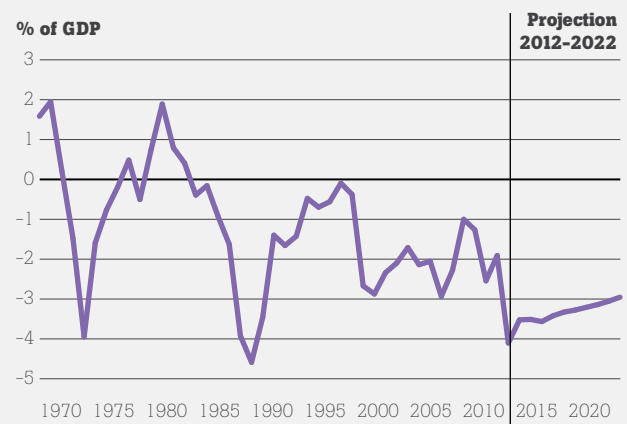
	2013	2014	2015-22
Real domestic expenditure	1%	2%	3%
World trade	4%	5%	6%
Relative domestic to world unit labour cost (real exchange rate)	1%	1%	0%
Nominal unit wage and salary growth	0%	3%	3%
Real price of oil and gas	1%	1%	1%
Volume of oil & gas production	-1%	-1%	-5%
Volume of UK consumption of oil & gas	0%	0%	0%
Real rate of return on finance & insurance assets*	-1.4%	0%	1.6%
Real rate of return on finance & insurance liabilities*	-1.5%	-0.1%	1.5%
Real rates of return on external assets and liabilities*	0.0%	0.2%	0.5%

Source: Coutts, K. and Rowthorn, R. (2013). *Income as a percentage of assets and liabilities

The main results for the base projection for 2022 are as follows:

- Balance of Payments Current Account: the current account shown in Figure 4.14⁴⁸ is in deficit throughout the projection period.
- Manufactures: the deficit on manufacturing trade increases in monetary terms from an estimated £67 billion in 2012 to £85 billion in 2022. However, relative to the economy as a whole it declines from 4.4% of GDP in 2012 to 3.3% in 2022 (see Figure 4.15)⁴⁹. There is a continued decline in the performance of oil and gas relative to GDP and a continued deficit on food and basic materials.

Figure 4.14: Current account balance (% of GDP)



Source: Coutts, K. & Rowthorn, R. (2013)

Sensitivity analysis: Since the balance of trade is the difference between two large magnitudes, a proportionate error in projecting exports or imports may result in a larger proportionate error in the trade balance in manufactures. Table 4.7⁵⁰ lists a number of changes that would individually cause the current account balance in 2022 to deteriorate by 1% of GDP. If all or most of the assumptions shown in this figure occurred simultaneously, then by 2022 the UK would have a very large current account deficit. Conversely, if similar changes were to occur simultaneously in the opposite direction, there would be a current account surplus.

Figure 4.15: Balance of trade in goods (% of GDP)

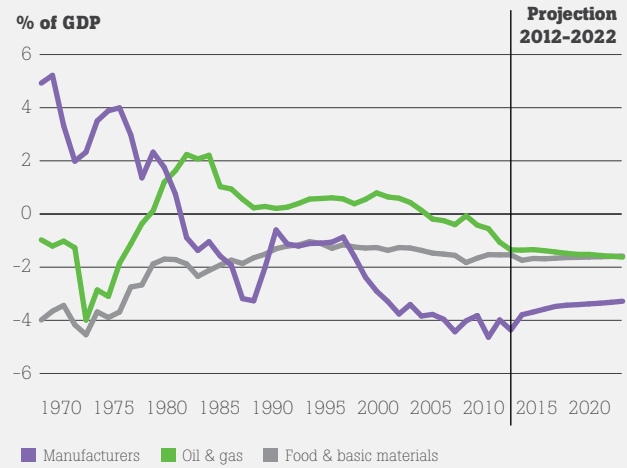


Table 4.7: Individual changes that worsen the current account by 1% of GDP by 2022

	BASE PROJECTION	ALTERNATIVE ASSUMPTION
Slower growth of world trade	6.0% p.a.	5.3% p.a.
Currency revaluation (increase in relative unit labour costs)	0% p.a.	20% p.a.
Faster growth of domestic spending	3.0% p.a.	3.36% p.a.
Real price increase of oil & gas	1% p.a.	9.0% p.a.
Faster decline in oil & gas production	-5% p.a.	-20% p.a.
Lower long term rate of return on UK investments	0.5%	0.2%
Slower growth in real exports of financial services	3.8% p.a.	0.5% p.a.
Slower growth in real exports of other knowledge-intensive services	5.8% p.a.	1.5% p.a.
Slower growth in real exports of manufactures	5.2% p.a.	4.2% p.a.

Source: Coutts, K. and Rowthorn, R. (2013)

Base projection: This assumes that present trends continue and a strong economic recovery is sustained, leading to a current account deficit equal to 3% of GDP by 2022 (see Table 4.8)⁵¹. On the upside, earnings from overseas investments might recover or the City of London might perform better than the cautious assumptions imply.

Optimistic scenario: Under these assumptions, the current account deficit shrinks from 4.1% of GDP in 2012 to 0.7% in 2022 (see Table 4.8). This involves domestic demand increasing more slowly than the base projection; net investment income remaining in surplus; and the UK balance of trade deficit with regard to manufacturers decreasing faster than the base projection. These assumptions and the trajectory for the deficit are similar to forecasts made by the Office for Budget Responsibility in December 2012⁵²

Pessimistic scenario: Under these assumptions, there is a current account deficit equal to 5.2% of GDP (Table 4.8). And the balance of trade in manufacturing is -4.4% of the GDP compared to -3.3% under the base projection. This is much larger than under the base projection. This involves decreasing the annual growth rate of world trade compared to the base

projection; output of oil & gas falling at a faster annual rate; real net exports of financial and insurance services growing at the same rate as under the base projection; and real net exports of other knowledge-intensive services growing at a slower annual rate than the base projection.

Under the pessimistic scenario, the current account deficit would be a cause for serious alarm, as the relentless deterioration in the balance of payments would not be sustainable. As the deficit built up, pressure on the exchange rate would mount, leading eventually to a large currency devaluation and domestic inflation⁵³. The government and central bank might also intervene by restraining demand to combat inflation and limit the growth of imports. This combination would bring down the deficit but at the cost of lost output and unemployment. A key conclusion emerges from this analysis. This is that given the orders of magnitude involved, any policy for strengthening the balance of payments must assign a significant role to manufacturing. UK trade in manufactures (exports plus imports) is several times larger than exports of the City of London and other knowledge-intensive services put together.

Table 4.8: Comparison of projections for the balance of payments

	ESTIMATED 2012	BASE PROJECTION 2022	OPTIMISTIC SCENARIO 2022	PESSIMISTIC SCENARIO 2022
Real domestic expenditure (% p.a. long-run growth rate)		3.0	2.7	3.0
GDP (% p.a. long-run growth rate)		3.1	2.9	2.8
Balance of trade in manufactures (% GDP)	-4.4	-3.3	-2.7	-4.4
Balance of trade in other goods (% GDP)	-2.9	-3.2	-3.0	-3.6
Balance of trade in services (%GDP)	+4.6	+6.1	+6.3	+5.5
Investment income (%GDP)	0.0	-1.1	+0.2	-1.3
Current account (%GDP)	-4.1	-3.0	-0.7	-5.2

Source: Coutts, K. and Rowthorn, R. (2013)

⁵¹ Evidence Paper 30: Rowthorn, B. & Coutts, K. (2013) ⁵² Office for Budget Responsibility (2012). The OBR forecasts that GDP growth will accelerate to 2.8% p.a. by 2017 and the current account balance in 2017 will be -1.4% of GDP. ⁵³ In their econometric analysis of industrial countries, Freund and Warnock (2007) find that deficit adjustment typically involves a decrease in GDP growth and may involve currency depreciation. Larger deficits take longer to adjust and are associated with slower output growth during current account recovery than smaller deficits. Freund, C. & Warnock, F. (2007).

4.1.5 CAPITAL INVESTMENT

The UK share of capital investment in output has been low relative to competitor economies for many decades, for the whole economy and for manufacturing (see Table 4.9). These trends are reflected in growth rates of the fixed capital stock, which were negative for capital stock growth 2000-08 (see Table 4.9)⁵⁴.

Because the UK has experienced rapid decline in manufacturing employment in recent decades, the lower capital investment is consistent with a better performance in growth of capital per worker and has been about the average of competitor countries. This capital deepening is not the result of re-allocation of resources between sectors but is common across sectors. There are no official current figures for capital per worker levels at sectoral level, but the McKinsey Global Institute estimates that there is a large gap between UK manufacturing in terms of the capital shortfall to match the best performing comparator countries⁵⁵.

Table 4.9: Ratio of Gross Fixed Capital Formation to GVA

MANUFACTURING				
	1970-79	1980-89	1990-99	2000-07
Canada	13.9	15.1	13.7	10.2
Denmark	12.6	14.3	17	17.2
France	17.0	16.1	15.9	15.3
Germany	–		15.1	13.4
Italy	25.0	22.2	23.3	25.3
Japan	–	–	–	–
Korea	32.3	31.8	33.0	28.8
Netherlands	15.7	18.2	17.1	13.4
Sweden	18.9	19.0	18.2	17.0
UK	13.4	13.2	13.2	10.5
US	11.2	12.1	13.3	11.4

Source: Evidence Paper 8 Driver and Temple (2013)

A major consequence of the lower growth in net investment and thus the capital stock is that when this is set against faster growth in UK manufacturing total factor productivity (TFP) (see Chapter 2); and lower growth in value-added, it implies that higher TFP was dependent on efficiency gains designed to ensure costs fell faster than the decline in output, rather than in quality enhancing improvements in technology associated more with new product development⁵⁶.

During 1980-2009, UK manufacturing achieved modest output growth (0.5% p.a. on average) compared to 2.3% in Japan and 2.5% in the US; only Germany had lower overall growth in real value-added⁵⁷. However, in the UK, this was achieved in quite a different way to its more successful competitors. Figure 4.17 helps to make this clear by showing that relative to the US, output in the UK was on average 2% p.a. lower and this was achieved with high TFP alongside relative cut-backs in both labour and capital. Compared to the US, manufacturing in the UK achieved what were on average cost-cutting efficiency gains that led to relatively high TFP. In the US, this TFP growth also went alongside significant investment in fixed capital.

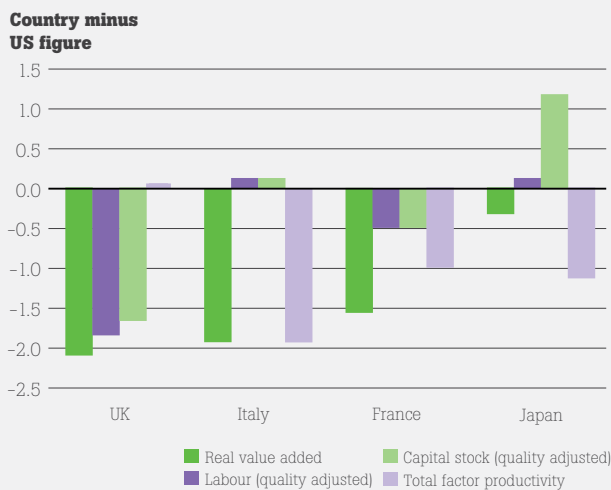
Compared to the US, both Italy and France also did poorly in terms of growth in output. However in both countries this coincided with relatively low gains in efficiency and/or technical progress. It would appear that they over-invested in their capital stocks, given demand for their products. Only Japan performed in a similar way to the US, although with less reliance on TFP growth and more on fixed capital accumulation.

During 2000-08, relative to US, manufacturing in the UK continued to underperform in terms of output growth, with again an emphasis on cost-cutting TFP (see Figure 4.16). Germany and Japan both achieved higher output growth than the US, alongside relatively higher growth in capital and labour inputs (and slightly lower TFP growth). Italy and France achieved modest output growth (hence they underperformed against the US), which coincided with relatively higher growth of capital and labour inputs, but relatively poor TFP growth (implying few if any gains in efficiency and/or overall technical progress).

⁵⁴ Evidence Paper 8: Driver, C. & Temple, P. (2013) ⁵⁵ McKinsey Global Institute (2012) ⁵⁶ On the supply-side, GVA is determined by how much capital and labour inputs are used to produce output, with the other major input being TFP (essentially those factors that determine the 'efficiency' with which labour ⁵⁷ EUKLEMS

Overall, this analysis shows that UK manufacturing has underperformed in recent years compared to the US, Japan and (more recently) Germany. Despite strong growth in TFP, there has been a relatively higher shedding of labour and in particular under-investment in the capital stock.

Figure 4.16: Manufacturing growth rates 1980-2009 (% p.a. differences from US figures)



Source: EUKLEMS

This implies overall efficiency gains were achieved alongside a lower demand for the goods and services produced by UK manufacturers. The low level of investment in capital equipment for expansion is mirrored by the low levels of investment in R&D in the UK. Both are consistent with a reluctance of UK firms and the capital markets which serve them to invest for long term growth and innovation⁵⁸. The next section shows that UK manufacturing has under-invested in R&D, indicating a reluctance of UK firms and capital markets to invest for the long term.

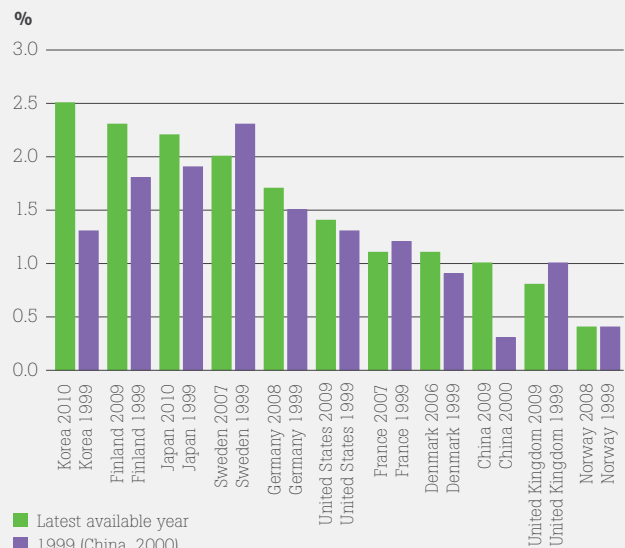
4.1.6 INVESTMENT IN R&D AND INNOVATION

A central factor in determining the trade and export performance of UK firms is their innovation and productivity performance. Investment in innovation via R&D will have a major impact on productivity through increasing absorptive capacity,

and generating process and product innovations. Process innovation results in greater efficiency (as costs are lowered) while new products are introduced typically using better technology than existing products.

In the UK, R&D is heavily concentrated in a few manufacturing sectors and is dominated by a handful of the largest firms⁵⁹. For manufacturing as a whole, expenditure on R&D in the UK has been relatively weak and the UK ranks at the lower end of the countries analysed in Figure 4.17⁶⁰. The ratio of manufacturing R&D to GDP has fallen since 1999^{61, 62}.

Figure 4.17: Manufacturing R&D as a percentage of GDP, 1999 & latest available year

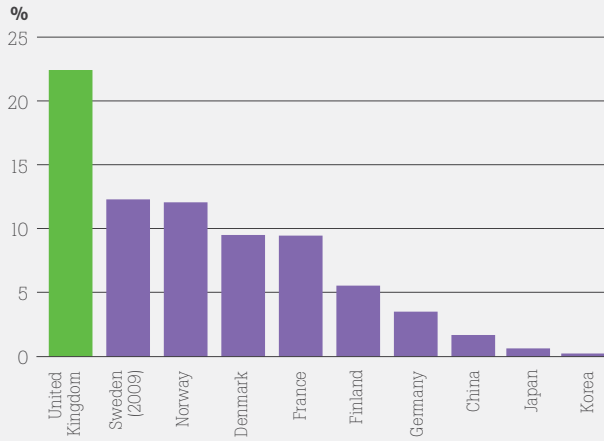


Source: Evidence Paper 16: Hughes, A. (2013)

In addition to having a relatively low commitment to spending on R&D, the UK is an extreme outlier in terms of relying on overseas funding for its R&D. The proportion of R&D in UK manufacturing and services which is funded from overseas sources is twice as high as the nearest country shown in Figure 4.18⁶³ and about five times as high as in Germany (comparable data is not available for the United States). Overseas funding of business R&D is negligible in the cases of Japan and Korea. The UK is thus particularly vulnerable to any changes which might lead to a relocation of these potentially mobile funding sources.

⁵⁸ Evidence paper 16: Hughes, A. (2013) ⁵⁹ Independent SMEs employing less than 250 people accounted for less than 4% of total UK R&D spend in 2009. Evidence Paper 16: Hughes, A. (2013) ⁶⁰ Evidence paper 16: Hughes, A. (2013) ⁶¹ Because Manufacturing is more R&D intensive than the rest of the economy, Figure 4.17 is influenced by variations across countries in the share of manufacturing in GDP; however, Hughes (2013) shows that when R&D intensity (spending on R&D divided by value added in manufacturing) is compared across the same set of countries, the UK remains second to bottom (only above Norway). ⁶² Data on capital investment on fixed assets (plant, machinery, buildings, ICT, etc.) in UK manufacturing is also low compared to other countries as shown in Table 1 of Evidence Paper 8: Driver (2013). ⁶³ Evidence paper 16: Hughes, A. (2013)

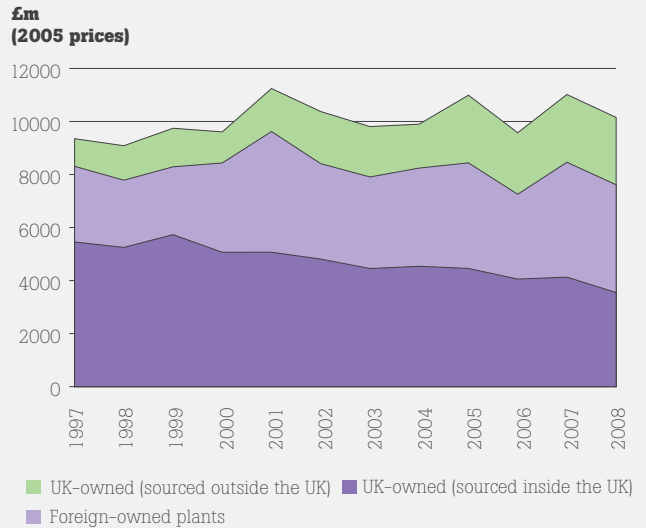
Figure 4.18: R&D funds from abroad, 2010
(as a % of business enterprise R&D): all sectors



Source: Evidence Paper 16: Hughes, A. (2013)

The ownership characteristic of businesses carrying out R&D expenditure in the UK is another useful indicator of the internationalisation of the UK R&D effort. Figure 4.19⁶⁴ shows that spending by manufacturing on R&D in 2008 was higher in foreign-owned firms than UK-owned and that about 42% of the funding for UK-owned firms was from sources outside the UK⁶⁵. This reflects the relative importance of inward FDI to the UK. However, there may be (now or in the future) issues over the extent to which the UK manufacturing sector can maintain an effective and independent research effort linked to the development of future goods and services. Overseas owned and financed R&D investments are likely to be subject to strategic relocations by the headquarters of a multinational company if returns to investment are not sufficient or it changes its strategic focus.

Figure 4.19: UK manufacturing business expenditure on R&D (£m 2005 prices), 1997-2008

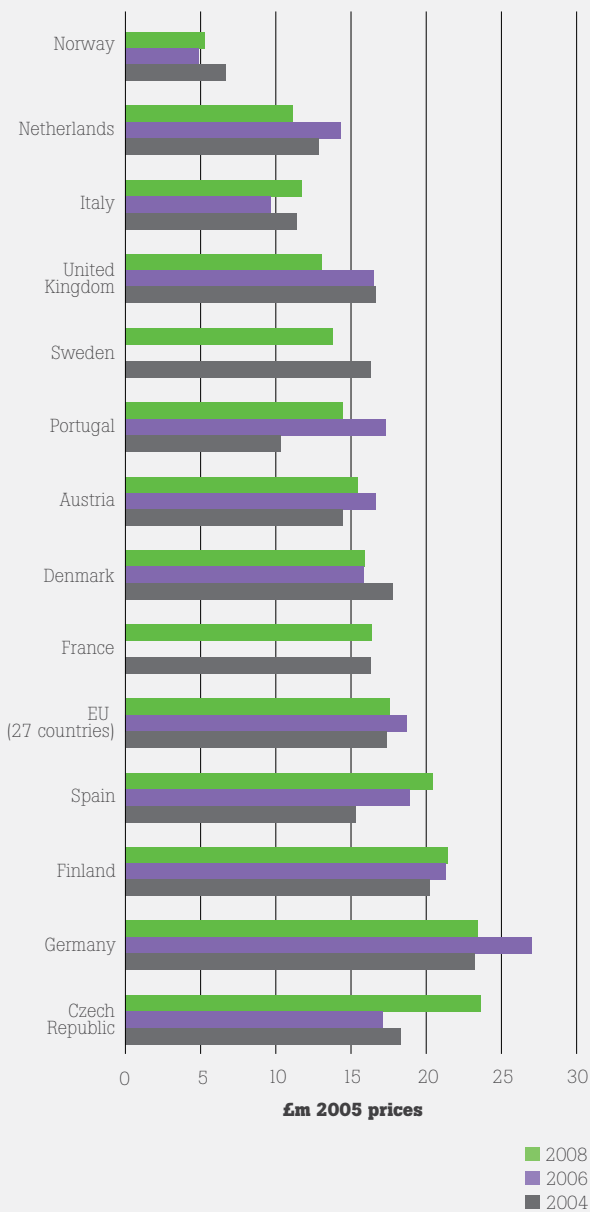


Source: Adapted from tables A.3 & A.5. Evidence Paper 23 Moffat, J. (2013)

In addition to R&D spending being low by international standards, product innovation in new goods and services is lower in UK manufacturing (Figure 4.20)^{66, 67}. In 2008, just over 13% of UK turnover was attributable to products which were new to the market. In Germany, the comparable figure was nearly double this amount. The UK was also significantly below the EU average in 2008. Other indicators of innovation performance are patents, trademarks, and industrial design rights.

⁶⁴ Evidence Paper 23: Moffat, J. (2013) ⁶⁵ Evidence Paper 23: Moffat, J. (2013) ⁶⁶ Eurostat (2013) ⁶⁷ The data also include mining, construction and utilities but are dominated by the manufacturing sector.

Figure 4.20: Turnover from innovation in industry⁶⁸, 2004-2008, EU27

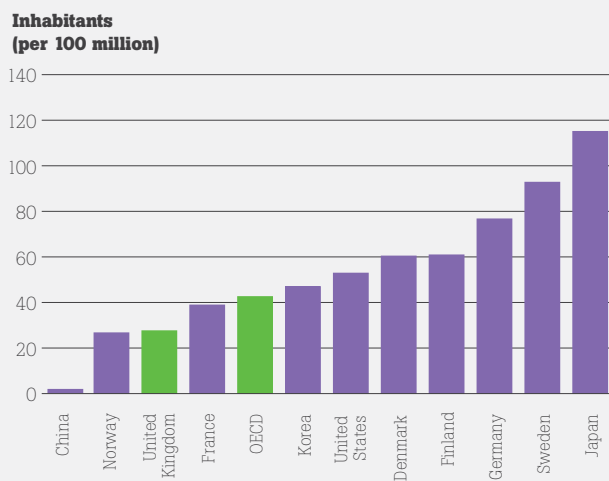


Source: Eurostat (2013)

Note: Defined as turnover from products new to the market as a % of total turnover in firms classified to industry (rather than services). Countries are ranked low to high based on 2008 figures.

Here once again the UK is considerably behind its major competitors in patenting (see Figure 4.21) and in the case of trademark applications (see Figure 4.22⁶⁹) has been flat-lining below other countries particularly from 2000 onwards.

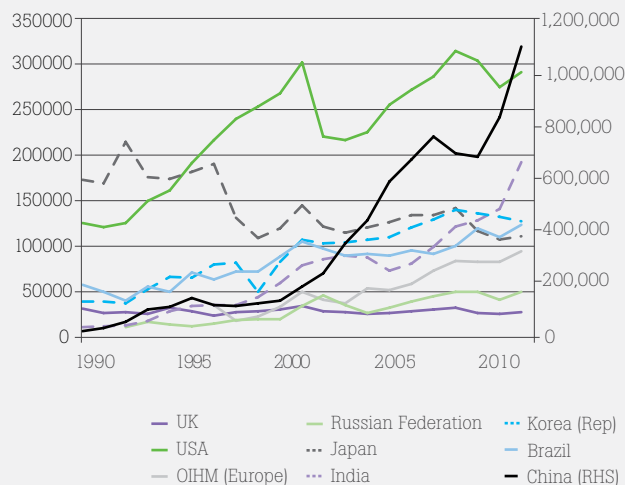
Figure 4.21: Triadic Patent Families⁷⁰ per 100 million inhabitants



Source: OECD Factbook 2010: Economic, Environmental & Social Statistics. Science and technology - Research and Development - Patents

Note: A triadic patent family refers to inventions which have been patented at the European Patent Office, the Japan Patent Office and the US Patent and Trademark Office.

Figure 4.22: Trends in Trademark applications at the major offices



Source: Evidence Paper 12: Hall, B. (2013)

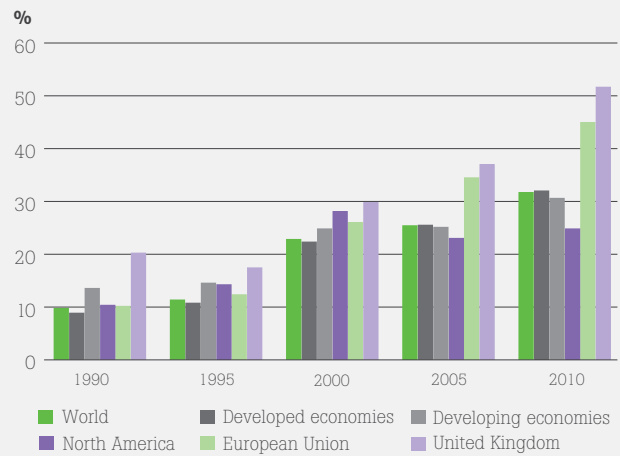
⁶⁸ Defined as turnover from products new to the market as a % of total turnover in firms classified to industry (rather than services). Countries are ranked low-to-high based on 2008 figures. ⁶⁹ Evidence Paper 12: Hall, B. (2013) ⁷⁰ A triadic patent family refers to inventions which have been patented at the European Patent Office, the Japan Patent Office, and the United States Patent and Trademark Office (USPTO)

In 2011, services amounted to around one-third of all global trademark applications⁷¹. UK manufacturing performance in this area is relatively weak. Applicants are over-represented in all service sectors (business, personal, and telecommunications and transport), as well as instruments and consumer goods. Instruments are an R&D-intensive area encompassing a wide range of medical and surgical instruments, as well as electrical and electronic equipment. Consumer goods are also somewhat innovation-intensive areas, comprising jewellery, clocks and watches, games and sporting equipment, musical instruments, firearms, and explosives⁷².

4.1.7. FLOWS OF FOREIGN DIRECT INVESTMENT

In the previous section, the reliance on overseas funding for UK R&D and the scale of R&D activity accounted for by overseas businesses located in the UK was highlighted. The pattern of overseas ownership of businesses in the UK more generally is strongly linked to the UK's position in global flows of direct investment. Since 1990, the UK has been a major recipient of inward foreign direct investment (IFDI) in the form of greenfield investments, and mergers and acquisitions. This has led to a six fold increase in the UK FDI stock⁷³. This was associated with a much faster growth in the stock of FDI relative to GDP than elsewhere in the world (see Figure 4.23)⁷⁴.

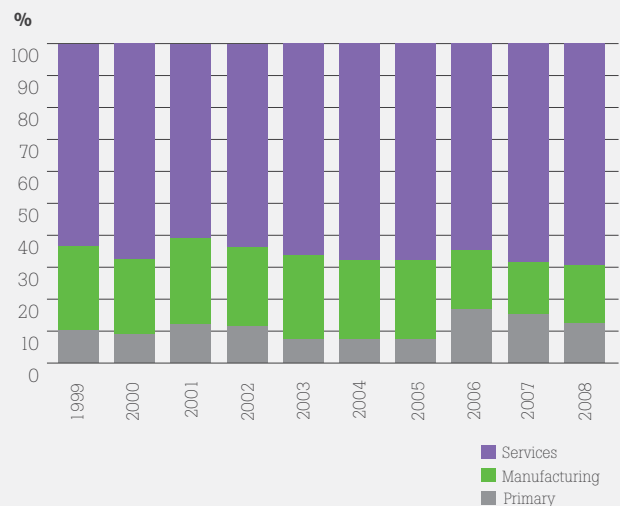
Figure 4.23: FDI stocks as a percentage of gross domestic product



Source: Evidence paper 7: Driffield, N. et al. (2013)

The majority of this investment and stock of assets was in services rather than manufacturing (see Figure 4.24)⁷⁵, but it accompanied a major increase in the contribution of foreign firms to total manufacturing output which doubled between 1998 -2008 (see Figure 4.25)⁷⁶.

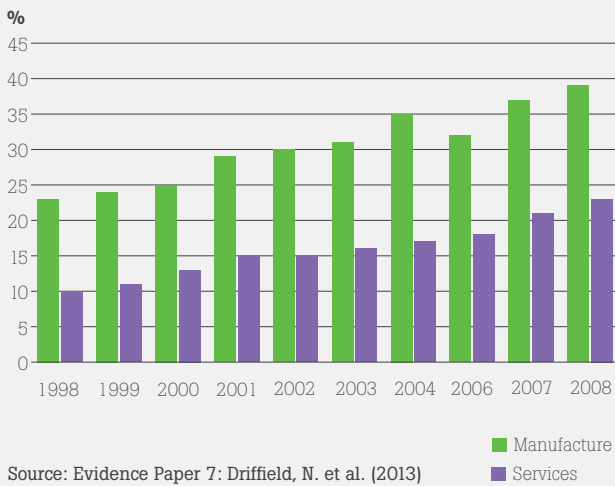
Figure 4.24: Net Inward FDI stock in the UK by sector, 1999–2008, percentage



Source: Evidence Paper 7: Driffield, N. et al. (2013)

⁷¹ Evidence Paper 12: Hall, B. (2013) ⁷² In Evidence Paper 12: Hall, B. (2013) notes the fact that pharmaceutical trade marking is relatively low. This doubtless reflects that fact there is very active trade marking in this area in developing countries for the introduction of a product into the country, rather than for new products. ⁷³ Evidence Paper 7: Driffield, N. et al. (2013) ⁷⁴ Evidence Paper 7: Driffield, N. et al. (2013) ⁷⁵ Evidence Paper 7: Driffield, N. et al. (2013) ⁷⁶ Evidence Paper 7: Driffield, N. et al. (2013)

Figure 4.25: Contribution of foreign firms to total manufacturing & services output



Based on analysis of the key determinants of FDI in Table 4.10, the UK remains in a relatively good position to continue to attract an above-average share of FDI coming into Europe. But FDI in Europe is likely to be a dwindling share of global FDI flows, and the UK will face growing competition from BRIC and other emerging economies. For example, while labour flexibility is an advantage for the UK generally, this is much less of a positive aspect relative to many emerging economies. Similar arguments apply to labour costs, corporate tax rates and issues of distance. As a result, it is difficult to envisage anything other than a continuing decline in the share of manufacturing as a proportion of total IFDI into the UK⁷⁷.

Table 4.10: Key issues affecting foreign direct investment flows

Note: The table provides an indication of the importance of each determinant, based on the literature; a summary of the UK's position relative to both the EU and emerging market economies (green=good; orange=moderate; red=problematic); and a brief summary of the UK's position.

ISSUE	IMPORTANCE	UK COMPARED WITH EU	UK COMPARED WITH EMERGING MARKETS	OVERALL POSITION
Market size	high	●	●	Large economy in EU but not compared with BRICS
Host sector performance	medium	●	●	Less innovative or productive than some of EU, innovation rates still ahead of Emerging economies
Openness	medium	●	●	Possibly the most open economy in the world
Distance	medium	●	●	Close to but not at the heart of Europe, a long way from Asia
Infrastructure	low	●	●	Issues with transport
Corporate tax rates	low	●	●	Comparable with developed world, and historically relaxed on tax avoidance
Labour costs	high	●	●	Low compared with EU12, high compared with Asia
Labour market flexibility	high	●	●	Most flexible labour market for any developed economy apart from US
Institutions	high	●	●	Very highly regarded legal system and institutions
Incentives/aftercare	medium	●	●	Traditionally strong, current position at a local level unclear
Exchange rate risk	low	●	●	Outside Euro, sterling traditionally safe
Agglomeration/supply linkages	medium	●	●	Some hollowing out of supply chains in recent years

Source: Driffield et al. (2013)

4.1.8 FOREIGN OWNERSHIP OF MANUFACTURING BUSINESSES

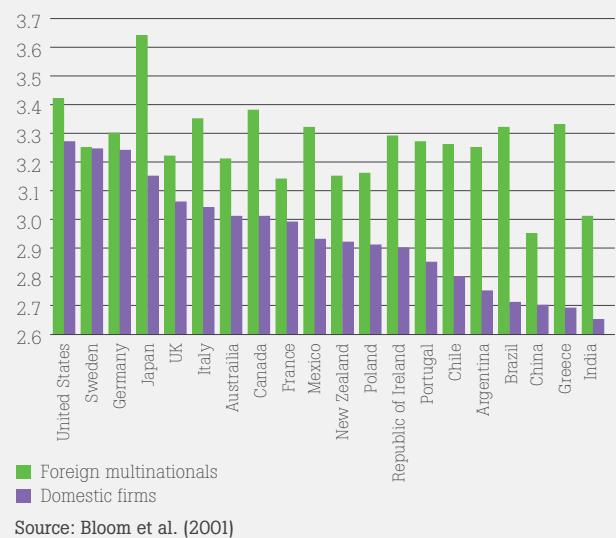
UK output in foreign-owned manufacturing was almost as high in 2009 as in UK-owned manufacturing, having been almost six times smaller in 1973, meaning that the UK was an attractive place for foreign investment over the period. In 1973–2009, the United States-owned plants in the UK increased their gross output by 58%. In contrast, EU-owned plants began the period with gross output of £8 billion (2000 prices) and finished it with £79 billion, signalling the importance of investment within the common market.

The value of gross output produced by South East Asia-owned plants in the UK increased dramatically between 1973–2009. However, in 2008, UK-owned plants spent around 50% more than foreign-owned plants on R&D which suggests that foreign-owned firms tend to do much of their R&D at home rather than in the UK. Throughout 1997–2008, UK-owned plants used foreign sources to fund their R&D to a far greater extent than foreign-owned plants used UK sources to fund their R&D. It is likely that the foreign-owned manufacturing sector within the UK will soon account for a larger share of output, GVA and employment than the UK-owned sector. If the trends observed between 1973 and 2009 continue this will occur around 2020 for gross output and 2015 for employment. By 2011 overseas owned businesses already accounted for 54% of UK manufacturing R&D⁷⁸.

The implications for UK exports are not clear cut. A high and increasing MNC presence can lead to a substitution of overseas production for domestic production at the expense of exports, when MNCs relocate manufacturing activity abroad, in response to transaction, transport, and manufacturing costs. This substitution effect may be offset by a positive effect on exports through enhanced efficiency in

the domestic economy. It is also clear that MNC presence is associated with superior management performance (Figure 4.26)⁷⁹. Taken together with evidence in Chapter 6 on poor UK management practice, this suggests that an increased degree of openness, and MNC presence should be associated with an improvement of the competitive and potential export performance of the UK's largest firms. However, there are uncertainties about the proportion of the profits from manufacturing that would remain in the UK.

Figure 4.26: Management scores of multinationals (manufacturing & retail)



Note: Sample of 7,262 manufacturing and 61 retail firms, of which 5,441 are purely domestic and 2,482 are foreign multinationals.

4.1.9 CHINESE ECONOMIC GROWTH TO 2050

China accounted for less than 5% of world GDP in the mid-1970s (at PPP). Today this figure is approaching 20%. China's growth in the recent past has been close to 10% per year with Chinese GDP forecast to overtake the United States between 2017 and 2026. The Chinese economy has been on a path of rapid catch-up growth following earlier examples such as Western Europe and Japan after World War II, and the East Asian Tigers from the 1960s but, starting from a lower level, and growing faster. It seems obvious to many people that growth will continue, with China achieving income levels similar to those in advanced western economies.

This is not what projections by mainstream economists indicate. OECD (2012) sees the Chinese level of real GDP per person at 55% of the level in the US in 2050 while the Chinese share of world GDP will increase to 28% by 2030 but flat-lines thereafter. This is based on a projected slowdown in real GDP growth from 8.9% per year in 2012-17 to 5.5% in 2018-30 and 2.8% in 2031-50, with two main factors expected to contribute. First, demographics will become much less favourable with labour force growth turning negative from the 2020s and secondly, growth in labour productivity will slow from 9% per year currently to 3.6% in 2031-50 (Table 4.11)⁸⁰.

This weakening of productivity growth is modelled as the 'automatic' consequence of narrowing the gap with the leader. In other words, productivity growth is seen as an inverse function of the gap between China and the United States which implies that it decreases as there is less scope for 'catch-up'. In addition, the structure of the economy will become less industrial, which will tend anyway to reduce productivity growth, and more orientated to the service sector where convergence with the leader is more problematic⁸¹.

Economic history suggests that the OECD projections may well be too optimistic. Continuation of catch-up typically requires continual economic reform to improve institutions and policies. It is quite common that this process is found to be politically too difficult with the result that catch-up ceases as, for example, both Italy and Japan have found in the last 25 years. However, both Italy and Japan were much closer to US per capita GDP than China is forecast to be by 2050 when catch-up stalled so there may still be further scope for continued Chinese catch-up.

In this context, however, Chinese growth has been based on an idiosyncratic and potentially fragile institutional design, epitomising Gerschenkron's idea⁸² that development from conditions of initial backwardness can be based on 'substitutes for prerequisites'. 'Property rights' were protected not by the legal system but by incentive structures informing the actions of officials. The Regionally Decentralized Authoritarian (RDA) regime embodies strong competition between regions where success in promoting economic growth is rewarded by promotion for officials within the communist party hierarchy⁸³. This is unlikely to work well if policy objectives become less focussed on growth as China becomes wealthier and would collapse if China moves towards democracy. Replacing the RDA regime entails a difficult institutional transformation but pressures to embrace democracy are likely to intensify with economic development. The world has not seen rapid growth based on a hybrid of communism and a market economy before. Nevertheless, history suggests that it is quite conceivable that the Chinese catch-up may stall before 2050.

Table 4.11: OECD Projection of Chinese Growth (% per year)

	2012-7	2018-30	2031-50
Real GDP	8.9	5.5	2.8
Employment	0.5	-0.3	-0.8
Labour productivity	8.4	5.9	3.6

Source: OECD (2012)

4.2 SPATIAL DISTRIBUTION, DE-INDUSTRIALISATION AND RE-INDUSTRIALISATION

KEY MESSAGES

Global fragmentation of value chains will continue to be the dominant force in the spatial distribution of manufacturing, with onshoring bringing some production back to the UK:

- The future spatial distribution of manufacturing matters, with implications for employment, and regional and local industrial specialisation. There are prospects for 'phoenix industries' emerging in older industrial areas which offer advantages such as institutional networks and technical skills.
- Manufacturing clusters will continue to be important for competitiveness as they increase productivity and the capacity for innovation, and stimulate and enable new business formation.
- Fragmentation of manufacturing value chains is likely to continue in the future, resulting in a potential spatial reconfiguration of design, production and assembly.
- Onshoring (or 'reshoring') is a recent trend occurring in the majority of developed market economies. It typically involves repatriation of production from low cost locations, investment in onshore production to enhance capability, and sourcing of components from onshore, rather than from overseas. Detailed evidence is scarce, and has led to claims that it may prove to be more of 'a trickle than a 'flood'.
- Factors driving onshoring include changing labour, transport and energy costs, and a need to be close to the market.

