THE PRINCE OF WALES'S
CORPORATE LEADERS GROUP

DISCUSSION PAPER

UK Industrial Strategy

Navigating a changing world

UNIVERSITY OF CAMBRIDGE
INSTITUTE FOR SUSTAINABILITY LEADERSHIP

The Prince of Wales's Corporate Leaders Group

The Prince of Wales's Corporate Leaders Group (CLG) is a select club of European business leaders working together, under the patronage of The Prince of Wales, to advocate solutions to climate change to policymakers and business peers at the highest level, both within the EU and globally.

Cambridge Institute for Sustainability Leadership

For 800 years, the University of Cambridge has fostered leadership, ideas and innovations that have benefited and transformed societies. The University now has a critical role to play to help the world respond to a singular challenge: how to provide for as many as nine billion people by 2050 within a finite envelope of land, water and natural resources, whilst adapting to a warmer, less-predictable climate.

The University of Cambridge Institute for Sustainability Leadership (CISL) empowers business and policy leaders to make the necessary adjustments to their organisations, industries and economic systems in light of this challenge. By bringing together multidisciplinary researchers with influential business and policy practitioners across the globe, we foster an exchange of ideas across traditional boundaries to generate new solutions-oriented thinking.

Publication details

Disclaimer
The opinions expressed here are those of the authors and do not represent an official position of CLG, CISL, the wider University of Cambridge, or clients.

Author and acknowledgements
This business briefing was authored by Timothy Laing with editorial input from Eliot Whittington, Jill Duggan and Joanna Gaches, as well as comments from CLG members.

Reference
Please refer to this policy briefing as University of Cambridge Institute for Sustainability Leadership (CISL). (2017). *UK Industrial Strategy: Navigating a changing world.* Cambridge, UK: The Prince of Wales's Corporate Leaders Group.

Copies
This full document can be downloaded from CISL's website: www.cisl.cam.ac.uk/publications

Contact
To obtain more information on the report, please contact Adele Williams:
E: adele.williams@cisl.cam.ac.uk
T: +44(0)1223 768451

January 2017

This discussion paper has been commissioned by The Prince of Wales's Corporate Leaders Group to inform development of an industrial strategy fit for the 21st century. The Corporate Leaders Group is comprised of leading businesses with experience and insight of the challenges of developing new business practice as part of the ongoing shift to sustainable, resilient, zero carbon economy. The paper draws on key topics of interest to CLG members but does not represent their specific views or positions.

Contents

Corporate Leaders Group members

Summary

The UK government's decision to pursue a new industrial policy comes as the country faces three major challenges – boosting sluggish economic growth and stagnating productivity; promoting greater regional development; and moving toward a more sustainable economy with lower greenhouse gas emissions. A strategy that can meet these challenges must be cognisant of global trends that are changing how industry operates and interacts with its consumers. These trends fit into four broad categories:

Changing patterns of demand for industrial products -Shifting demographics and increased digitalisation are just two of the drivers changing patterns of demand for industrial products. New products need to be created, and technological improvements allow new services to be offered to consumers. The UK has already benefited from increasing demand for space-based services and any industrial strategy needs to be aware of both opportunities and risks for industry in such shifting patterns.

Changing ways industrial products can meet changing patterns in demand-Technological improvements and changing tastes vary the manner in which industrial products can meet changing patterns in demand. 'Servitisation' is spreading through several sectors, opening the space for increasing dematerialisation in future industry and helping to improve sustainability. These changes offer benefits for productivity and real wages, but only if skills can be suitably supplied, and if new business models are incentivised to facilitate such changes.

Changing ways industrial products are produced-Technological change is also evolving new processes through which industrial products can be produced. The shift to re-distributed, regional manufacturing, facilitated by new technologies such as 3-D printing, have profound economic and environmental implications for the UK. Moves to a circular economy where industrial products are re-used, recycled, and remanufactured could increase growth whilst helping to achieve sustainability. Facilitating such trends, and helping build new business models to promote them, should be a key part of industrial strategy.