- The future spatial distribution of manufacturing is also likely to be influenced by technologies such as additive manufacturing which allow production close to the point of consumption.
- The spatial distribution of manufacturing will be influenced by 'the factories of the future' which are likely to be increasingly diverse, distributed, mobile, urban and home-based.

The UK has undergone 'deindustrialisation', with declining shares of manufacturing in employment and GDP, but the high-tech sector displays strength for the future:

- Many developed economies have experienced declining shares of manufacturing in employment and/or GDP over recent decades, with the UK manufacturing share of employment at 10% in 2010⁸⁴ and the share of GDP at 10% in 2011⁸⁵. Against this general trend of deindustrialisation, the UK has had some success in its developing high tech sector. Its share of gross output is increasing and has broadly matched the decline in the low-tech sector share between 1973 and 2009.
- 'Business-as-usual' projections of the structure of the UK economy show a continuing tendency to de-industrialisation, with manufacturing employment projected to fall between 2010 and 2020 by anywhere from 140,000, 170,000 or 550,000 roles.

The prospect of future 'reindustrialisation' looks weak (based on current metrics) but there is potential for future declines in the manufacturing share of GDP to be at a slower pace:

- Scenarios developed by the project consider if it is possible to envisage a scenario in which the recent declines in the share of manufacturing in GDP and employment could be reversed.
- The answer to this is probably no, but there is perhaps some chance that the future rate of decline could be at a slower pace, with the most plausible scenarios producing a manufacturing share of GDP of either 7.3% or 9.7% in 2035.

4.2.1 INTRODUCTION

The UK manufacturing sector has been influenced by a number of important trends shaping its spatial distribution, and has experienced ongoing 'deindustrialisation' in recent decades. The significance of these developments are discussed in this section, with consideration given to their significance for how the UK creates and captures value from manufacturing in the future.

4.2.2 CHANGING SPATIAL DISTRIBUTION

This section examines trends in the geography of manufacturing and how it is likely to evolve in the future in the UK, and around the world. It discusses how the geography of manufacturing influences and is influenced by:

- The utilisation of assets and resources of local areas;
- The associated implications for local and regional specialisations;
- Opportunities to capture different parts of the value chain with implications for regional competitiveness; and
- Spatial variations in the quantity and quality of employment⁸⁶, including the vulnerabilities of local areas to employment loss.

The spatial distribution of manufacturing in the UK

Historically, domestic industry was home-based and relatively widespread geographically, with many goods made in small workshops behind shops well into the 19th century. The industrial revolution, and particularly the development of factories, heralded a change in the geography of manufacturing. In the UK local specialisations became more apparent. At the outset these were closely tied to the availability of natural resources, such as water and coal, and other local assets⁸⁷.

These features help explain why the cotton industry became established in Lancashire and metal industries in the Black Country. In 1841, most districts had 20-30% of workers employed in manufacturing. But in some towns dominated by single manufacturing industries, well over half the workforce was engaged in manufacturing. For example, in Oldham and Blackburn where textiles were predominant, over 70% of the workforce was employed in manufacturing and in the 'Potteries' towns of the Stoke-on-Trent area, 62%⁸⁸. Prior to 1931, the manufacturing geography of employment in the UK was oriented towards the north and midlands, although London was also a major manufacturing centre. From 1931 onwards, the growth of industries producing consumer goods in southern England led to a shift further south, as exemplified by the growth of Slough, where 53% of workers were in manufacturing jobs in 1971, compared to 13% of workers in 1881.

In the 1970s the spatial distribution of manufacturing experienced a urban-rural shift⁸⁹. This has been explained by requirements for production and floorspace in the context of the rising capital intensity of manufacturing, and also by labour requirements, for example a preference for non-unionised labour⁹⁰. This led to a move away from manufacturing in urban centres. Regional policy also played a role here, as expansion in the growing regions of London became more difficult, and incentives for locating in other parts of the UK were provided. Since the 1970s, de-industrialisation (see following section), has led to the share of total employment declining dramatically with the occupational structure shifting away from production to professional, associate professional, and technical occupations (see Chapter 6).

Yet manufacturing employment continues to display an uneven distribution at the sub-national scale. As a share of total employment, manufacturing jobs are concentrated in the metropolitan West Midlands, West Yorkshire, South Yorkshire, parts of Lancashire, Derby and Leicester in the East Midlands, north-east Wales, and in and around Glasgow. Analysis at the regional scale in Great Britain indicates that in 2011, the East Midlands and West Midlands had the highest shares of manufacturing jobs relative to the average in Great Britain⁹¹. These jobs were

⁸⁶ At local level the geography of manufacturing tends to be measured in terms of spatial variations in employment in manufacturing. ⁸⁷ Allen, J.C. (1961) ⁸⁸ See the 'Britain Through Time' website which brings together information from historical Censuses of Population at: http://www.visionofbritain.org.uk/atlas/data_map_page.jsp?data_theme=T_IND&data_rate=R_IND_MAN&data_year=2001&date_type=1Y&u_type=MOD_DIST&u_label=District%2fUnitary+Authority ⁸⁹ Fothergill, S. and Gudgin, G. (1982) and Fothergill S., Kitson M. and Monk S. (1985). ⁹⁰ Massey, D. (1984) ⁹¹ Campos, C. and Prothero, R. (2012)

also highly represented in Wales and the northern regions of England, but virtually absent in London.

Disaggregation by manufacturing sub-sector reveals local areas with high shares of spatially concentrated employment⁹². Some subsectors display a spatial distribution of employment which contrasts with the general pattern. For example, jobs in the manufacture of computer, electronic and optical products are located predominantly in the south-east of England where shares of total employment in manufacturing tend to be relatively low.

These historical and contemporary trends in the spatial distribution of manufacturing are relevant to the future of the sector for a number of reasons:

- Implications for employment: some local areas have proved particularly vulnerable to decline in manufacturing employment⁹³ (discussed in Chapter 6);
- Local and regional industrial specialisation: which can have both positive and negative effects (discussed below); and
- Implications of evolutionary economic geography: including 'path dependency' and prospects for 'phoenix industries' (outlined below).

Local and regional industrial specialisation, and 'cluster policies'

Local and regional industrial specialisation can have both positive and negative effects⁹⁴. For example, positive effects may include potential productivity gains, depending on the sub-sector; while negative effects might be vulnerability to sudden decline. Policies to promote the development of clusters often attract the interest of regional and local policy makers who seek to encourage the development of specialisms to accrue benefits, and resilience to negative shocks.

The idea of local concentrations of specialised activities yielding benefits in terms of higher productivity is well established. The economist Alfred Marshall⁹⁵ noted that once established, specialised industrial activities can reinforce themselves by attracting complementary activities at various stages in the supply chain. They also create a pool of specialised labour which aids the spillover of knowledge between firms.

Similar ideas have been advanced on 'industrial districts', 'new industrial spaces', and 'regional industrial complexes', but the term 'cluster', coined by Michael Porter, is the most prominent in the academic and policy debate. Porter⁹⁶ attributed national success in competitive advantage in particular industries to the fact that successful groups of firms, together with associated businesses at various stages of the supply chain, form 'clusters'. In these conditions high productivity is the outcome of four factors⁹⁷: firm strategy, structure and rivalry; factor conditions (human resources, material resources, knowledge, infrastructure,); demand conditions; and the presence of related and supporting industries. Paradoxically, rivalry coupled with collaboration and networking between firms is seen as an important ingredient of success.

The geographical concentration of clusters affects competitiveness by:

- Increasing productivity: Firms can operate with lower levels of stock because of the local presence of specialised suppliers, and they have access to specialised skills, supported by specialised local training providers;
- Increasing the capacity for innovation by facilitating interaction and the dissemination of knowledge. Competition between firms raises the incentive to innovate, which increases the capacity to adapt to changes and external shocks; and
- Stimulating and enabling new business formation through spin off enterprises which face lower barriers to entry than in other local areas.

The idea of clusters has been influential at national and regional levels in the UK and many other countries⁹⁸. Programmes to support clusters and regional specialisation stem from one or more of regional policy, science and technology policy and industrial or enterprise policy, and favour co-operative and often place-based approaches⁹⁹. Their common aim is to improve competitiveness and innovation capacity.

In England, for example, four Regional Development Agencies in England invested in motorsport firms in 'motorsport valley', while in the north east region of England regional partners promoted a cluster on food and drink by developing and funding a

⁹² Campos, C. and Prothero, R. (2012) (the data source used in these analyses excludes Northern Ireland.) ⁹³ Evidence Paper 9: Fothergill, S. & Gore, T. (2013). ⁹⁴ Prothero, R. (2012) ⁹⁵ Marshall, A. (1890) ⁹⁶ Porter, M. E. (1990) ⁹⁷ These are known as the four elements of 'Porter's Diamond'. ⁹⁸ OECD (2007) ⁹⁹ See Section 4.3 for discussion of the importance of co-location and of the 'industrial commons'

food group for the region, building supply chain capacity, providing start-up grants for new firms in the sector, addressing shortages of premises, supporting export initiatives, and promoting access to training and development.

Implications of evolutionary economic geography perspectives

The notion that 'history matters' in understanding processes of economic growth and their geographical footprint has become increasingly prominent in recent years. There is a widespread consensus that pre-existing industrial structures, institutions, resources, skills and experiences of places serve to shape the environments within which new paths of growth are constrained or enabled. Exponents of evolutionary economic geography argue that regional and local economic trajectories are shaped by historical and current circumstances¹⁰⁰. The notion of 'path dependency' (i.e. that previous circumstances influence present options, even though those previous circumstances may no longer be relevant) is pertinent here. Differences in pathways for sectoral development, knowledge assets and local innovation systems will have an important influence on future economic trajectories¹⁰¹.

Thus in some circumstances, the local environment may constrain the development of new technologies and industries, as development paths become associated with the reinforcement of existing technologies and increasingly rigid ways of doing business. In other circumstances there may be a dynamic process of incremental, path-dependent renewal of technologies and local industries. It is this latter process that has enabled innovative, advanced manufacturing specialisms to have emerged 'phoenix-like' from the ashes of old mass manufacturing industries in some locations in the UK such as Sheffield¹⁰² (see Section 4.3.6) and in the US, encouraged in some instances by local sectoral policies.

These so-called 'phoenix industries' benefit from a series of place-based initial advantages and capabilities, for example socio-institutional networks, technical skills and R&D collaborations, which foster processes of diversification into new

technologies and markets¹⁰³; (see Section 4.3 for further discussion). Often phoenix industries are made up of SMEs rather than large companies. They typically develop technologies used across a range of sub-sectors rather than make end products for one sector alone. In the future there will be more opportunities for the legacies of know-how, skills and institutions, including specialised engineering departments and research programmes, to help old manufacturing regions develop phoenix industries. Place-specific economic and non-economic factors, including history and place-associated brands, can play an important role in the competitive advantage of these new developments.

The global geography of manufacturing and fragmentation of the value chain

The wider global manufacturing system¹⁰⁴ and its distribution is important, and is likely to become more so in the future as manufacturing shifts to to an even more complex system of value creation.

Globalisation has played a key role in the distribution of manufacturing, and has driven two transformations or 'unbundlings' of the manufacturing sector. The first occurred when steam technology significantly reduced shipping costs, and the second began in the mid-1980s when advances in ICT made it possible to co-ordinate activities across international borders. This enabled processes previously performed in close geographical proximity to become more spatially dispersed leading to 'offshoring'¹⁰⁵, with manufacturers arranging for mass production activities, in particular, to move to low cost countries¹⁰⁶.

Globalisation has therefore led to offshoring and the international fragmentation of manufacturing value chains, with the extent of fragmentation varying by subsector. Offshoring, which can also involve international intra-firm trade conducted primarily by multinational enterprises benefiting from the advantages of different locations, has been driven by diverse factors including:

¹⁰⁰ Boschma R.A. (2004) and Garretsen, H. and Martin, R. (2010). ¹⁰¹ Simmie, J., Carpenter, J., Chadwick, A. and Martin, R. (2008) ¹⁰² Christopherson, S. (2009) ¹⁰³ Christopherson, S. (n.d.) ¹⁰⁴ World Economic Forum (2012a) ¹⁰⁵ See Annex C for full definitions of 'outsourcing' and 'offshoring'. ¹⁰⁶ Baldwin, F. & Evenett, S.J. (2012b), Pg. 74

- Higher labour costs in developed economies have made it attractive for manufacturers in the UK to transfer production and assembly elements of the mass production of relatively low cost goods to countries with low labour costs.
- The ICT revolution has made it easier to coordinate the production process across international borders, meaning that manufacturers can locate higher value-added elements of the manufacturing value chain in one country, and the lower value-added elements in another.
- The lowering of transportation costs, especially air freight costs and improved containerisation methods, has made it cheaper and faster to move components from one location to another.
- Multilateral trade liberalisation has encouraged the fragmentation of trade across national borders; even a small tariff reduction can have a significant effect.
- Technological developments, especially those that enable better coordination through the Internet, have supported high-throughput and tightly coordinated manufacturing. Product-specific technology has also allowed different parts of production processes to be split across international borders¹⁰⁷. For example, the manufacture of vehicles and electronics has increasingly been separated into discrete production stages relating to components, assembly, testing and packaging, with different skill requirements, scales and inputs¹⁰⁸.
- Continuous improvement and integration of suppliers into product development processes has occurred through the diffusion of new ideas and business practices such as Just-in-Time^{109, 110}.
- Outsourcing has also been one implication of fragmentation, as firms have contracted work to a third party to focus on their 'core' activities such as production.

Fragmentation of the manufacturing value chain is a therefore a complex process which has been largely confined to mass production of relatively low cost goods. In the case of supply-chains for intermediate goods (i.e., importing and exporting of intermediate

and unfinished manufacturing goods) most nations are largely self-sufficient¹¹¹. For example, in 2009, a sample of 40 economies showed that local sourcing was above 50% and in many instances, above 70%. Trade in final goods currently far exceeds trade in intermediate goods. For example, in 2009, 44% of manufactured final goods were exported compared to only 27% of manufactured intermediate goods.

It appears likely, therefore, is that globalisation and the 'second unbundling' may still develop much further¹¹², with fragmentation of the value chain likely to continue in the future. This will offer potential for the spatial reconfiguration of design, production and assembly and a reassertion of the importance of place.

Focus on onshoring

In recent decades, the global geography of manufacturing has shifted away from many locations with high labour costs as companies focussed on cost control and searched for locations which provided them with location-specific advantages^{113, 114}. The rise of Asia Pacific as an important manufacturing location has been enabled by advantages in factor conditions. However, many of these advantages are now being challenged by wage inflation and the emergence of a large internal consumer market. Economic changes in countries in this region for example China, India, Bangladesh, and Vietnam coupled with volatility in energy prices have the potential to change the geography of global manufacturing in the decades ahead.

A relatively new trend that could gather pace is the 'onshoring' (or 'reshoring') of production activities back to developed market economies. It typically involves repatriation of production from low cost locations, investment in onshore production to enhance capability, and sourcing of components from onshore, rather than from overseas. Onshoring is likely to be driven in the future by a number of factors^{115, 116}, with the relative importance of each of these varying by activity and technology¹¹⁷ (see Table 4.12). These factors suggest that it is becoming possible for the UK to compete with lower cost

¹⁰⁷ Yamashita, N. (2010) p.8 ¹⁰⁸ In contrast, the continuous production process of some industries, for example the chemical industry creates technical difficulties in separating production into discrete steps. ¹⁰⁹ The quality of leadership and management practices are also important here (see Chapter 4). ¹¹⁰ Evidence Paper 21: McLaughlin, P. (2013) ¹¹¹ Baldwin, R. & Lopez-Gonzalez, J. (2013) ¹¹² Baldwin and Lopez-Gonzalez (2013, Table 2) show that manufactured exports in 2009 comprised \$3.4 trillion of final goods and \$4.8 trillion of intermediate goods (almost 60% of manufactured exports comprised intermediates rather than final goods). But since manufacturing is dominated by the production of intermediate goods, most intermediate production (\$17.9 trillion in 2009) stays within domestic borders, while approaching half of the \$7.8 trillion of manufactured final goods is exported, so there is scope for further unbundling of supply-chains leading to a higher level of exports for intermediates. ¹¹³ Vernon, R. (1966) ¹¹⁴ Dunning, J. (2001) ¹¹⁵ EEF/BDO (2009) ¹¹⁶ Mulhall, J. and Bryson, J.R. (2012) ¹¹⁷ Lane D. (2012)

locations on quality, delivery speed, customisation and sometimes price.

Detailed evidence on onshoring is scarce, and has led to claims that it may prove to be a relatively minor process, and more of 'a trickle than a flood'¹²⁰. However, there is recognition that onshoring is occurring in the majority of developed market economies in transportation goods, computers and electronics, fabricated metal products, machinery, plastics and rubber, appliances and electrical equipment, furniture, ceramics and textiles¹²¹. Low volume products, for example automotive

and aerospace parts, appliances and construction equipment in which labour accounts for a minor proportion of total costs, are considered the most suitable for onshoring.

A 2009 survey of 300 UK based manufacturing firms also revealed that 14% of firms had brought production back to the UK from other countries over the past two years¹²². In the US a small but growing number of firms are repatriating production, including General Electric, NCR and Caterpillar¹²³. Recent examples of UK onshoring are provided in Box 4.1.

Table 4.12: Key drivers relating to the onshoring of manufacturing activities

DRIVER	OF PARTICULAR RELEVANCE FOR	POTENTIAL SPATIAL IMPLICATIONS
Narrowing of differentials in labour costs ¹¹⁸	Production activities offshored to take advantage of lower labour costs	Onshoring of some production activity to the UK
Higher transport costs ¹¹⁹	Production activities offshored to take advantage of lower labour costs	Onshoring of some production activity to the UK
Need to be close to the market	Products customised to the market with short-term fashion cycles	Combination of manufacturing in high cost and low cost locations
Product quality concerns	All products, especially those where a premium is placed on quality	Onshoring of some activities
Theft of intellectual property	Product innovation, process innovation less easy to copy due to tacit knowledge	Onshoring of activities where intellectual property is important
Economic downturn and reductions in size of orders	Large scale components orders from low cost locations	Opportunities for local suppliers willing to supply small batch orders
Advantages of co-location of design, R&D and production	Spatially separated activities	Greater co-location of activity in the UK and/ or outside the UK
Changing energy costs	Energy-intensive activities	Relocation to areas with low costs

¹¹⁸ Boston Consulting Group, reported in Evidence paper 19: Livesey (2013). ¹¹⁹ Boston Consulting Group, reported in Evidence paper 19: Livesey, F. (2013). ¹²⁰ USA Today (2010) ¹²¹ BCG, (2011) ¹²² EEF/BDO (2009) ¹²³ Lipscomb, T. (2011)

BOX 4.1: UK SPECIFIC EXAMPLES OF ONSHORING

John Lewis plc: During July 2013¹²⁴, the retailer emphasised its commitment to increasing sales of products manufactured in the UK by announcing a two-year 15 per cent growth target for all sales of goods in its shops that are made in the UK. In addition, it has increased its number of UK suppliers from 132 in 2012 to 207 in 2013.

Hornby plc: In November 2012 the UK model maker decided to return the production of 60% of its model paint brand, Humbrol, from China to the UK. This decision was taken to improve supply, and ensure high quality standards continue to be met, but from an easier location nearer to the Margate Head Office¹²⁵.

Laxtons Ltd: This spinning company, established in 1907, is now a design-driven yarn manufacturer. Like nearly all British textile companies production was offshored, but it has now returned to Yorkshire, reducing the firm's carbon footprint and lead times and increasing its control over quality and raw materials¹²⁶.

Bathrooms.com: During July 2013¹²⁷ the online bathroom specialist confirmed that it was handing 50% of the contracts currently held by Chinese manufacturers to UK businesses in the Midlands, to decrease the time taken from design through to production from four to six months to six weeks.

Marks & Spencer plc: During October 2013¹²⁸, the retailer launched its Best of British collection selling womenswear and menswear collections which emphasise British craftsmanship and quality, which feature a combination of British heritage, sourcing and production, as part of a three-year deal with the British Fashion Council to support domestic talent and increase its sourcing from the UK.

The future geography of manufacturing

Looking out to 2050, the geography of manufacturing will be influenced by a range of drivers¹²⁹ with the importance of each varying between industries. They include changes in the importance of different factors of production including capital and labour; labour costs; transport costs; energy costs; changes in the relative (dis) advantages of co-location of manufacturing tasks and activities; skills availability; changing technologies, and changes in consumer preferences and demands.

Additive manufacturing (see Chapter 3) is likely to play an increasingly important role by allowing customised parts to be produced close to the point of consumption, making manufacturing more distributed as an activity. Movement towards the point of consumption suggests a revival of more local 'distributed' manufacturing, and of urban manufacturing. Environmental developments will mean that manufacturing will be more of a 'good', as opposed to a 'bad' neighbour. The spatial distribution of manufacturing may become more even as a result of these trends. Chapter 3 provides a fuller discussion on the factories of the future, and concludes that they are likely to become more diverse, more distributed, more mobile, more urban and more home-based. The spatial distribution of manufacturing in the UK will clearly be influenced by these developments.

4.2.3 DE-INDUSTRIALISATION

'De-industrialisation' refers to declining shares of manufacturing in employment and/or GDP. These trends are apparent in many developed economies, including the countries shown in Table 4.13, over the past 40 years, with pronounced declines seen in the UK.

Table 4.13: Shares of manufacturing in employment and GDP (%)

	1973 SHARE IN EMPLOYMENT	1973 SHARE IN GDP	2007 SHARE IN EMPLOYMENT	2007 SHARE IN GDP
France	24.1	22.4	12.7	12.3
Germany	32.8	31.6	18.5	23.1
UK	27.4	29.1	11.0	10.8
US	20.5	23.4	9.7	13.3

Source: EUKLEMS except UK 2007 employment share from ONS. Note: GDP share measured at current prices; USA data for 1977 not 1973.

The decline in the share of GDP has resulted from slower growth in the volume of output in the manufacturing sector compared with the whole economy, and from price falls relative to services where productivity growth has been faster. The share of employment in manufacturing in the UK stabilised at around 10% in 2010¹³⁰, with the decline caused by sources including:

- The relatively strong growth in domestic demand for services as incomes increase;
- The relatively faster growth in domestic labour productivity in services; and
- The greater labour intensity of imports compared with exports meaning that an expansion of trade also reduces manufacturing employment in developed economies.

Analysis of the decrease in employment in manufacturing within developed economies (see Table 4.14)¹³¹ shows that internal factors related to the process of economic growth have a larger impact than the trade effects, though trade growth has clearly been de-industrialising. However, the large residual for the UK indicates that not all of its deindustrialisation can be fully explained although trade effects may have been underestimated¹³².

Table 4.14: Percentage change in share of manufacturing employment 1962-2008

	EU-3	JAPAN	UK	US
Change due to:				
Normal growth	-5.6	-6.0	-6.9	-8.6
Investment	-0.9	-2.5	-0.7	-0.3
German restructuring	0.6	0.0	0.0	0.0
Total internal	-5.9	-8.5	-7.6	-9.0
North-South trade	-2.6	-2.7	-3.4	-4.3
Other trade	0.5	0.4	-0.9	-0.2
Total external	-2.1	-2.3	-4.3	-4.5
Unexplained residual	-3.9	1.6	-6.6	1.3
Total change	-11.9	-9.2	-18.6	-12.2

Source: Rowthorn and Coutts (2013). Note: EU-3 is France, Germany and Italy.

Against this general trend of deindustrialisation, the UK has had some success in its developing high tech sector (see Table 4.15)¹³². The share of high-tech sectors in gross output has increased and has more or less matched the decline in the low-tech sectors' share. However, faster productivity growth in high-tech sectors means that employment shares in these sectors in 2009 were not very different from 1973.

¹³⁰ Evidence Paper 36: Hogarth, T. & Wilson, R. (2013) ¹³¹ Evidence Paper 31: Rowthorn, R. & Coutts, K. (2013) ¹³² Rowthorn and Coutts (2013) suggest that the trade effect is probably greater than the estimated equation, which implies and that at least two points of the residual is attributable to this. In a subsequent analysis, they conclude that it is especially the deterioration in manufacturing trade balance from +4.8% of GDP in 1970 to -4.4% of GDP in 2010 which accounts for the greater extent of deindustrialisation in the UK compared with other European countries. Two possibly related factors that have affected the manufacturing trade balance are the strength of the UK's position in international trade in services and trends in relative unit labour costs in manufacturing reflecting the exchange rate for the pound which was notably strong from 1996 to 2007.

Table 4.15: Shares of different types of manufacturing in total UK output and employment (%)

	1973 SHARE IN EMPLOYMENT	1973 SHARE IN GROSS OUTPUT	2009 SHARE IN EMPLOYMENT	2009 SHARE IN GROSS OUTPUT
High-Tech	11.1	8.4	13.5	17.5
Medium-Tech	52.8	50.1	48.3	50.7
Low-Tech	36.1	41.5	38.2	31.8

Source: Moffat (2013)

4.2.4 RE-INDUSTRIALISATION IN THE MEDIUM TERM?

Is it possible to envisage a scenario in which the recent declines in the share of manufacturing in GDP and employment are reversed? The answer to this is probably no but there is perhaps some chance that the future rate of decline could be at a slower pace. Three different scenarios looking forward 25 years from 2010 explore this question (see Table 4.16, and Figure 4.27)¹³³. It is important to emphasise that these scenarios focus on the performance of manufacturing as it is measured (output from production), as opposed to any wider value chain activity.

Under 'business-as-usual' it is assumed that the manufacturing trade balance remains in deficit to the same extent as in 2010 and that the internal growth contribution to deindustrialisation follows the trend of the last 40 years driven by increasing incomes and changes in relative prices. Under this scenario, manufacturing continues to decline and its

share of GDP in 2035 has fallen to 7.3 per cent¹³⁴. If this scenario is modified by assuming that an 'improved manufacturing trade balance' with the manufacturing trade deficit eliminated by 2035, then deindustrialisation would continue but at a much slower pace such that manufacturing's share of GDP would be 9.7 per cent in 2035.

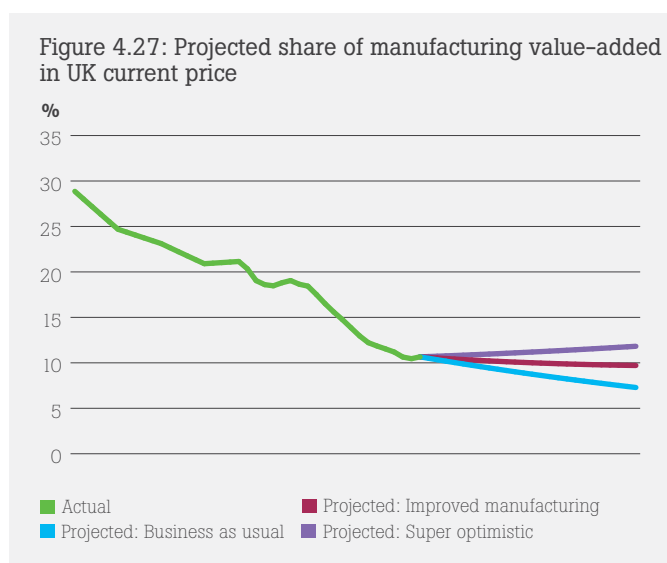
In the 'super optimistic' scenario, manufacturing trade is in surplus in 2035. The assumption of a surplus equal to 2% of GDP is probably at the upper end of what is feasible given the UK's strength in services trade. Here, a better trade performance can be thought of as necessary but not sufficient to reverse deindustrialisation and the internal growth contribution to deindustrialisation has to be diluted, for example by assuming that relative manufacturing prices fall less rapidly in future. The combination of assumptions required to deliver even this modest increase over 2010 in manufacturing's share, to 11.8 per cent in 2035, is improbable¹³⁵.

¹³³ Evidence Paper 23: Moffat, J. (2013) ¹³⁴ Assuming that employment and GDP shares decline at the same rate. ¹³⁵ The Coutts and Rowthorn projections embody rather different assumptions about future labour productivity growth in manufacturing but, even so, the various authors are agreed that, under almost any scenario, there is unlikely to be a significant increase in the employment share of manufacturing.

Table 4.16: Future scenarios for the manufacturing share of GDP in 2035

	BUSINESS-AS-USUAL	IMPROVED MANUFACTURING TRADE BALANCE	SUPER OPTIMISTIC
Manufacturing share (%GDP)			
2010	10.7	10.7	10.7
2035	7.3	9.7	11.8
Contributions to change in share			
Internal growth	-3.3	-3.3	-2.3
Trade balance	0.0	2.4	3.5
Memorandum Item			
Manufacturing trade balance/GDP (%)	-4.4	0.0	2.0

Source: Rowthorn and Coutts (2013)



4.3. IMPLICATIONS FOR GOVERNMENT

KEY MESSAGES

Several factors will play an important role in the long-run global competitiveness of the UK manufacturing sector, particularly as manufacturing continues to evolve, as outlined in Chapter 2. There are seven factors which will be particularly critical to competitiveness in future manufacturing:

- The control of manufacturing value chains, linked to new business models;
- The importance of co-location and maintaining an 'industrial commons';
- The emergence of manufacturing services;
- Access to future markets for goods and services, and maximising the benefits of inward investment;
- Support for 'phoenix' industries building on older capabilities;
- The role of 'infrastructure' (including the physical landscape & long-term financing);

- Facilitation of the future commercialisation of technology and support for innovation;
- The importance of highly skilled 'hybrid' workers (see Chapter 6); and
- The importance of energy needs for manufacturing (see Chapter 5).

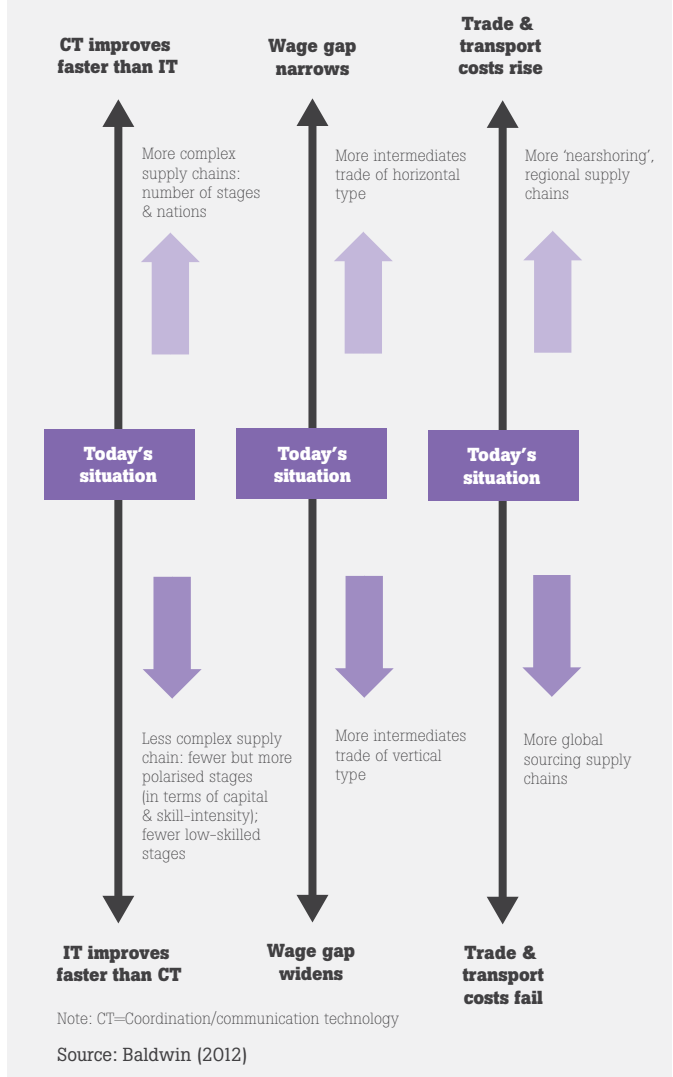
4.3.1 INTRODUCTION

Diverse, economic, technological, environmental, and sociological changes will determine the long-run competitiveness of the UK manufacturing sector, and therefore the long-run growth of the UK economy. This section discusses the role of seven particularly important factors listed above¹³⁶, and their implications for policy, with several concerning the globalisation of value creation involving trade¹³⁷.

4.3.2 THE CONTROL OF MANUFACTURING VALUE CHAINS¹³⁸

As outlined earlier, it is likely that globalisation and the 'second unbundling' may still develop much further, with fragmentation of the value chain likely to continue in the future. The interplay between future developments in information and coordination technologies, changes in transportation costs, and differences in labour costs between nations will all influence the future structure of international value and supply chains (see Figure 4.28)¹³⁹.

Figure 4.28: Factors affecting the future development of international supply chains



Rapid improvements in coordination and communication technology, for example advances in telepresence technology and workflow organisation, will allow further fragmentation of supply chains, both functionally and geographically, and create more complexity. The major influences which may drive a trend to less global and more regional supply chains include:

- The impact of increases in oil prices on transportation costs;
- The emergence of additive manufacturing technology, which is likely to reduce the importance of economies of scale as a factor in the location of some types of manufacturing¹⁴⁰ and allow for production to be located in a greater diversity of locations, from small

¹³⁶ The last two are considered separately in Chapters 5 and 6. ¹³⁷ Baldwin, R. & Evenett, S.J. (2012a) ¹³⁸ Discussion in this Section focuses on manufacturing value chains (see Chapter 2) including supporting supply chains and distribution networks. ¹³⁹ Baldwin, R. (2012b) ¹⁴⁰ Evidence Paper 17: Kneller, R. (2013)

reconfigurable local units to capital intensive super factories (see Chapter 3). This shift would produce a different geography of production¹⁴¹.

- The potential role of onshoring, as discussed earlier in this chapter¹⁴², which may result in stronger regional value chains within Europe. However, ¹⁴³ suggests that so-called globalised trade is already heavily segmented into three regional blocks, Europe with Germany at its hub, North East Asia dominated by Japan, and the third in North America with the US as the 'headquarter' nation.

These possible developments do not reduce the significance of fragmentation, but highlight the potential for the UK to (re)locate production and assembly closer to other activities. The weight of the evidence and analysis suggests a continued, likely and significant growth in the internationalisation of supply-chains. This conclusion agrees with expert views¹⁴⁴ that a critical element of future competitiveness will be an ability to create and then operate international manufacturing value chains:

'It is seen as very important that businesses have the skills and capabilities to create the value chain as an integrated system – the key step – and to operate it. Operation of the value chain, essentially the co-ordination of supply chain members to operate a cross-organisational business process, is seen as complex but less challenging than creating it. Lean supply chains balancing global and local are a given but lean must be exquisitely balanced with resilience. Materials management and resource conservation is also critical' Ridgeway, K. et al. (2013)¹⁴⁵.

This emphasis on value chain creation and operation is linked with the development of new business models (see Chapter 2). These models recognise that goods and services have become more complex because of technological and other developments. They in turn will increasingly exploit technological developments to capture new sources of value. For example, manufacturers will be able to identify and characterise people, places, and organisations in more detail, resulting in new information, new relationships and hence new ways of creating value such as making products more personalised¹⁴⁶ (see Chapter 3). Products are also likely to generate data relating to usage, and allow firms to exploit this new information.

ADVICE FOR POLICY-MAKERS:

Government needs to be at the forefront of understanding the evolution of manufacturing business models, and how manufacturers can be supported to take advantage of expanding international manufacturing value-chains. Government has a role to play as a:

- Champion of best-practice, working to disseminate and coordinate through industrial partner organisations.
- Facilitator, helping manufacturers to adapt through integrated and adequately resourced policies across different domains including regulatory, skills and education, technology, international trade, and industrial policies.

Businesses will need to have strong managerial capabilities and leadership to provide the knowledge and skills to create value chains as an integrated system.

4.3.3 THE IMPORTANCE CO-LOCATION AND 'INDUSTRIAL COMMONS'

As discussed in Chapter 2, manufacturing was previously understood to be the production process, which could be divided from the other parts of the value-chain, and located in the lowest cost location. It is now increasingly recognised that manufacturing encompasses the whole of the value-chain including production, research, design, and elements of service provision, in which the role of knowledge is likely to become even more significant. This broader approach in turn raises issues of co-location of activities, and how and when they affect value creation.

The concept of the 'industrial commons' defined below, points to the interrelatedness of activities in the manufacturing value chain, and argues that their co-location is important for growth and innovation.

The 'industrial commons': '... the R&D and manufacturing infrastructure, know-how, process-development skills, and engineering capabilities residing in firms, universities, and other organisations that provide the foundation for growth and innovation in a wide range of industries'¹⁴⁷.

The notion of benefits and spillovers from co-location have been debated for many years¹⁴⁸. The discussion here concerns the process of innovation and how it works. The emphasis is on the spatial link between R&D, more generally, and manufacturing.

Innovation concerns the movement of ideas from the conceptual stage into the customer's hands. For some highly complex products, for example flat panel displays, photovoltaic cells, and biotechnology drugs, the transfer from R&D into production is a messy and non-linear affair, requiring tight coordination and a transfer of learning between designers and 'producers'. If R&D operations have a poor understanding of the production environment, then design of the product may well be more difficult¹⁴⁹.

Hence, companies that spatially separate the location of different parts of the value chain (for example, Apple products are typically 'designed in California' and 'assembled in China') risk loosening the transfer of tacit knowledge between different parts of the business. Competitive advantages may be lost unless the research, design and development of the product is also offshored closer to the production hub, or production is onshored. It is not only the company itself that might suffer: there are wider implications for specialist suppliers located in the original 'industrial commons'. As Pisano and Shih observe:

"As capabilities erode, it is harder for companies that require access [to the 'industrial commons'] to stay in business. They are forced to move their operations or their supplier base to the new commons. As they move, it is harder for existing suppliers to sustain themselves. Ultimately, they must either close shop or move their operations"¹⁵⁰.

The unravelling of the commons is therefore potentially a vicious circle, as it becomes increasingly difficult for suppliers to justify investing in new technologies or training workers. This lack of investment leads to further erosion in competitive performance, which makes it more attractive for other companies to move supply bases overseas¹⁵¹.

The need for co-location of research, development, design and depends on the degree of modularity (the extent to which a system's components can be separated) and the maturity of the manufacturing process technology¹⁵². As shown in Figure 4.29, only when both modularity and process maturity are high (the top right-hand quadrant) does separation not lead to any loss of competitiveness. The design and production of Apples' iPad is illustrative. Pisano and Shih again:

"... It falls into the pure-product-innovation quadrant, which explains why the product could be designed in California while many of its components are designed and produced in Asia, where final assembly occurs. A number of components (e.g., lithium ion batteries and the touchscreen) fall into different quadrants, where it's important for R&D and manufacturing to be located near each other. The location of those R&D and manufacturing capabilities in other countries means that for the future products that need those capabilities will come from those countries, too"¹⁵³.

Research on UK manufacturing has identified the importance of the co-location of design, research and development services within manufacturing. Over half of UK firms surveyed in 2007 considered it very important to co-locate production together with design and development¹⁵⁴. In the US, the geography of industrial design tends to mirror that of production. For example, over 60% of the design consultancies in the Los Angeles area are focused on electronics or aerospace markets, 76% of Detroit's design companies serve the automotive or machinery sectors, and half of San Francisco's design companies cater to clients in the aerospace industries¹⁵⁵.