Changing key inputs into industrial processes-Energy generation is likely to change dramatically if the UK is to meet its legal climate change obligations. Innovative materials are being developed that could promote more durable industrial products, reducing waste and improving sustainability and productivity. Moving to closed-loop systems would also transform how industry views waste and inputs. All three necessitate changes in the way that industry operates, requiring innovation in both technology and business models.

From these four key trends, we have formulated seven strategic recommendations to be considered when designing the UK's industrial strategy:

1. Define a primary goal, such as improving productivity within a sustainable, inclusive economy, and provide a long-term timeframe, sufficient to guide major investments - build a strategy to meet that goal.

2. Focus on sectors that provide strategically important functions and assist them to develop innovative products, functions, and business models – use them to help build UK expertise for export.

3. Focus on innovations in business practice, new business strategies and new business models as well as innovation in science and technologies. This must not be a trade off: support for basic science and research is still essential, but needs to be coupled with support for business innovation. Such support needs to explicitly engage in helping businesses transition from out-of-date business models to new approaches.

4. Build greater linkages between government, industry and other key stakeholders to help foster growth of different sectors – but keep at arm's length from companies to avoid picking winners.

5. Create greater incentives for businesses to invest in long-term productive developments, through fiscal and corporate governance regimes that emphasise long-term results.

6. Seek to match demand and supply of highly skilled labour by looking at the future prospects for the economy and acting where needed to boost demand as well as supply. Many educational institutions focus on meeting the needs of the recent past, rather than the near future, or the potential future. Improving linkages between trainers and educators and industry will be one way of addressing this.

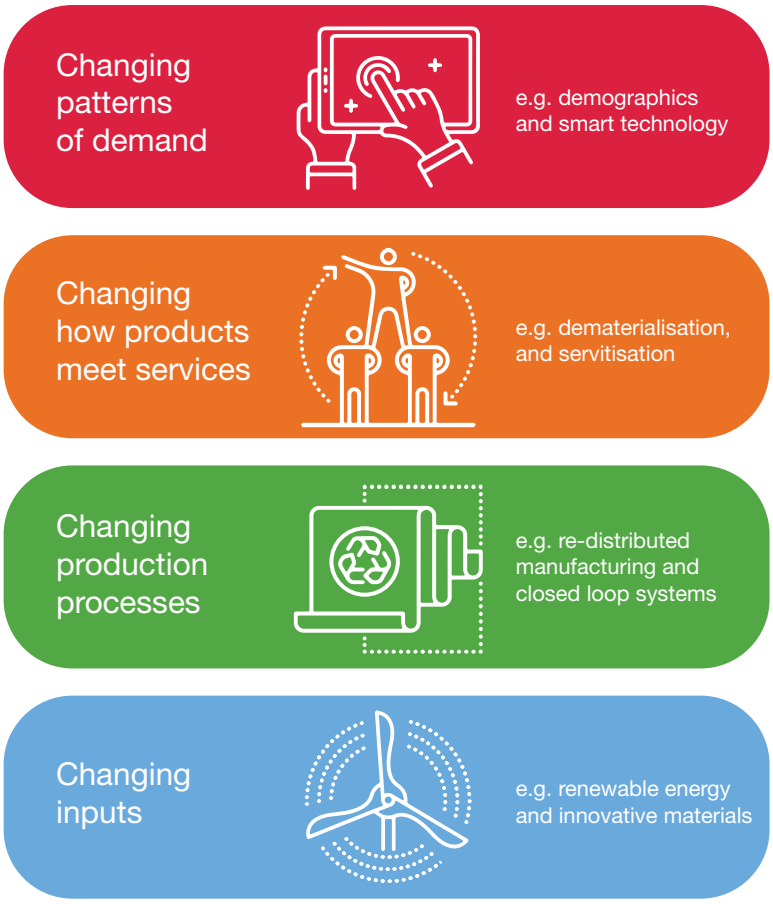
7. Co-ordinate all significant policy instruments, including procurement, infrastructure development and planning, to meet the needs of the strategy. Procurement particularly has particular under realised value as a policy delivery tool.

Introduction

Theresa May's announcement in July 2016 that her government would pursue a new industrial[1] policy for the UK comes at a time when the economy is experiencing a prolonged period of sluggish economic growth, stagnation in labour productivity, a slump in real wages, a collapse in living standards and a national economy that is unbalanced, both in its composition (with a heavy bias on financial services) and also regionally (with strong job creation in the south east and little elsewhere).

Economic growth has been concentrated in London and the south-east – between 2010 and 2014 gross value added in London increased by 24 per cent, in the South East by almost 17 per cent, but only around 11 per cent in Yorkshire and Humber and the North West.[2] Productivity in the UK has only just recovered to its pre-downturn 2008 level, with output per hour in the second quarter of 2016 being calculated at almost 20 per cent below the pre-downturn trend.[3,4] These changes are further reinforcing existing regional imbalances, with living standards in many parts of the country hit by a dangerous combination of rising costs (principally housing), and real wage stagnation. These problems can be particularly acute in communities with high dependence on a particular industry, especially where those industries have been struggling, such as Port Talbot with steel, or the issues faced by former coal-mining towns in Nottinghamshire.

AN EMERGING FUTURE FOR INDUSTRY



A new industrial strategy for the UK can contribute to addressing these problems, and more. Alongside this challenging macroeconomic environment, the UK has committed itself to dramatic improvements in the sustainability of its economy. Under the Climate Change Act there is a commitment for UK industry to become zero carbon by 2050. A new industrial strategy must therefore work to create jobs, improve productivity, boost innovation, create regional growth across the UK, at the same time as working to make industry low carbon and sustainable. This is a daunting task, but also offers a great opportunity for the UK to become a more balanced, socially equitable, productive, sustainable and greener economy that is better structured to compete internationally. This is especially important given the increasing trend towards protectionism in a number of countries (including, arguably the UK, given the move towards Brexit) that could make it even more difficult for firms to enter international markets and compete with domestic incumbents.

We have identified four broad trends that are affecting both demand and supply for the products that industry provides:

1. changes in patterns of demand for industrial products
2. changes in the way industrial products can meet these changing patterns in demand
3. changes in the way industrial products are produced, and
4. changes in the way key inputs into industrial processes (such as energy) are produced.

The UK's industrial strategy must be cognisant of, and consistent with, these trends, to meet its overarching objectives.

Key considerations for industrial strategy

Objectives: what is the highest priority objective (or objectives) of the strategy being formulated? Having too many competing goals and objectives risks policy confusion. The advantages of focusing on one specific challenge – and harnessing the creativity and innovation of industry to meet that challenge – is demonstrated in history through projects to put a man on the moon, or to create the internet. Using such a 'mission-oriented innovation policy' can guide industrial strategy through targeted public investments to stimulate innovation, investment and growth.[5]

One ultimate goal of industrial productivity should be to boost productivity of industry. Such a boost can be consistent with, and even help to achieve, a more balanced economy (both sectorally and regionally) – one in which real wages are rising and the UK is becoming more competitive, while at the same time helping industry become low carbon, sustainable, and resource efficient.

Timing: Once the key objectives have been clarified, a follow-up question is what is the expected timeframe of the strategy. The Confederation of British Industry (CBI) has stressed the importance of a long-term focus as one of the key principles of industrial strategy for business.[6] In many industrial areas (and related sectors such as energy), investment decisions are made on the basis of decades rather than years, and this long-term focus is difficult to achieve in the realm of five-year-long election periods. Building cross-party and stakeholder consensus on the components of any industrial strategy is vital to create a strategy that will have long-term buy-in and stability.[7]

Identifying limiting factors: Any industrial strategy must be cognisant of the factors in the economy that are currently limiting industrial development in the country. These could include: lack of supply of (or demand for) high-skilled employment; lack of investment in capital and other productive enterprises; lack of export competitiveness due to high costs, low levels of productivity or high exchange rates; technical barriers to the development of existing or new industries; or poor infrastructure that hampers growth, movement of goods, services and skills across the economy.