¹⁴⁷ Pisano, G. & Shih, W. (2012). ¹⁴⁸ This importance of 'place' has gained renewed impact since the development of the 'New Economic Geography' (see, for example, the discussion in Harris, R. (2011) 'Models of Regional Growth: Past, Present and Future' [Academic paper] *Journal of Economic Surveys*, vol. 25(5), pp. 913-951) ¹⁴⁹ Pisano, G. & Shih, W. (2012), p.15 ¹⁵⁰ Pisano, G. & Shih, W. (2012), p.16 ¹⁵¹ Pisano, G. & Shih, W. (2012), p.17 ¹⁵² Pisano, G. & Shih, W. (2012) ¹⁵³ Pisano, G. & Shih, W. (2012) p. 70 ¹⁵⁴ Evidence Paper 3: Bryson, J. et al. (2013) ¹⁵⁵ MacPherson, A & Vanchan, V. (2010)

Figure 4.29: The modularity-maturity matrix



Source: Pisano & Shih (2012)

Co-location and the concept of the industrial commons clearly have substantial policy implications for the future of manufacturing in the UK. There is a critical strategic role for government in helping to develop and maintain existing design and R&D clusters, stimulate the creation of new clusters, and encourage the co-location of manufacturing activities. This is important given the role of collaboration between firms in future business models (see Chapter 2). There is also a role for 'collaborative communities' of individuals, firms, and governments who have capabilities and infrastructure which facilitate collaboration, and shared access to the industrial commons¹⁵⁶.

ADVICE FOR POLICY-MAKERS:

The 'industrial commons', i.e. the interrelatedness of the various parts of the manufacturing value chain from R&D through production to disposal and recycling, is clearly important to the UK's international manufacturing competitiveness, and critical in keeping specific manufacturing activities located in the UK. There is a need to ensure that industrial strategy across and between all relevant stages of the manufacturing value chain works to strengthen appropriate clustering and co-location, taking into account the specific context of the UK.

4.3.4 THE EMERGENCE OF MANUFACTURING SERVICES

The emergence of manufacturing services, which act to complement and enhance products and create additional or new revenue for manufacturers, is likely to be one stage in a much more complex process which involves the hybridisation of manufacturing and services to produce hybrid products¹⁵⁷. These products involve adding post-production services to the product, and provide their producers with the opportunity to obtain profit from developing and exploiting assets. This 'capture' of profit is based on the opportunity to sell additional service contracts, to persuade existing customers to upgrade, to co-innovate with strategic customers, to sell existing or new services and also to provide spare parts¹⁵⁸.

The incorporation of services into manufacturing and the move towards hybrid products requires firms to have the necessary (intangible) assets, capabilities, and business models. The risk of investing in specific assets and capabilities inevitably involves some degree of technological lock-in. However, that risk is unavoidable if firms are to be able to exploit potential opportunities in providing services.

ADVICE FOR POLICY MAKERS:

There is an opportunity for government to help manufacturing firms to increase their ability to create new and additional revenue streams through manufacturing services by identifying and sharing examples of UK and international 'best practice', and by strengthening UK manufacturing leadership and management capacity to help manufacturers adapt.

4.3.5 ACCESS TO FUTURE MARKETS FOR GOODS AND SERVICES

The UK is the 10th largest exporter of goods globally,¹⁵⁹ however its global market share in terms of the export of manufactured goods declined from 7.2% in 1980 to 2.9% in 2012¹⁶⁰. Part of this decline can be explained by the rapid opening-up of countries such as China and other emerging economies to international trade, and the subsequent catch-up of these economies. Falling export shares also occurred in France and Japan, although they were constant or rising in Germany and the U.S.

Falling export shares are almost inevitable, given developments in emerging economies, but this does not necessarily imply falling export values. Rapid growth in world trade in recent decades and associated growth in supply chains provided an opportunity for increases in the overall value of UK exports. But while there has been an increase, this has not been strong relative to the UK's major competitors, including France and Germany¹⁶¹. So there are other reasons why the UK has been losing its export market share over and above the strong performance of countries like China, India and Brazil.

The explanation behind the UK's underperformance relative to two of its competitors, France and Germany, is to be found in the relatively smaller size of the manufacturing sector in the UK and the relative underperformance of large UK exporters compared to other countries, especially Germany. In terms of the size of the sector, the overall percentage of manufacturing firms engaged in exporting (the extensive margin) and the percentage of total output that is exported (the intensive margin) are similar across these three countries. But France and Germany have more manufacturing firms than the UK. So while the propensity to export does not differ significantly, the UK has fewer firms available for exporting.

When the data on exporting are considered by firm-size, another more important difference emerges. Fewer UK large firms (i.e. with more than 250 employees) export, and those that do export a smaller proportion of output relative to large German firms¹⁶². Around 81% of UK firms with more than 249 employees export, whereas the figure is 88% in France and 84% in Germany. (see Chapter 4 for further discussion).

The UK export market is over-represented by small firms both in terms of the number of exporters, and the proportion of output they export, while large firms are under-represented. Given that smaller firms produce lower quantities than larger firms, the value of exports created by the additional smaller firms is not sufficient to compensate for the value of exports foregone by larger firms who do not. A more detailed analysis of the relative difference in exporting performance of the largest firms shows that the UK and France are fairly similar with both having a much smaller proportion of large 'exporting superstars' compared to Germany (see Box 4.2).

BOX 4.2: EXPORTING BY FIRM SIZE IN THE UK, FRANCE AND GERMANY¹⁶³

In all countries, the majority of firms export a small number of products to a small number of markets. In 2010, 14% of all UK exporters exported 10 or more products to 10 or more markets, but they accounted for 89% of the total value of UK goods exports. These are the 'exporting superstars'. In fact in 2010 just 1% of UK firms accounted for 70% of total export value with the top 5% accounting for 90%. For France, firms who export more than 10 products and to more than 10 destinations again represent only 11% of all exporters, but they account for 76% of the value of exports. But in Germany 39% of exporting firms sell 10+ products to 10+ destinations, accounting for 91% of the total value of exports. It seems reasonable to conclude from this evidence that this difference explains the export gap between Germany with France and the UK.

These exporting superstars are very likely to be multinational corporations (see Chapter 4) that rely heavily on FDI and/or international outsourcing. The former involves operating affiliates overseas while the latter does not necessarily involve owning firms in the supply chain. The evidence for this characterisation is that 38% of German firms with 250+ employees are involved in FDI or international outsourcing compared to 23% for the UK¹⁶⁴.

The conclusion is therefore that once the smaller size of the UK manufacturing sector is taken into account, on most measures it performs similarly to France. The exceptional performer is Germany, where this difference is explained by the performance of its large firms and greater number of export superstars¹⁶⁵. Box 4.3 summarises some of the key features of German manufacturing, which help to explain its strong performance.

BOX 4.3: KEY FEATURES OF GERMAN MANUFACTURING¹⁶⁶

Finance: A key point of contrast with the UK in the German 'stakeholder' system of industrial finance for larger firms is the role of the *hausbank*, the primary long-term relationship banker to a business, with equity finance playing a more limited role than in the UK. It is not the prominence of bank finance alone that provides a contrast, but also the character of the relationship. German manufacturers have access to bank finance not typically provided on the basis of publicly available data or current returns. The relationship hinges on a two-way exchange of information between banks and firms and the *hausbank* may simultaneously lend money to a firm, own shares, have seats on its board and vote at shareholders' meetings. Small and medium sized firms, the so-called *Mittelstand*, have access to finance through a system based on local savings banks (*Sparkassen*) which provide about two-thirds of all lending to *Mittelstand* companies along with co-operative banks.

Firm coordination and innovation strategies: German manufacturers excel in the production of sophisticated engineering products requiring deployment of long-term, patient capital and a highly skilled labour force. Firms tend to specialise in established but complex production processes relating to machine tools, engines, consumer 'white goods', cars and materials processing, complemented with after-sales service and long-term customer relationships. Incremental innovation is defined as 'competence-preserving', with the product line improved rather than rendered obsolete as new market opportunities are explored. It is important for maintaining competitiveness in the production of capital goods where the challenge is to maintain a high quality established product line while devising improvements to maintain quality and hold down costs. Incremental innovation is often contrasted with 'radical' innovation pursued by many British firms, particularly in hi-technology sectors. Radical innovation is 'competence-destroying', in that firms may innovate themselves out of previous tasks to seek out new product niches. But Germany outperforms the UK in both novel or radical innovation as well as incremental innovation with the latter is often central to full exploitation of the former¹⁶⁷.

Institutional complementarity: Germany's manufacturing institutional make-up, based on sophisticated skills, patient capital, dense inter-firm networks, leading to the production of complex medium technology capital and consumer goods, could be construed as a 'comparative institutional advantage'. Its success is the result of these interactions between different sub-systems, all guided by the same institutional principles, which allow them to move in tandem.

One area where the UK may be able to develop a comparative advantage in the future is in the exporting of services, which increased as a percentage of UK total final demand from 6.3% in 1997 to nearly 9.4% by 2010¹⁶⁸. Currently, this advantage does not extend to services linked to UK manufacturing exports¹⁶⁹. Given earlier arguments above about the importance of servitisation in manufacturing, this is likely to be a factor that can drive competitiveness and manufacturing export performance in the future.

There has been significant growth in world trade in recent decades (see Chapter 4). However, UK exports to economies predicted to be in the top 30 by 2050 including the BRIC countries and some

of the 'Next 11'¹⁷⁰ are a very small share of the total value of UK exports (2.6% in 2010¹⁷¹). Even rapid growth in demand for UK exports from these countries in the future is only likely to have a modest effect on the total value of UK exports¹⁷².

Relative export performance is determined by the competitiveness of UK products, which in turn is dependent on productivity and innovation (linked with quality), value for money, and delivery to specification. These emerged as key criteria in a survey of customers in China, India, and the US¹⁷³. Products from the U.S. were perceived as strong in innovation, and those from Germany and Japan as competitive in value for money, quality, and delivery. Exports from the UK are typically viewed as

¹⁶⁶ Evidence Paper 13: Hancké, B. & Coulter, S. (2013) ¹⁶⁷ Evidence paper 16: Hughes, A. (2013) ¹⁶⁸ Office for National Statistics. 'Supply and Use Tables' [Online] Available from: <http://www.statistics.gov.uk/hub/economy/national-accounts/supply-and-use-tables> ¹⁶⁹ UK manufacturing exports of services were 2.7% of total manufacturing exports in 1997 and 2010. ¹⁷⁰ 'Next Eleven' economies likely to undergo significant growth: Bangladesh, Egypt, Indonesia, Iran, Korea, Mexico, Nigeria, Pakistan, Philippines, Turkey, and Vietnam. ¹⁷¹ Department for Business, Innovation and Skills (2012b) ¹⁷² Evidence Paper 17: Kneller, R. (2013) ¹⁷³ Evidence Paper 17: Kneller, R. (2013)

weaker in terms of these criteria, with exports from France viewed as weaker still. Overall, US customers have the most positive perceptions of UK exports, with Chinese customers the least positive and Indian customers slightly more positive than Chinese customers.

ADVICE FOR POLICY-MAKERS:

There is a need to understand what prevents the UK from having more exporting 'superstars'.

Exporting, generally, is undertaken by firms with relatively higher levels of productivity (i.e., those that focus on value, rarity, and hard to imitate resources and capabilities¹⁷⁴). Therefore policies that impact on productivity levels, for example by raising the quality of leadership and management, will be key. This is in addition to the traditional role of UK Trade & Investment that facilitates exporting through providing advice and market-based intelligence to companies looking to export (more), and support to businesses once they are operating in a market, for example in the areas of language and culture.

There are also more fundamental questions relating to how firms obtain finance (for investment in R&D, exporting and growth activities more generally), the role of 'patient capital', and institutional complementarity (see Section 4.3.7).

4.3.6 SUPPORT FOR 'PHOENIX' INDUSTRIES BUILDING ON OLDER CAPABILITIES

A recent analysis of US manufacturing argues that in order to understand where the potential for expansion of US manufacturing is greatest, there is a need to examine original 'manufacturing strongholds' to focus on rebuilding regional strengths¹⁷⁵. These strongholds include remnants of supply chains, and specialised knowledge in regional labour markets.

This has given rise to the idea of 'phoenix industries'. These are firms that benefit from pre-existing personal networks, technical skills, and market knowledge which have developed over a long period¹⁷⁶. This argument is based around the strategic assets that old industrial regions still possess including specialised engineering departments and research programmes. There are strong parallels with the idea of there being 'regional innovation systems'¹⁷⁷.

Phoenix industries, particularly as they exist in the U.S., are considered to be very different to old manufacturing industries. They consist of many small and medium-sized firms and rarely make complete products, but specialise in the production of high-value sophisticated components which are sold to equipment manufacturers¹⁷⁸. As a consequence, regions with strong research universities but without dynamic small firm networks frequently find those innovations commercialised elsewhere. Essentially the regional economy lacks the ability to absorb product and process innovations. For newer regional economies without established manufacturing capacity, investment in university-based high-tech research may have little impact on localised manufacturing¹⁷⁹.

This issue is important for the UK where historically, R&D has been concentrated within a few universities and there have not been strong links between them and industry. There is some evidence of infrastructure for phoenix industries developing in the UK with the recent introduction of specialised training and research programmes by Sheffield University. As the Sheffield Initiative demonstrates, a university programme can act as an intermediary between industries developing from small-medium enterprises by advising policy-makers and the public of the advantages of advanced manufacturing, providing technical assistance and access to new technology, and fostering internships between graduates and local companies¹⁸⁰.

ADVICE FOR POLICY-MAKERS:

Industrial policies focussed on strengthening the manufacturing sector need to recognise the importance of place, with resources and assets of local areas utilised.

Indeed, industrial strategy tends to work most effectively when based on a 'bottom-up' approach that takes account of local partnerships, rather than on exclusively a 'top-down' approach. There is potential for making better use of strong local intelligence, for example through Local Enterprise Partnerships, in identifying where policy intervention is most needed in the manufacturing sector.

4.3.7 THE ROLE OF 'INFRASTRUCTURE'

Three attributes that make the UK attractive to overseas investors are: quality of life, culture and language; the stable political environment, and technology and infrastructure¹⁸¹. This section looks at two areas which affect current and future competitiveness:

- The importance of 'physical' infrastructure for manufacturing¹⁸², defined here as long-lived and costly capital assets often with complex design architectures required for economic growth and development in the public and private sectors¹⁸³.
- The importance of the UK's institutional infrastructure, including the legal framework governing the operation of firms, how funds are raised, and employment protection.

Physical infrastructure

It is generally recognised that interactions between manufacturing and physical infrastructure are very poorly understood. However recent survey evidence has highlighted that¹⁸⁴:

- The quality and reliability of transport and digital infrastructure is a significant factor in investment decisions (more than 80% of manufacturing sector respondents agreed).
- Digital networks are of growing importance and a major factor for the smallest firms.
- Energy infrastructure costs are important to investment (90% of manufacturing sector respondents agreed), with energy infrastructure cost is a greater concern than its quality.

E-infrastructure: The US, China and Japan are investing heavily in e-infrastructure to support future growth in industrial and commercial sectors, and to enable the development of e-science in healthcare, transportation, renewable and clean energy, and climate modelling. The UK government¹⁸⁵ was presented with a potential 10-year strategy in 2011 for bringing scientific, industrial and public sector users, hardware and software developers, and vendors closer together. This area merits further investigation to ensure UK businesses are not left behind those of competitor nations.

Transport infrastructure: There are two ways in which investment in public capital including in transport infrastructure can be thought to raise output, either directly by facilitating production or indirectly as an influence on total factor productivity (TFP). This second effect will come through a favourable impact on costs of production in businesses which benefit from investment in infrastructure. However, transport infrastructure also has potential impacts on productivity which are not characteristic of rebuilding regional strengths¹⁸⁶. Most obviously, transport improvements have benefits in the form of time savings. There are also distinctive wider economic benefits of cheaper transport. These include better access to markets, and potential growth in the size of agglomerations with attendant productivity gains.

It is not surprising that the majority of UK manufacturers regard transport networks, especially roads, as important or critical to their business. In a recent survey, around 70% of participants viewed investment in roads as the highest priority for investment while half considered that the state of UK roads significantly increases operating costs¹⁸⁷. As road traffic has grown much faster than road capacity, government has been criticised for predicting but not providing¹⁸⁸. Average kilometres per vehicle doubled between 1979 and 2007, while the total length of the road network increased by 17%.

Transport infrastructure, particularly roads, is a critical aspect of public capital where there is a strong case for more investment. Estimates suggest, in the absence of road pricing, a case for investment of £30 billion on strategic roads between 2015-2025 to deliver annual welfare benefits of £3.4 billion per year; and a GDP impact of £2.3 billion

per year in 2025^{189, 190}. Most of this investment has not been made. Reviews of unfunded transport schemes regularly show a large number of schemes with high benefit-cost ratios^{191, 192, 193}. From a growth perspective, the UK has been investing too little in infrastructure. The UK net stock of public capital relative to GDP fell between 1980-2000 from around 64.% to 40.%, with the UK net stock of public capital relative to the stock of private capital falling from around 61.% to 37%. Recent levels of public investment imply these ratios will continue to fall. To maintain the level of public capital to GDP at a growth-maximising level, investment of about 2.7 per cent of GDP per year would be needed¹⁹⁴ but over 1997-2008 the UK invested only 1.5% of GDP. Over the period 2012/13 to 2017/18 this will fall to an average of about 1%¹⁹⁵.

The LSE Growth Commission¹⁹⁶ recently suggested that failures in institutional architecture are at the root of a failure in UK investment in public capital. They propose several new institutions with powers delegated by Parliament, comprising an infrastructure strategy board with statutory responsibility for strategy, an infrastructure planning commission with responsibility for delivery and an infrastructure bank to provide finance. An alternative potential solution to systemic government failure could be to make the road network a regulated utility with statutory obligations^{197, 198, 199}.

Institutional infrastructure

Turning to the legal framework governing firms in the UK, it is useful to compare different corporate governance models operating in other countries. In the US, northern Europe and Japan²⁰⁰, there are two dominant models. The Silicon Valley model of venture capital-funded growth depends on liquid capital markets and flexible labour markets. The 'productive coalition' model is based on long-term innovation, stable ownership, and institutionalised worker-management cooperation. These are ideal types and most countries, like the UK, use hybrid systems with some of the characteristics of each model. However, there is evidence that the existing corporate governance framework operating in the UK, which generally favours shareholders,

acts negatively on innovation, with particularly unfavourable impact on manufacturing²⁰¹.

On balance, it is possible to argue that the current legal framework in the UK is a deterrent to (manufacturing) firms' undertaking complementary investments in knowledge-based technologies and firm-specific human capital, given that both generate returns over an extended period. However, the UK has been successful recently in generating venture capital funding for start-ups in sectors such as IT and biotechnology²⁰². The question therefore is whether a shift in the regulatory framework towards a 'productive coalition' model could only be achieved at the cost of deterring venture capital and related forms of start-up financing for high-tech firms. This is an open question, but it should not be assumed that this would be the case. Levels of venture capital funding are higher in per capita terms in several European countries which do not have the same kind of legal underpinning for financial and labour markets as the UK. Liberal personal bankruptcy laws and fiscal support for early-stage financing may be more important determinants of the size of the venture capital sector than laws on shareholder and employee protection²⁰³. It is possible to conclude that it may be that existing levels of legal support for shareholder rights are too high and employment protection laws are too weak to provide necessary stimuli to firm-level innovation.

On employment protection, there is evidence of a strong and consistent relationship between the legal regulation of termination of employment and a pro-innovation environment at the firm level²⁰⁴. Findings from studies on innovative firms, including start-ups, suggest that a hire-and-fire regime is not necessarily optimal for venture capital-funded firms. It appears that there is little or no prospect of increased innovation deriving from policies of labour market deregulation²⁰⁵. Overall, there seems to be strong endorsement of the need to move towards less shareholder protection/liquid capital markets and more employee protection.

¹⁸⁹ Eddington, R. (2006) ¹⁹⁰ If road pricing were to be implemented, then the much smaller road-investment programme (£5-8 billion) that would be justified would generate welfare benefits of about £30 billion (about 1.6 per cent of GDP) and a GDP gain of about half that figure. ¹⁹¹ Dodgson, J. (2009) ¹⁹² Smith, J.W., Alexander, J. & Phillips, D. (2011) ¹⁹³ The typical unfunded scheme has a BCR of 3.6 – about 3 times the latest estimate for HS2. ¹⁹⁴ Kamps, C. (2005) ¹⁹⁵ Office for Budget Responsibility (2012) ¹⁹⁶ LSE Growth Commission (2013) ¹⁹⁷ CBI (2012) ¹⁹⁸ Glaister, S. & Smith, J.W. (2009) ¹⁹⁹ Newbery, D. (2005) ²⁰⁰ Evidence Paper 5: Deakin, S. (2013) ²⁰¹ Evidence Paper 5: Deakin, S. (2013), Evidence Paper 16: Hughes, A. (2013) ²⁰² Evidence Paper 5: Deakin, S. (2013) ²⁰³ Evidence Paper 5: Deakin, S. (2013) ²⁰⁴ Evidence Paper 5: Deakin, S. (2013) ²⁰⁵ Evidence Paper 5: Deakin, S. (2013)

ADVICE FOR POLICY-MAKERS:

Evidence suggests that failures in the UK's institutional architecture are at the root of a persistent failure in UK investment in public capital. A much more coordinated approach that cuts across all areas of government is required to help to ensure that the needs of manufacturing are incorporated into the design of infrastructure investments. Coordination issues are discussed in more detail in Chapter 7.

As to whether a shift in the regulatory framework towards a 'productive coalition' model is warranted, some evidence suggests that existing levels of legal support for shareholder rights are too high and, conversely, that employment protection laws are too weak to provide necessary stimuli to improving productivity levels. This requires a more thorough examination to take place within government.

4.3.8 FACILITATION OF THE FUTURE COMMERCIALISATION OF TECHNOLOGY AND SUPPORT FOR INNOVATION

Technology and its commercialisation is discussed fully in Chapter 3. However it is important to recognise here that the evolution of existing technologies, in addition to new product and process innovations (i.e., new goods and services to replacing older, obsolete ones, a process known as 'creative destruction')²⁰⁶ will continue to shape the demand and supply of such goods and services.

The use of new technologies by firms will require, amongst other things, 'capabilities' and 'resources' for their development and operation. Both require sufficient investment in R&D and other intangible assets to achieve the requisite levels of absorptive

capacity in firms. These will include advanced design methodologies and tools, advanced supply chain management (and advanced customers), and the requisite skills base. Given the uncertainty and risk that surrounds technological advances, a key factor is firms having the capabilities to respond positively to change, and take advantage of opportunities, rather than be 'left behind'²⁰⁷.

The levels of public sector support for R&D in the UK are low compared to other countries (Table 4.17)²⁰⁸. The UK Government financed R&D, in 2011, at a level of 0.57% of GDP, was significantly below Korea, the US, Germany, and France. The UK figure was some three quarters of the OECD average, and some 20% below the EU level of spending. This low level of support in the UK was not compensated by relatively higher spending on R&D financed by industry.

The most recent OECD data for 2010 shows how government outlays on R&D are allocated across different sectors. In most countries, including the UK, the main recipients are 'general university funds', defence, economic development, and health and environment. In the UK, in 2010, 'general university funds' and health and environment²⁰⁹ both received about 24% of total outlays, with defence receiving just over 18%, and economic development less than 8%. In comparison, in the U.S., over 51% went to defence,²¹⁰ and nearly 28% to health and environment. Of the major OECD countries apart from the US, the UK government allocated the smallest amount to economic development (the OECD average was around 15%; the EU over 21%, Germany 22% and France over 17%; the comparable figure for the UK was 7.6%).

²⁰⁶ See Schumpeter (1942) ²⁰⁷ See Harris, R. and Moffat, J. (2013b) ²⁰⁸ The OECD produce these data (see http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2011/government-funding-of-r-d_sti_scoreboard-2011-34-en). ²⁰⁹ Evidence Paper 24: Morton, B. et. al. (2013) have considered the importance of government procurement for manufacturing, and in the area of health they note several opportunities for UK manufacturing assuming a coordinated approach from government. ²¹⁰ As the UK is the world's 2nd largest exporter of defence equipment and technology, defence procurement has a very large impact on R&D and production in manufacturing in the UK.

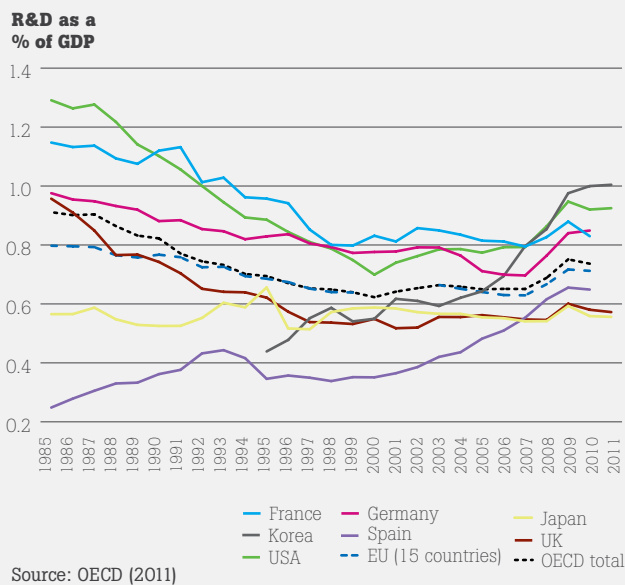
Table 4.17: Gross Domestic Expenditure on R&D (GERD) as a % of GDP, 2011

COUNTRY	TOTAL	FINANCED BY	
		GOVERNMENT	INDUSTRY
Austria	2.75	1.05	1.70
Korea	3.74	1.00	2.74
Finland	3.78	0.95	2.84
Sweden	3.37	0.93	2.45
United States	2.77	0.92	1.84
Denmark	3.09	0.85	2.24
Germany	2.84	0.85	1.99
Singapore	2.09	0.84	1.25
France	2.25	0.83	1.42
Chinese Taipei	2.90	0.80	2.10
Russian Federation	1.12	0.75	0.37
OECD Total	2.38	0.74	1.64
Portugal	1.49	0.71	0.78
European Union (15 countries)	2.08	0.71	1.37
European Union (25 countries)	1.97	0.69	1.29
European Union (27 countries)	1.94	0.68	1.26
Canada	1.74	0.67	1.07
Spain	1.33	0.65	0.69
United Kingdom	1.77	0.57	1.20
Japan	3.26	0.56	2.70
Ireland	1.72	0.54	1.19
Italy	1.25	0.53	0.73
Poland	0.77	0.43	0.34
China	1.76	0.42	1.34

Source: OECD (2011). Figures in red refer to data for 2010.

UK Government support for R&D spending has declined to some 60% of the 1985 level (see Figure 4.30)²¹¹, while since 2000, the U.S. and to some extent Germany have reversed the decline seen throughout this period.

Figure 4.30: Gross Domestic Expenditure on R&D (GERD) financed by Government as a % of GDP, 1985–2011 (selected countries)



Source: OECD (2011)

New initiatives are taking place to support R&D in manufacturing in many countries²¹², specifically to tackle the need to overcome what is termed the 'valley of death'. This is the period of time from applied R&D to full manufacturing-scale demonstration (see Chapter 3). For example, the Advanced Manufacturing Office of the US Government has recognised the need to support R&D on technology projects which will help manufacturers become more robust, adaptable, profitable, and globally competitive²¹³. Working jointly with industry stakeholders, universities and others, AMO invests in cross-cutting technologies to benefit a broad range of manufacturers. These include pre-competitive projects that emphasise the innovative capacity of small and medium enterprises, and innovation stages which involve

technical risks from applied research through commercial systems integration. The US also has a Small Business Innovation Research Program (SBIR), which currently lets \$2 billion of contracts annually. Since its inception the programme has worked with over 15,000 firms, developed more than \$21 billion worth of research, and over 45,000 patents²¹⁴.

ADVICE FOR POLICY-MAKERS:

There is a compelling case for the UK to invest more in R&D and more widely defined intangible assets, for example ICT, to help ensure that manufacturers are well placed to exploit technological change in the future and compete internationally.

While there is a need to maintain existing policies that aim to increase connections and encourage collaborations between firms by making greater use of existing schemes such as Knowledge Transfer Partnerships, there needs to be a greater emphasis on the firm. Unless firms have sufficient absorptive capacity, or ability capitalise on new information, they will not be able to fully internalise the benefits of any knowledge spillovers, no matter how large such spillovers may potentially be.

Linked to this is the need for a significant increase in public support to help with the development of these new and, by definition, riskier and more uncertain technologies (and thus overcome the 'Valley of Death'). International evidence suggests that the UK is lagging behind its competitors here (see Chapter 3).

²¹¹ The OECD produce these data (see http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2011/government-funding-of-r-d_sti_scoreboard-2011-34-en). ²¹² See also Evidence Paper 4: Chang, H. et al. (2013) ²¹³ United States Advanced Manufacturing Office: <https://www1.eere.energy.gov/manufacturing/>. ²¹⁴ See also its sister initiative the US Small Business Technology Transfer Programme: (<http://www.sbir.gov/about/about-sbir>).



5. MORE SUSTAINABLE

In the period up to 2050, interactions between manufacturing and the natural environment will be subject to a number of powerful changes. Growing global populations will raise demand for resources, particularly as they become wealthier. Climate change is likely to increase the vulnerability of global supply chains. Consumers will call for products that meet higher environmental standards, and governments may increase their use of environmental regulations.

Manufacturers will therefore need to strive for greater efficiency in their use of materials and energy, which will provide resilience to the resulting volatility in the price and availability of resources. Manufacturers will also need to explore new ways of doing business, for example by expanding into 're-manufacturing' of end of life products, or by producing increasingly robust products for 'collaborative' consumption by consumers.

This Chapter examines a number of these important changes and concludes by outlining a range of implications for Government, and relevant advice where needed, that will need to be addressed as manufacturing increasingly becomes more sustainable.

5.1 MANUFACTURING AND THE NATURAL ENVIRONMENT

KEY MESSAGES

Interactions between manufacturing and the natural environment will be subject to a number of changes in the decades ahead. Some of these 'environmental mega-trends' are discussed here, alongside some of the government and consumer reactions to these trends that will impact the manufacturing sector.

A growing and increasingly urban global population will raise demand for natural resources and influence the location of manufacturing

There are predicted to be 3 billion more people in the world in 2050, with global population reaching over 9 billion and 70% of the global population living in urban areas. The world's middle classes will expand dramatically and the population will be older and richer. These demographic changes will influence resource availability and location decisions of manufacturing firms – for example, as certain firms will increasingly want to locate close to the customer, this will necessitate the location of some factories within urban areas.

Climate change is likely to increase the vulnerability of global supply chains and increase the pressure on manufacturers to reduce their greenhouse gas (GHG) emissions

There is overwhelming scientific agreement that the climate is changing and further change is inevitable without reductions in GHG emissions. A warmer climate is expected to bring changes to rainfall patterns, further sea level rise and an increased risk of certain extreme weather events, including floods, droughts and heatwaves, in many parts of the world. These changes are likely to increase supply chain vulnerability.

As demand increases for natural resources there is likely to be greater volatility in their prices with potential disruptions in their availability

Trends in population and urbanisation will increase demand for materials, water, energy and land. As a result, these resources will be subject to greater competition and therefore increasing prices. In some instances this competition could turn into resource conflict with clear implications for manufacturing firms that tend to have their supply chain distributed globally.

'Sustainability standards' and environmental regulations are likely to be used more widely

Governments around the world are likely to set increasingly stringent environmental regulations due to environmental pressures and as public views change

An important future trend is likely to be 'pricing of the environment', which involves attaching an economic value to particular natural resources

There is a trend for pricing natural resources such as carbon and water, and pricing ecosystem services such as the ability to clean the air. This will provide both challenges and opportunities for UK manufacturers.

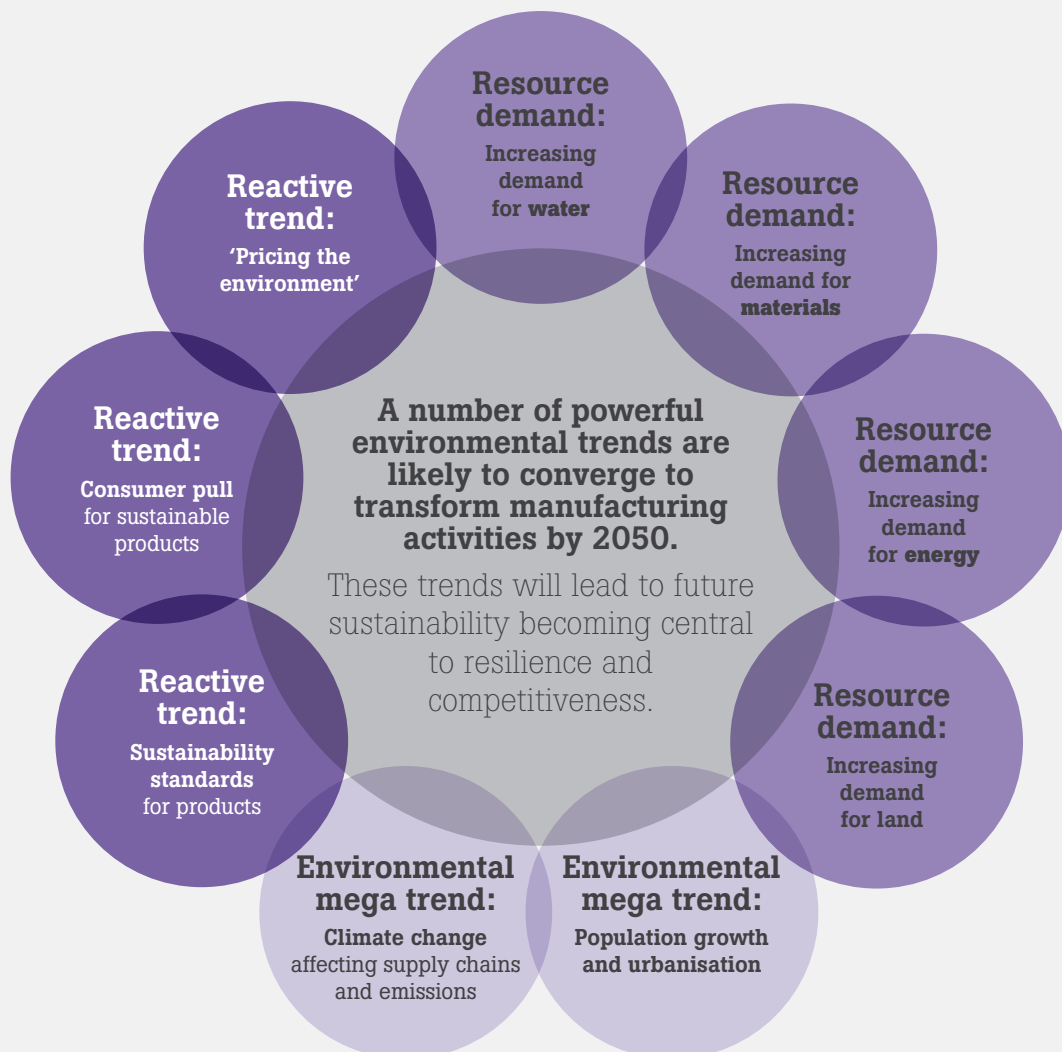
An ongoing important trend is likely to be 'consumer environmental pull' for products do not involve environmental degradation

Continual environmental damage and the resultant human costs may mean that customers, through their choices, push manufacturing firms to continue to reduce their wider environmental impacts.

5.1.1 INTRODUCTION

In the period up to 2050, interactions between manufacturing and the natural environment will be subject to a number of changes, with significant implications for UK manufacturing. The size of the global population, where people live, the climate, the likelihood of extreme weather events and the availability of resources will all undergo significant change. In addition, in response to the changing environment, there will be developments in the push and pull on manufacturers from both consumers and government. All of these interrelated issues are discussed here and illustrated in Figure 5.1.

Figure 5.1: Environmental trends most likely to converge, leading to manufacturing activities becoming more sustainable and resilient



BOX 5.1: WHAT IS SUSTAINABILITY?

In this report the terms 'sustainable manufacturing' and the 'drive towards sustainability' are frequently used. The definition of sustainability adopted here is that described in the widely cited Brundtland Report: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"¹. The premise here is that the current widespread economic model already requires a world with a greater capacity to provide resources and process harmful wastes than is possible.

5.1.2 POPULATION GROWTH AND URBANISATION

Out to 2050, demographic changes will be significant. Not only will the global population increase, but there will be changes to the age profiles, levels of urbanisation and average income of populations across the world. Effects will vary between countries, but the average person will be older, wealthier and more likely to live in a city. Demographic changes within the UK and abroad will have significant implications for UK manufacturers. In this section, trends in population size, urbanisation, and wealth are discussed, along with what it means for UK manufacturing. These issues are also touched on in Chapter 6, where the impact of ageing populations is discussed.

Population growth: It is predicted that there will be 3 billion more people in the world by 2050, with the global population reaching over 9.6 billion². 97% of population growth by 2050 will take place in developing regions, with 38% taking place in the 'least developed countries'³. By 2050, many African and Asian states will have a population of over 50 million people, a significant increase from 2012. UK projections suggest the population will increase from 62.7 million people in 2010 to 77 million by the end of 2050⁴.

Urbanisation: As the global population grows, urban centres are expected to absorb the bulk of this increase. Forecasts suggest that 70% of the global population will live in urban areas by 2050⁵. In developed countries the urban population is expected to increase very slowly, from 0.9 billion in 2000 to 1 billion in 2030. Of the 23 cities expected to reach 10 million plus by 2015, 19 will be in developing countries⁶.

Wealth: For the first time in history, a truly global 'middle class' socio-economic group is emerging, with annual per capita expenditure between US\$3,650 and US\$36,500 (2005 prices)⁷. By 2030, it is estimated that:

- This global group will more than double in size from 2 billion in 2012 to 4.9 billion;
- European and US middle class will shrink from 50% of the total to just 22%;
- Rapid economic growth in China, India, Indonesia, Vietnam, Thailand, and Malaysia will cause Asia's share of the new middle class to more than double from its current 30%; and
- 64% of the global middle class will be residing in Asia, accounting for over 40% of global middle-class consumption of manufactured products.

What does this mean for UK manufacturing?

A larger, wealthier population will result in increased global demand for manufactured products. Given that most of the population increase and growing middle class will be in developing regions, especially Asia, manufacturers will need capabilities to understand the new, growing markets and how they are set to change (see also Chapter 4). This increase in demand for products will result in an increased demand for resources: energy, water, land, materials and food⁸.

The trend for urbanisation will mean that consumption will be concentrated in cities, which will influence the location decisions of manufacturing firms. Manufacturers will increasingly locate closer to the customer and this, for some, will involve setting up factories within cities⁹. The implication of the need to locate in or near to cities will be that manufacturers will design their factories accordingly. Firms will not only need to be increasingly welcoming to the customer through 'open' factories (see Chapter 3), but will need to integrate with a greater diversity of players as part of the 'circular economy', an idea discussed in further detail below.

5.1.3 CLIMATE CHANGE

Global average temperature is projected to rise between 0.7 and 2.4°C by mid-century (relative to the start of the century) depending on the level of greenhouse gas emissions¹⁰. As the climate warms rainfall patterns are expected to change, sea level will continue to rise, and the risk of some types of extreme event, like flooding, heatwaves and drought, will increase. The level of warming and the associated impacts will vary globally.

The impact of climate change on the location of manufacturing processes globally is extremely difficult to forecast, however, an increase in frequency or intensity of extreme weather events in particular has the potential to damage infrastructure and transportation links and disrupt global supply chains. Floods in Thailand in 2011, for example, shut down factories and disrupted supplies of computer hardware to companies in the UK and elsewhere. The effects of climate change on food, water, health and general regional stability will also affect the supply of human resource and cost of labour around the world. These combined physical and societal impacts of climate change result in potentially significant implications for some regions' ability to maintain or develop their manufacturing base.