Learning the lessons from history and from others: The term 'industrial strategy' in the UK comes with significant baggage, mainly due to the failed policies of the 1970s.[8] These policies failed because they focused on picking winners and attempted to shape technology, rather than facilitating the market to identify winners that provided the benefits desired by the government. Analysis of the issues behind UK's productivity and competitiveness problems, such as the report by Porter and Ketels in 2003, outlines two potential models for the UK: one consisting of high skills, and high quality products; the other consisting of low-skills, low-paid, mass-market products.[9] The UK economy today consists of elements of both, but any industrial strategy must define which of these paths should be the overall focus of UK industry.

Experience from outside the UK is also relevant. For example, Sweden's proposal to offer tax breaks on repairs is an interesting fiscal tool to incentivise greater re-use of industrial products[10], as well as increasing manufacturing jobs focused on maintenance and repair. Germany has also had great success – through building close links between government, industry, community, and academia they have built a high-skilled, export based economy. Specific success stories such as the network of Frauhofer institutes[11] and its resource efficiency programme, ProgRess, should also be examined.[12] More holistic programmes such as Japan's Revitalisation Strategy that aim to reform regulation, boost innovation, cultivate new markets, and lead to revolution in productivity should also be examined to understand what has succeeded.[13]

Bearing these questions in mind, this paper discusses the four major identified trends identified: how they will have an impact on the UK industrial strategy, how they can positively contribute to the economic, social and environmental goals of any industrial strategy, what actions needs to be taken in order for the positive benefits of those trends to be realised, and what are the risks and challenges associated with each trend. We then draw together a series of recommendations for inclusion in the UK's industrial strategy, drawing on academic studies, reports from industry and international experience.

Trend 1:
Changes to the patterns of demand for industrial products

Industrial products in their own right are of no value to society. A television has no intrinsic value, neither does a car, nor a steel girder. These products are only useful to the extent to which they provide a desired function.

A television helps to meet individual's need for entertainment. A car helps to meet individual's transportation goals, whether for employment or leisure. A steel girder fulfils a huge range of functions across the economy, as diverse as healthcare (if used in a hospital), to consumer products (if used in a shopping mall), to accommodation (if used in an apartment block). It is providing these functions that is the ultimate *raison d'etre* for industry.

But these functions are not fixed, they change with developments in society, technology, tastes and wealth. Industry needs to have the inherent flexibility to adapt to these shifting patterns, so industrial strategy policies must offer long-term stability and predictability, but must also incentivise industry to rapidly adapt to meet these ever-changing demands.

Demographic changes

An important driving factor behind this shifting demand is demographic changes. Globally the population is aging, and this is only occurring more slowly in the UK than other countries due to recent rises in immigration which may not be sustained in the future. An aging society has different requirements than a young population, and meeting these changed needs requires a new range of industrial products. Japan's investment in human-style robotics is in part motivated by trying to solve the looming problem of care and companionship for the elderly, and so industry forms a key part of Japan's Revitalisation strategy.[14] Car technology is also adapting to meet the needs of an ageing population through the introduction of parking sensors and collision-avoidance systems.[15] Understanding the future needs of an elderly population will have and providing suitable incentives for businesses to meet those needs should be a key component of the UK's industrial strategy.

An aging population also shifts the dependency ratio,[16] reducing the number of workers available to provide for the elderly generation. Industries that require less labour per output are likely to become increasingly attractive, implying even greater drives to reduce labour input in industry. Aging populations, coupled with weakening economic conditions are placing an increasing strain on pension provision, and individuals are likely to be required to stay active in the labour force for far longer. This opens up a new group of individuals seeking work, with a certain set of skills and physical abilities – unlikely to be able to undertake physically demanding positions, but possessing great experience, knowledge and skills. Creating an industrial strategy that taps into this expertise will have great benefit in reducing poverty in old-age, and help to overcome issues with the dependency ratio.