What does this mean for UK manufacturing?

Climate change could have significant implications for manufacturing if supply chains are disrupted and if resources such as fresh water are diverted to maintain the basic needs of the growing population. The extent of the impact will depend both on actions taken to mitigate the risks of climate change through reducing emissions, but also to adapt to the expected impacts. Regulatory pressure to reduce emissions in manufacturing is likely to increase. Manufacturers will also need to build resilience to future climate into their business models.

5.1.4 FUTURE DEMAND FOR RESOURCE

Increases in the global population will lead to increasing demand for manufactured products, accompanied by greater global demand for resources. Non-renewable resources such as fossil fuels will be progressively depleted and the changing climate will make resources such as freshwater scarce in some parts of the world. The combination of these factors is likely to increase the likelihood of resource conflicts. The end result for manufacturing will be a reduction in the availability of many resources that are key to the sector, with greater volatility in their prices. The top four natural resources that are critical to manufacturing, which will see substantial increases in demand, are materials, water, energy and land.

⁹ Further details provided in Chapter 3. ¹⁰ Inter-Governmental Panel on Climate Change (2013). The provisional final draft Working Group One contribution to the Inter-Governmental Panel on Climate Change Fifth Assessment Report gives projections of warming for the period 2046 - 2065 (compared to 1986 - 2005) for four illustrative scenarios: 1.0°C (+/- 0.3) warming for Representative Concentration Pathway (RCP) 2.6; 1.4°C (+/- 0.3) warming for RCP4.5; 1.3°C (+/- 0.3) warming for RCP6.0; and 2.0°C (+/- 0.4) warming for RCP8.6.

The future security of supply of materials

Raw materials used for the manufacturing process, including ores, minerals and liquid fossil deposits, are unlikely to be depleted in the near future, but their extraction is predicted to become economically unattractive as easily-exploited and high quality sources are used up¹¹. Many important manufacturing materials originate in a small number of locations outside of Europe. For example, about 40% of cobalt (uses include batteries, alloys and catalysts) is produced in the Democratic Republic of Congo and 92% of niobium (used in automotive and aerospace industries) is produced in Brazil, with most of it coming from a single mine¹². Mining and production activity responds over time to market pressures and price signals to set levels for what it is economically viable to survey and exploit. However, the fact that the availability of mined materials is subject to marked geo-political risk is the critical issue that is likely to worsen in the future as the accessibility of traditional resources decreases but demand grows, resulting in increased competition.

As emerging economies develop, it seems likely that competition for resources will be fierce and protectionism may ensue as the few countries that are suppliers of the rarer metals cease to export them. Consequently, the UK manufacturing industry faces a growing problem of securing supply chains linked to particular materials. This issue was highlighted in 2010 when China restricted exports of rare earth elements¹³ used in many electronic and advanced technology applications and are currently produced by a very limited number of countries, principally China, which produces around 97% of the global supply¹⁴.

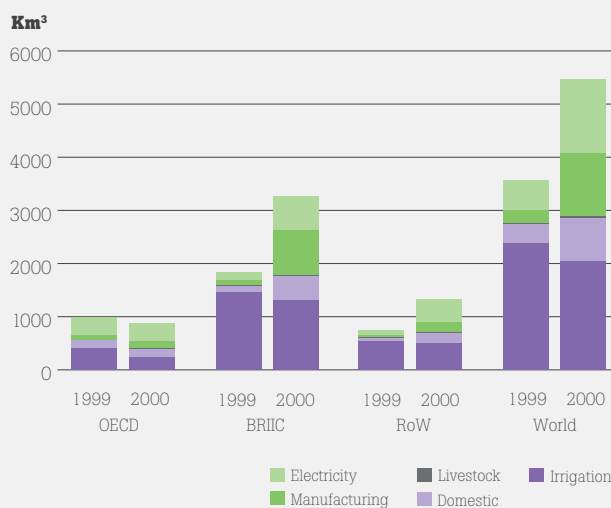
To remain competitive, manufacturers will need to develop material-efficient processes and manage supply chain disruptions, as well as recovering precious materials with enhanced product stewardship. One such strategy is termed the circular economy (see Chapter 3 and later discussion in this Chapter) which aims to re-use materials rather than extracting materials, using them and discarding them, only to start again with virgin material.

The future security of supply of water

Water is a finite resource, with less than 1% of all fresh water on the planet available for use¹⁵. Future competition for water, driven by population growth, urbanisation and demographic shifts, may put the manufacturing sector in direct competition with food production and the basic needs of society. By 2050, forecasts suggest that global blue water (freshwater from the surface or the ground) demand will increase by 55% compared to 2000, with a 400% increased demand from manufacturing and 140% from electricity generation (see Figure 5.2)¹⁶. Water supply crises are predicted to be the second greatest global risk out to 2022¹⁷.

Low-income countries will be particularly subject to future water scarcity, with 39% of low-income countries experiencing a more severe shift towards water stress than wealthier, more industrialised countries. In China and India, for example, 2.7 billion people will be living in water-scarce basins in these countries alone by 2050, up from 1.4 billion today¹⁸. However, areas such as California in the US will also be subject to increased risk¹⁹.

Figure 5.2: Blue water demand to 2050 by sector



Source: Evidence Paper 35: Tennant (2013) (replotted from OECD 2012)

¹¹ Evidence Paper 35: Tennant, M. (2013) ¹² Evidence Paper 27: Parker, D. et al., (2013) ¹³ Note that REEs or rare earth elements refer to a collection of seventeen chemical elements in the periodic table, namely; Scandium, Yttrium and the fifteen lanthanides. The name comes from the rare earth minerals from which they were first isolated. ¹⁴ Evidence Paper 27: Parker, D. et al., (2013) ¹⁵ United Nations Water: (n.d.) ¹⁶ Evidence Paper 35: Tennant, M. (2013). [Replotted from OECD (2012a)] ¹⁷ World Economic Forum (2012b) ¹⁸ Veolia Water (n.d.) ¹⁹ Veolia Water (n.d.)

70% of global water is currently extracted for agricultural use and 19% for industrial use²⁰. In the UK, over half of the water abstracted is used to supply electricity (55%), about one third is used for the public water supply (30%), and only 9% by industry²¹. The manufacturing sector is the largest industrial consumer of water (using 27% of volume)²². UK consumption relies heavily on 'virtual water' imported and embedded in goods that are produced from water drawn in their countries of origin. Important factors in the future availability of water for manufacturing include:

The amount of energy needed to clean and move water: This has been increasing in recent years in the UK due to a lowering of the groundwater table²³. As groundwater sources in the UK and globally become further depleted, more energy will be required to extract the same amount of water through unconventional methods such as desalination and rain water harvesting, which could be more than ten times as costly as conventional surface or groundwater pumping²⁴.

The growing global middle class and likely changes in diet: This will put added pressure on water supply, as more meat and vegetable oils are consumed in place of grains and pulses. Production of one kilogram of beef requires 15,500 litres of water, while the equivalent amount of wheat requires 1,300 litres²⁵. Studies have predicted increases in per capita consumption (kg/capita/annum) from 37 kg in 2011 to 52 kg by the middle of the century, on average, and from 26–44 kg in low-income countries²⁶. However, it is important to note that looking out to 2050, there may be some consumption of laboratory grown meat, which, it has been estimated, could reduce water usage by 94% when compared to conventional meats²⁷.

The future security of supply of energy

Energy demand: In 2010, manufacturing accounted for 16.5% of energy demand in the UK²⁸. Projections for future energy consumption by the manufacturing sector depend upon assumptions regarding the output and energy-intensity of its production. Baseline scenarios are typically based on small

improvements in energy efficiency (0.2% per year), whereas other scenarios, including predictions by the UK Department for Energy and Climate Change (DECC), envisage energy demand from industry falling by up to 25% from current levels. This would involve significant improvements in energy efficiency, fuel switching and the use of carbon capture and storage technologies²⁹. The critical factor that will influence reductions in energy usage will be the cost of doing so, however energy saving is likely to become cheaper³⁰. A recent report has studied energy efficiency activities in the UK as sector averages and identified best practice companies, also based in the UK, who have out-performed their own sector significantly³¹. For example, chemical companies have reduced their energy intensity by 50% in 15 years. Even in energy intensive sectors, the variation from best to average offers great scope for competitive advantage.

Energy prices: Out to 2050, there will be a drive towards decarbonising the energy system; however fossil fuels are still predicted to dominate the energy mix. In the short and medium term, the move towards a decarbonised energy system is likely to involve higher energy prices than the current energy system³². However, in the longer term, research and development is likely to reduce the costs of renewable energy³³. Prices of fossil fuels, on the other hand, are likely to rise. The DECC has projected the price of fossil fuels (oil, gas and coal) out to 2030 under three different scenarios³⁵. Under two of the three scenarios, the price of all three fossil fuels increases. For example, the price of gas could rise from 61.4p/therm in 2013 to 73.8p/therm in 2030 under the 'central' scenario. However, under the low scenario, the price could fall to 42.2p/therm in 2030. But whatever happens to the underlying cost of fossil fuels, applying carbon capture and storage (CCS) to a power station (which most studies suggest will need to be part of any reasonably affordable low-carbon system) must increase its costs³⁶. These trends in energy prices are illustrated in Table 5.1³⁷. Increasing energy prices will have significant cost implications for manufacturers who do not reduce their energy usage to a sufficient degree.

20 Evidence Paper 35: Tennant, M. (2013) 21 Evidence Paper 35: Tennant, M. (2013) 22 Wrap (2011a) 23 McKinsey Global Institute (2011b) 24 McKinsey Global Institute (2011b) 25 Evidence Paper 35: Tennant, M. (2013) 26 Foresight (2011b) 27 Tuomisto, H & Roy, A. (2012) 28 Evidence paper 11: Green, R. & Zhang, X. (2013) 29 Evidence paper 11: Green, R. & Zhang, X. (2013) 30 Evidence paper 11: Green, R. & Zhang, X. (2013) 31 Lavery Pennell (2013) 32 Evidence Paper 35: Tennant, M. (2013) 33 Evidence paper 11: Green, R. & Zhang, X. (2013) 34 Evidence paper 11: Green, R. & Zhang, X. (2013) 35 DECC (2012) 36 Evidence paper 11: Green, R. & Zhang, X. (2013) 37 DECC (2013)

Table 5.1: Levelised electricity generation cost estimates³⁸ (£/Megawatt hour)

GENERATION METHOD	PLANTS BUILT IN 2014	PLANTS BUILT IN 2030
Combined Cycle Gas Turbine (CCGT)	75	88
CCGT with carbon capture and storage	–	104
Nuclear	–	77
Onshore wind >5 Megawatts	104	97
Large scale solar PV	158	90

Source: The Department of Energy & Climate Change (DECC) (2013) 'Central scenario'

On a global scale, world energy consumption is predicted to increase dramatically (Figure 5.3³⁹). In non-OECD countries, industrial consumption will rise by around 1.8% per year, however in OECD countries it is only expected to increase by 0.6% per year (Figure 5.4⁴⁰).

Figure 5.3: World energy consumption, 1990-2040 (quadrillion Btu)

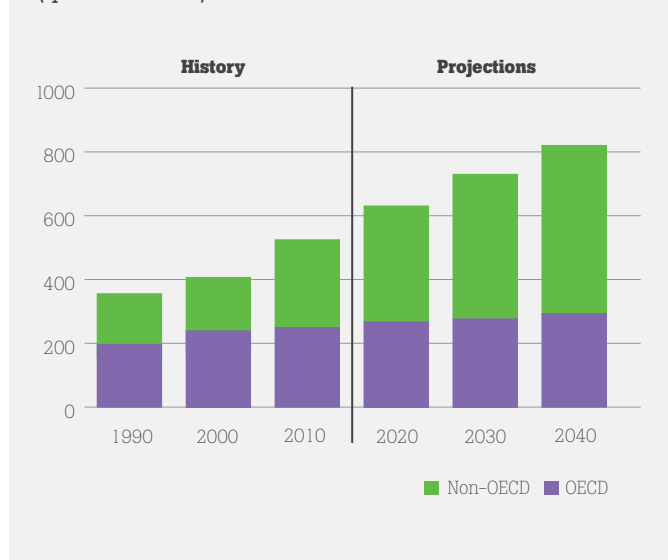
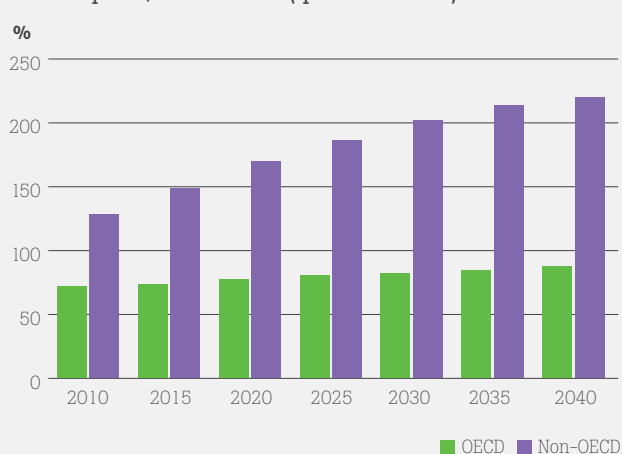


Figure 5.4: World industrial sector delivered energy consumption, 2010-2040 (quadrillion Btu)



Energy reliability: The concern over energy security of supply is ubiquitous, but is likely to be exacerbated by local conditions in the UK. Currently, the average UK consumer loses electricity supply for 80 minutes a year⁴¹. Most of these outages are due to problems in the local distribution systems, but the greatest disruption comes when millions of people, including businesses, are simultaneously affected by a problem in the transmission system or a shortage of generation. In the future, there is likely to be an increased risk of UK electricity system failure.

A low-carbon electricity system in the UK, which is the aim for 2050⁴², is likely to involve a significant proportion of wind generation, which is dependent on the weather⁴³. To make the most efficient use of the various renewable resources in Europe, it is likely that much more electricity will be transmitted over long distances. Wind power will come from around the Atlantic seaboard (including the British Isles) and the North Sea, while solar power will most economically come from the south of Europe and from North Africa. Hydro-electric stations in Scandinavia and the Alps will be able to balance the inevitably intermittent output from other sources⁴⁴.

Scenario analysis by the UK Office for Gas and Electricity Markets (Ofgem) indicates that the risk of capacity shortfall is low in the immediate future, when substantial spare capacity exists, but it rises sharply by 2016-17 as older plants retire. These

³⁸ A 'levelised cost' is the average cost over the lifetime of the plant per MWh of electricity generated. They reflect the cost of building, operating and decommissioning a generic plant for each technology) ³⁹ Energy Information Administration Energy Outlook (2013) ⁴⁰ Energy Information Administration Energy Outlook (2013) ⁴¹ Evidence paper 11: Green, R. & Zhang, X. (2013) ⁴² DECC commitment to reducing GHG emissions by 80% ⁴³ Evidence paper 11: Green, R. & Zhang, X. (2013) ⁴⁴ Evidence paper 11: Green, R. & Zhang, X. (2013)

scenarios do not assess the risk of power cuts caused by disturbances to the transmission system or sudden changes in generation away from the peak hours but it is likely that these risks will rise from very low levels as the level of wind generation increase⁴⁵.

Two threats to UK-based manufacturers therefore include the price of energy in the UK continuing to rise at a faster pace than in competitor counties, placing UK manufacturers at a disadvantage. The second threat is that a low-carbon electricity supply may be unreliable, and that the cost of power cuts will rise. There are however two important opportunities. UK manufacturers who can reduce their electricity usage at times when the power system is under stress are already paid for doing so. The need for such demand-side management, the options for providing it, and the price paid are all likely to increase over time. The second opportunity is that new low-carbon products will be needed, not least in the transport sector, and UK-based firms may be able to break into these new markets.

Land space

There are only 1.9 global hectares of biologically productive space available per person on earth. Given that the average world citizen currently has an ecological footprint of 2.3 global hectares⁴⁶, current levels of consumption are clearly unsustainable. This is combined with the trend of an increasing global population and rising incomes, especially in emerging economies. In addition, estimates suggest that of the 11.5 billion hectares of vegetated land on earth, about 24% had undergone human-induced soil degradation in 2009, with erosion the main process of degradation⁴⁷. Although cropland occupies only 12% of land area, almost 20% of the degraded land was once cropped. However, around 16% of total land area, including cropland, rangeland and forests, is improving, with some significant land reclamation projects, for instance, in northern China⁴⁸.

The outcome will be much greater competition for land space between agricultural crops, living space for people, biofuels and industry. Manufacturing firms, alongside all other sectors in the economy, will

therefore need to increase the efficiency with which they use land. Developments in the size and location of factories, in particular the decrease in size and movement of some factories into urban areas, could help in this regard (see Chapter 3).

5.1.5 FUTURE POTENTIAL FOR 'PRICING THE ENVIRONMENT'

Ecosystem services are services provided by the natural environment that benefit people⁴⁹. Examples include water purification, air purification, groundwater recharge, pollination and the decomposition of waste. While many of these ecosystem services are seemingly free, estimates of their monetary value show this to be far from true. For example, sea defence services have been calculated to be worth between £53 – 199 million per annum in Wales alone⁵⁰. Work is currently being undertaken to value many of these ecosystem services⁵¹ and it may be that in future, those who reduce the ability of the natural environment to provide ecosystem services must bear a cost, and the main beneficiaries of ecosystem services must pay to sustain them.

In addition, resources such as carbon and water are increasingly being priced into the economy through mechanisms such as the EU Emissions Trading Scheme and the UK Carbon Price Floor. This trend is likely to continue as countries look to ensure GHG emissions are taken into account by businesses when making decisions with the aim of reducing the environmental impacts.

5.1.6 FUTURE 'SUSTAINABILITY STANDARDS' AND ENVIRONMENTAL REGULATION

Within the last 40 years greater effort has been made by some governments to encourage improved environmental performance in the industrial sector. By setting standards such as ISO14001, environmental management in factories in many countries has improved. Out to 2050, standards will become increasingly important in emerging economies as the population becomes wealthier and increasingly demands and expects better standards from manufacturers.

However, moving from standards to reduce local, immediate pollution to standards for global, long-term pollution related to areas such as resource extraction, where effects will extend across generations, will be challenging. Legislation is likely to move away from a focus on reducing pollution which has been largely successful in western countries, to a focus on resource productivity, for example EU legislation diverting electrical equipment waste away from landfill. Legislation is likely to increasingly concern itself with encouraging innovation and changes to business practice.

5.1.7 CONSUMERS AND THE ENVIRONMENT

Consumer demand for sustainable products, involving reduced energy and material use, is growing⁵², however it is difficult to measure the degree to which customers are pushing for these types of products, and whether they may be willing to pay a premium for such products. However, it is possible that in the period out to 2050, given increasing awareness of environmental degradation and the likely increase in the number of extreme

weather events, consumers will demand better corporate social and environmental responsibility from manufacturers.

A number of major companies are taking initiatives in this direction, sensing that consumers will favour more responsible behaviour, or eschew products and services from companies taking the contrary view. Unilever's pledge to double turnover without increasing GHG emissions⁵³ and Marks & Spencer's Plan A to go 'beyond compliance' on the environment⁵⁴ are good examples.

Manufacturers will also increasingly need to consider the reputational risk of exposure to the consumption of energy and other issues throughout their value chains. High levels of sustainable performance are expected of many suppliers and this will only increase. UK manufacturing firms are affected by this in their own operations but also in the operations of their supply chain, from the distribution lorries on UK motorways to the recognition of 'virtual water' and 'virtual energy' embedded in products, material extraction and working practices of their entire supply chain. This is expected to place increasing demand for provenance information and we can expect future products to present data on the sustainability of all the activities along the value chain.

How will UK manufacturers fair in this changing world?

UK manufacturing is in a reasonable position to deal with the environmental constraints of the future. UK manufacturers also have capabilities in areas that will increase in importance out to 2050. For example, the UK is internationally competitive in lightweight technologies through companies such as Jaguar Land Rover, McLaren and others⁵⁵. These lightweight technologies will be increasingly important in improving energy efficiency in transport systems and there will likely be cross-sector transfer of this technological know-how from the transport industries to other industries such as construction. The UK could therefore sell both lightweight technologies and its knowledge in this area to generate revenue.

The UK has also moved beyond pollution prevention and hence offers better environmental performance in its domestic and exported products than most countries. Of course, some of the UK's leading international competitors enjoy a similar position, though the strengths vary across countries and sectors. This will create certain comparative advantages for the UK out to 2050, for example in exporting UK know-how and research in the 'green' space – from low-energy drying technology, to consultancy services, to the development of exciting new bio-materials.

It is not correct to describe the UK as world-leading in putting sustainability at the heart of manufacturing; indeed this is a position claimed by no country as yet. With most developed countries prioritising environmental performance as being critical to their future industrial strategies, the opportunity exists to take advantage of UK strengths in pollution prevention, in adopting resource efficiency, and in clean technology.

5.2 IMPLICATIONS FOR GOVERNMENT

KEY MESSAGES

Sustainable manufacturing, requiring manufacturers to use less material, energy and other inputs, will become critical in giving manufacturers resilience to potential volatility in the price and availability of commodities, and in supporting competitiveness.

Growing competition for resources and the potential for increased volatility of commodity prices, along with a changing climate, will create conditions where manufacturers will have to take action to help safeguard their future competitiveness.

A shift to more sustainable manufacturing will be critical, requiring manufacturers to use less material, energy and other inputs; make better use of alternative inputs; and embrace alternative business models. Sustainable manufacturing will be important in supporting the economic sustainability and competitiveness of manufacturers, and will make valuable

contributions to wider environmental sustainability.

A range of technological advances, including the full integration of ICT and sensors into manufacturing processes, will help enable movement towards a more sustainable manufacturing system.

There are three key areas for the UK Government to focus on to help manufacturers address this shift to sustainable manufacturing as it no longer becomes optional:

- **Near term changes:** The need to maximise efficiency and resilience in the supply and use of materials, energy, water and land, and to support developments, including urban manufacturing, close to the customer.
- **Preparing for 2025 and beyond:** The need for industry-government-academia partnerships to be formed to prepare for disruptions in the price and availability of material, energy and other inputs, with experimentation and new business models including the 'circular economy' approach to reusing end of life products encouraged; and by ensuring supply-chain resilience.
- **Preparing for 2050 and beyond:** The need to help manufacturers create value from any 'positive externalities' of their operations. These would include any private or societal benefits to a third party caused when a product is consumed. For example, new developments in technology could enable factories to become cleaner, quieter, and sought after neighbours in densely populated areas.

5.2.1 INTRODUCTION

The combination of trends relating to the natural environment, particularly the growing competition for resources and a changing climate, will create conditions where manufacturers will have to act to safeguard their future competitiveness. In addition, technological trends (see Chapter 3) such as the full integration of ICT and sensors into manufacturing processes, lightweight materials, material substitution, and evolving process technologies will help enable this transition towards a more sustainable manufacturing system⁵⁶.

⁵⁶ See Chapter 3 for further discussion of the technological trends impacting manufacturing out to 2050

The onset of this transition can already be observed in the UK. For example, sensors are currently used for monitoring the performance of many vehicles, to ensure repair and remanufacturing takes place before breakdown occurs, whilst local customisation and personalisation of products is already well established in products such as Nike trainers and 'made to order' Dell computers.

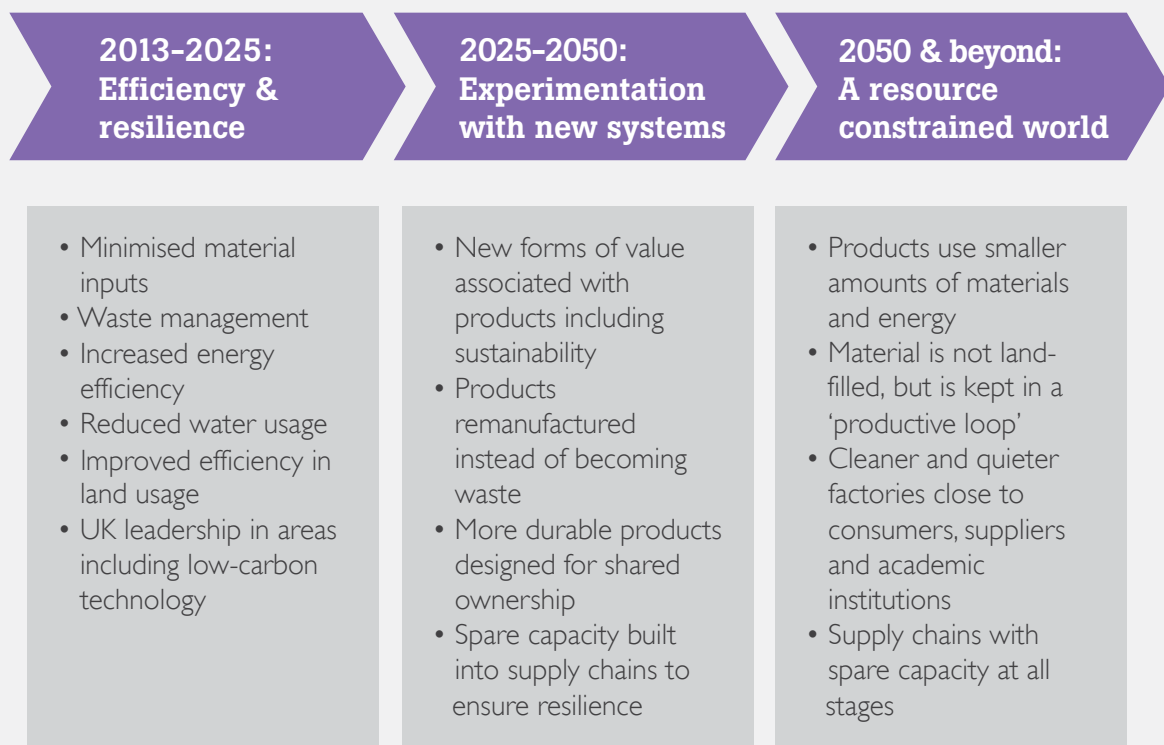
As well as becoming increasingly necessary from an economic and environmental perspective, sustainable manufacturing will become an important basis for differentiation in the market place, and for additional, and innovative value-creation. There are valuable opportunities here for the UK in utilising its skills and knowledge to research, develop and commercialise products that can be produced and used in a sustainable manner. However, the drive towards sustainable manufacturing will also create challenges and industry will have to conceive business propositions and technologies which satisfy multiple constraints simultaneously.

In this section, the need to shift towards a more sustainable manufacturing sector is discussed, focussing on three stages of transition: efficiency and resilience (2013 – 2025), experimentation with new systems and business models (2025 – 2050) and the world of 2050 (see Figure 5.5).

5.2.2 A FOCUS ON EFFICIENCY AND RESILIENCE (2013 – 2025)

During the period 2013-2025, sustainable manufacturing can be expected to focus primarily on achieving improvements and efficiencies in the use of raw materials, for example metals^{57,58}, and other inputs such as energy, as a strategy to hedge against volatility in commodity prices and increasingly vulnerable supply chains.

Figure 5.5: Three phases in the shift to sustainable manufacturing



Capital costs in factory design and infrastructure will constrain the magnitude of physical changes that are feasible. However the UK manufacturing sector, particularly the aerospace and automotive sub-sectors, has strengths in adapting to best practice⁵⁹ and making small adjustments. This section considers the resource management techniques that will be important out to 2025.

Resource management

Delivering the highest possible output of products from a given volume of resources (resource productivity) and using the lowest possible volume of resources to deliver a particular output (resource efficiency) are overarching strategic goals for industrial manufacturing processes. The improvement of both resource productivity and efficiency will become increasingly critical for the manufacturing sector in the future⁶⁰ as a result of changes in the availability and cost of materials, water and energy; government environmental regulations; 'pricing' of the environment⁶¹; and consumer 'pull' for more environmentally and socially sustainable goods. Manufacturers are likely to use a combination of approaches to resource management to remain competitive over the next decade and beyond which include:

- **Efficiency gains through best practice:** For example, 27% of freight truck journeys in 2007 involved a vehicle running without a load⁶². Efficiency gains can reduce costs and enhance reputation in terms of cost-effectiveness and green credentials.
- **Clean and resource efficient technologies:** These are needed to drive re-manufacturing and recycling, and to enable more effective management of materials, energy and water.
- **Widespread integration of sensors into products and factories:** These will generate vast amounts of information, 'big data', which leading manufacturers will use to analyse how their customers, factories and supply chains are operating. Sensors will also enable new products and processes which will provide opportunities to reduce material waste and increase the quantities of products which are monitored, repaired or refurbished before breakdown.

The key risk for the UK manufacturing sector is that it will be slow to adapt to these changes in resource management, making it vulnerable to supply chain shocks and rising resource costs. However, each new method for resource management provides an opportunity for the UK. If it can adapt quickly, it could gain first mover advantages. The need for improved resource management techniques will open up many new markets and opportunities for manufacturers, for example, in novel materials that are biodegradable, and in energy and water efficient technologies. The UK must therefore ensure that it is competitive in the design, development and commercialisation of these new technologies. The next section covers the key areas in which effective resource management will be needed: materials, energy, water and land.

Materials

Growing demand for materials, resulting in greater competition, higher prices and greater geo-political risk, means that manufacturers, out to 2025 and beyond, will need to increase the efficiency with which they use materials. A number of approaches are possible:

- **Minimising material inputs – substitution:** This involves replacing a critical material input to manufacturing with an alternative material, with any approach depending on the material and the product. Most progress has been made in finding alternatives to petro-chemically-derived materials that are susceptible to strong price volatility, for example fibres for structural composites derived from sustainable bio-feedstocks, such as hemp and flax⁶³. However, some materials used widely in UK manufacturing are not easily substitutable. Platinum, used in catalytic converters in motor vehicles is one such example. Reserves and production of platinum are concentrated in one country, South Africa⁶⁴, so any restrictions in supply would have a detrimental effect on the UK automotive industry, which accounts for around 5% of manufacturing GVA⁶⁵. In addition, some materials are becoming more expensive and difficult to dispose of, so there is a strong case for substituting them with materials⁶⁶ derived from sustainable sources or materials that are readily bio-degraded after use.

⁵⁹ Evidence Paper 21: McLaughlin, P. (2013) ⁶⁰ Lavery Pennell (2013) ⁶¹ For example pricing carbon and water (see Section 5.1.5 for further detail)

⁶² Lavery Pennell (2013) ⁶³ Evidence Paper 10: Grant, P. & Mason, T. (2013) ⁶⁴ Evidence Paper 27: Parker, D. et al., (2013) ⁶⁵ Defined as 'motor vehicles, trailers and semi-trailers'. ⁶⁶ Evidence Paper 10: Grant, P. & Mason, T. (2013)

- **Minimising material inputs – dematerialisation:** This involves using less material to achieve the same level of functionality in a product and is an area which the UK is strongly placed to exploit existing capabilities in lightweight materials including composites⁶⁷. The UK has additional potential to lead research into multifunctional materials, where combinations of material properties are used to conduct two or more tasks⁶⁸.
- **Waste management (re-use, re-manufacturing and recycling):** This entails reducing waste, recycling larger volumes and developing increasingly efficient recycling methods. Businesses such as British Gypsum are already embracing this way of operating (see Box 5.2) and the approach is being applied to certain materials for example cobalt, which had an 'end of life recycling rate' of 68% in 2010 driven by its high cost⁶⁹. Rising demand for recycling capability will provide an opportunity for UK manufacturers who produce recycling technologies. It is also worth stressing that additive manufacturing technology (see Chapter 3) is likely to make important contributions to waste per unit of output falling⁷⁰. However, the ability to recycle critical materials varies considerably across materials. For example, recycling of fluorspar, a material important within the chemicals sector, is usually not feasible⁷¹. Firms may need to develop capabilities in recycling and re-manufacturing their products to increase their resilience to supply chain shocks.

BOX 5.2: BRITISH GYPSUM CASE STUDY

In 2011, British Gypsum recycled 34,000 metric tonnes of used plasterboard to make new products and recovered 93,000 pallets from customers for re-use. This has reduced the need for raw gypsum from its quarry significantly. The initiative has been combined with a zero-waste to landfill target and the application of world class manufacturing production techniques. As a result, British Gypsum has avoided paying £9m a year in landfill tax and closed three in-house landfills, placing plasterboard on a stronger sustainable footing for the future⁷². The role of government in shaping the actions of the gypsum industry has been crucial and has included working with Department for Environment Food and Rural Affairs (DEFRA) (waste strategy 2007 and site waste management plans), the Environment Agency (position statement on land filling of gypsum, and work with the Waste and Resources Action Programme (WRAP) on quality protocols for gypsum) and the DEFRA programme to produce a gypsum road-map with the sector⁷³.

It is useful to distinguish here between the different methods for dealing with a product once the consumer no longer wants it, which is often not at the 'end of life' stage:

- **Re-use:** Redeploying a product without the need for refurbishment, for example second hand motor vehicles.
- **Re-manufacturing:** Returning a product to the performance specification of the Original Equipment Manufacturer and giving a warranty close to that of a newly manufactured equivalent.
- **Cascaded use:** Using a product for a lower value purpose, for example turning used clothes into pillow stuffing or redeploying computers within a business for less demanding applications.
- **Recycling:** Extracting a product's raw materials and using them for new products, for example aluminium and steel are widely recycled.
- **Recovery:** Using a product's materials for a basic, low value purpose such as road base or combustion to produce heat⁷⁴.

⁶⁷ Evidence Paper 10: Grant, P. & Mason, T. (2013) ⁶⁸ Evidence Paper 6: Dickens, P. et al. (2013) ⁶⁹ Evidence Paper 27: Parker, D. et al., (2013) ⁷⁰ Evidence paper 6: Dickens, P. et al. (2013) ⁷¹ Evidence Paper 27: Parker, D. et al. (2013) ⁷² EEF (2009) ⁷³ Plasterboard Sustainability Partnership (2012). ⁷⁴ Definitions are taken from: Lavery Pennell (2013)

The first two methods in the list are likely to increase in importance in the future. Re-use and re-manufacturing tend to capture more value than recycling as they preserve much of the value created through the manufacturing process. For example, a re-used iPhone retains around 48% of its original value, whereas its value as recycle is just 0.24%⁷⁵.

However, it is important to note that although rates of recycling in the UK have been rapidly improving in the last decade, re-manufacturing is currently limited: In 2011, re-manufacturing only represented approximately 1% of the total UK manufacturing sector turnover⁷⁶. This is likely to continue to be the case out to 2025, but looking out to 2050, the value that manufacturers gain from re-manufacturing will change drastically as it becomes an increasingly integral part of the manufacturing process.

Energy

In the decades ahead, the world is likely to experience rising energy costs, greater demand for energy from manufacturing firms, decreased security of energy supply and a growing imperative to decarbonise the global economy⁷⁷. The associated challenges and opportunities for manufacturers will depend on whether they are users of energy, providers of technology used in energy generation or transmission, and the energy required to use their product. The actions that will need to be taken can be broadly grouped into improving energy efficiency, decarbonising manufacturing energy, and improving the security of energy supply.

Energy efficiency: Since 2002, with the rapid rise in energy prices, manufacturers have expanded their energy efficiency programmes to reduce costs, with most manufacturing sub-sectors improving their energy intensity at 4% per annum or more⁷⁸. Approaches have included improving the design of equipment, better management practices, improved production processes, and off-shoring⁷⁹. Moving the entire UK manufacturing sector to current 'best practice' improvement rates would offer an energy savings of £1.9 billion per year⁸⁰. From an environmental perspective, estimates indicate that a 20% reduction in energy use by

manufacturing firms would result in a reduction in carbon dioxide emissions of 4.6Mt⁸¹. Developments in sensor technology (see Chapter 3) will provide opportunities for manufacturers to monitor their energy usage and improve energy efficiency. Additionally, the greater freedom of design that additive manufacturing will allow could be used to help develop energy efficient products which will improve overall competitiveness by providing a cost saving for the customer.

Decarbonising manufacturing energy: Firms which use significant amounts of energy are likely to face higher energy costs in the future resulting from a rising carbon price⁸². There are a number of actions that can be taken to minimise costs, including sourcing energy from low-carbon suppliers, producing low-carbon energy in-house, and reducing energy usage by co-locating with other industries to use any waste energy. If the UK can develop capabilities in specific renewable energy technologies, it could provide both increased security of energy supply for the UK and gain a significant market share if it is a first mover. For example, the UK's island geography means that it is well suited to generating tidal wave energy⁸³. This technology is not yet highly commercialised and as such provides an opportunity for the UK to lead. It has also been estimated that UK manufacturing can potentially capture value from low-carbon technologies relating to areas including tidal and wave energy, carbon capture and storage, and offshore wind worth £39.5 – £126.5 billion between 2010-2050, rising to £190 – £878 billion if supply chains are considered⁸⁴.

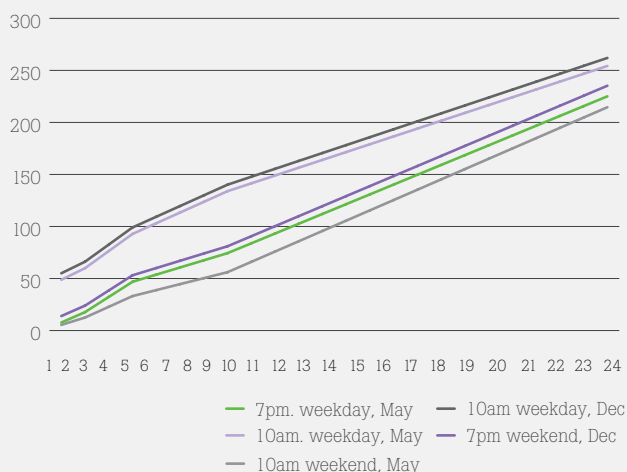
⁷⁵ Green Alliance (2013) ⁷⁶ Lavery Pennell (2013) ⁷⁷ Evidence Paper 35:Tennant, M. (2013)

⁷⁸ Evidence Paper 35:Tennant, M. (2013) ⁷⁹ Lavery Pennell (2013) ⁸⁰ Evidence Paper 35:Tennant, M. (2013) ⁸¹ Lavery Pennell (2013) ⁸² Evidence Paper 11: Green, R. & Zhang, X. (2013) ⁸³ Evidence Paper 25: Peng, M. & Meyer, K. (2013) ⁸⁴ EEF (2013a)

Ensuring security of the UK energy supply: Power system outages or disturbances have significant impact on the reliability and quality of the worldwide electricity supply. In an increasingly digital future world, even the slightest disturbances in power quality and reliability would cause loss of information, processes and productivity. The security of supply of the future UK energy system is likely to worsen, even in the short term. Figure 5.6⁸⁵ illustrates the potential economic impact of power outages on UK manufacturers. Significant investment in electricity networks is therefore likely to be needed, particularly in new technologies for transmission, distribution and energy storage. Their potential benefits include enabling low carbon energy supply systems, and facilitating flexible control and efficiency to ensure security of supply when power flows are variable. These variable power flows arise from uncertainties of generation, demand and energy market transactions. The demand for these new technologies will provide significant manufacturing opportunities out to 2050.

Figure 5.6: Impact of power outages on UK manufacturing

£ per employee



Source: Evidence Paper X: Tennant, M. (2013)

Water

Rising demand and therefore the rising cost of water in the future⁸⁶ will drive increased water efficiency amongst manufacturers, as well as the development of technologies which maximise water efficiency⁸⁷. Trends in water supply, cost and quality could have particularly significant implications for the

biotechnology sector, as there may be impacts on costs for using living organisms in the manufacturing process. Some UK manufacturers are leading the way on water efficiency. For example, Unilever is on track to abstract 40% less water per tonne of production in 2020 relative to 2008 across its network of global factories⁸⁸.

Increasing demand for water efficiency is likely to provide new markets for manufacturers of machinery and technology used in a wide range of industrial processes. However, UK manufacturers will face strong international competition in this area. Siemens Water Technologies, for example, are already leaders in providing water solutions, both equipment and services, to companies around the world⁸⁹. The growing demand for clean water by people, concentrated in cities, and manufacturing processes will provide manufacturers with new markets. For example, desalination technologies will become more important, as will efficient methods for transporting water from source to sink. By locating closer to one another, manufacturing firms in the UK could minimise their water usage and maximise opportunities to use, for example, waste water within a cooling process which does not require a high quality of water.

Land

Demographic trends suggest that the global population will, by 2050, on average be larger, wealthier and more urbanised⁹⁰. These trends, combined with a greater demand for food and bio-fuels, will place pressure on land use around the world, including in the UK, causing land prices to rise. Looking out to 2025, the likely reaction of manufacturing firms will be to improve the efficiency with which they use land in production processes. Manufacturers may, for example, increasingly build vertically rather than horizontally, co-locate different parts of the value chain, and share resources with other firms and sectors. More changes can also be expected in the farming-industrial system in terms of cooperation between farms and supply chains. Already companies such as AB Sugar in the UK help their farmers to reduce their use of energy, water and fertiliser while increasing yield⁹¹. However, the more radical and exciting developments in land use, for example through locating factories within cities, are more likely to be seen post-2025.

⁸⁵ Evidence Paper 11: Green, R. & Zhang, X. (2013) ⁸⁶ Evidence Paper 35: Tennant, M. (2013) ⁸⁷ See Section 3.1.2 for further details of how pressure on the global water system will increase dramatically out to 2050. For example, water supply crises are predicted to be the second greatest global risk out to 2022 ⁸⁸ For further details see: <http://www.unilever.com/sustainable-living/water/reducingwateruseinmanufacturing/index.aspx> ⁸⁹ Siemens Water Technologies [Online] Accessible from: <http://www.water.siemens.com/en/Pages/default.aspx> ⁹⁰ See Section 5.1.2 for further detail ⁹¹ Institute for Manufacturing (2013), [Online] Available from: <http://www.ifm.eng.cam.ac.uk/research/industrial-sustainability/resources/case-study-examples/ab-sugar/>

Looking to the future – what does this mean for UK manufacturing?

There is strong evidence that the UK manufacturing sector possesses the capabilities required to address the challenges of efficiency and supply chain resilience, which will be critical out to 2025. However, its performance is currently undermined by a lack of sufficient directed investment, resulting in the UK being a mediocre performer in resource management compared to its peers in the EU-27⁹². Some countries, for example China, are already making significant advances in resource efficiency (see Box 5.3). Support for improved resource management in manufacturing needs to be a priority for UK policy makers over the next decade.

BOX 5.3: EFFICIENCY IN CHINESE MANUFACTURING

Re-use of industrial waste in China is already being implemented via the enforcement of a 'Circular Economy Promotion Law' in 2009, with theories of 'industrial symbiosis'⁹³ put into practice by national and provincial governments who plan the agricultural, industrial, service, and other sectors. Numerous eco-industrial parks have also been implemented^{94 95}. China plans to spend some US\$454bn over the next five years on environmental protection, a doubling over the previous period, and a signal of a growing market for environmentally effective manufacturing technologies⁹⁶.

ADVICE FOR POLICY MAKERS:

Adapting regulations

Regulation for energy reduction: Effective energy reduction at no cost to the consumer has been demonstrated by some innovative schemes such as 'Top-Runner' in Japan⁹⁷. In this initiative, future product standards are set so that all products manufactured at a set point in the future must be at least as good as the best performance of today. This consumer-facing scheme could potentially be mirrored by 'top-runner factories' in the UK, assessed on energy usage.

Regulation on landfill reduction: The UK could consider going beyond the current landfill tax escalator, for example by putting a future landfill ban on glass, metal and other materials with a high energy input. This could be followed by slowly escalating the ban, for example by preventing recycled glass from being used in road-building, to promote re-use, re-manufacturing and recycling.

Forward looking government procurement:

Procedures need to be established to encourage supply of the best 'clean technology' equipment measured by long-term environmental and social performance in government procurement, as an incentive to UK manufacturers.

Integration into the industrial strategy: Using UK industry and research competence to ensure that sustainability is an integral part of the UK's industrial strategy. Failure to do this may encourage a trade-off between industrial success and sustainability.

Targeting R&D to improve resource efficiency

Material science: The development of novel materials is a potential UK strength given the UK's strong research capabilities in this area. The search for new materials that use local resources, or reduce the weight of energy-using products, or allow new functions to minimise waste, should be given high priority

Improved and more rapid recycling and recovery technologies: For example, to enable non-destructive removal of high-value parts from electronics within seconds, or recovery of metals from complex end-of-life products such as vehicles and aeroplanes.

Flow analyses for raw materials: This could differentiate dependencies on materials imported as raw material versus those embedded within finished or semi-finished components to inform a programme to reduce vulnerability to key materials.

Quantify potential reserves of critical raw materials in the UK: For example, assess the reserves of important manufacturing materials in UK mines.

⁹² Evidence Paper 35: Tennant, M. (2013) ⁹³ Industrial symbiosis is an association between two or more industrial facilities or companies in which the wastes or by-products of one become the raw materials for another. ⁹⁴ Chertow, M. R. (2004). ⁹⁵ Mathews, J. A. & Tan, H. (2011). ⁹⁶ Bloomberg (2013) ⁹⁷ Kimurao, O. (2010)

Conduct road-mapping activities with industry, government and academia to identify 'cool-spots': Cool-spots are specific technologies, performances and opportunities for value creation that are locally accessible and offer competitive advantage. Road-maps could show how industry-government-academia can deliver resilience and efficiency.

Sharing information

Consumer understanding and information:

Consumers who are aware of the water, energy and material footprint that a product holds need to be encouraged to make informed choices. To meet the demand from consumers for more information on the provenance of products requires improved product standards, information-labels and education materials.

Rapidly increasing the competence of the industrial system: The UK already has notable leaders in many of the dimensions of industrial sustainability, plus a number of competent institutional systems (for example the Technology Strategy Board, and Waste and Resources Action Programme). Actions already being taken by these and other organisations could be scaled up to ensure manufacturers have access to information to help them improve their sustainability.

5.2.3 EXPERIMENTATION WITH NEW SYSTEMS AND BUSINESS MODELS (2025 – 2050)

Looking beyond 2025, efficiency improvements are unlikely to be enough for UK manufacturers to thrive in a rapidly changing world. UK manufacturers will have to move beyond 'regular' innovations in terms of increasing efficiency through material extraction, use and dumping. They will need to embrace experimentation with new systems of manufacturing and new business models⁹⁸ which significantly increase their sustainability. This is also likely to support a 'decoupling' of national economic growth and well-being from environmental impacts such as the emission of harmful substances. Absolute decoupling

will only occur with a shift in thinking amongst manufacturers away from the simple 'make, use and dispose' approach. While there are some leading companies making significant efforts in this area, for example, Unilever and Marks & Spencer, efforts in the UK are uncoordinated and distant from what is required in terms of scale or scope.

In the period 2025-2050, when efficiency measures are likely to have been exhausted, there will be a need not only for radical innovation in business models but also in supply chains to provide greater resilience. The increasing incidence of extreme weather events and susceptibility of factories and resources located around the world will increase a range of global risks for the UK manufacturing sector⁹⁹. Both areas, business models and supply chain resilience are discussed in the next section.

Future business models and sustainability – creating value in a changing world

It is likely that many more aspects of value associated with manufactured products will become important in the future, including sustainability, personalisation, guarantees of provenance, and information which becomes 'attached' to products. At the same time, ownership will become increasingly decoupled from product use, facilitated by technology. The business models used by firms to create, deliver and capture this value (see Chapter 2) are therefore likely to change.

New forms of value associated with environmental and social sustainability mean that firms and policy bodies must understand, exploit and influence the role of standards, accreditations and other mechanisms by which value is captured. An obvious development here is for growth in demand from customers for products with guaranteed provenance which are supported by ubiquitous ICT and sensors. Concerns about treatment of remote supply chain workers, for example Bangladeshi textile workers, point to greater demand for more oversight and responsibility. Information technology will also allow changes to be made to systems and products, allowing further radical de-constructing and re-constructing of the activities involved in product manufacturing and product use. In this section, three relevant business models are considered: the circular economy, servitisation, and

⁹⁸ See the USA Advanced Manufacturing Initiative for early examples of this. The White House (2012) ⁹⁹ Further details of extreme weather events and their potential impact on supply chains can be found in Section 5.1.3

collaborative consumption. They provide solutions to different problems and therefore should not be considered as mutually exclusive.

The circular economy

The scarcity of materials, combined with growing costs and environmental impacts of energy consumption and waste disposal make the original manufacture of products less desirable. Manufacturing firms will be pushed towards systems that entail a 'circular flow' of products and allow a shift from a linear economy to a circular economy i.e. from an economy based on the conversion of raw materials into products which end their lives as waste, to an economy where products are re-used, 're-purposed', repaired, re-manufactured and recycled, cascaded, and recovered (see earlier definitions in this chapter) rather than being used and discarded. This concept of the circular economy is already established in some firms (see Box 5.4).

BOX 5.4: EXAMPLES OF FIRMS EMBRACING THE 'CIRCULAR ECONOMY'

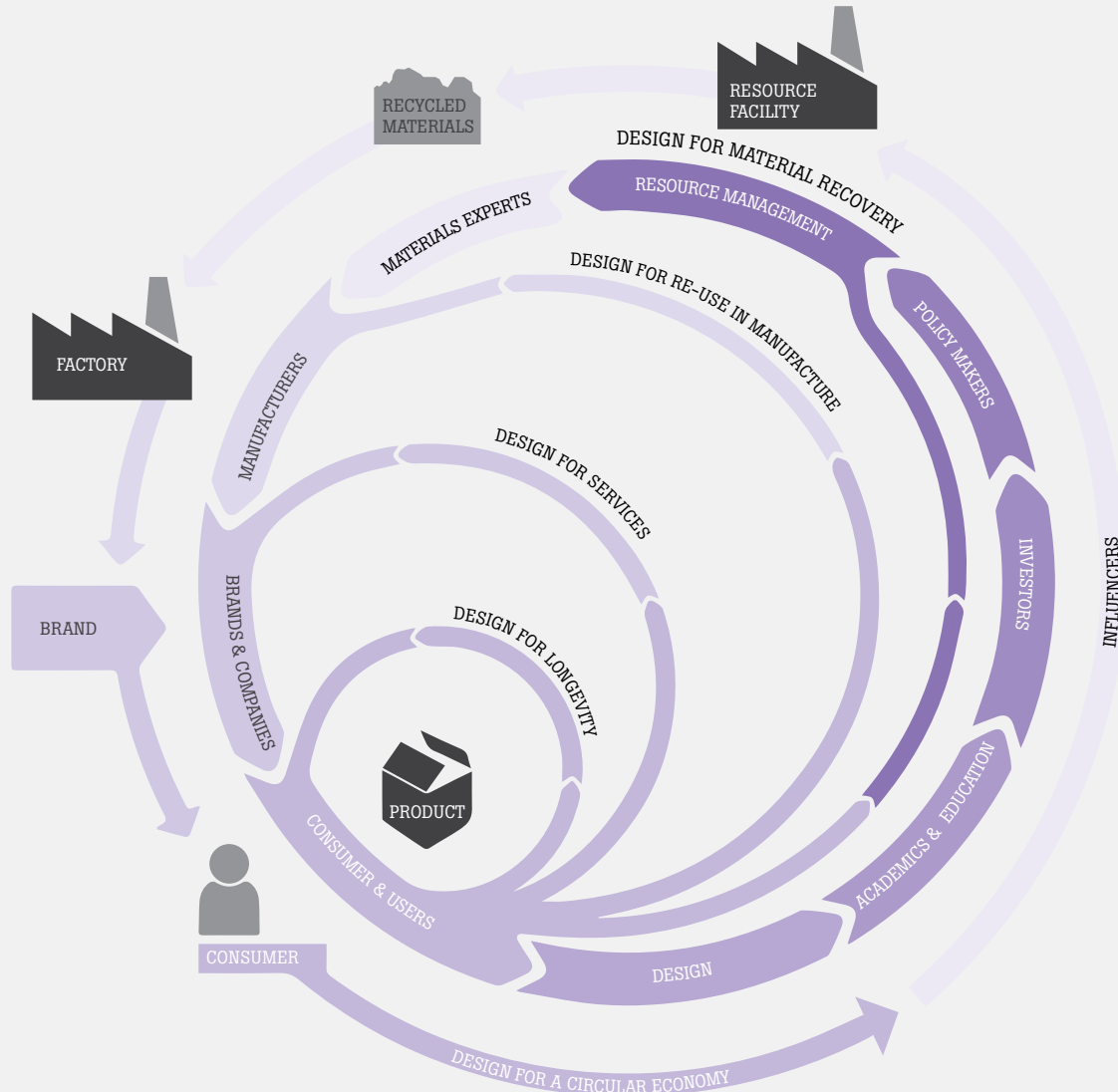
Caterpillar Inc.: Caterpillar is a US based leading manufacturer of construction and mining equipment, diesel and natural gas engines, industrial gas turbines, and diesel-electric trains. The business runs 'Cat Reman', a re-manufacturing programme that returns products at the end of their lives to same-as-new condition, and seeks to find new ways to reduce, re-use, recycle, and reclaim materials which once would have gone into a landfill. During 2012, Cat Reman took back over 2.2 million end-of-life units for re-manufacturing¹⁰⁰.

JC Bamford Excavators Ltd (JCB): JCB is one of the world's top three manufacturers of construction equipment, based in the UK. Through the JCB Service Exchange, the business helps plant users to reduce owning and operating costs, with a comprehensive range of re-manufactured parts for all its machines. Around 1 650 high quality parts, all re-manufactured to Original Equipment Manufacturer standards and protected by the same warranty conditions as new parts, are offered. With typical savings against new parts of 40-50%, the re-manufactured parts can restore machines to their optimum condition at a more affordable price. Furthermore, re-manufactured parts are upgraded to incorporate the latest technology¹⁰¹.

By associating a cost with both end and waste products of a linear value chain, the chain can be joined up either with other value chains, forming networks of industrial symbiosis, or with itself, as conceived in 'closed-loop', 'cradle-to-cradle' or 'circular economy' strategies¹⁰² (see Figure 5.7¹⁰³, which shows how materials can be kept within the value system). These ideas were discussed extensively at the project's three international workshops¹⁰⁴ and are being developed in the UK by organisations including the Royal Society for the Arts, Manufactures and Commerce (RSA) and the Ellen MacArthur Foundation¹⁰⁵.

Material scarcity, oil prices, extreme weather events and wider sustainability pressures may lead to a desire for greater self-sufficiency within national borders, or at least within Europe. As such, it is possible to envisage a manufacturing system where re-manufacturing and re-use is the norm, and origination of products from virgin raw materials is the exception. Manufacturing sub-sectors that offer the greatest opportunities to capture significant value from circular resource use are electrical, electronic and optical products, machinery, and equipment and transport equipment¹⁰⁶.

Figure 5.7: The circular economy model demonstrating how materials can be kept within a productive loop



Source: RSA (2013)

The shift towards a circular economy, combined with a trend of pricing ecosystem services, could provide manufacturing firms with new revenue streams. Currently manufacturing can involve the production of by-products which are considered waste and with a zero price value, for example waste heat, and ecosystem services which produce clean water. As these by-products become increasingly valuable, they can be traded between manufacturing firms and more widely in the economy. Business models that capture value from under-utilised resources include those characterised as 'industrial ecology', where industries are generally

co-located to utilise what would be waste for one business as resource for another. This has the potential to reduce reliance on virgin raw materials and mitigate against volatility in energy prices (see Box 5.5).

BOX 5.5: INDUSTRIAL ECOLOGY CASE STUDY

Adnams plc: Adnams, a UK brewer, has developed a number of initiatives based on principles of industrial ecology. A solar-powered anaerobic digester converts brewery and local food waste to fertiliser and biogas, replacing liquid fossil fuel in their transport fleet. This approach, when implemented, is predicted to reduce the company's CO₂ emissions by 200%¹⁰⁷.

However, all these developments will only be possible with the innovative use of existing technology, and further technological developments. The integration of ICT and sensors (see Chapter 3), enabling the sharing and intelligent use of information, will enable greater coordination and collaboration between businesses, and between business and consumers. This coordination and collaboration is critical to establishing the circular economy as a viable business model in the UK manufacturing sector.

Servitisation

Services will provide important ways to create extra value (see Chapter 2) as manufacturers support, complement or enhance their products. Servitisation will become an intrinsic part of a manufacturing which exists within more circular, interactive ecosystems where value is created between, rather than predominantly within, firms.

However, managers in manufacturing firms often find organisational, conceptual and institutional obstacles to bringing about these bold moves into services. If the addition of services is at least in part an indication of innovation in business models, the UK lags behind a number of international comparator nations, with the US being the most advanced¹⁰⁸. Service innovation is much more inter-organisational in nature than product innovation and, especially, process innovation. This suggests that firms' capabilities in interacting with network counterparts to bring about the types of innovation needed to develop new business models may need to be strengthened.

Collaborative consumption and changing ownership

'Collaborative consumption'¹⁰⁹, a type of rental model, may become more prevalent in the face of environmental pressures. It focuses on developing business models based on shared use of assets, rather than individual outright ownership, facilitated by online methods for finding, booking and paying for use. It shifts consumer values from ownership to access. Collaborative consumption is also linked to the trend of servitisation of the manufacturing sector.

Examples of collaborative consumption are leasing of car fleets, and car rental. In a rental model, firms are providing customers with the service that the product offers, rather than the product itself. Benefits for the customer include low-capital requirements and lower risk from not owning the product. Collaborative consumption also creates wider social, environmental and financial benefits by deliberately setting out to internalise costs which are traditionally externalised, and where the superior technical knowledge and/or co-ordinating capacity of the manufacturer can be used to reduce the impacts of total life cycles.

For example, contracts that provide customers with cars at a fixed cost per mile travelled (including fuel) would encourage the car manufacturer to offer very efficient vehicles as they make increased profit by purchasing less fuel but offering the same miles travelled. Collaborative consumption and experimentation with business models hold great potential but require well developed buyer-supplier co-ordination. There is a potentially important role for government procurement which uses a whole 'life cost' approach as a tool for reducing costs and supporting industrial innovation.

Looking to the future

The exact approach to models for a circular economy and collaborative consumption will vary depending on the firm. However, there are common principles that will be required. These include products that need to be designed for durability, standardisation of components, modularity and ease of disassembly to facilitate upgrading and re-manufacture, and low toxicity to allow for biodegradation.

Technological trends therefore have important implications for the types of business models that can be used in the future. New manufacturing technologies, such as additive manufacturing and green chemistry¹¹⁰, will decrease the material and energy intensity of products, with the additional benefit of being economic at a smaller scale than traditional manufacturing equipment. This will encourage experimentation with the scale and location of manufacturing, as well as business models. For example, some factories may choose to locate next to customers and use more local materials, while others might locate near a reliable source of renewable energy. Consumers will be offered much greater product choice which approaches personalisation. In some cases products may be personalised, for example, drug delivery systems. Physical components will be replaced with software where possible, offering manufacturers' choice in where they locate their activities.

It is important to note that these business models have not been extensively tested and it is not clear how they will work for businesses and consumers in a hyper-consumptive economy or in rapidly growing markets where ownership can be a sign of affluence. Numerous barriers have to be overcome for the circular economy model to be fully adopted in manufacturing. What is clear is that it will fundamentally change the way manufacturing is conducted as products will have to be redesigned to be considerably more durable.

Sustainability¹¹¹ has become a pervasive long-term theme in the discourse on the future development of manufacturing business models. However, other than niche companies, there is little evidence to suggest that the UK is engaging with this radical

agenda at the scale necessary to either reactively or proactively capture future value from the challenges to sustainability expected in the next 20 years. Support for research in the broad area of sustainable manufacturing and the development of new business models, plus support with translating research findings into commercial value, would lead to significant opportunities for the UK. This support is currently lacking¹¹².

Resilience of supply chains

Traditionally, businesses have prioritised short-term cost-efficiency, through for example off-shoring and out-sourcing manufacturing, and reduced inventory capacities, and many have come to rely on single sourcing rather than having alternative suppliers. However, in recent years supply chains have become more vulnerable as a consequence of globalisation and this trend is likely to become stronger as environmental challenges grow in the future.

Lower costs and a lack of in-house or national capability lead many UK manufacturers to have part of their supply chain located overseas. Twenty per cent have half of their suppliers outside of the UK, with Asia supplying over half of UK manufacturers¹¹³. Asia and Pacific countries supply materials which are essential to the UK manufacturing sector, including iron ores, copper, aluminium and industrial minerals¹¹⁴. The most significant impacts of disruption to overseas supply chains are reported to be loss of orders and revenue, followed by delayed cash flows¹¹⁵. UK manufacturers have responded to the challenge of vulnerable supply chains by expanding overseas collaboration, sourcing from multiple suppliers (despite quality control issues and increased transaction costs), and increasing their use of local suppliers and on-shoring.

Looking out to 2050, supply chains will need to show redundancy to be resilient. This means having alternative distribution networks, including alternative modes of transport and suppliers. A supply network where multiple potential supply chains can form as needed should be more resilient, but would be accompanied by increased transaction costs. Redundancy is ostensibly at odds with efficiency, where buffering capacity is removed to save transaction costs. However, in the long

¹¹⁰ Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. ¹¹¹ See Section 5.1.1 for a definition ¹¹² Evidence Paper 35:Tennant, M. (2013) ¹¹³ Evidence Paper 35:Tennant, M. (2013) ¹¹⁴ Evidence Paper 35:Tennant, M. (2013) ¹¹⁵ Evidence Paper 35:Tennant, M. (2013)

term and in the face of significant disruption from the effects of climate change and rising population growth, additional costs may be negligible compared to the costs of inflexibility. A more collaborative approach to supplier interaction is yielding significant benefits for pioneering manufacturers who are creating efficiencies between multiple steps in their supply chains (vertical collaboration¹¹⁶) and across a breadth of suppliers (horizontal collaboration¹¹⁷).

ADVICE FOR POLICY MAKERS:

Business model innovation: This is a critical component of preparing for a disrupted world. The potential of new business models need to be explored at increasing pace, depth and scale. Barriers, such as differential tax rates for services or service innovation and investment, need to be removed.

Business model innovation through internalisation: There is a need to reward and recognise those business models that seek to internalise environmental costs. For example, by encouraging business models that focus on re-manufacturing and re-use, and avoid dissipation of polluting or harmful substances. An encouraging study carried out by WRAP has shown there is a great opportunity for businesses to repair and re-sell home electronics. Waste from electrical and electronic equipment (disposed of via household waste recycling centres) is estimated to be worth £200 million in gross revenue per year¹¹⁸.

Procurement: There is a case for building competence in government procurement which encourages innovation, accounts for the impacts of decisions on product life cycles, and seeks to internalise environmental costs. This could be achieved through challenge-led procurement i.e. asking manufacturers to develop a solution to a particular problem rather than asking them to provide an existing product or service.

Urban planning: In the future, some factories will want to be closer to the customer or to supplies of materials. These factories may be much smaller and less polluting; they may even be in the local retailer. The UK planning system will need to adjust as needed so that appropriate mixed-use development is not discouraged.

Experience shows that it is often best to experiment before a disruption occurs, so that knowledge and tools are already available to tackle any adverse impacts, and take advantage of any new opportunities. Many of these actions could begin now and slowly scale-up to create significant UK adaptive capability.

5.2.4 SUSTAINABLE MANUFACTURING IN 2050

The drive for sustainability will create a multitude of challenges and opportunities for global manufacturing which the UK needs to grasp. By 2050:

- Manufacturing firms could be part of a wider 'circular economy', requiring some degree of co-location with other firms.
- Many products will have more value but use smaller amounts of energy and material, where the material is not land-filled but kept in a productive loop.
- Technological developments resulting in cleaner, quieter factories that reduce pollution levels through their processes, will enable factories to be built in more densely populated areas.
- Urban manufacturing could foster greater levels of collaboration due to the close proximity of suppliers, competitors, consumers and academic institutions.
- Waste heat from factories could be used in nearby schools, and the greater interaction between industrial enterprises and schoolchildren would help to dispel the misconceptions about manufacturing that many people hold¹¹⁹.
- Resilient supply chains will have in-built redundancy at all stages, including re-manufacture and recycling; greater security of energy supply will lead to increased resilience to power disruption.

¹¹⁶ Vertical collaboration is the pooling of resources and capabilities by complementary organisations up and down the supply chain ¹¹⁷ Horizontal collaboration is the pooling of resources and capabilities by competing organisations across the supply chain ¹¹⁸ WRAP (2013) ¹¹⁹ Evidence paper 19: Livesey, F. (2013)

- Factories that allow customers to interact with their products as they are being made could enable greater personalisation of certain goods. A customer that can see their car being made will feel more involved in the process and may be willing to pay more for a personalised product.
- The relationship between customer and manufacturer will undergo profound changes, with more customers having their data used to create personalised products, and to identify other needs that even the customer is unaware of.
- Governments may lean towards the implementation of policy regimes which recognise the public good of manufacturing, and help manufacturers to internalise those effects.
- The ability of manufacturers to access finance and technical resources will mean that factories can for example, bring potable water to a village or offer waste heat for local housing.

A more sustainable manufacturing sector in 2050 has the potential to be both exciting and competitive. Ultimately it will be essential in a dramatically changed world. However its success will depend on both an appropriate policy environment created by government and a UK industry which is willing to take radical steps to innovate in the way it does business.

ADVICE FOR POLICY MAKERS:

Policy measures that facilitate a shift towards a circular economy: This also directly addresses conservation of critical resources. Product policies such as eco-design standards involving minimisation of critical raw materials, and design for recovery; developing purchasing demand through green public procurement; continually introducing measures for producer responsibility to promote value recovery¹²⁰ (i.e. producers have a responsibility to deal with a product after the customer has finished using it); and supporting efforts to scale-up circular material flows by, for example, promoting information sharing and collaboration between firms and wider society.

Sub-sector detail: The future form of sustainable manufacturing operations needs to be explored in detail for each subsector through research and collaborative road-mapping. For example, WRAP provide several studies explaining the business cases for the repair and re-sale of specific types of technology, for example white goods, power tools and desktop computers. It also offers one-to-one support for businesses who wish to implement a repair service as part of their offering¹²¹.

International cooperation strategies: To help ensure competitiveness, the UK needs to play a central role in developing international strategies for resource extraction and use. These are likely to become increasingly important out to 2050 as growing demand will place greater pressure on natural resources.

Intellectual Property: The regulatory system for intellectual property needs to become more flexible and adaptable as new technologies and business models develop and become commonplace. Government must consider the implications of the shift towards a circular economy for intellectual property as rates of repair and re-manufacturing rise. The boundary between repair and reproduction is currently blurred and may become more so with the ease of copying parts¹²².



6. INCREASINGLY DEPENDENT ON HIGHLY SKILLED WORKERS

The people who work in the UK manufacturing sector will play a critical role in how manufacturers create and capture future value.

Strong future demand for workers is likely, however within a context of small further reductions in the total workforce size. Demand will be for workers with 'hybrid skills' – deep technical specialism combined with commercial and problem solving abilities – and with Science, Technology, Engineering and Mathematics (STEM) qualifications.

Manufacturers will need to rise to new challenges including accommodating greater numbers of older workers, and considering the potential role of future human enhancement. Ongoing issues will also need addressing, including the poor public perception of manufacturing, particularly amongst young people and women, and the quality of UK manufacturing leaders and managers compared to key international competitors.

This Chapter examines a number of important changes relating to the role of people in manufacturing. It concludes by outlining a range of implications for Government relating to the future quantity, quality and utilisation of suitably skilled people who will be critical as manufacturing becomes increasingly dependent on highly skilled workers.

6.1 THE ROLE OF PEOPLE IN MANUFACTURING

KEY MESSAGES

Despite historic declines, future demand for manufacturing workers will be strong

- UK manufacturing employment has declined significantly in the past (nine million people in 1966 and below three million in 2011). Any future declines will be much smaller, with around 170,000 fewer people in the sector expected by 2020 compared to 2010.
- However, there will still be strong demand for workers, with around 800,000 roles to be filled up to 2020 as people retire or leave the sector. Manufacturing output is likely to continue increasing without associated increases in direct employment.
- Over the period to 2050 the UK will have an ageing population, with the number of people aged 65 years and over (i.e. of 'traditional' retirement age) set to increase, while the numbers of 'traditional' working age are set to decrease. By 2030, 17% of the population will be aged between 60-74.
- Manufacturers may need to accommodate greater numbers of older workers, and respond to growing markets for 'age-neutral' and 'age-specific' products.

Demand will be for workers with a technical specialism combined with commercial and problem-solving abilities, in addition to STEM qualifications

- To be successful in high value manufacturing, the UK and other developed economies will need to compete in the future on the quality of their workforce.
- With regard to future demand for skills, by 2020 an additional 80,000 people in the UK are expected to be employed in managerial, professional and technical roles in manufacturing. This is likely to contribute towards these roles eventually accounting

for around 40% of total manufacturing employment.

- Factories of the future are likely to require workers with a breadth, depth and mix of skills. Interdisciplinary 'hybrid skills' will need to blend specific technical skills, with commercial competence and problem-solving abilities.
- This implies strong demand for workers at apprentice, degree and technician level with STEM qualifications, particularly in product design and development roles. Future demand could exceed supply, particularly as only a quarter of engineering and technology graduates tend to work in manufacturing six months after graduation.

Perception of manufacturing and the quality of leaders and managers are key issues

- The UK currently fares poorly, when compared internationally, on the quality of its managers. For example, 42% of managers in UK manufacturing firms have degrees, compared with 60% or more in India, Japan, Germany, the USA and France. Strong leadership teams and distributed leaders in key positions throughout manufacturing businesses will become critical in the future.
- Young people and women tend to have a negative perception of manufacturing, with 67% of girls aged 7-11 years indicated that they would not like a job in manufacturing compared with 44% of boys. If this continues, it may well affect the number and profile of people considering or choosing manufacturing as a career.

Other key issues include changing labour costs and potential human enhancement

- Changes in relative labour costs by country will be complicated by changes in exchange rates, advances in technology and automation, productivity differentials and other factors. As a result, the identities of competitors will continue to change.
- By 2050, human enhancement to improve mental performance and mobility, and to counter biological ageing, may have impact on the manufacturing workforce.

6.1.1 INTRODUCTION

The people who work in the UK manufacturing sector will play a critical role in how manufacturers create and capture future value. Nine areas of change, summarised in Figure 6.1, are reviewed in detail in this section. Individually, each area of change has the potential to have high impact. Collectively and in their various potential combinations, the changes are likely to transform the number and nature of manufacturing jobs available.

Figure 6.1: The nine areas of change likely to transform the role that people play in how UK manufacturing activities create and capture future value by 2050



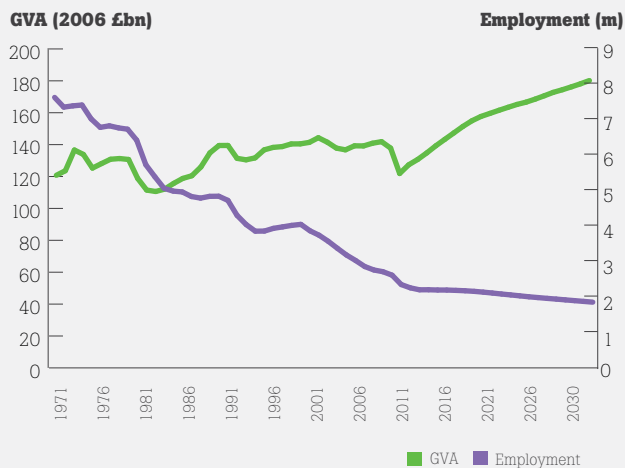
6.1.2 THE LONG-TERM DECLINE OF EMPLOYMENT IN MANUFACTURING

There has been a long-term decline in employment in manufacturing in the UK. It seems likely that the biggest reductions in employment have already occurred in the final three decades of the 20th century. In 1966 there were nearly nine million people employed in manufacturing in the UK (defined according to the Standard Industrial Classification (SIC)). By 2011 this had decreased to below three million, or 10% of the workforce^{1,2}, (see Figure 6.2)³. Amongst the largest declines were those experienced by the textiles industry, which employed over 800,000 workers in 1966 and only 70,000 in 2011. Similarly, the shipbuilding and marine engineering industry employed over 200,000 people in 1966 but only 40,000 in 2011.

The use of Standard Industrial Classification (SIC) categories to measure employment tends to overstate the loss of manufacturing employment. Some activities formerly coded to manufacturing now appear in services but it is beyond doubt that the overall loss of jobs in manufacturing has been substantial. The pattern of a declining share of total employment accounted for by manufacturing as an economy becomes more prosperous is evident in many countries⁴. By 2011, the proportion of total employment in manufacturing in the UK at about 10%⁵ was not substantially different from most of the rest of Western Europe and North America, although it was lower than in Germany, Italy and Japan.

The most acute impact of manufacturing job loss in Great Britain has been felt at the scale of the local labour market in the north and the midlands. Those in manual and unskilled occupations have been affected most acutely⁶ (see Box 6.1). It is not only the manufacturing workforce which has borne the brunt of job losses in the sector. More broadly, competition in the labour market means that worklessness gravitates to those with the weakest positions in the labour market, who have low skills, poor health and unstable work histories. This tendency is likely to continue in the future.

Figure 6.2: Output & Employment in Manufacturing: historical & projected trends 1971 to 2030



Source: Cambridge Econometrics MDM

¹ Derived from the Department for Employment; Business Register Employment Survey; and Annual Population Survey Workplace Statistics; reported in Evidence Paper 9: Fothergill, S. & Gore, T. (2013). ² Evidence Paper 36: Wilson, R. & Hogarth, T. (2013) ³ This is a reproduction of Figure 2.1 in Evidence Paper 36: Wilson, R. & Hogarth, T. (2013) ⁴ McKinsey Global Institute (2013a) ⁵ Evidence Paper 36: Wilson, R. & Hogarth, T. (2013) ⁶ Clayton N. (2011)

BOX 6.1 IMPACTS OF REDUNCIENCIES IN MANUFACTURING

Closures of large manufacturing plants tend to be well publicised. The very large redundancies such as the loss of 6,500 jobs at the MG Rover plant at Longbridge in the West Midlands in 2005 are now infrequent but job losses still have important local, regional and human impacts. When localised manufacturing job losses occur, the employment outcomes and trajectories of the workers involved are a function of:

- The employability attributes of the individuals concerned;
- Local demand, and geographical mobility which influence transitions into new employment; and
- The effectiveness and take up of policy interventions to help redundant workers⁷.

Three years after the closure of the MG Rover plant, and in the context of a relatively buoyant economy, 90% of the workers had gained new employment. However, the majority of individuals reported a decline in real earnings. It was the younger and more highly skilled workers who were able to find new jobs most quickly, often in the manufacturing sector; whereas older and less skilled workers took longer to find work, and after retraining often took up positions in services.

These outcomes were achieved in the context of significant economic growth and diversification of the local and regional economy. They were supported by policies to up-skill the local and regional workforce and a policy response to mitigate the impact of the closure⁸.

Future manufacturing employment

It is likely that future increases in output in manufacturing will be associated with some further reductions in the overall size of the manufacturing workforce, with around 170,000 jobs expected to be lost between 2010 and 2020⁹ (see key messages box in Chapter 4 for alternative projections).

Despite this overall decline, projections indicate that there will still be about 800,000 manufacturing roles to be filled by 2020 due to people leaving or moving within the labour market.

Looking to the decades ahead, it seems likely that few 'low value and high employment' manufacturing activities will remain in the UK, even in the context of some onshoring (see Chapter 4). Manufacturing in the UK will therefore be mainly 'high value, low employment'¹⁰ and is unlikely to lead to the creation of significant numbers of new jobs¹¹. Activities that do not fit with this expected trend are likely to be in market niches that:

- Are relatively insulated from international competition; and/or
- Have difficulty in transporting raw materials/products long distances; and/or
- Are intimately associated with where they are produced¹², for example food associated with a specific region, or branded clothing associated with a specific country.

6.1.3 COMPETING ON WORKFORCE QUALITY

To be successful in high value manufacturing activities, the UK and other advanced economies will need to compete in the future on the quality of their workforce¹³. Currently the UK has longstanding strengths in advanced manufacturing sub-sectors, such as pharmaceuticals and aerospace, where workforce quality is a key ingredient. Developments in existing and new technologies provide potential opportunities to enhance strengths in these and other high value manufacturing activities. If these opportunities are to be realised, the supply of skills will need to keep pace with the demand for a high quality workforce.

⁷ Shuttleworth I., Tyler P. & McKinstry D. (2005) ⁸ Bailey, D, Chapain, C. & de Ruyter, A. (2012) ⁹ Evidence Paper 36: Wilson, R. & Hogarth, T. (2013)

¹⁰ Evidence Paper 9: Fothergill, S. & Gore, T. (2013) ¹¹ Livesey, F. & Thompson, J. (2013) ¹² Evidence Paper 9: Fothergill, S. & Gore, T. (2013).
Wilson, R. & Hogarth, T. (2013) ¹³ Evidence Paper 36: Wilson, R. & Hogarth, T. (2013)

6.1.4 CHANGING LABOUR COSTS

Even though workforce quality will be critically important in the future, labour costs will not be irrelevant. The share of labour costs, compared to materials, energy and other costs, varies markedly between sub-sectors of manufacturing. With trade liberalisation, labour-intensive tradable sub-sectors of manufacturing, including clothing, textiles and footwear, have shifted away from Western Europe and the US to low-cost locations. These locations have changed over time, as shown by the shift away from China to countries such as Bangladesh, Cambodia, Indonesia and Vietnam. Consumers' concerns about working conditions in some of these countries may lead to increased labour and production costs in the future, so reducing the current comparative advantage of low-cost labour¹⁴. In some other segments of manufacturing, labour costs are lower as a share of total costs and so there has been less imperative to seek low labour cost locations.

Changes in relative labour costs in different countries compared to the UK mean that the identity of the UK's competitor countries might change. Over time, low-cost locations may potentially shift to become higher-cost locations. The picture is likely to be complicated further by changes in exchange rates, and advances in technology and automation. For example, advances in technology and automation appear set to imply reductions in labour content, so making labour costs a less important factor. However, a shift away from mass production towards small batch manufacturing may mean increased labour costs in terms of research and development (R&D), and design, and limited potential for cost savings in production.

6.1.5 CHANGING DEMAND FOR SKILLS

Skills demand is driven by a mix of factors including technical change, regulation, globalisation, political change, demographic change, and strategic locational choices made by companies. At the firm level, the marketing strategy for products is a key driver of demand for skills. Some firms demand relatively low skills and pay relatively low wages in a low value added segment of the market, while others have a product market strategy demanding high skills, pay relatively high wages and compete in high value added markets¹⁵.

Medium-term employment projections by occupation for the UK suggest an increase in the share of employment in managerial, professional and associate professional and technical roles in manufacturing between 2010 and 2020. A net increase of nearly 80,000 additional people employed in these roles in the UK is projected (see rows 1, 2 and 3 in Table 6.1¹⁶), which would result in these roles comprising around 40% of the total projected manufacturing employment of around 2.4 million in 2020. This implies a continuing demand for workers at degree and technician level, particularly in product design and development roles.