Digitalisation

A further trend that is dramatically changing the nature of demand is the increasing digitalisation of modern life. Rapid development of smart technology and dramatic increases in computer power are helping to launch a range of new products that previous generations could not have imagined. New technology is allowing consumers to manage the temperature of their home remotely, or allowing the house itself to predict when its occupants will return home and adjust the heating plan accordingly.[17] New developments in wearable health technology are improving real-time health monitoring allowing improved healthcare to be provided.[18] The use of new contactless technology in transportation, such as Transport for London's Oyster card system have brought advantages to customers in terms of faster access to transport services, and also to operators through much greater data about travel patterns, improving planning for operation and investment. Smart power generation infrastructure offers the increased prospect of 'demand side response' as part of the power grid – dynamically managing heavy electricity users' patterns of demand to match more closely with supply.

These examples show how smart technology can identify changing patterns of use, leading to new products, which in turn change patterns of demand as consumers adapt to the new 'possible'. For example, the greater control offered by digitalisation is prompting changing consumer behaviours as some consumers seek more control of, or to take part in, production of their own energy, entertainment, and other benefits. The latter effect is often described as the 'rise of the prosumer'.

Such examples require new industrial products to offer these improved levels of service, but also require new businesses with new business plans and strategies to offer these products to consumers. Innovation is occurring in incumbent firms, such as British Gas's development of the Hive Active Heating product,[19] and also in new start-ups such as Intelligent Textiles, which is developing electrically active woven fibres, or e-textiles that are in high demand from both UK and US military.[20]

The growth of new smart technologies presents both opportunities and potential challenges. On the one hand design and production, and its related software, are clear areas in which the UK's current skills base could be globally competitive.[21] On the other hand, these developments threaten employment in some service sectors, with jobs being replaced by the improved technology. Smart technology is starting to enter industries such as financial services (robotic fund managers)[22] and healthcare (automated pharmacies with lower error rates dispensing medicines than their human counterparts).[23]

Various barriers need to be overcome to develop an 'internet of things', in which a wide range of industrial products are connected. These barriers include: skills shortages for software developers; the development of open standards for interoperability of devices; apportionment of the radio spectrum for device-to-device communication; and security and data protection.[24]

Changes in demand from business and government

Changing patterns of demand will affect B2B companies as well as B2C. For example, one recent success story of UK industry has been the space sector. The development of satellite technology has facilitated the provision of a wide range of new products including satellite television, mobile-phone communication and GPS mapping. The UK's space industry has grown dramatically, doubling turnover between 2005 and 2015, with annual growth rates above 8 per cent.[25] With developments in private sector space travel through initiatives such as Space-X there are future avenues for the industry to become an even more important export industry.

The sector is a good example of how government intervention can help facilitate growth in an industry, with numerous targeted strategies, including the latest Space Growth Action Plan that covers the period up to 2030,[26] along with the creation of the Satellite Applications Catapult.[27] The space industry offers high-skilled jobs, and also the ability to create regional growth hubs and areas of expertise – for example Airbus's satellites are designed in Portsmouth, with structures built in Stevenage.[28] One area in which the industry has been successful, but in which continuing work is required, is in promoting the benefits of space technology to business, government and other service providers.[29] In this way the bridge between innovation and science and commercial business can be crossed.

Trend 2:
Changes in the way industrial products can meet changing patterns in demand

There are also ongoing changes in how industrial products can meet changing demand, which in turn change our future expectations of what products can deliver. Sub-trends in this area include the growth of de-materialisation, and the dramatic current and future predicted rise in digitalisation and smart technology.

Dematerialisation

Dematerialisation refers to a reduction in the absolute mass of material throughput in economies and societies. For example, transitioning from selling physical products (cars) to selling services (access to cars via a car club). The concept is not new – Schumacher described the overall economic, social and environmental advantages in his 1973 book Small is Beautiful.[30] A world designed to have lower material throughput creates different incentives: when a company captures value from providing a service delivered by industrial products, rather than selling the product itself, the incentives are to build long-lasting, efficient products, with reuseable components, rather than a product that consumers will be required to replace at regular intervals. This concept of 'servitisation'[31] has significant advantages for sustainability and resource efficiency – fewer industrial products are required to meet the same level of demand.