This increase is projected to occur in the context of a projected overall net decline of 170,000 jobs in manufacturing across all occupations by 2020¹⁷, with skilled trades occupations and process, plant and machine operatives being the largest contributors to employment decline. However, once 'replacement demands' created by people leaving the workforce due to retirement or moving within the labour market due to career changes and other reasons are factored in, there will be a positive total requirement in each occupational group and for nearly 800,000 jobs to be filled overall by 2020¹⁸. Many roles and sub-sectors in manufacturing will face significant net requirements for workers. This means that despite a projected employment decline in total manufacturing jobs, employment opportunities in manufacturing will remain.

¹⁴ McKinsey Global Institute (2013a). ¹⁵ The former may be characterised as being in a 'low skills equilibrium', while the latter are in a 'high skills equilibrium' (see Finegold, D. & Soskice, D. (1988)). ¹⁶ This is a reproduction of Table 2.1 in Evidence Paper 36: Wilson, R. & Hogarth, T. (2013) ¹⁷ Evidence Paper 36: Wilson, R. & Hogarth, T. (2013) ¹⁸ Wilson, R.A. & Homenidou, K. (2012)

These projections are for the period to 2020, based on assumptions about the future made at the time that the projections were prepared. There is greater uncertainty regarding employment projections further into the future. However, in the absence of major breaks in trend, a similar pattern of change would be expected although sub-sectors within manufacturing may have specific requirements (see Table 6.2^{19,20} for selected sub-sectors). However, beyond 2020, there are likely to be future skill demands for managers, professional staff and technicians across all these sub-sectors.

Table 6.1: Projections for employment and replacement demands by occupation in UK manufacturing, 2000-2020

ACTUAL (000s)	2000	2010	2020	CHANGE 2010-2020		
				NET CHANGE	REPLACEMENT DEMANDS	TOTAL REQUIREMENT
1. Managers, etc.	337	267	297	30	111	141
2. Professionals	432	319	349	30	113	143
3. Associate professionals	462	288	305	17	104	121
4. Administrative and secretarial	416	191	173	-19	85	66
5. Skilled trades occupations	1437	651	543	-108	245	136
6. Caring , leisure and other service	30	20	25	5	8	13
7. Sales and customer service	100	76	74	-3	25	22
8. Process, plant and machine operatives	1338	503	389	-114	199	85
9. Elementary occupations	393	202	193	-9	75	66
Total	4944	2518	2347	-170	965	795

Source: Working Futures

Table 6.2: Long term skill demands in selected manufacturing sub-sectors and technologies

SUB-SECTOR	MANAGEMENT SKILLS	PROFESSIONAL SKILLS	TECHNICAL SKILLS
Aerospace	Capacity to negotiate in complex global markets	Mix of technical and business skills required to manage complex projects and international supply chains involved in design and R&D	Engineering (electrical and mechanical)/software (modelling and simulation); knowledge of advanced materials
Plastic and silicon electronics	Ability to bring new products to market and manage the transition from producing prototypes to higher volume production		Testing, prototyping and being able to implement new designs. Skills related to using plastic electronics
Biotechnology/ Pharmaceuticals	Management of new product development	Need for scientists capable of working across boundaries of biology/genetics/chemistry/chemical engineering	Technicians capable of working with the new production systems required to produce biotechnology products
New materials/ composites	Skills related to the commercialisation of new materials	Scientists and technologists are required to develop new composites applicable to sectors e.g. automotive, aerospace,	Technicians capable of working with the new production systems required to produce biotechnology products
Nanotechnology	As a new embryonic technology there is a need for managers and professionals (especially scientists) across the manufacturing sector to identify how nanotechnologies can be incorporated in to products and processes		Higher level skilled technicians will be required in the handling and use of nanotechnologies.

Source: derived from information provided in SEMTA (2009)

The importance of STEM skills

It has long been recognised that the acquisition and utilisation of STEM skills is critical to the ability of UK manufacturing to develop and maintain high value product market strategies. The total demand²¹ for Science, Engineering and Technology (SET) professionals between 2012 and 2020 in manufacturing has been estimated at 100,000 in the UK. Construction, business services, and computing and telecommunications display similar or higher levels of demand for SET professionals over this period, with a total demand of 830,000 across these sectors of the economy²².

Demand for STEM graduates is high, with employers across many sectors of the economy seeking generic skills associated with STEM qualifications (for example numeracy, IT skills and logical thinking). This is borne out by findings from the Futuretrack study which showed that STEM graduates believed that the subject they studied was an advantage when looking for employment and were more likely than non-STEM graduates to find the job they wanted^{23, 24, 25}.

²¹ Calculated as expansion demand plus replacement demand. ²² Harrison, M. (2012) ²³ Futuretrack tracked applicants for a full-time place in higher education in 2006 as they made their way through the undergraduate stages of higher education and onwards ²⁴ Purcell, K., Elias, P., Atfield, G., Behle, H. Ellison, R. & Luchinskaya, D. (2013) ²⁵ See relevant work, due to be published shortly, on the supply and demand of high level STEM skills, by the Institute of Employment, University of Warwick, on behalf of the UK Commission for Employment and Skills.

Is the future supply of skills sufficient to meet future demand?

Analysis by the UK Commission for Employment and Skills has suggested that by 2010 across the economy as a whole there were more people with STEM degrees in the UK than were working in roles defined as STEM graduate occupations²⁶, highlighting that a STEM degree does not always lead to a STEM graduate occupation. However concerns remain about a shortage of STEM graduates for manufacturing and econometric research reported by the Royal Academy of Engineering in 2012 indicated that the projected demand for 830,000 SET professionals in 2020 exceeds supply.

The situation for engineering and manufacturing is exacerbated by the pervasive demand for STEM skills across the economy²⁷. Statistics from Higher Education Statistics Agency (HESA) reveal that only around a quarter of engineering and technology graduates are working in manufacturing six months after graduation. The remainder, accounting for the majority of STEM graduates, are working in distribution, finance and business services²⁸. It seems likely that manufacturing will continue to face strong competition from other sectors for STEM graduates.

Some employers recruit from outside the UK to meet shortfalls in supply, and to seek the best talent, more generally, and for strategically important skills²⁹. Changing immigration rules may mean that some employers will face greater challenges in sourcing some of their skills requirements internationally, with implications for UK competitiveness. There may be scope to reduce levels of recruitment of non-European Economic Area (EEA) migrants through improvements to education and training for UK potential employees, but employers argue that this shift requires government investment and support³⁰.

The supply and demand for STEM skills is not limited to graduates. Good quality apprenticeships also have a role to play in attracting high calibre entrants to manufacturing to fill technician roles (see later discussion in section 6.2). The opportunity of 'learning while earning' is proving increasingly

attractive to young people and offers the advantage to them, and to the employer, of developing vocational expertise alongside an understanding of the business. Apprentice Academies set up by major manufacturing employers, for example Rolls Royce and Mercedes Benz, show what can be achieved.

6.1.6 THE FUTURE NEED FOR 'HYBRID SKILLS'

The 'factory of the future' is likely to be characterised by flatter management structures, a more highly skilled and IT literate workforce capable of being reskilled in advanced technologies, and soft skills for managing operations effectively, and understanding the customer³¹ (see Chapter 3). This suggests a need for a breadth, depth and mix of skills. Manufacturing activities will require people to work in multi-disciplinary teams and to have inter-disciplinary expertise. This is because different skill sets are needed to optimise business performance for different product market strategies and at different stages of product and service life cycles.

'Hybrid skills' which encompass knowledge of different technologies, combinations of specific technical knowledge and generic skills, and the ability to work collaboratively across networks combining technical and commercial competence, will be increasingly important in the decades ahead.

This has been recognised in the US, where a survey commissioned by the Manufacturing Leadership Council³² has suggested that while engineering and technical skills dominate future skills needs, management and computer science were ranked third and fourth. In terms of future functional requirements, understanding the principles of lean manufacturing, and collaborative skills were ranked equal first in order of importance, followed closely by computer proficiency, and design and sales skills. The requirement for engineering and technical

²⁶ UK Commission for Employment and Skills (2011) ²⁷ Harrison, M. (2012) ²⁸ Higher Education Statistics Agency (2011) ²⁹ George, A., Lalani, M., Mason, G. Rolfe, H. & Bondibene, C. (2012) ³⁰ George, A., Lalani, M., Mason, G. Rolfe, H. and Bondibene, C. (2012) ³¹ Evidence Paper 29: Ridgeway, K. et al. (2013) ³² Brousell, M. Moad, J.R. & Tate, P. (2013)

skills is not new, but in future what will be required is greater expertise in computing-related fields and greater competencies in organisational collaboration. These requirements place an enhanced responsibility on management to ensure that requirements are met, both technologically and culturally.

6.1.7 THE FUTURE ROLE OF LEADERS AND MANAGERS

Leaders and managers play an important part in dealing with the technological, economic, political and social forces affecting manufacturing firms. Their role is to:

- Align activities and resources with strategy, up and down the organisational hierarchy;
- To coordinate across units, along the entire supply chain, and with the stakeholder community (including universities and training providers) and
- To adapt to changing circumstances and future market shifts.

Leaders and managers have a central position in driving the future role of people in manufacturing activities. Strong management practices are associated with high quality firm performance, with substantial differences in management style evident across countries. The profile of manufacturing CEOs in the UK is similar to the US and Germany in terms of gender (mostly male) and age. But UK CEOs are generally less educated in comparison to their global peers³³. Average scores for management practices in surveys of manufacturing in different countries show that Great Britain scores below the US, Japan, Germany, Sweden and Canada, but is on a par with Australia, Italy and France.

One driver of these scores is the skill level of managers. The UK fares relatively poorly on this indicator, with only 42% of managers in manufacturing firms having degrees, compared with 60% or more in India, Japan, Germany, the US and France³⁴. But differences in management practice

scores vary more within countries than between them. A key challenge facing UK manufacturing is the longer tail of poorly managed firms in Great Britain (7% of the total) than in countries such as the US (less than 2% of the total)³⁵. Yet in Great Britain as in other countries, the average manager thinks that his or her firm's management is well-above average. Raising the management quality of British firms is critically important.

In the face of future globalisation, technological developments and macroeconomic uncertainty, leaders need to adopt a forward-looking perspective while not being susceptible to every new trend. Looking out to 2050, it is not only the role of CEOs that is crucial, but also senior leadership teams and distributed leaders in critical positions throughout organisations. In the future, the role of distributed leaders in coordinating organisational activities across networks and aligning firm strategy up and down hierarchies will become increasingly important³⁶.

6.1.8 MANUFACTURING AND PUBLIC PERCEPTION

Over at least the last decade there has been concern about the possible impact of a negative image of manufacturing amongst the public in the UK. There are similar concerns in the US that manufacturing work is seen as 'dull, dirty and dangerous'³⁷. Negative attitudes to manufacturing can matter, particularly when these attitudes reflect an out-dated perception. If people are not attracted to the sector, there are potential implications for skills shortages which may constrain growth. However, it is unclear whether there are particular thresholds at which negative views of manufacturing should be a cause for future concern.

³³ Only 83% of the top-100 UK CEOs hold a university degree and 29% an MBA, compared with 100% holding a university degree in the USA and Germany, and 40% holding an MBA in the USA. See Evidence Paper 15: Homkes, R. (2013) ³⁴ See www.worldmanagementsurvey.com ³⁵ Evidence Paper 15: Homkes, R. (2013); see also Campbell, M. (2013) ³⁶ Evidence Paper 15: Homkes R. (2013) ³⁷ President's Council of Advisors on Science and Technology (2012)

'Myths' and 'realities': evidence on public perceptions of manufacturing

Despite the policy debate on the image of manufacturing, the evidence base on public perceptions of manufacturing is thin. A nationally representative survey of 1,452 adults in the UK undertaken in January 2012 with eight core questions showed that, on balance, the public believed manufacturing to be a high technology industry, with jobs that are unstable, low paid, and the first to be moved to other countries³⁸. The survey also emphasised the view that the UK produces many good ideas but is not good at translating those into products and businesses. On balance, there was disagreement with the statement that 'the UK economy can grow without a strong manufacturing sector'.

This disagreement was greater amongst older than younger respondents. Younger respondents (18-34 years) had a lower level of agreement that manufacturing requires high skills (36% agree, 21% disagree) than the over 55s (49% agree, 23% disagree). There was a marked age difference in whether respondents would encourage their child to pursue a career in manufacturing with 31% agreeing and 18% disagreeing amongst older respondents (aged 55 and over) and 13% agreeing and 34% disagreeing amongst younger respondents (18-34 years).

Young people and women tend not to have a positive image of manufacturing and this may impinge on the number and profile of people considering or choosing manufacturing as a career. Evidence also suggests that over half of secondary school students believe manufacturing to be 'dirty', 40% consider that manufacturing is boring, and only 15% say they would consider a career in manufacturing³⁹. The review does not cover how many teachers have experience in manufacturing and whether, if there were more, they would present a more positive view.

Women have more negative attitudes towards manufacturing than men, and these are apparent from an early age. This is evident at ages 7-11 years, when 44% of boys indicated that they would not like a job in manufacturing compared with 67% of girls⁴⁰ and more women (46%) than men (35%) aged 17-19 years describe manufacturing as 'male dominated'⁴¹. For women in their penultimate year of university 'engineering' is considerably less appealing as a career (12% said they would be interested), compared with science (26%) and education (27%)⁴².

The negative perceptions held by women are significant, particularly given that they only account for 23% of the UK manufacturing workforce⁴³, with 31% of FTSE 100 manufacturing firms having a board composition of 25% or more women⁴⁴. The situation in the US is similar, where women account for 24% of the manufacturing workforce⁴⁵. The Perkins Review of Engineering Skills, due to be published shortly, will provide analysis on a number of important strategic issues, including gender balance⁴⁶.

An improving image?

There is some evidence suggesting that since the economic crisis in 2008, and in the context of debate on the rebalancing of the economy, the public image of manufacturing has become somewhat more positive. Over half of the adult population in the UK in recent surveys identify the manufacturing sector as high-tech and the most important sector in helping the UK economy to grow in the short- and medium-term future. A survey of 1,748 adults in Great Britain in July 2012 showed that 55% of the sample believed that manufacturing will be one of the most important industries in helping the economy to grow in the next two years (i.e. 2012 to 2014), and 53% believe it will be important in the next 10-20 years⁴⁷.

³⁸ Livesey, F. (2012) ³⁹ From surveys carried out by Ipsos MORI for the Engineering and Marine Training Association (EMTA) reported in Evidence Paper 19: Livesey, F. (2013) ⁴⁰ FreshMinds Research (2010) ⁴¹ FreshMinds Research (2010) ⁴² Council for Industry and Higher Education (2011) ⁴³ ONS employee jobs by industry (UK totals) updated December 2012: http://www.ons.gov.uk/ons/publications/re-reference-tables.html?newquery=*&newoffset=25&pageSize=25&edition=tcm%3A77-222531 ⁴⁴ EEF (2013b) ⁴⁵ Deloitte and the Manufacturing Institute (2013) ⁴⁶ For further details see: www.gov.uk ⁴⁷ You-Gov Cambridge (2012) 'Britain in a state of poorly regulated manufacturing decline' [Online data] London, reported in Evidence Paper 19: Livesey (2012)

6.1.9 DEMOGRAPHIC CHANGE AND THE AGEING SOCIETY

One of the more uncertain trends affecting manufacturing is the ageing of the population. This is a global phenomenon, with the pace of change, and projected population age profiles varying between countries. The ageing of the population in the UK is not particularly fast by European standards, nor in a global context, where the Asia-Pacific region has the oldest (Japan), largest (China) and many of the fastest growing ageing populations (China and Singapore)⁴⁸.

Over the period to 2050, the number of people aged 65 years and over (i.e. of 'traditional' retirement age) is projected to increase, with the fastest growth amongst the 'very old' age groups, while the numbers of 'traditional' working age are projected to decrease. By 2030, 17% of the population will be aged between 60-74, with the proportion of the population over 75 overtaking this group in 2050. This ageing of the population is often posed as a challenge, but it also presents opportunities.

More time in good health and working longer

Despite the heterogeneity of the older population, for most individuals an extended lifespan will not mean extended 'old age', but more time in good health, accompanied by more disposable time and income than was the case for previous generations. The increase in healthy life expectancy has led to a 'third age' of active retirement, affecting both consumption patterns and attitudes to work.

Some older people may want to stay in work longer beyond 'traditional' retirement age. Policy is operating in the same direction, encouraging individuals to 'work longer'⁴⁹. A previous trend to early retirement has been reversed. The employment rate of people aged 55-64 years in the UK rose from 50.7% in 2000 to 57.1% in 2012, and the employment rate of people aged over 65 years has seen marked increases in the

last few years, reaching 6.7% in 2012. UK pension arrangements and flexible labour markets make it easier to organise delayed and flexible retirement in the UK than in most competitor countries.

In general, policies for age management in the workplace endeavour to achieve a balance between older workers' resources (including their health, functional capacity, competences, values, attitudes and motivations) and work demands (the work organisation; the work community; and leadership). Longitudinal research suggests that line managers play a key role here, but that training is required to raise their awareness⁵⁰. Training, provision of assistance to older job seekers, addressing negative employer's perceptions of older workers, relatively higher labour costs (if wages are not in line with productivity), improving working conditions for older workers (ergonomically and otherwise) and offering more flexible working, including part-time work, are important in strengthening the employability of older workers⁵¹.

There are particular challenges of making manufacturing attractive to older workers, especially through more flexible working and phased retirement. Currently, employers in manufacturing lag behind those in other sectors in managing ageing workforces. Older workers in manufacturing are more likely to report excessive workloads and have a worse work-life balance than older workers in other sectors⁵² (see Table 6.3)⁵³. They experience lower levels of flexible working making other sectors more attractive to many older people. The challenge is particularly pertinent for sub-sectors with the oldest age profiles, including manufacture of machinery, fabricated metal products, basic metals, and other transport. These sub-sectors are projected to face significant 'replacement demand' to replace large numbers of retirees. This challenge has particularly important consequences for Small and Medium Enterprises (SMEs) where older workers are disproportionately concentrated⁵⁴.

From an employer's perspective, workers in different age groups may be regarded, either on the basis of 'myths' or 'experience', as having different attributes including physical strength, technical skills, organisational skills and 'soft skills'. It is possible that employers may distinguish between groups of (potential) workers on this basis. In general, employers tend to suggest older workers are particularly strong in 'soft skills' (compared to younger people), but this is less applicable in manufacturing where older workers have traditionally had little contact with customers.

Living longer – active retirees as a growth market

With a rise in the share of the population in older age groups there is likely to be a big growth market in demand for 'age neutral' products (i.e. those designed for people of all ages) by older people who are active, healthy and have greater spending power. This suggests that successful manufacturers will need to take an age inclusive approach to product development, extending their market reach, and focussing less of their marketing on youth than in the past. Views differ on whether the spending habits of older generations in the future will be different from those in the past⁵⁵. One important distinction is that current and future older generations are more ICT literate.

Table 6.3: Older workers' views on work by comparison with younger workers

OLDER WORKERS IN ALL SECTORS	OLDER WORKERS IN MANUFACTURING
Less frequent excessive workload	More frequent excessive workload (25% everyday)
/	Too much workload (48%)
More difficulty in finding a new job if necessary	More difficulty in finding a new job if necessary
Better work-life balance	Worse work-life balance
Greater job satisfaction	/
Less frequent work appraisals (25% of respondents reporting "never")	Less frequent appraisals (47% reporting never)
Better mental health	/
Slightly worse physical health	Equally good physical health and neither more nor less likely to be in physically demanding work.
More likely to be in a job which requires a high level of physical ability	/

Source: CIPD Employee Outlook

Living longer – the very old

Alongside the growth in demand for 'age neutral' products by older people, an increase in the numbers of the very old suggests that there will be growing demand for 'age specific' products and services geared towards older people with limited capabilities associated with the features of 'biological ageing'. These are increasingly common after the age of 70 years (including deteriorations in vision, hearing, thinking, communication, locomotion, reach and stretch, and dexterity). Such 'age specific' products and services are especially (but not exclusively) associated with healthcare, so that older people can remain independent for longer. This suggests that an ageing population offers opportunities for exploitation of new markets for products aimed specifically at those older people (and others) with limited capabilities. The UK has existing strengths in sub-sectors which are likely to grow as a result of an ageing population, including:

- Medical technology (including the growing healthcare market for remote diagnosis, self-testing and home-monitoring of medical conditions, and telecare): to enable people to maintain their independence and to manage complex health problems and disabilities;
- Pharmaceuticals and biosciences: to minimise or prevent the medical conditions of old age;
- Food and drink: to respond to growing numbers of single person households and concerns about nutrition; and
- Automotive: to respond to drivers with limited capabilities, and the mobility needs of those no longer able to drive.

6.1.10 POTENTIAL HUMAN ENHANCEMENT

'Human enhancement' encompasses a range of approaches which may be used to restore or improve aspects of human function such as memory, hearing and mobility, for purposes of either restoring an impaired function to previous or average levels, or to raise functionality to a level considered to be 'beyond the norm' for humans. This may be achieved through technological means by cognitive enhancing drugs to improve memory and concentration, the use of aids and implants to improve sensory perception, and the use of bionic limbs to restore or enhance mobility.

The development of enhancement technologies might offer economic opportunities for some sub-sectors of manufacturing. More broadly, enhancement technologies could change how people work along a spectrum from increasing participation among those people who might otherwise be disadvantaged, including some older people, to improving the efficiency of workers beyond the current limits of human capacity⁵⁶.

There are ethical, societal and political issues concerning the utilisation of human enhancement techniques and associated uncertainties about the extent to which human enhancement techniques will be used in the UK and elsewhere. They could for example be used to increase the competitiveness of the workforce and improve aspects of human functionality which tend to deteriorate with 'biological ageing'. These techniques could have important positive and negative implications for the future of manufacturing and the future of work more generally.

6.2. IMPLICATIONS FOR GOVERNMENT

KEY MESSAGES

The future quantity, quality and utilisation of suitably skilled people will be crucial in ensuring the future competitiveness of the UK manufacturing sector. Recent government efforts to increase the number of apprenticeships, promote STEM skills, and help ensure the retention of talent in the manufacturing sector are all important steps in the right direction.

The changes and uncertainties highlighted in this Report indicate three critically important areas which the UK will need to address to meet future human capital requirements in manufacturing. However the government needs to expand the scale and ambition of its current initiatives significantly.

Quantity: Increasing and diversifying the supply of manufacturing workers to avoid future shortfalls.

- This will entail reaching out to young people in the education system consistently to encourage them to study STEM subjects to keep their future options open; a focus on accessing and attracting international talent; and building and maintaining existing workforce capability.

Quality: Equipping future workers with high quality 'hybrid' skills (deep technical knowledge allied with generic skills and problem-solving capabilities) that manufacturers will need.

- Potential workers will need to be as 'business ready' as possible, to meet the need for new skills sets driven by changing business models, technology and other factors. Higher level skills, vocational training, apprenticeships and STEM qualifications will play a critical role, particularly in meeting demand for workers in managerial, professional and technical roles.

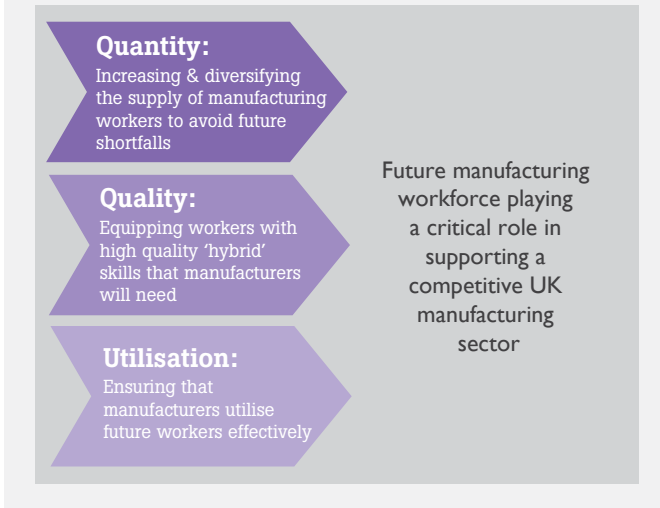
- **Utilisation: Ensuring that manufacturers utilise future workers effectively.**
- Employer demand will need to be raised to stimulate a supply of skills which meets their needs as closely as possible. Employers also need to design jobs that enable the full utilisation of employee skills. Skills utilisation needs to receive greater attention.

6.2.1 INTRODUCTION

People will play an increasingly important role in the UK's manufacturing competitiveness in the future, particularly in the context of important wider changes and uncertainties outlined above and in the previous chapters of this Report. These include jobless growth, the prospect of developed economies increasingly competing on the quality of their workforces, and changes in relative labour costs. There will also be growth in the number of professional roles, a demand for workers with 'hybrid' skills, and continuing poor perception of manufacturing amongst young people and women. Ageing populations in the UK will also affect the workforce, and product demand.

This section assesses the implications of these various changes and presents options for policy makers (see Figure 6.3). A key message is that current approaches to providing and utilising human capital for manufacturing activities will need to adapt and change. More UK manufacturing firms will need to move from a situation of 'low skills equilibrium'⁵⁷ characterised by low value-added, low skills and low wages to a 'high skills equilibrium' characterised by high value-added, high skills and high wages. Deficiencies in management capability, discussed earlier, are also important here.

Figure 6.3: Key issues in ensuring the necessary quantity, quality and utilisation of highly skilled workers



6.2.2 QUANTITY: EXPANDING AND DIVERSIFYING THE SUPPLY OF MANUFACTURING WORKERS TO AVOID FUTURE SHORTFALLS

(I) INTERVENTION IN THE EDUCATION SYSTEM – THE NEED TO REACH OUT CONSISTENTLY TO YOUNG PEOPLE

Compulsory education

The skills pipeline for the future manufacturing workforce begins with primary school children and young people, whose interest in manufacturing needs to be consistently sparked, captured, maintained and stimulated. Given the likely future demand for workers at apprentice, technician and degree level with STEM qualifications, greater effort needs to be made in reaching out to children at primary school to ensure that they are encouraged

to study STEM subjects to keep their future career options open, and to stimulate their interest in science, design, and 'how things are made and work'. The impact of careers advice is high at a young age and there is very considerable scope for the involvement of local employers in educational projects from primary school age⁵⁸ onwards.

This interest needs to be maintained and/or re-stimulated at secondary school level through the promotion of science and engineering careers advice, and STEM-specific initiatives. Professional bodies, careers advisers, work experience, and contact with working people have important roles to play in providing information on manufacturing careers and apprenticeship opportunities (see Section 6.2.3). Recent initiatives such as the Government Inspiration Vision Statement⁵⁹, which emphasises the importance of aspiration and inspiration being included within careers advice, are welcome, however the scale and coordination of current measures needs to be increased.

There have been concerns that the potential removal of the statutory duty on secondary schools to provide work experience⁶⁰ will have a detrimental effect on the knowledge of young people about working in manufacturing, and the workplace in general. Furthermore, with changes in the provision of careers advice in England, it is unclear whether young people will be able to access quality face-to-face careers advice to provide guidance about labour markets, and subject and careers choices⁶¹. Again there is scope for greater involvement of local employers with secondary schools, to advise on careers in manufacturing, and on the demands of recruiters. Partnerships with schools would also provide employers with greater insight into how they might contribute to stimulate interest in manufacturing amongst young people and help them to contribute to the development of knowledge and skills which manufacturing needs. It would be valuable for example to highlight how 'factories of the future' might develop, and the increasing importance of design skills, now and in the future.

The 'Make Things, Do Stuff' campaign⁶² provides an example of how young people's interest in digital media can be harnessed to encourage them to move beyond being passive users to use technology to 'make things'. Progressive improvements in technology could also enhance students' learning experiences. For example, there is scope to make greater use of e-learning to help provide a broader curriculum for young learners.

It is particularly important to address the negative perception of manufacturing held by girls and young women, a point which was reinforced at the international project workshops⁶³. Attracting more young women will increase the potential pool of workers on which manufacturing can draw and is likely to require initiatives and activities aimed specifically at girls as they make their subject choices. It is notable that most students studying STEM subjects do so because of interest and enjoyment in the subject or because of their aptitude⁶⁴.

In general, there has been little formal evaluation of programmes and initiatives aimed at improving knowledge of, and promoting the image of, manufacturing in schools. Yet there is some evidence that the impacts of some initiatives have been positive. For example, the STEM Ambassadors programme works with 3,000 employers across the UK to create effective links with education, and reports there has been a positive impact on participating pupils' motivations and attitudes towards STEM⁶⁵. Over the last decade, there have been several national initiatives aimed at increasing the supply of STEM skills in schools, and higher education⁶⁶. These have had some success, with numbers of students studying STEM subjects at degree level increasing by over 25% between 2002-3 and 2009-10. This impetus needs to be maintained and enhanced in the future.

University level

Maintenance and stimulation of interest in manufacturing careers needs to continue at university, particularly amongst students studying for degrees in STEM subjects, as this is when ideas about careers tend to crystallise. Career paths are neither simple nor predictable, as choosing to study a STEM subject does not translate by default into choosing, or gaining entry into a STEM job as highlighted earlier. There is evidence, however, that entering postgraduate study is often a deliberate path towards a STEM career⁶⁷. This means that funding structures, including fees and loans for degrees at Masters level, need to be readily accessible to ensure that individuals are not deterred from postgraduate studies.

Because up to a quarter of STEM undergraduate students expect to take time out or enter temporary employment after graduation⁶⁸, advice on deferring long-term career decisions needs to be provided. Evidence from surveys shows that most graduates value 'interesting' work; starting salary and prospective earnings is a key driver for only a minority of graduates who are almost exclusively male. Terms and conditions of work, and work-life balance issues more generally are also known to be important factors in attracting and keeping skilled workers⁶⁹. These wider issues concerning experience of work, workforce diversity, worker autonomy and the intensity of work should not be overlooked in efforts to attract people to careers in manufacturing.

Equipping graduates with relevant experience

One reason why some manufacturing employers are (re)turning to apprentices to fill associate professional and technical occupations is that they have the practical experience which is lacking in many graduates with theoretical knowledge. Sandwich courses and work experience placements in manufacturing help provide higher education students with relevant practical experience, increase their employability, and provide them with insights into what working in manufacturing entails. They are likewise valued by employers⁷⁰.

⁶² See <http://makethingsdostuff.co.uk/> ⁶³ Evidence Paper 1: Foresight and Arup (2013) ⁶⁴ Mellors-Bourne, R., Connor, H. & Jackson, C. (2011) ⁶⁵ STEMNET (2013) ⁶⁶ For example, the STEMNET programme aims to inspire young people by providing enrichment activities in science, technology, engineering and maths; while the HE STEM Programme provides support in attracting students to STEM subjects. Other initiatives have focused on groups under-represented in STEM – notably girls and women ⁶⁷ Mellors-Bourne, R., Connor, H. & Jackson, C. (2011) ⁶⁸ Mellors-Bourne, R., Connor, H. & Jackson, C. (2011) ⁶⁹ Evidence Paper 35: Hogarth, T. (2013) ⁷⁰ Hogarth T., Winterbotham M., Hasluck C., Carter K. Daniel WW, Green A.E. & Morrison J. (2007)

Other potential workers

Employers also need to be increasingly sensitive to the ways in which different population groups access information about employment opportunities, and encourage them to demonstrate their potential. This means giving greater consideration to where and how to advertise and the range of recruitment and selection methods used to attract a wide and diverse pool of people⁷¹.

(II) ACCESSING AND ATTRACTING INTERNATIONAL TALENT

Looking out to 2050, it will become increasingly important for the UK to identify, access and attract people who are at the cutting edge of technological developments with 'design-make' expertise, to help maintain and raise national competitiveness^{72,73}. It seems likely that most of the future workforce will be drawn from the UK. However the UK will also need to identify external sources of skills which can be drawn upon when required to fill specific gaps in the future. The Migration Advisory Committee identifies a Shortage Occupation List for Tier 2 of the Points-Based System and there are some specific engineering occupations included. The UK will therefore need to maintain and widen access to the large, diverse pool of international talent available. It might include, for example, facilitating the mobility of managers from countries with strong track records in leadership and management such as the US⁷⁴.

One way of increasing the UK's future attractiveness to highly qualified people from outside the European Economic Area would be the re-introduction of the post-study work route for individuals undertaking Masters and PhD degrees in STEM subjects. This would require the introduction of 'science visas' for those offered post-doctoral research posts in engineering or science at recognised higher education institutions. Development of specific courses likely to be attractive to international, as well as to home students, is one option. As skills policies are typically designed nationally, but a growing number of employers operate internationally, future promotion of cross-border skills policies also makes sense. The position of English as the dominant world language

of the internet is likely to be a strong factor in the UK attracting international talent.

(III) BUILDING AND MAINTAINING WORKFORCE CAPABILITY

Continuing vocational education and training

Developed economies are likely to compete on the quality of their workforces in the future, which means that skills policies need to help develop and maintain the capability of the manufacturing workforce. This requires an emphasis on increasing the demand for skills (see Section 6.2.4), addressing current and likely future skills gaps, and ensuring that skills are in place to exploit the opportunities associated with new technologies.

While much of the debate on skills policy focuses on new entrants to manufacturing, and initial vocational education and training, the importance of continuing vocational education and training should not be underestimated since it will be needed throughout working lives. How work is organised and how jobs are designed are important factors for continuing vocational education and training, given their role in facilitating workplace learning and in the process of workplace innovation⁷⁵. E-learning may also play an expanding role in updating workers' skills in the future, particularly for people working in SMEs or remote locations.

The example of Balmoral Offshore Engineering (see Box 6.2) shows how one employer has taken responsibility for developing a skilled workforce by bringing together existing employees and new recruits to address skills shortages and ensure workforce capability. This is consistent with the approach which is likely to be needed in the future.

The UK's lacklustre performance in terms of leadership and management capabilities will need to be addressed out to 2050 for the UK to remain competitive. Some progress is being made in this area, for example through the Growth Accelerator which provides access to up to £2000 of matched funding for senior managers to develop their leadership and management skills.

BOX 6.2: THE ROLE OF AN IN-HOUSE ACADEMY IN ADDRESSING SKILLS REQUIREMENTS: THE EXAMPLE OF BALMORAL OFFSHORE ENGINEERING

Balmoral Offshore Engineering is a deepwater buoyancy, insulation and elastomer product specialist. To address skills shortages the company has invested in the 'Balmoral Skills Academy' at its Aberdeen headquarters to provide hands-on training for production process leaders. The company appointed a qualified trainer and registered assessor and sought accreditation from the Scottish Qualifications Authority to gain accreditation as an approved training centre. The first group of candidates for a six-month training programme, leading to a Scottish Vocational Qualification at Level 2 in 'Performing Manufacturing Operations', were selected from existing employees and new recruits on the basis of interviews and psychometric assessment. The course is designed to provide structured training and in-depth understanding of Balmoral-specific manufacturing operations, while providing the trainee with a nationally recognised qualification.

The ageing of the UK workforce will also create a need for lifelong learning as well as initial training. Manufacturing apprenticeships tend to be focused disproportionately on young people who have just completed full-time education. Evidence from case studies shows that, apprenticeships in manufacturing are highly structured, training intensive, and costly programmes which are rarely used to up-skill or accredit the skills of existing employees⁷⁶. This youth centred strategy needs to diversify. Evidence from Australia and the Netherlands on the development of intermediate level skills and apprenticeships suggests that modularised and competence based systems are more flexible than curricula based systems (as in Germany), and are better attuned to the inclusion of intermediate vocational training for adult learners⁷⁷. A modular system helps to improve the flexibility of training pathways and the development of 'hybrid' skills.

Valuing older workers

In the UK, those employed in skilled trades and associated professional jobs have an older than average age profile^{78,79}. As individuals retire, employers cannot always resort to the external labour market to recruit individuals with similar

skills, as the pool from which they are likely to be recruiting is getting older and smaller. The retirement of existing workers, along with workers moving to jobs in other sectors, is an important element of the challenge faced by UK manufacturing of filling nearly 800,000 jobs by 2020 (see Section 6.1).

Multiple approaches are needed to maintain and enhance a high quality workforce. To do otherwise would be to risk the future competitiveness of UK manufacturing. Apprenticeship training and other vocational training will need to be bolstered further to help address these 'replacement demand' requirements. Enhanced diversity in recruitment to manufacturing, from the UK and internationally will also play a role. But since few jobs are considered beyond the capacity of the average 70 year old⁸⁰, encouraging older workers to delay retirement may provide extra time in which to prepare, while also making efficient use of skills and tacit knowledge. This aspect is important as a lack of certification of qualifications amongst older workers can be a problem if they lose their jobs, as experience and knowledge can be overlooked. With early retirement schemes in decline, the abolition of the default retirement age, and an increase in the age of eligibility for the state pension, working longer may be attractive for some individuals.

Employers can encourage retention of older workers through implementing a variety of age management policies covering work organisation, mobility management, task design, working time arrangements (especially enabling flexible working arrangements), and continuing training including knowledge transfer. Lifelong learning and targeted training, especially in mid-career, can improve employability in later life and discourage early withdrawal from the labour market.

'Second chance' pathways

Individuals who are not currently working or who are unemployed could form part of the potential future workforce for manufacturing. Some of these people have relevant skills for manufacturing, or could develop existing skills to make them more relevant to manufacturing. More attention needs to be paid to encouraging people with relevant skills into manufacturing activities, which could be part of the solution to meeting skills requirements.

⁷⁶ Hogarth, T., Gambin, L., Winterbotham, M., Baldauf, B., Briscoe, G., Gunstone, B., Hasluck, C., Koerbitz, C. & Taylor, C. (2012). ⁷⁷ Vogler-Ludwig, K., Giernalczyk, H. & Stock, L. (2012). ⁷⁸ Mason, G. (2012) ⁷⁹ Jagger, N., Sigala, M., & Sumption, F. ⁸⁰ Evidence Paper 23: McNair, S. (2013).

Maintaining 'ports of entry' at various stages of workers' careers, and 'second chance' pathways for them to develop skills and pursue careers, will enable flows into manufacturing and help develop a diverse workforce.

ADVICE FOR POLICY MAKERS:

Strengthening pre-16 science and engineering careers advice

There is a strong case for a statutory duty to remain on schools to provide work experience, and for science and engineering to be promoted to a greater extent through careers advisers when pupils are making subject choices. There is also scope for employers to create stronger links with primary and secondary schools, potentially via the Make it in Great Britain campaign⁸¹, for example to form relationships with local schools.

Making STEM PhDs more attractive

To provide the high level knowledge and expertise important for manufacturing activities, more university graduates need to be attracted to a career in manufacturing. Given the evidence that entering postgraduate study is often a deliberate path to a STEM career, funding structures for postgraduate degrees need to be made simple to navigate and access, with PhD students studying STEM subjects eligible for additional government remuneration.

Equipping graduates with relevant experience through sandwich courses and project placements

There is value in encouraging employers to provide a greater number of STEM-related work experience opportunities or 'sandwich' project placements for students. This would enable students to make a more informed choice about what a STEM-related career in manufacturing might offer. There is already some availability of these courses and programmes across the UK. However a stronger message from Government about their importance would help establish these courses.

Immigration policy that allows the UK to compete successfully for global skills

UK manufacturing activities are likely to benefit from future immigration policies that are sensitive to the international competition for global skills. Changes to immigration rules mean that some employers face difficulties in sourcing some of their skills requirements internationally, with implications for UK competitiveness. The attractiveness of the UK to international skilled workers will be judged, in part, on the basis of how welcoming (or otherwise) future UK immigration policy is, in comparison to the policies of the UK's competitors.

Promotion of cross-border skills policies

Skills policies are typically designed nationally. However, as UK manufacturing activities are likely to continue having international operations⁸² the promotion of cross-border skills policies is likely to be beneficial. These might include investing in skills outside the UK; encouraging international students to stay in the UK and utilise their skills; and encouraging more international exchanges involving UK higher education students.

Encouraging continuing vocational education and training, particularly for older workers

It will be important for public agencies to be involved in setting and maintaining standards for rigorous modularised and competence based training, including e-learning. In addition, policies to increase the availability of flexible working and training have a role in helping manufacturing businesses to compete for workers.

Appreciating the importance of workplace configuration

Policies to promote ergonomic workplace configurations are likely to have particular benefits for older workers, but are likely to be beneficial for other workers too. Policies to promote greater interest and appreciation in standards of workplace design, to promote healthy workplaces that are conducive to workplace co-operation, learning and innovation at work, have the potential to yield economic and social benefits, for organisations and individuals.

⁸¹ For further details see: <http://www.makeitgreatbritain.bis.gov.uk/Career-zone> ⁸² Livesey, F. & Thompson, J. (2013).

6.2.3 QUALITY: EQUIPPING FUTURE WORKERS WITH HIGH QUALITY SKILLS THAT MANUFACTURERS WILL NEED

(I) ENSURING THAT PEOPLE ENTERING THE WORKPLACE ARE ‘BUSINESS READY’

Product cycles and skills needs

Skill needs at all organisational levels change over time in response to factors including product market position, the development of products over the lifecycle, product complexity, and market demand (Table 6.4)⁸³. Evidence⁸⁴ suggests that UK manufacturing activity will be increasingly concentrated on high value goods, which is likely to be reflected in an increased demand for employees with high level skills, including workers with undergraduate and postgraduate degrees, and project management skills to bring new products to market.

It will therefore be essential to ensure that there is a stock and flow of suitably qualified people with ‘hybrid’ skills [i.e. a deep vertical technical knowledge allied with a broad transversal set of generic skills and problem-solving capabilities], as businesses seek to balance their investment in skills and automation across the manufacturing sector⁸⁵. Manufacturing activities will in the future will increasingly require a mix of skills to perform a particular group of tasks and to provide a base for broader learning and progression⁸⁶ which meets employer needs.

(II) MEETING THE NEED FOR NEW SKILLS SETS

In addition to the focus on high value goods requiring workers to have a greater mix of complementary skills, changes in future business models (see Chapter 2) and in other areas including advances in technologies will all change the type of skills that will be required in the next decade and beyond. Each of these factors is considered in turn.

Table 6.4: Product lifecycles and skill needs

		PRODUCT COMPLEXITY	
MARKET DEMAND	UNCERTAIN	High value goods Highly complex products that consist of many components in a market with uncertainty, e.g. aerospace <ul style="list-style-type: none"> • Project management • Research & development • Product design skills • Craft production skills 	Fashion products Relatively simple products in fickle markets with short product lifecycles, e.g. toys. <ul style="list-style-type: none"> • Marketing • Logistics • Craft production skills
	CERTAIN / PREDICTABLE	Consumer durables Moderate complexity products in high volume markets of lower uncertainty, e.g. automotive <ul style="list-style-type: none"> • Team working • Manufacturing system design • Cellular manufacturing (working by functional area) 	Commodities Simple products in high volume from dedicated process lines at minimal cost. e.g. simple food products <ul style="list-style-type: none"> • Cost control • System design • Plant maintenance • Logistics and operations

Source: CIPD Employee Outlook

83 Davis, C., Buckley T., Hogarth ,T. & Shackleton, R. (2002) 84 Evidence Paper 14: Hay, G. (2013); Evidence Paper 25: Peng, M. & Meyer, K. (2013). 85 Evidence Paper 1: Foresight and Arup (2013). 86 Brockman, M., Clarke, L. & Winch, C. (2011)

Future business models

The new business models that will develop over the next four decades will necessitate a workforce with a different mix of skills. Engineers are likely to need to be able to facilitate increasing amounts of collaboration between different factories, with the demand for mixes of technical and non-technical skills likely to increase further as servitisation becomes widespread.

The shift towards the circular economy (see Chapter 5) will involve greater collaboration between factories with different specialisms, and between factories and other organisations. For example, a shift to more urban manufacturing may help facilitate greater interaction between factories and schools. Some employees are likely to spend most of their time developing solutions to enable effective collaboration with other firms or institutions. In addition, the manufacturing workforce will not only need the skills to create products from raw materials, but also the skills to identify problems with finished products and repair or re-manufacture them.

The increasing trend towards servitisation of the manufacturing sector will not only require a workforce with hybrid skills but a greater share of employees involved in non-production and non-technical roles. Customer-focused skills will be in increasing demand. Employers will need to make clear to potential employees that a diversity of roles will become increasingly available within manufacturing.

Future technologies

Technological developments such as the full integration of ICT and sensors, and the growing use of additive manufacturing will require a workforce that is adept at both analysing vast quantities of data and focussing on design. Firms will need to employ and train design engineers who can help enable reconfigurable factories of the future to produce a wider range of products (see Chapter 3).

As the amount of data available to firms and customers increases, the most competitive firms will hire teams with computing skills and expertise in data management. Government can help ensure

that these capabilities are developed throughout the education and training system. For example, STEM degrees could have a 'data management' component.

The need to encourage the rapid movement of technologies through technology readiness levels (TRLs) from concept to product (see Chapter 3) has implications for the education system and for workforce skills. Courses that provide an opportunity to develop a combination of cutting edge scientific and entrepreneurial expertise need to be more commonplace in the future. One example that has been particularly attractive to international talent is shown in Box 6.3.

BOX 6.3: BUILDING AND BRIDGING ACADEMIC AND COMMERCIAL SKILLS WITH INTERNATIONAL TALENT: THE EXAMPLE OF THE UNIVERSITY OF CAMBRIDGE MASTER'S IN BIOSCIENCE ENTERPRISE (MBE)

This MBE programme is a science and business 'professional practice course' designed for graduates with a degree in biological, medical, physical or engineering sciences or a financial or legal background who have the ambition to found technology companies or take leading roles in the life science sector. Based at the Institute of Biotechnology at the University of Cambridge, the course offers opportunities for students to work with world-class academics and experienced entrepreneurs, with learning experiences based on real life business scenarios and case studies. The focus is on how bioscience businesses are created, funded and successfully developed.

Since the course was founded in 2002, there have been nearly 1,500 applications for places on the course, with 251 students admitted. The course has an international reach: of those admitted 61 were from the UK, 49 from the rest of the EU, 37 from the US and 104 from the rest of the world. 47% of MBE graduates have remained as taxpayers in the UK. To date, at least 18 new company start-ups have been founded by participants on the course.

Future environmental changes

As demand for natural resources rises and accessibility decreases, manufacturers will need to increase the resource efficiency of their processes. However, this may not be sufficient when looking out over four decades (see Chapter 5). Greater resource efficiency will need to be supplemented by the development and use of novel materials and where possible, the utilisation of locally available materials. This shift has implications for the type of R&D which will need to be funded and the skills requirements of researchers within academic institutions and industry.

Environmental trends will create a growing need for research scientists and engineers not only in more traditional fields such as material science, chemistry and bio-chemistry, but in newer fields for example green chemistry, and in fields such as bioengineering which cut across the natural and physical sciences. Cross-cutting degrees with greater multi-disciplinarity are likely to become increasingly important in providing people with the necessary breadth and depth of technical understanding.

Future markets

As emerging economies continue to grow, manufacturing firms will need to take advantage of new markets. In particular, firms will need to be able to identify where opportunities will arise, and acquire relevant cultural understanding to develop long-lasting customer relationships. However, the currently inadequate language skills and associated cultural understanding amongst many native English speakers may place UK manufacturers at an increasing disadvantage in manufacturing businesses operating on a global basis, and in SMEs seeking export sales⁸⁷. At the same time, foreign direct investment (FDI) into Europe as a proportion of worldwide FDI is set to decrease⁸⁸. Firms will require a number of capabilities to draw in as much investment as possible from future markets into the UK.

Higher level skills

Given the growing significance of higher level skills in manufacturing, particularly graduate and postgraduate skills, it is vital that the higher education (HE) sector is able to provide sufficient numbers of suitably qualified graduates and postgraduates with academic, technical and practical skills. Policies which facilitate collaboration

and knowledge transfer between HE and industry are likely to become more important.

Greater business sponsorship of PhD students would provide a stronger industry pull for research, and will help ensure that graduates and other educational leavers are equipped with the skills required for future manufacturing environments. Given higher levels of student debt in recent years, business sponsorship would be particularly helpful. However, it is unlikely to be sufficient, and in sectors of strategic importance such as manufacturing, there is a case for central government funding for postgraduate courses to safeguard the volume of graduates coming out of HE programmes. Some significant progress is being made in this area, for example through the EPSRC Centres for Doctoral Training (see Box 6.4). However further effort is needed to ensure that the UK does not fall further behind its competitors in the provision of STEM graduates.

BOX 6.4: EPSRC CENTRES FOR DOCTORAL TRAINING⁸⁹

These Centres bring together diverse areas of expertise to train engineers and scientists in a specific research area or theme. Training includes technical and transferrable skills training, as well as a research element. They are funded mainly by government, although many Centres leverage additional studentships from other sources. A subset of the Centres, called Industrial Doctorate Centres, provide an alternative to the traditional PhD for students who want a career in industry. Here a four-year programme combines PhD-level research projects with taught courses, and students spend about 75 per cent of their time working directly with a company.

More generally, effective government engagement is required to stimulate future co-investment with employers and individuals in high level skills in specialist sectors. The nuclear sector is a good example of this situation (see Box 6.5).

BOX 6.5: EFFECT OF THE PROSPECT OF NUCLEAR ENERGY DEPLOYMENT ON STUDENT INTEREST

The government decision to encourage energy companies to build new nuclear power plants in 2006 represented a turning point for UK energy policy⁹⁰, indicating opportunities for UK businesses to be involved as part of the supply chain with the creation of new jobs to build and run the new plant. A critical issue is to ensure a workforce with the necessary skills and knowledge, given previous policy uncertainty in a sector where there are long lead times for training and building experience.

There are promising signs that at postgraduate level, student interest in acquiring necessary skills is responsive to perceived opportunities. The Physics, Technology and Nuclear Reactors Masters course at the University of Birmingham has been in operation since 1956. There is a strong correlation between the perception of opportunities in the nuclear industry and the entry numbers for the course. The government decision in 2006 is likely to be the main stimulus for a rise in applications, with further increases expected as new nuclear build is encouraged.

A significant proportion of current funding for students comes from industry, with students funding the remainder. The level of industrial support which students receive depends on degree class obtained. As national postgraduate tuition fees rise, industry support may need to rise in tandem to avoid the risk of discouraging students from applying.

There is also growing interest at the undergraduate level with the University of Birmingham introducing an undergraduate programme in Nuclear Engineering (MEng, with a BSc counterpart) and an MSc in Nuclear Waste Management and Decommissioning. When these are up to capacity they will deliver around 100 students a year to the nuclear sector⁹¹.

Vocational training and the role of apprenticeships

Initial vocational education through apprenticeships is a critical pathway for delivering intermediate level skills. The continuing promotion of the 'apprenticeship' brand, which has been stronger in engineering than in many other sectors, helps to raise the profile of intermediate skills which are important to manufacturing now, and are likely to remain so in the future. Evidence^{92, 93, 94} suggests that employers find that the combination of theory and practice provided by apprenticeships is beneficial for their businesses. They deliver the skills employers need and provide a cadre of skilled workers from which future supervisors and managers can be selected.

Although manufacturing employers encounter relatively high costs in providing apprenticeships compared with other non-manufacturing sectors, they can be recouped soon after training if the employer can retain apprentices after completion⁹⁵. Consequently apprenticeships offer advantages both to employers who obtain the skills they need, and to apprentices who obtain relatively good returns in wages and being in employment^{96, 97}. The opportunity to earn whilst learning is an increasingly attractive option to young people particularly with higher HE fees and when there is potential to progress on to Higher Apprenticeships^{98, 99}.

The 2012 Richard Review of Apprenticeships¹⁰⁰ highlighted the need for an emphasis on the 'quality' of apprenticeships. It argued that employers should design apprenticeships to meet the future requirements for their industry, with employers and government safeguarding quality. This is likely to mean that 'islands of excellence' are produced¹⁰¹ where some of the large manufacturing firms have excellent provision. The challenge is how to get greater demand for apprenticeships from a wider spectrum of employers, especially SMEs, to create a coherent, sustainable and widely distributed capacity for skill formation in young people. There

⁹⁰ This decision was announced by the Prime Minister during 2006, with the following published shortly afterwards. Department for Business, Enterprise and Regulatory Reform (2007). ⁹¹ Data kindly provided by Prof Martin Freer, Director of the Birmingham Centre for Nuclear Education and Research.

⁹² Hogarth, T., Gambin L., Winterbotham M., Baldauf B., Briscoe G., Gunstone B., Hasluck C., Koerbitz C. & Taylor C. (2012). ⁹³ Lewis P. (2012a). ⁹⁴ Lewis, P. (2012b). ⁹⁵ At the high value end of the spectrum estimates indicate that it costs Rolls-Royce approximately £90,000 to put an individual through a three-year Advanced Apprenticeship course, with approximate levels of Government funding for the total programme being about £16,000 for 16-19 year olds and £9,000 for 19-24 year olds. Other case study evidence on the net costs of training from the 'Fifth Net Benefits of Training to Employers Survey' suggests that the net cost for an Engineering Apprentice at Level 2 and 3 combined is £39,600, which is more than in other sectors. The payback period for a Level 3 Engineering Apprentice is 3 years and 7 months. (For further details see Hogarth T., Gambin L., Winterbotham M., Baldauf B., Briscoe G., Gunstone B., Hasluck C., Koerbitz C. & Taylor C. (2012). ⁹⁶ London Economics (2011) ⁹⁷ Greenwood, C., Harrison, M. & Vignoles, A. (2011). ⁹⁸ Hogarth T., Gambin L., Winterbotham M., Baldauf B., Briscoe G., Gunstone B., Hasluck C., Koerbitz C. & Taylor C. (2012). ⁹⁹ Mason, G. (2012). ¹⁰⁰ Richard D. (2012). ¹⁰¹ Fuller A. and Unwin L. (2012)

is a role for large employers in manufacturing to stimulate demand from SMEs which face constraints in cost and capacity in providing training. There are also other models. These include Group Training Associations, which are formal partnerships funded through a membership fee, where employers come together to address common business service, recruitment and/or training challenges¹⁰². Such Group Training Associations can help employers navigate the complexity of the current apprenticeship system¹⁰³.

ADVICE FOR POLICY MAKERS:

Raising the quality of vocational training

The 'quality' of apprenticeships needs to be emphasised¹⁰⁴. A critical future challenge is how to get greater demand for apprenticeships from a wider spectrum of employers, especially SMEs, to create a coherent, sustainable and widely distributed capacity.

In England the current development of 'apprenticeship hubs' as part of the City Deals initiative may help catalyse new apprenticeships in small businesses. Local Enterprise Partnerships also have an ongoing role to play in promoting apprenticeships and other vocational training to meet local skills needs as part of local skills strategies.

Anticipating the demand for future manufacturing skills

As requirements for human capital shifts towards more hybrid skills and more workers in highly skilled jobs, it will be essential for Government and others to anticipate future demand and communicate the requirements across skills providers.

Equipping workers to become and remain agile in keeping pace with changing technologies, products, and markets

The future manufacturing workforce will need to be agile enough to:

- adapt to changing market positions of goods (i.e. develop systems which accommodate mass production if a product shifts from a 'high value good' to a commodity);

- and develop the next range of high value products¹⁰⁵.

Education and training systems need to equip employers and workers with 't-shaped' or 'hybrid' skills, to ensure they become agile in management, market and technical terms. This can be achieved by ensuring the coverage of STEM courses is refreshed regularly to ensure that employer needs are being met.

Supporting higher level skills by facilitating academic-industry collaboration

Considerable progress has been made in recent decades in strengthening UK academic-industry links, with the National Centre for Universities and Business launched in 2013. However, a great deal remains to be done. Greater emphasis is needed on policies which facilitate collaboration and knowledge transfer between universities and industry. One obvious step is greater business sponsorship of PhD students, with the role of SMEs outside major supply chains given special consideration to avoid important areas of knowledge transfer being overlooked.

It is worth noting that in the US, community colleges play an important role acting as a hub for careers coaches and stakeholders to create education, training and employment pathways into manufacturing. The Government response to Sir Andrew Witty's review into universities and growth¹⁰⁶ will provide a potential opportunity to strengthen academic-industry collaboration.

Resourcing

The level of resource needed for engineering students is relatively high compared with many other subjects, given the access they require to high performance computers and other equipment. HE funding policy needs to ensure that resources are protected in the future, and are at a level that is at least comparable with those of the UK's competitors.

Improving UK capability in language skills and inter-cultural understanding

Policies promoting language skills in Mandarin, Spanish, Hindi and Arabic, which are set to be amongst the most widely spoken languages worldwide in 2050, alongside technical and business skills, are likely to benefit UK manufacturing activities by helping businesses enter new markets¹⁰⁷. A 'languages for business' element to the National Curriculum would be one way of rising to this challenge. MBA courses that ensure competence in more than one language (for example the London Business School MBA course¹⁰⁸) are another.

6.2.4 UTILISATION: ENSURING THAT MANUFACTURERS UTILISE FUTURE WORKERS EFFECTIVELY

The manufacturing workforce in the UK will need to be more diverse in the future. Development of the necessary skills in the decades ahead will be critical. In driving these changes employers should not only aim to benefit themselves but wider society, by providing sufficient demand for the new skills that will be available and by providing interesting, well designed job opportunities.

(I) RAISING EMPLOYERS' DEMAND FOR SKILLS

Stimulating demand

Traditionally, skills policy has tended to focus on the supply of skills. Now demand side issues (i.e. how employers develop and use skills) are increasingly recognised as being equally significant¹⁰⁹; a position reinforced by the OECD's Skills Strategy (2012)^{110 111}. This policy message needs to be promoted to stimulate demand for skills in manufacturing, and to ensure that employers maximise utilisation of the skills of existing workforces, and that investments in skills are put to optimal use¹¹².

Understanding future skills needs

If employers are to be competitive in the short-term and capitalise on medium to long-term future opportunities, it is critical that they are as clear as possible about their future skills needs. These requirements need to be communicated effectively to the education sector, training providers and individuals. This need for concerted action highlights the continued importance of Government coordinating the skills landscape across compulsory education, further education, vocational education and higher education¹¹³.

Government policy needs to be sensitive to the need for stability and simplicity within the skills system to secure employer engagement, increase familiarity with different types of qualifications, and to advise and guide organisations on navigating the system. This is especially so given the future role of Government as an 'enabler' increasingly empowering employers, individuals, and learning providers to work better together through promoting employers demand for skills, individual ambition and responsive provision, rather than to act as a 'provider'¹¹⁴.

To enhance responsiveness to future requirements for skills, manufacturing employers would benefit from strengthening their knowledge of skills which are currently available, and skills likely to become available in the future. This survey would need to include workers within the organisation, subcontractors within the supply chain, and external sources of skills which might be drawn on when necessary. Once they have assessed internal and external potential sources of workers, employers will need to plan ahead to determine gaps between available and required skills, and identify strategies to develop, populate and implement skills pipelines to counter future shortages^{115 116}. The challenge will be to ensure necessary organisational ability to access skills when they are required.

(II) DESIGNING JOBS TO ENABLE UTILISATION OF A WIDER RANGE OF SKILLS

Once employers have a better understanding of current and future skills capabilities and

¹⁰⁷ Business Forum for Multilingualism established by the European Commission (2008). ¹⁰⁸ London Business School: Language Learning. ¹⁰⁹ Payne, J. and Keep, E. (2012). ¹¹⁰ OECD (2012e). ¹¹¹ Green, A. (2013). ¹¹² UK CES (2009). ¹¹³ Responsibility for skills is devolved to the nations of the UK. ¹¹⁴ UK CES (2009). ¹¹⁵ Human Capital Institute Research (2011). ¹¹⁶ Oracle (2012).

requirements, they can potentially be supported in using this knowledge to design jobs which people will want and where they can maximise use of their skills. There is a general lack of evaluation of policies for skills utilisation, but there is some evidence that policies have had a positive impact in the industries in which they have been implemented¹¹⁷. Research also suggests that the way in which jobs are designed, in terms of the complexity of tasks and the level of autonomy and discretion afforded to workers, has a significant bearing on the scope that workers have to develop and deploy their skills in the workplace¹¹⁸.

There is growing interest in skills utilisation in policy discourse^{119 120 121}. Effective skills utilisation concerns confident, motivated and relevantly skilled individuals who are aware of the skills they possess and how best to use them. It also focuses on workplaces which provide meaningful and appropriate encouragement, opportunity and support for employees to use their skills effectively to increase performance and productivity, improve job satisfaction and employee well-being and stimulate investment, enterprise and innovation¹²². A coherent approach to the most effective application of skills in the workplace to maximise performance in the future would involve the interplay of employers, employees, sector bodies, education and training providers and government, and the use of a range of HR, management and working practices.

ADVICE FOR POLICY MAKERS:

The Employer Ownership of Skills agenda

The future role of government will increasingly be to stimulate employer demand, individual aspiration and a responsive provision of learning and skills development, rather than to provide funding per se. This role entails provision of information for individuals on projected future employment opportunities, skills requirements and pay levels, and involves employers making their current and future skills requirements as clear as possible to individuals and training providers. Pricing signals, incentives and strategic leadership are needed to encourage a more skills intensive economy, in which workers with a range of skills are capable of responding creatively to diverse opportunities in the future.

Defining the skills pipeline in manufacturing businesses

There is a strong case for Government to encourage manufacturing employers to assess their own skills pipelines to identify expected future shortfalls, potentially through the Manufacturing Advisory Service.

Raising demand for skills

Demand side skills issues, including how employers develop and use skills, are becoming more important. For the future, local and national skills strategies need to take account of the need to raise the demand for skills, alongside the supply of skills, especially at higher levels.

Focusing on developing and using skills

Skills policies have the potential to play a critical role in helping employers to optimise utilisation of existing workforces. Examples include encouraging work to be redesigned where possible to give workers the ability to use a wider range of skills, and modifying jobs to ensure they make best use of skills available in the workforce.



7. SYSTEMIC AREAS FOR GOVERNMENT FOCUS: PRIORITIES AND NEXT STEPS

This Chapter draws together the key messages from previous chapters to set out a vision for how future Government policy needs to adapt in response to fundamental changes in the wider manufacturing system.

This will be critical in ensuring that in the future, the UK manufacturing sector is able to seize new opportunities to thrive, supporting economic growth and benefitting the quality of life for UK citizens.

The Chapter begins by briefly reviewing key conclusions of previous Chapters before discussing the nature of wider industrial policies, and setting out the key priorities for new policies. Finally, it discusses what needs to happen next.

Introduction: Future challenges and opportunities for UK manufacturing

The UK manufacturing sector now accounts for a significantly smaller proportion of the UK economy's output than it did 30 years ago and it employs significantly fewer people. These trends, whilst apparent in developed economies including the US, France and Germany, have been more marked in the UK.

UK manufacturing also compares poorly to key competitors, in terms of expenditure on capital investment, and research and development. Around a half of manufacturing R&D in the UK is carried out by overseas controlled multinationals and compared to other major economies, UK manufacturing R&D as a whole is far more reliant on overseas funding. These characteristics are important, given:

- The powerful contributions that the manufacturing sector can make to an economy by stimulating innovation, achieving high levels of productivity, leading in exports and providing high quality jobs; and
- That manufacturing will enter a dynamic new phase in the decades ahead, as it is transformed by global forces and competition intensifies for flows of foreign direct investment and where manufacturing is located (see Box 7.1).

Without action from policy makers and manufacturers, there is a high risk that the UK will fail to capitalise on substantial new opportunities for creating future value. Inaction will also risk further reductions in the relative size of this sector of the economy with its vital and complementary links to other sectors.

This Report provides advice for Government and industry on four future characteristics of manufacturing, each of which will present a wide range of opportunities for UK manufacturers:

1. Faster, more responsive and closer to customers (Chapter 3)
2. Exposed to new market opportunities (Chapter 4)
3. More sustainable (Chapter 5)
4. Increasingly dependent on highly skilled workers (Chapter 6)

Manufacturing will be subject to rapid and pervasive technological change, transforming business models and increasing the complexity of manufacturing value chains, with production remaining centrally important. This Report argues that these transformations, which will affect manufacturing in the UK over the next three decades, require a much more systemic approach to policy making. This will require innovation in metrics to capture changes in the scale and nature of manufacturing activity as a key input into policy development. It will also require Government to invest in the enhancement of policy makers' capacity to both understand and design policy in specific sectoral and technological contexts and take a cross-departmental, long-term and consistent approach to policy intervention. The following three areas are put forward as 'systemic' future priorities for Government:

- Taking a more integrated view of value creation in the manufacturing system: New metrics that go beyond measuring production output would be an important first step in assessing how value is being created in new ways, and how manufacturing connects with other parts of the economy.
- Adapting industrial policy to take a systems approach, allowing better targeting of specific stages of the manufacturing value chain: New measures are suggested in this report which would be informed by the new metrics and a 'systems-based' approach to the design of interventions, tailored to specific emerging technologies, and specific manufacturing sub-sectors. A 'systems-based approach' to industrial policy would also emphasise the linkages and overlaps between science, technology and innovation policies; make it easier to identify potential unintended consequences of policies, and identify areas where intervention would achieve the greatest impact.
- Enhancing Government capability in evaluating and coordinating policy over the long term: Policies across government have direct and indirect effects on the manufacturing sector, which are often felt over many years. It is vital that in introducing and developing policy, a long-term perspective is adopted which matches long-term commitments in terms of investment, and research and development which the private sector must make to grasp the opportunities ahead. UK governments must enhance their capability to identify which policies

work best in the long-term in a diverse range of manufacturing sub-sectors. It is also essential that policy is maintained in a consistent way over time. There are examples from other countries

which suggest that one option to ensure long-term consistency in policy development and applications would be to create a UK 'Office for Manufacturing' (see Section 7.3).

BOX 7.1: THE CHANGING NATURE OF THE MANUFACTURING SECTOR

As outlined in earlier chapters, in the decades ahead manufacturing will become:

Faster, more responsive and closer to customers:

Advances in technologies including sensors, additive manufacturing and ICT will 'digitise' manufacturing. It will take place closer to the customer, with a much greater range of products becoming more 'personalised' and tailored to specific needs. Factories of the future will be more diverse in their scale, with potential for mobile and home manufacturing. Government will need to ensure that UK manufacturers are able to take advantage of the technological revolution in how products are designed, made, offered, used and recycled. In particular, there is a strong case for better overall coordination of the technology pipe line for manufacturing technology (see Chapter 3).

Exposed to new market opportunities and challenges:

BRIC economies are likely to become larger than the US by 2015 and the G7 by 2032. Current markets for UK manufacturers, including the US and Europe, will continue to be important. Demand for products will change in response to ageing populations and changing levels of personal wealth in developed and emerging economies. At the same time, some new foreign investments in manufacturing are likely to be drawn away from Europe. Government will need to ensure that UK manufacturers are prepared to adapt to a world of increasingly fierce competition for trade, inward investment, and controlling value chains. Government will also need to work to address areas of current underperformance and underinvestment, including exporting by large firms, capital investment, and R&D (see Chapter 4).

More sustainable:

Increasing competition for resources is likely to result in greater price volatility in commodities. Successful manufacturers will significantly reduce inputs (for example materials and energy) while increasing the value to the customer. They will also place much greater emphasis on new ways of doing business, such as moving to a 'circular economy' model, with 'end of life' products either re-manufactured or used as inputs to the production process. Government will need to support manufacturers in their drive for resource efficiency and as they experiment with new ways of doing business (see Chapter 5).

Increasingly dependent on highly skilled workers:

Manufacturers in developed economies will increasingly use the quality of their workforces to compete in high value manufacturing activities. Ensuring access to high quality workers with science, technology, engineering and mathematics (STEM) qualifications and deep technical knowledge combined with strong commercial awareness, will be important. Government will need to increase the scale and ambition of its current programmes to ensure sufficient quantity, quality and utilisation of future manufacturing workers (see Chapter 6).

Much more than just making a product and selling it:

New revenue streams are being created as manufacturers make use of a wider 'value chain' embracing R&D, production, services and other activities. For example, 39% of UK manufacturers derived value from 'manufacturing services' in 2011 compared to 24% in 2007. Other new ways of doing business include becoming 'factoryless goods producers' who design and sell products but who outsource production. Government will need to play a central role in helping manufacturers adapt to new ways of doing business and controlling value chains (see Chapter 2).

7.1 TAKING A MORE INTEGRATED VIEW OF VALUE CREATION IN THE MANUFACTURING SECTOR

Manufacturing is no longer just about 'production' – making a product and then selling it. Manufacturers are increasingly using a wider 'value chain' to generate new and additional revenue from pre- and post-production activities, with production playing a critical role in allowing these other activities to occur. For example, 39% of UK manufacturers with 100 or more employees derived value from 'manufacturing services' related to their products in 2011, compared to 24% in 2007¹. Future sources of new and additional revenue for manufacturers are likely to include the following²:

- Selling services in combination with products much more extensively;
- Using products to generate new information about consumers and the usage of products;
- Becoming 'factoryless goods producers', capturing value by selling technological knowledge and leaving production to others;
- Shifting to a 'circular economy' way of doing business, with end of life products re-manufactured and returned to original specifications or better;

- Adapting to changing patterns of product ownership, by providing more robust products for 'collaborative consumption' amongst customers as opposed to outright ownership of a product;
- Forming strategic alliances with manufacturers in the same and different sub-sectors, leading to collaborative communities which may become more significant in manufacturing activity than networks dominated by lead firms; and
- Using operational capabilities combined with greater entrepreneurial insight to respond rapidly to technological developments.

New metrics will capture the novel ways in which manufacturers are creating value, and reveal the scale and location of important changes within the sector (see Box 7.2). These will be critical in revealing key interconnections in the economy, and helping identify where in the value chain future policy intervention should focus to support manufacturers as they create and capture new and additional revenue streams.

BOX 7.2: MEASURING MANUFACTURING

The performance of the manufacturing sector is currently measured by classifying the output of manufacturing firms by the main type of economic activity in which they are engaged³, with the ONS using the Standard Industrial Classification (SIC) system. This provides a limited and incomplete picture since it fails to capture the wider manufacturing value chain or the incorporation of pre- and post-production services within the firm (see Chapter 2).

For example, the SIC metrics fail to capture some activities which are carried out in businesses classified to service sectors which could be classified as manufacturing. A recent study of the US manufacturing sector found that a large number of firms classified to the wholesale sector also designed and coordinated the production of the goods they were wholesaling. Classifying these factoryless goods producers to manufacturing would have shifted 14% of jobs and 16% of output from wholesaling to manufacturing⁴. Another example is provided by Berger in a recent study of manufacturing in the US⁵.

“Repairs are another service that manufacturing firms have offered. We do not have measures across the economy of how significant a fraction of manufacturing company revenues derive from repair services, but the interviews suggest it may be substantial. The CEO of a New England company that makes tanks and piping for biotech firms estimated that about a quarter of his revenues derive from repairs on equipment – from all makers, not only their own – and fully one half of his profits.”

In addition, there is evidence⁶ that in 2009 UK firms that engaged in both manufacturing and other non-manufacturing activities accounted for around 23% of all market-sector output, whereas their manufacturing activities alone accounted for slightly less than 8% of total UK output⁷.

Another deficiency with existing metrics used in the UK is their failure to quantify the value of goods and services systematically along the value-chain.

The ONS collects some limited data on the type of goods and services bought-in by firms, and to which broad sectors goods and services are sold (input-output linkages of firms and products). This allows them to construct Supply-and-Use and Input-Output tables for the UK⁸ which show in aggregate the flow of goods and services along the supply chain. However, it is not possible to use these data to measure which ‘core’ fabricated products also involve ‘manufacturing-dependent’ pre- and post-production goods and services. To do this would require access to individual firm data supplied to the ONS, with information on:

- What goods and services are bought-in and to whom output is sold; and
- Which plants and firms supply and purchase these goods and services, and what proportion of the value added of a firm classified to manufacturing consists, for example, of value added through R&D and post sales services compared to the manufacturing process *per se*.

Careful consideration would need to be given to the level of the business unit at which the data are collected, and its potential sensitivity. A new pilot project could be undertaken by the ONS. This would allow the importance of manufacturing in the economy to be assessed more accurately, and the potential cost in terms of business reporting and survey administrative costs to be evaluated. It would also provide important insights into the nature of the value-added chain in the pilot sample. This would be a key factor in understanding the determinants of competitiveness identified in Chapter 4 (covering not only control of value chains, but other issues such as co-location, and the importance of the service content of the products of manufacturing firms (servitisation)).

It is important to note that the rationale for developing new metrics is not to ‘increase’ the size of the manufacturing sector; but to provide a means of assessing the significance of service content in the success of manufacturing business models and the interrelationship between manufacturing and other sectors.

³ For further details see: <http://www.ons.gov.uk/ons/guide-method/classifications/current-standard-classifications/standard-industrial-classification/index.html>

⁴ Bernard, A. & Fort, T. (2013). ⁵ Berger, S. (2013). ⁶ Evidence Paper 23: Moffat, J. (2013). ⁷ If these enterprises (engaged in manufacturing and non-manufacturing) are operating their different firms and plants as part of a vertically integrated supply-chain. It is likely that most are operating plants that are ‘trading’ with each other. However, other enterprises could be operating firms and plants in distinct industries (i.e., as a conglomerate). Conversely, firms and plants operating along the value-added chain do not need to belong to a common enterprise, so the estimate of 23% may be a major underestimate. ⁸ ONS (2011)

7.2 TARGETING SPECIFIC STAGES OF THE MANUFACTURING VALUE CHAIN

Manufacturing has changed dramatically since the heyday of industrial policies in the 1970s. In particular, there is now greater competition to control, operate and integrate manufacturing value chains, greater mobility of investment capital, lower trade costs, and heightened tax competition⁹. An industrial strategy for the next three decades must take account of these changes.

First, in a more globalised world, the weight of government support needs to shift towards 'high spillover, low mobility' factors where the UK can be more certain of capturing and retaining value, for example, enhancing human capital rather than transferable technology. The widening of the range of feasible destinations across the world for FDI in a context of tax competition means that government will have to pay greater attention to ensuring that the UK can continue to be an attractive location. Policies to nurture successful agglomerations deserve a high priority and go beyond clustering based on the promotion of high tech sectors per se. This agglomeration policy may have implications for the design of corporate taxation but also for a wider range of factors that influence mobile capital including infrastructure, the science base, availability of skills, and the regulatory environment. Most important of all is to recognise the value of increasing the geographical 'stickiness' of economic activity by making alternative locations less good substitutes¹⁰.

Secondly, a sharper targeting of specific parts of the manufacturing value chain is needed. The changes to manufacturing, including fragmentation linked to globalisation, the emergence of new business models, and the global environment in which manufacturing operates have profound implications for policy¹¹. At a fundamental level, there is a clear case to build upon existing support for

manufacturing subsectors and partnerships between Government and industry, and to ensure that policy interventions, where needed, are more targeted at different technologies, sectors and stages in the manufacturing value chain.

Future industrial policies, informed by updated metrics (see Section 7.1), will need to be used to develop new measures tailored to specific requirements of manufacturing sub-sectors and the technologies upon which successful future business models will be built. This will include, for example:

- Facilitating the emergence of challenger businesses. These exploit new business models and cross cutting approaches in technologies, across sub-sectors, to drive 'disruptive growth' in manufacturing. For example, support might focus on businesses specialising in advanced materials, big data or related applications, or additive manufacturing technology, all of which collaborate with others to work across manufacturing sub-sectors;
- Enhancing UK capabilities that cannot easily be relocated abroad. This is particularly important given the increasing ease with which manufacturing activities and the different elements of value chains can now be relocated around the world. This will include the promotion of the 'co-location' of R&D with production and the science base, particularly for products dependent on process innovation. A new emphasis on vibrant labour markets, digital and transport infrastructure will be key.
- Supporting the creation of new revenue streams from manufacturing services, for example capitalising upon knowledge generated by sensors embedded in products; and
- Helping manufacturers to expand their capabilities in re-manufacturing and resource efficiency.

Meeting these requirements will require a shift by Government towards a systems based rationale for the design and delivery of industrial policy.

MOVING TOWARDS A 'SYSTEMS BASED APPROACH' TO INDUSTRIAL POLICY

Learning from the past¹²

A wide variety of definitions of industrial policy exist. A helpful and broad recent definition is the following: 'Industrial policy is any type of intervention or Government policy that attempts to improve the business environment or to alter the structure of economic activity towards sectors, technologies or tasks that are expected to offer better prospects for economic growth or societal welfare than would occur in the absence of any such intervention ...' (Warwick, K. 2013¹³).

The market failure rationale for industrial policy is based on the view that because some kinds of investments yield gains which go beyond the individual firm making the investment, there will be a systematic tendency for under-investment by the private sector. To the extent that these investments are important for the overall economic growth of the country and for the future growth of societal welfare, governments may need to intervene so that the level of investment is raised. Examples of such interventions by Governments to offset the problems of market failure include investments in human capital through education and training, and in R&D. In both cases the private return is likely to be lower than the social rate of return as 'knowledge' generated from undertaking R&D often 'spills-over' to those not directly involved in making the initial investment. Workers who have been trained by one firm may leave to transfer their skills to another which did not pay for the training.

Traditionally, this market failure rationale for intervention has resulted in industrial policy that can broadly be distinguished in terms of 'horizontal' and 'selective' industrial policies (see Table 7.1). The latter are aimed specifically at improving the performance of particular industries or firms while the former are designed to benefit the economy more generally.

Table 7.1: Examples of Instruments for industrial policy

	HORIZONTAL	SELECTIVE
Product market	Competition policy	National champions
	Indirect tax	Nationalisation/ privatisation
	Product market regulation	State aids
	Exchange rate policy	Trade policy
		Public procurement
Labour & skills	Education policies	Targeted skills policy
	Training subsidies	Apprenticeship policies
	Wage subsidies	
	Labour market regulation	
	Employment taxes	
Capital market	Corporate tax policy	State investment bank
	Financial market regulation	Strategic investment fund
		Emergency loans
Land	Land-use planning rules	Place-based clusters policy
	Infrastructure policy	Enterprise zones
Technology	R&D tax credit	Public procurement
	Science budget	Patent box
	Intellectual property rights	Selective technology funding

¹² For detailed discussion on industrial policy please see Evidence Paper 37: Crafts, N. & Hughes, A. (2013). ¹³ Warwick, K. (2013)

Although there are many examples of successful industrial policies in developed economies¹⁴, 'industrial policy' has long had a bad press in the UK¹⁵. There is a good reason for this, namely, the policy failures of the 1960s and, especially, the 1970s¹⁶. Although the widely recognised failures of that period relate to selective policies, there were also flaws in the design of horizontal policies. Both types of policy turned out often to be poor value for money either by giving support to firms or projects with no viable long-term future or through incurring large 'deadweight losses' by subsidising activities such as investment expenditure where most expenditure would have happened anyway.

The downside of industrial policies is that they may be vulnerable to 'government failure' where the choice or implementation of policy is inefficient. The reasons for this can sometimes be inexperience or lack of information but there are also reasons to worry about systemic problems arising from the political process which may be prone to short-termism and unduly influenced by lobbying. Although these issues largely relate to selective policies, the problem goes wider, as is illustrated by the history of British investment in public infrastructure¹⁷.

The most obvious improvement in horizontal policies from the 1970s in relation to manufacturing was to increase competition across much of the economy through the abandonment of protectionism, entry into the Single European Market, deregulation and, ultimately, a strengthening of competition policy. Indeed, the overall trajectory of UK industrial policy since the late 1970s is perhaps best described as seeking to improve the workings of a 'liberal market economy' by addressing 'market failures'.