Although it often has a negative impact on traditional business models based on selling increasing, and frequent, volumes of industrial products, nonetheless, new forms of creative, disruptive innovation are occurring in key industrial sectors. New businesses have emerged that replace product sales with service sales. The digital economy has been the lead in this area with services such as Spotify and Netflix replacing physical sales of CDs and DVDs with monthly streaming packages for audio and video content. In the realm of industrial products, transportation sharing services such as ZipCar and Uber have sought to replace consumer car ownership through providing on-demand access to transportation.[32] The move to a sharing economy more efficiently utilises physical products by sharing them among many users.[33]

The process of servitisation has also been adopted by existing large industrial companies. A number of major jet engine manufacturers now sell 'power by the hour'[34] rather than selling jet engines. Through 'performance-based logistics' consumer firms purchase not just the product, but also superior, cost-effective maintenance and support services throughout the after-sales period – effectively aligning risks and incentives more equitably between consumer and supplier. In such a model, suppliers' payments become more closely linked to the value of the product generated by the consumer – reducing inefficiency in the economy, and potentially encouraging much greater levels of resource productivity.[35]

If such trends continue, traditional manufacturing firms will be forced to develop new competencies in order to combine their traditional products with a service offering. The challenge of widespread organisational change may be a key barrier to dematerialisation. This offers new opportunities and risks to the development of UK industry. Although traditional business models may be threatened, the development of dematerialisation and a sharing economy requires developments in areas such as verifying identity and insurance-offering new growth opportunities that new and existing UK businesses are well-placed to enter.[36]

Moves towards sharing economies, dematerialisation and servitisation also offer potential benefits to the regional economies of the UK. As the emphasis shifts from product manufacturing to product maintenance and service provision, industry is likely to become greatly far less concentrated, with the location of provision required to be closely located to use. These new business models will need to provide local services, maintenance and repair, which requires local employment and delivers local economic growth. New skills are likely to be required in the workforce to meet these new demands. There is likely to be a renewed focus on product design and innovation as companies move away from designing throw-away products towards products that are long-lasting, repairable and reuseable.

The move towards dematerialisation is one that is likely to be destructive to many existing businesses and is therefore likely face resistance initially. Government should be careful to be at best agnostic to such resistance and perhaps even critical if a move towards a more sustainable, regionally based, dematerialised, sharing economy is desired. An industrial strategy working towards a dematerialised economy must ensure that fiscal incentives and corporate governance rules are aligned to incentivise new firms entering into dematerialising sectors, and to encourage incumbent firms to change business models to adopt the process.

Innovation and development of business processes, strategies and skills to absorb these changes should be fostered and developed. This type of non-technical innovation has often been overlooked by previous industrial strategies (notably the most recent incarnation) but is crucial in developing sustainable, robust, economic businesses that can adapt to the dynamic global economy.

Trend 3:
Changes in the way that industrial products are produced

Some of the most fundamental changes occurring in global industry are how industrial products are produced and utilised. These include: decentralisation of manufacturing; development of additive manufacturing; developments in material efficiency; and the move towards closed-loop circular systems. All of these have economic, social and environmental implications, but also offer great potential to help the UK's industrial strategy meet its economic and environmental objectives.

Redistributed manufacturing, decentralised manufacturing, and additive technologies

The use of smart technology and the potential for additive manufacturing technology (such as 3D printing) has increased the economic viability of decentralised manufacturing.[37] Additive manufacturing allows for more geographically dispersed operations that can manufacture parts locally for quick turnarounds, with reduced transportation costs and associated environmental externalities. Such technologies could start to negate many of the key economies of scale of large industry. These changes are collectively referred to as 'redistributed manufacturing', which captures the changing geographies, organisational structures, value chains and distribution networks associated with these advances.[38]