Current thinking about policy development however, goes beyond traditional arguments about market-failure to embrace notions of 'systems failure', especially in innovation and technical change. A systems approach (see Box 7.3) focuses on coordination problems and is especially useful in the context of promoting the development, awareness and exploitation of new technological opportunities. Traditional approaches to selective industrial policy identified sectors or firms to support but a systems approach is based on selecting new ideas as they emerge from the science base and working back from sectoral problem-solving and technical challenges. Whereas the old vocabulary was about 'picking winners', the new terminology is that of 'choosing races and placing bets' in an uncertain and rapidly changing world¹⁸.

¹⁴ Evidence Paper 4: Chang, H. et al. (2013). ¹⁵ Evidence Paper 2: Broadberry, S. & Leunig, T. (2013). ¹⁶ Several examples are given in Evidence Paper 37: Crafts, N. & Hughes, A. (2013); for example, aircraft, shipbuilding, and motor vehicles (British Leyland is a prime example of the latter). ¹⁷ See, in particular, the report of the LSE Growth Commission (2013). ¹⁸ Evidence Paper 37: Crafts, N. & Hughes, A. (2013).

BOX 7.3: THREE CORE ELEMENTS OF A SYSTEMS APPROACH¹⁹

1. The economic 'actors' operating within the particular regional national or sector system. This includes private sector consumers and businesses, and the public and not-for-profit sectors. Firms in the system identify commercially attractive opportunities and devise business models to exploit them. In doing this they must invest in human and financial capital and a wide range of intangible assets including R&D, design and ICT. A firm's investment in R&D generates new knowledge and increases capacity to absorb ideas from external sources²⁰.
2. The second element is usually defined as 'institutions'. These are not to be understood as organisations or entities, but rather as the 'norms of conduct' or 'rules of the game', including contractual legal and regulatory systems within which economic actors operate.
3. The third element consists of the 'connections' between economic actors. System connections encompass a wide variety of non-market as well

as market relationships including collaborative and formal, and informal, interpersonal and inter-organisational networking connections. There may be significant variations across sectors, regions, technological trajectories and national systems in the strength, nature and variety of connections and their interplay with institutional differences²¹.

The institutions and connections define the 'institutional architecture' within which the economic actors operate. This institutional architecture will affect both the nature of systems failures and the feasibility and effectiveness of 'traditional' policy measures applied in different systems²². If for example the incentives for manufacturing firms to invest for the long term are not matched by incentives in the financial sector to support such investment, there will be a systems failure and the institutional architecture will lead to underinvestment in the long-term. In the case of the UK variety of capitalism (Box 7.4) there is substantial evidence that capital market connections to manufacturing investment are inhibited via an emphasis on short-termism in the financial sector²³. A systems perspective on policy therefore must address a wider range of issues than market failure.

BOX 7.4: INSTITUTIONAL ARCHITECTURE AND VARIETIES OF CAPITALISM

- Institutional architecture is related to the concept of 'varieties of capitalism' which has been used to suggest that the nature of investment will differ significantly between countries²⁴.
- For investment generally, and R&D in particular, it has been argued that the UK variety of liberal market capitalism inhibits long-term investment compared with more coordinated varieties exemplified by Germany and Japan²⁵.
- Impatient capital markets driven by an over-concern with short-term movements in stock market prices, the threat of takeover, and arms-length relationships between the providers and users of finance, serve to promote short-termism in investment decisions²⁶.

- Institutional architecture may also alter the nature of innovation by inhibiting incremental innovation. Impatient capital markets may be complementary to labour markets focused on 'hire and fire' relationships which inhibit more stable labour contracts that foster investment in firm specific training and skills²⁷.

¹⁹ Edquist, C. (2005). ²⁰ Cohen, W. & Levinthal, D. (1990). ²¹ Lundvall, B. (2007). ²² Dodgson, M., Foster, J., Hughes, A. and Metcalfe, J. (2011); Edquist, C. (2005); Lundvall, B. (2007); Nelson, R. (1993). ²³ Evidence paper 16: Hughes, A. (2013); and Kay, J. (2012). ²⁴ Hall, P. and Soskice, D. (2001). ²⁵ Dore, R. (2000). ²⁶ Haldane A. and Davies, R. (2011); Kay, J. (2012); Evidence paper 16: Hughes, A. (2013). ²⁷ Evidence Paper 5: Deakin, S. (2013); Evidence Paper 16: Hughes, A. (2013); and Evidence Paper 37: Crafts, N. & Hughes, A. (2013)

Market failure and systems failure

The mainstream arguments on market failure set out earlier provide important rationales for public sector intervention, but rarely provide sufficient guidance for the degree of intervention in particular instances or different systems. Nor do they address the many other potential institutional and connection failures which may arise when a systems-based approach is adopted²⁸.

System failures can arise from various sources. Transition and lock-in problems, for example, arise from inertia due to substantial sunk investment by private and public sectors in existing or dominant technologies. These are linked to transition failures in moving to new technological structures which pose major problems of investment and business reorganisation, for example, in the switch to low carbon vehicles²⁹. Institutional system failures arise when formal and informal rules and incentives affecting different parts of the system are inconsistent. An example is the alleged difference in norms and incentives between academic scientists and the private sector in conducting research. Here it is argued that the former emphasise open publication and disclosure, whilst the private sector, in its pursuit of research connected to private exploitation, is committed to secrecy and patent protection³⁰.

Systems failure and demand side policy

One of the most important implications arising from the development of more systemic views has been the emphasis given to the development of demand side as well as supply side policies in addressing lock in, and transition problems and uncertainties. This is based around the potential role in demand side policies of the public sector as a procurer of R&D and the role of public procurement more generally in influencing the scale, direction and form of the provision of the goods and services it purchases³¹. Public procurement is then seen as a potentially important demand side innovation policy device for reducing uncertainty in areas where lead user activities are important. Public procurement can also be seen as complementary to supply side measures linked to standard market failure arguments which, through taxation and subsidy, influence the relative prices at which businesses conduct their innovation related activities³².

Systems failure and the diffusion of innovations

An important aspect of productivity growth is the effective assimilation of new technology across economic actors in the system. Diffusion of new technologies may be inhibited where system lock-ins occur due to the strength of major past or 'sunk' investments supporting existing technologies (for example electric versus petrol-driven automobiles). Here sector-based selective industrial policies may include the use of demonstrator or pilot plants and public procurement. Policy can support diffusion through provision of information and the improvement of market and non-market connections between firms, and between them and the science base by enhancing the profitability of adopting innovations and by raising the absorptive capacity of firms³³. Absorptive capacity entails the ability of firms to search for, evaluate, assimilate, and exploit knowledge. This is underpinned by education and skills but also by investments in intangible capital including crucially R&D³⁴ but also training, flexibility in use of business models, effective cooperation with research organisations, and organisational capabilities so that each of these become part of the industrial policy domain³⁵.

Systems thinking and current UK policy

Systems thinking has already had an impact on UK industrial policy³⁶ development. A range of innovation policies inspired by systems thinking were reinforced or introduced from the 1990s onwards as a result of a series of innovation policy reviews³⁷.

A number of the most recent developments in policy have been designed to establish a richer institutional architecture linking universities and the business community, and the development of sectoral and technological strategies. This has included the development of a set of 'Catapult' centres, discussed in Chapter 3, focused around a selected set of themes and technologies³⁸. In general, evaluations of systems based interventions related to innovation have been more favourable than the market failure based industrial policies introduced in the 1970s³⁹.

A 'systems-based approach' for the future

In thinking about the next 30 years, the question is whether the UK will be better served by a continued mix of 'horizontal' and 'selective' industrial policies, or by an attempt to build on recent system-based policies. This systems approach would address aspects

of the institutional architecture which are recognised as inhibiting the future development of manufacturing within the economy. This report emphasises that this approach is the way forward, with three key challenges to meet in doing so:

- The need to integrate science technology and innovation policy with industrial policy. This will allow for enhanced coordination of policy and make it easier to identify potential unintended consequences of policies and to identify where policy intervention would achieve the greatest impact.
- The need to develop innovative ways of informing strategic choices when 'choosing races and placing bets'. This involves governments developing new metrics to capture the changing nature and role of manufacturing. Crucially it will also involve working with the private sector to develop a deep shared understanding of different sectoral or technological systems, their associated manufacturing value chains and the possibilities for capturing value added in the UK.

- The need to assess whether there are changes in policy architecture to support this approach. South Korea, for example, launched the Ministry of Science, ICT and Future Planning⁴⁰ in 2013 to integrate science and technology in general, and ICT, and to establish, coordinate, and evaluate policies related to science and technology⁴¹.

Integrating science, technology, innovation and industrial policy

Science policy, technology policy and innovation policy are often treated separately from industrial policy (see Figure 7.1). There is a strong overlap between the instruments of intervention, in particular as the focus moves from technology policy towards innovation policy and they must be developed and applied in an integrated fashion.

Strategic choices

An example of a strategic systems approach to technology selection along the lines advocated is shown in Box 7.5⁴².

Figure 7.1: A typology of policy domains

SCIENCE POLICY

Focus: Production of scientific knowledge

Instruments:

- Public research funds granted in competition
- (Semi-) Public research institutions (i.e.: laboratories, universities, research centres)
- Tax incentives to firms
- Higher education
- Intellectual property rights

TECHNOLOGY POLICY

Focus: Advancement and commercialisation of sectoral technical knowledge

Instruments:

- Public procurement
- Public aid to strategic sectors
- Bridging institutions (between research world & industry)
- Labour force training & improvement of technical skills
- Standardisation
- Technology forecasting
- Benchmarking industrial sectors

INNOVATION POLICY

Focus: Overall innovative performance of the economy

Instruments:

- Improving individual skills & learning abilities (through general education system & labour training)
- Improving organisational performance & learning (i.e. ISO 9000 standards, quality control, etc.)
- Improving access to information: Information society
- Environmental regulation
- Bioethical regulation
- Competition regulations
- Consumer protection
- Corporate law
- Improving social capital for regional development: Clusters & industrial districts
- Intellectual bench marking
- Intelligent, reflexive & democratic forecasting

Source: Lundvall and Borrás (2005)

²⁸ See for example Metcalfe, J. (2005); Dodgson, M. et al. (2011); BIS (2011) and for a comparison of systems and market failures Chaminade and Edquist (2010).

²⁹ HM Government (2008); King, J. (2008). ³⁰ This has engendered a major debate in the UK over the extent to which the allocation of public funds should be directed according to the motivations and the incentives of the former as compared to the latter; the nature of UK university-industry links, and the design of intermediary organisations on the boundaries of universities and industry (The Royal Society (2011); Hughes, A. (2012); Hauser, H. (2010); Mina, A. et al. (2009); Deiaci, E. et al. (2012); Hughes, A. and Kitson, M. (2012). ³¹ Edquist, C. et al. (2000); OECD (2010a); Connell, D. and Probert, J. (2010). ³² OECD (2010b).

³³ Geroski, P. (2000). ³⁴ Griffith, R. et al. (2004). ³⁵ Evidence Paper 23: Moffat, J. (2013). ³⁶ BIS (2011). ³⁷ Department for Trade and Industry (1998); Department for Trade and Industry (2003a); Department for Business, Innovation and Skills (2008); BIS (2011). ³⁸ This followed a review of practices in other countries and under the auspices of the Technology Strategy Board has led to the creation of seven catapult centres once again selectively focused on a range of sectoral or technological domains. See Hauser, H. (2010) and TSB, (2011). ³⁹ Evidence Paper 37: Crafts, N. & Hughes, A. (2013). ⁴⁰ For further details see: <http://www.msip.go.kr/index.do>

⁴¹ For further details see: <http://www.korea.net/AboutKorea/Economy/Leading-Industries> ⁴² Prime Minister's Council for Science and Technology (2007).

BOX 7.5: A SYSTEMS BASED APPROACH TO POLICY DEVELOPMENT

A 2007 UK Prime Minister's Council for Science and Technology (CST) report proposed a staged approach to technology selection and the design of policy support which is consistent with the approach advocated above. Key stages include:

- An assessment of where the UK possesses distinctive and outstanding scientific and technological competence in particular areas.
- An analysis of the potential market size of successful innovations in the relevant technology space.
- An assessment of the UK's capacity to deliver in terms of private and public sector investment in the innovation and commercialisation process. This includes a value chain analysis in areas of potential applications and an assessment of the extent to which it will be possible to appropriate a significantly large element of it. It is at this stage that internationalisation of the applications and value chains and their future potential trajectories must be identified and understood.

- An examination of the risks arising from the risk of failure in the design or implementation of public support policy failure and/or the failure of the developing technology itself.
- The final stage is to identify the form of government intervention which would be most appropriate, including the potential for the government to play a lead role as a procurer of R&D services, or ability of the public sector to promote (or not inhibit) appropriate co-location and agglomeration effects. It may include the development of appropriate intermediating organisations, e.g. catapult centres, which in particular science and technology areas may span both national and international university/industry boundaries and enhance the commercialisation process⁴³.

This process involves the development of an appropriate capacity in the public sector itself to generate, in combination with business, the kind of data required to drive such a process. It also requires persistence and incremental learning in the process of policy delivery and smart public procurement. Failure will be a feature of the system of support and a few successful outcomes will dominate overall gains, so political leadership will be essential.

Three elements, in particular, are critical to the design of effective policy for the longer term, and are consistent with Box 7.5⁴⁴:

- First, policy development needs to be embedded in private sector networks so it can draw upon and connect with and between information sources in that sector. A wide range of institutions may serve this purpose, from informal and formal development forums through to advisory councils and intermediating Research and Technology Organisations.
- The second feature is the necessity of combining incentives with disincentives and exercising options to enhance lines of support or to enable the weeding out of investments that fail or activities that become 'honourable dead-ends'⁴⁵.
- Third, policy must be viewed as a learning process. Policy-makers must accept a failure rate consistent with the underlying riskiness of the activity and the development of policy must be based on systematic and regular evaluation.

⁴³ Mina, A. et al. (2009) and Hauser, H. (2010). ⁴⁴ Rodrik, D. (2006). ⁴⁵ Rodrik, D. (2006).

7.3 ENHANCING GOVERNMENT CAPABILITY IN EVALUATING AND COORDINATING POLICY OVER THE LONG TERM

It is essential that policy architecture evolves so that governments can deliver the integrated systems approach advocated. A particular issue here is developing policy with a longer term perspective independent of the instabilities produced by the electoral cycle.

Examples of where this has been achieved in other areas of policy include: an independent Bank of England to implement monetary policy; the National Institute for Health and Care Excellence (NICE) to advise the NHS on the take-up of new treatments; and the removal of ministerial discretion on cases investigated by the Competition Commission. This has not generally been the case with regard to industrial strategy.

In considering future industrial strategy focused on the manufacturing sector and any related institutional reforms, it is recommended that close attention be paid to institutional developments in other countries. Three relevant examples are the US Advanced Manufacturing National Programme Office (AMNPO), the Australian Productivity Commission (APC), and the UK Independent Commission for Aid Impact (ICAI) (see Box 7.6).

It is also recommended that a better sharing of future understanding and intelligence between the Department for Business Innovation and Skills and the Technology Strategy Board is pursued, in effect a shift in balance from sponsorship towards knowledge transfer.

BOX 7.6: EXAMPLES OF INSTITUTIONAL DEVELOPMENTS IN THE US, AUSTRALIA AND THE UK

Advanced Manufacturing National Programme Office (AMNPO), United States: Charged with implementing a whole-of-government advanced manufacturing initiative to facilitate collaboration across federal agencies and convening private-public partnerships focused on manufacturing innovation. It is hosted by the National Institute of Standards and Technology (NIST), and is staffed by representatives from federal agencies with manufacturing-related missions and fellows from manufacturing businesses and universities. By coordinating resources and programmes, AMNPO will enhance technology transfer and help businesses overcome obstacles to scaling up production of new technologies. It was recommended by the Advanced Manufacturing Partnership Steering Committee and endorsed by the President's Council of Advisers on Science and Technology⁴⁶.

The Australian Productivity Commission (APC), Australia: The APC is the Australian Government's independent research and advisory body on a range of economic, social and environmental issues affecting the welfare of Australians. It is an advisory body and does not administer government programmes or exercise executive power; its contribution hinges on the value of the independent advice and information it provides. Its operating principles include Independence (the Commission operates under the powers of its own legislation, with its own budgetary allocation and permanent staff, and reports formally through the Treasurer to the Australian Parliament); transparency; and taking a community-wide perspective⁴⁷.

The Independent Commission for Aid Impact (ICAI), UK: ICAI is the independent body responsible for the scrutiny of UK aid. It focuses on maximising the impact and effectiveness of the UK aid budget for intended beneficiaries and the delivery of value for money for the UK taxpayer. Led by a Chief Commissioner, ICAI reports to Parliament through the House of Commons International Development Committee. It publishes transparent, impartial and objective reports on the effectiveness of UK aid, and ensures that its recommendations lead to change by providing evidence-based feedback into Government decision making. ICAI recommendations play a role in supporting the UK to spend aid on what works best.

Building on insights from the above examples, it is recommended that to strengthen future governments' capability in evaluating and coordinating policy over the long term, the UK Government should create an 'Office for Manufacturing'. This would:

- Regularly evaluate the effectiveness of industrial policies relevant to manufacturing, embracing a role similar to that of the Australian APC;
- Identify relevant international best practice and highlight this to government;
- Ensure the collation and effective use of new best practice metrics for manufacturing (see Section 7.1), also drawing in intelligence on manufacturing value chains from the wider public sector including Research Councils and the Technology Strategy Board; and
- Advise on where cross Government coordination can be strengthened and simplified.

7.4 AREAS FOR FURTHER INVESTIGATION

A number of specific areas of future importance to the manufacturing sector identified in this Report are also relevant to the wider economy, and merit further investigation. Policy makers are likely to benefit from examining three areas, outlined below which would help to inform actions being taken to support long term UK economic growth. Evidence commissioned by the Project could be used as a starting point.

POLICY DESIGN: ADAPTING AND LEARNING FROM INSTITUTIONAL ARRANGEMENTS IN PLACE IN OTHER COUNTRIES

There are several references in this Report to the roles of institutional architecture in support of manufacturing. Across the world, a variety of elements contribute to the institutional systems put in place to support firms, not only in manufacturing but in all forms of industrial activity. Simply seeking to transpose any particular institution to the UK would be misguided. Instead it is suggested that a

detailed study is commissioned to identify the role and effect of each element in these architectures and systems, identify gaps in the UK system and evaluate the institutional changes which may be needed in the UK to enhance its capacity to build on 'best and most effective practice' lessons from other countries. There is specific merit in applying the findings to the operation of capital and labour markets in manufacturing.

THE NEED FOR INCREASING THE AVAILABILITY AND QUALITY OF LONG TERM (OR PATIENT) CAPITAL TO SUPPORT LONG TERM SUSTAINABLE VALUE CREATION

A consequence of the manner of development of the UK's financial services industry over the past 40 years is that providers of finance have developed a behaviour whereby they generally have a greater alignment of interests with their own sources of funds than with the firm to whom they are providing the finance. This is inevitable, as providers of funds to banks and other financial institutions do so on a regular basis. They are repeat clients of the bank whereas the firm is an infrequent one. A similar phenomenon can occur with the equity markets where fund managers are quite correctly preoccupied with competing to meet the expectations of those who have placed savings with them rather than with the interests of the firm whose shares they might hold.

The consequent short termism or lack of patient capital which is linked to this is particularly important to manufacturing⁴⁸. A greater understanding of the impact of capital market behaviour on strategic decision taking and investment decisions by business leaders at all levels of economic activity would help inform public and private sector dialogue on the development of industrial strategy and other agendas. Further investigation should examine:

- The drivers and support for short-termism including disincentives to accumulate capital stock.
- The impact on exit rather than sustaining strategies by company leaders, as a result of share based executive reward plans, terms of reference of the take-over panel, tax treatment of interest, and short term performance requirements by fund managers.

- The consequences of short term timescales for meeting pension funding requirements on firms' availability of funds for investment and on strategic choices.
- The scope for delivering wider and deeper access to finance for SMEs through lower cost credit and greater administrative capacity for loan arrangements in banks to enhance the relationships between banks and firms, particularly manufacturers.

THE NEED FOR GOVERNMENT TO PROMOTE UNDERSTANDING OF THE ROLE OF THE FIRM AND VALUE CREATION IN CREATING HIGH SKILLED JOBS AND ADDRESSING SOCIO-ECONOMIC CHALLENGES

This Project has examined the performance of the UK manufacturing sector compared to competitor countries, highlighting various features associated with success and failure. One of these features encompasses the national belief in, and support for, value creation and perceptions of its role in high value job creation and addressing socio-economic challenges.

While difficult to measure objectively, in some of the more successful economies, such as the US, Germany, the Netherlands, Finland, Sweden, Japan, Singapore and Korea, it appears that a value creation 'mind-set' is embedded in the national psyche. This is potentially reflected in the level of interest in examining future trends affecting manufacturing⁴⁹. In the UK, this mind-set is less apparent and there is limited consensus about the importance of investing for the long-term, or that manufacturing matters in either a value creation or wider socio-economic setting. Indeed, research suggests that amongst a sizeable share of the population, including amongst younger people, manufacturing is held in relatively low esteem⁵⁰.

Looking to the future, there is a case for examining how the UK could strengthen its approach to nurturing and celebrating high quality job opportunities and value creation in manufacturing and the contributions to be made by innovation in manufacturing in addressing future environmental challenges in energy and sustainability. A study on this topic could build on evidence commissioned by this Project by considering:

- How governments communicate the role of industry and value creation across society
- How business behaviours in the countries identified above differ from those in the UK
- How attitudes in the countries identified above have developed, including high impact initiatives
- How value creation is recognised and/or celebrated by society
- How the link between value creation, high skilled job opportunities and wider socio-economic objectives is understood

7.5 NEXT STEPS – WHO NEEDS TO DO WHAT

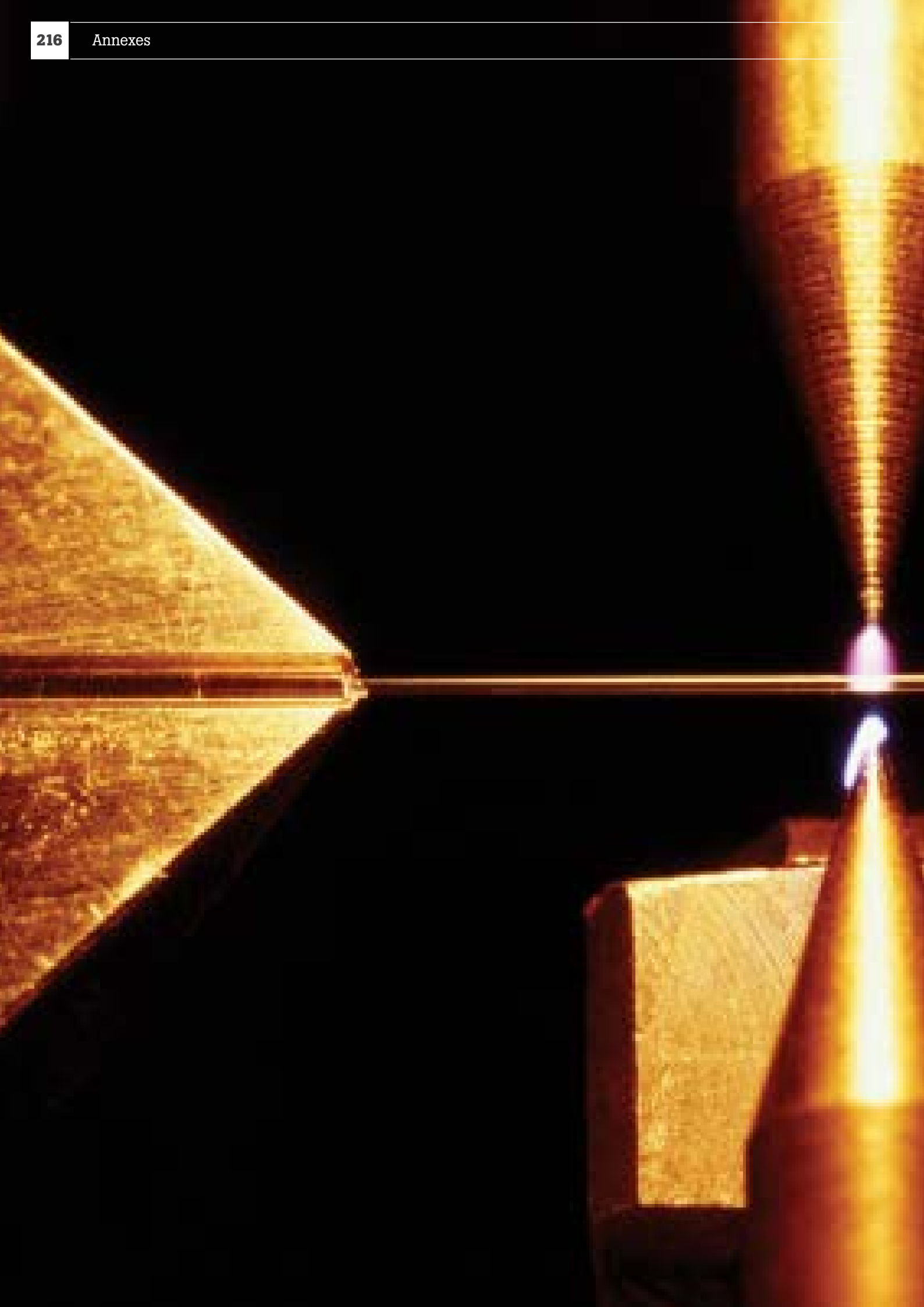
This chapter has set out a framework for Government action, in partnership with industry, which focuses on:

- four future characteristics of manufacturing;
- three systemic areas for Government focus; and
- three areas which require further investigation.

Taken together, the suggested changes amount to a fundamental shift in the focus, balance and operation of Government support, to help ensure that the manufacturing sector is able to thrive in the future.

This framework will need to be considered in the round, but immediate steps should be taken to prioritise and implement a number of the suggested measures, which should build upon existing initiatives where relevant. The detailed evidence papers are an important resource in explaining the rationale for the actions, and in providing more detail.

The framework for action needs to be followed up quickly. Failure to do so will hinder the efficiency and effectiveness of the detailed actions. This will further increase the potential for the UK to miss important new opportunities for value creation from manufacturing.



ANNEXES



ANNEX A: ACKNOWLEDGEMENTS

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*Individuals are listed only once. Where an individual contributed in multiple ways (for example produced an evidence paper and attended a workshop) they are listed only for their first recorded contribution.

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ANNEX C: GLOSSARY AND ACRONYMS

Absorptive capacity: A firm's ability to recognize the value of new information, assimilate it, and apply it to commercial ends.

Additionality: Net positive difference that results from intervention.

Additive manufacturing/3D Printing: A process of making a three-dimensional solid object of virtually any shape from a digital model. It is considered distinct from traditional machining techniques, which mostly rely on the removal of material by methods such as cutting or drilling (subtractive processes).

Balance of Payments: A record of financial transactions made between consumers, businesses and the government in one country with others. The BOP figures tell us about how much is being spent by consumers and firms on imported goods and services, and how successful firms have been in exporting to other countries.

Base projection: A projection showing the development that would occur if current trends are maintained.

Big data/Ubiquitous data: Datasets whose size is beyond the ability of typical database software tools to capture, store, manage and analyse.

Business model: The rationale of how an organization creates, delivers, and captures value (economic, social, cultural, or other forms of value).

Circular economy: A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life.

Collaborative consumption: A class of economic arrangements in which participants share access to products or services, rather than having individual ownership.

Cloud computing: A model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

Deindustrialisation/Reindustrialisation: Is a process of social and economic change caused by the removal or reduction of industrial capacity or activity in a country or region, especially heavy industry or manufacturing industry. Reindustrialisation therefore is an increase in industrial capacity following deindustrialisation.

Driver of change: A factor which causes a particular phenomenon to happen or develop.

Firm margin: Number of firms and export intensity.

Firm-product margin: Number of products each firm sells and average export value.

Firm-product-destination margin: Number of destinations in which a firm sells and average export value.

Foreign Direct Investment (FDI): FDI is defined as cross-border investment by a resident entity in one economy with the objective of obtaining a lasting interest in an enterprise resident in another economy.

General Purpose Technology (GPT):

A term coined to describe a new method of producing and inventing that is important enough to have a protracted aggregate impact. Electricity and information technology (IT) probably are the two most important GPTs so far.

Greenfield investment: A term often used in the context of FDI, it is the expansion of existing facilities or a direct investment in new facilities (in an area where no previous facilities exist). The name comes from the idea of building a facility verbatim on a “green” field, such as farmland or a forest. Over time the term has become more metaphoric.

Gross Domestic Product (GDP): A measure of the value of the goods and services produced in the economy in the year. It is a good indicator of the wealth and economic development of a country.

Gross Value Added (GVA): A measure of the value of the goods and services produced in the economy and is used to monitor the performance of the national economy as a whole. GVA is calculated as: the value of sales of goods and services minus the cost of purchases of energy goods, materials and services.

Horizontal collaboration: The pooling of resources and capabilities by competing organizations across the supply chain.

Industrial commons: The embedded knowledge and technology framework that enhances the efficiency, effectiveness, and productivity of the proprietary capital and labour that use it.

Industrial ecology: Involves the study of the “flows” of materials and energy through socio-economic systems with a view to optimizing their use.

Industrial symbiosis: An association between two or more industrial facilities or companies in which the wastes or byproducts of one become the raw materials for another.

Internet of things: Is widely presented as the next revolution towards massively distributed information, where any real world object can participate in the internet and thus be globally discovered and queried.

International Standard Industrial Classification (ISIC): ISIC is a system created by the United Nations for classifying business establishments and other statistical units by the type of economic activity in which they are engaged.

Manufacturing Value Added (MVA): Manufacturing refers to industries belonging to SIC divisions 15-37. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources.

Offshoring: The move of a company's processes or services overseas.

Onshoring/Reshoring:

Onshoring, sometimes known as reshoring is a term used to describe the relocation of firms operations back to the country from which they originated.

Purchasing Power Parity (PPP):

An economic theory and a technique used to determine the relative value of currencies, estimating the amount of adjustment needed on the exchange rate between countries in order for the exchange to be equivalent to (or on par with) each currency's purchasing power.

Resilience:

The term describes the ability of companies or individuals to come to terms with changing circumstances and adjust their business or personal strategies and models accordingly.

Servitization:

Products today have a higher service component than in previous decades. In the management literature this is referred to as the servitization of products. Virtually every product today has a service component to it.

Spillover:

Spillover effects are externalities of economic activity or processes (such as knowledge or technology) that affect those who are not directly involved.

Sustainability:

The creation and maintenance of the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations.

Sustainable development: Development that meets the needs of the present, without compromising the ability of future generations to meet their own needs.

Sustainable technologies: Technologies that reduce material or energy use to levels considered sustainable in the long term. This covers a very broad range of technologies from the more obvious clean energy technologies such as wind and solar, to everyday products with better environmental performance such as paint booths that use less water for cleaning.

Systems view: The view that the component parts of a system can best be understood in the context of relationships with each other and with other systems, rather than in isolation. Systems thinking focuses on cyclical rather than linear cause and effect.

Total Factor Productivity (TFP): Total Factor Productivity (TFP) is the portion of output not explained by the amount of inputs used in production. As such, its level is determined by how efficiently and intensely the inputs are utilized in production, and by technological change.

Value chain: The value chain describes the full range of activities that firms and workers do to bring a product from its conception to its end use and beyond. Value chain activities can produce goods or services, and can be contained within a single geographical location or spread over wider areas.

Vertical collaboration: Pooling of resources and capabilities by complementary organizations up and down the supply chain.

ABI	Annual Business Inquiry	FoF	Factory of the Future
AM	Additive Manufacturing	GDP	Gross Domestic Product
AMO	Advanced Manufacturing Office (US Government)	GERD	Gross Domestic Expenditure on Research & Development
ARD	Annual Respondents' Database	GPT	General-Purpose Technologies
BERD	Business Enterprise Research and Development	GVA	Gross Value Added
BIS	Department for Business Innovation and Skills	GO-Science	Government Office for Science
BRIC	Brazil, Russia, India and China	HE	Higher Education
BRIIC	Brazil, Russia, India, Indonesia and China	HESA	Higher Education Statistics Authority
CAD	Computer-Aided Design	HMT	Her Majesty's Treasury
CBI	Confederation of British Industry	HSBC	Hong Kong and Shanghai Banking Corporation
CBR	Centre for Business Research, Cambridge	HS&E	Health, Safety and Environmental
CEGB	Central Electricity Generating Board	IBZL	Infinite Bandwidth/Zero Latency
CIM	Computer Integrated Manufacturing	ICT	Information and Communications Technology
CIPD	Chartered Institute of Personnel and Development	IDBR	Inter-Departmental Business Register
CIS	UK Community Innovation Survey	IO	Input Output
CVET	Continuing Vocational Education & Training	ISIC	International Standard Industrial Classification
DCLG	Department for Communities and Local Government	IT	Information Technology
DCMS	Department for Culture Media and Sport	IVET	Initial Vocational Education & Training
DECC	Department for Energy and Climate Change	IPR	Intellectual Property Rights
DEFRA	Department for Environment Food and Rural Affairs	LEG	Lead Expert Group
DETINI	Department of Enterprise Trade and Investment Northern Ireland	LMT	Low and Medium Tech
DfE	Department for Education	MBA	Master of Business Administration
EEA	European Economic Area	MNC	Multi National Corporation
EEF	Engineering Employers Federation	MOD	Ministry of Defence
EPA	Environmental Protection Agency	MVA	Manufacturing Value Added
EU	European Union	NASA	National Aeronautics and Space Administration
FDI	Foreign Direct Investment	NCMS	US National Center for Manufacturing Sciences
		NMR	Nuclear Magnetic Resonance
		N-11	Next 11 countries
		OBR	Office of Budget Responsibility

OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics
PLC	Public Limited Company
PM	Prime Minister
PPP	Purchasing Power Parity
PV	Photovoltaic
RDA	Regionally Decentralized Authoritarian
REE	Rare Earth Element
REER	Real Effective Exchange Rate
R&D	Research and Development
SBIR	Small Business Innovation Research Program (United States)
SEMTA	Sector Skills Council for Science, Engineering and Manufacturing Technologies
SET	Science, Engineering and Technology
SIC	Standard Industrial Classification
SME	Small to Medium Enterprise
STEM	Science, Technology, Engineering and Mathematics
SUTs	Supply and Use Tables
TFP	Total Factor Productivity
TSB	Technology Strategy Board
UKCES	United Kingdom Commission for Employment and Skills
UN	United Nations
UN COMTRADE	United Nations Commodity Trade Statistics Database
UNIDO	United Nations Industrial Development Organisation
USD	United States Dollar
WTO	World Trade Organisation

ANNEX D: PROJECT REPORTS AND PAPERS

The evidence papers detailed below were commissioned by Foresight, Government Office for Science, London in 2013.

Evidence Paper 1:	Foresight & Arup The Future of Manufacturing International Perspectives Workshop Report.
Evidence Paper 2:	Broadberry, S. & Leunig, T. The Impact of Government Policies on UK Manufacturing since 1945.
Evidence Paper 3:	Bryson, J.R. Clark, J. and Mulhall, R. The Competitiveness and Evolving Geography of British Manufacturing: Where is manufacturing tied locally and how might this change?
Evidence Paper 4:	Chang, H. Andreoni, A. & Kuan, M. International Industrial Policy experiences and the Lessons for the UK.
Evidence Paper 5:	Deakin, S. The Legal Framework Governing Business Firms and its Implications for Manufacturing Scale and Performance: The UK Experience in International Perspective.
Evidence Paper 6:	Dickens, P. Kelly, M. & Williams, J. What are the significant trends shaping technology relevant to manufacturing.
Evidence Paper 7:	Driffield, N. How attractive is the UK for future foreign direct investment?
Evidence Paper 8:	Driver, C. & Temple, P. Capital investment: what are the main long term trends in relation to UK manufacturing businesses, and how do these compare internationally?
Evidence Paper 9:	Fothergill, S. & Gore, T. The Implications for employment of the shift to high value manufacturing.
Evidence Paper 10:	Grant, P. & Mason, T. What impact will the development and, potentially, the commercialisation of new and advanced materials have on the future of manufacturing activities in the UK?
Evidence Paper 11:	Green, R. & Zhang, X. What will be the future role of energy (including supply, distribution and security) in manufacturing activities?
Evidence Paper 12:	Hall, B. What role will the protection of intellectual property play in the future?
Evidence Paper 13:	Hancke, B. & Coulter, S. The German Manufacturing sector Unpacked: policies and future trajectories.
Evidence Paper 14:	Hay, G., Beaven, R., Robins, I., Stevens, J. & Sobina, K. What are the recent macro- economic trends and what do they tell us about the future?
Evidence Paper 15:	Homkes, R. What role will leadership play in the future performance of manufacturing businesses?
Evidence Paper 16:	Hughes, A. Short-Termism, Impatient Capital and Finance for Manufacturing Innovation in the UK.
Evidence Paper 17:	Kneller, R. What are the constraints on potential UK exporters?
Evidence Paper 18:	Li, C. & Bascavusoglu-Moreau, E. Knowledge spillovers in manufacturing firms and future sources of knowledge for innovation. .
Evidence Paper 19:	Livesey, F. What is the public image of manufacturing and how might this change?

Evidence Paper 20:	Luger, M., Gil, N. & Winch, G. What areas of infrastructure are important for the UK's future competitiveness in manufacturing activities?
Evidence Paper 21:	McLaughlin, P. What kind of system will encourage best practice principles in UK manufacturing activities?
Evidence Paper 22:	McNair, S., Flynn, M., Myerson, J., Gheerawo, R. & Ramster, G. What are the supply (workforce) and demand (product) implications of an ageing society?
Evidence Paper 23:	Moffat, J. What are the recent micro- economic trends and what do they tell us about the future?
Evidence Paper 24:	Morton, B., Paget, G. & Mena, C. What role does Government procurement play in manufacturing in the UK and internationally, and how might this change in the future?
Evidence Paper 25:	Peng, M. & Meyer, K. Where are the future markets for manufacturing output?
Evidence Paper 26:	O'Sullivan, E. & Mitchell, N. What are the key international approaches to understanding the future of manufacturing?
Evidence Paper 27:	Parker, D., Arendoft, A., Chapman, A. & Thompson, P. What impact will the availability of materials and resources in the future have on the future manufacturing outlook in the UK?
Evidence Paper 28:	Pike, A., Dawley, S. & Tomaney, J. How does manufacturing contribute to UK resilience?
Evidence Paper 29:	Ridgway, K., Clegg, C. & Williams, D. What are the main trends shaping the factory of the future?
Evidence Paper 30:	Rowthorn, R. & Coutts, K. Update of Prospects for the UK Balance of Payments.
Evidence Paper 31:	Rowthorn, R. & Coutts, K. De-industrialisation and the Balance of Payments in Advanced Economies.
Evidence Paper 32:	Rowthorn, R. & Coutts, K. Re-industrialisation: A Commentary.
Evidence Paper 33:	Spring, M. Which business models might ensure UK value from emerging sectors?
Evidence Paper 34:	Stehrer, R. What will be the future role of BRIC countries in providing global manufacturing output?
Evidence Paper 35:	Tennant, M. What are the business opportunities presented by the drive for sustainability?
Evidence Paper 36:	Wilson, R. & Hogarth, T. What type of future manufacturing workforce will the UK need?
Evidence Paper 37:	Crafts, N. & Hughes, A. Industrial policy for the medium-long term.

PROJECT REPORT

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