Although additive manufacturing and decentralised manufacturing often go hand in hand, it is important to distinguish between the two: for example 3D printing technology can be used in small decentralised facilities, but it can also be used in centralised manufacturing locations to produce specialised components in small batches at reduced costs.[39] Decentralised manufacturing offers the potential for the development of more vibrant regional economies as manufacturing moves to smaller scales at more local locations, and both processes allow for the construction of specialised products at much lower cost, improving efficiency and productivity and helping to boost growth. There are challenges to employment if large centralised facilities are threatened, but adopting additive manufacturing technology in these facilities, and retraining staff to work in them, may mitigate such effects. Decentralised manufacturing may offer businesses valuable benefits such as additional process resilience (less reliance on suppliers) and flexibility (quicker adaptation of product).
The move towards a redistributed Manufacturing sector has wide-ranging challenges. It requires the development of new business models to supply the new types of personalised products that would now be able to be produced cheaply and locally. Technical challenges exist in the fields of engineering, materials, computing, infrastructure and chemicals, accompanied by challenges in organisation, business strategy, training, regulation, design and marketing.[40] The rapid development of this sector has both the potential to help solve, and create, problems surrounding the employment of STEM (science, technology, engineering and mathematics) graduates. Currently only a quarter of these work in manufacturing six months after graduation.[41] The creation of a new, more dynamic, flexible redistributed manufacturing sector may help to retain high-skilled graduates in this area. But it is likely that this new sector will require graduates with skills in STEM as well as business management and organisation: educational facilities may need to adapt their programmes to provide such skills.

The development of a re-distributed manufacturing economy thus requires government assistance to overcome both technical barriers and challenges. Support is needed with research and development; enabling new business models to emerge and develop; helping applied research on new business practices and regulation to emerge; and encouraging both new entrant and incumbent firms, through fiscal regimes and corporate governance rules, to transition to a new manufacturing future.

Circular economy

Industry has traditionally worked on a linear basis – resources are extracted, manufactured into products that deliver functions, and are then discarded at the end of life. This approach has been found to be wasteful, depletes natural resources and has led to significant negative environmental and social impacts. A new form of economic structure is being implemented in several companies and countries that offers significant economic and environmental advantages over the traditional approach – the move to a circular economy. A circular economy has been defined as keeping "resources in use for as long as possible to minimise waste and the need for extraction from primary sources. Resources are reused then recycled and products are repaired then remanufactured."[42]

Moves to a circular economy bring significant improvements in material and resource productivity. Resources are effectively reused, recycled and remanufactured many times over instead of being discarded. Productivity (as measured by output per resource) therefore improves significantly as a result. Economic efficiency improves, environmental damage is minimised, and global moves to such a system could add trillions to the global economy.[43]

A circular economy therefore offers significant potential to boost the UK's flagging productivity, help solve regional and sectoral imbalances in the UK, help the country meet its climate change

and sustainability commitments, and reduce the UK's exposure to resource scarcity and price volatility. It has the potential to boost employment, as moving to a circular economy effectively substitutes labour for the resources that are no longer required – requiring extra labour to repair and dismantle products, and assist in the reuse, recycling and remanufacturing processes. Many of the jobs are also likely to be location specific (especially those focused on repair and dismantling), and may be able to replace those that are lost in the move away from traditional industry. This is especially useful in communities that were heavily dependent on a single source of employment.

There may also be spin-off benefits in other industries from the development of a circular economy. Technological enablers are required to facilitate the trend, many of which can spin off into potentially profitable separate industries, and in which the UK already has strong skills and potential competitive advantage. Further development is needed in the industrial internet of things, with the spin-off benefits discussed above: online platforms allowing industries to share assets (and waste products) to improve productivity and industrial symbiosis would greatly facilitate the move to closed-loop systems, and could become significant businesses in their own right similar to the development of Air BnB. Large-scale data analysis would also be required to track inputs, resources, products and repairs – the UK has significant relevant skills and expertise and the development of businesses in this area would have great potential for expansion into overseas markets.

The ultimate outcome of a circular economy would be the creation of closed-loop manufacturing systems, with resources being reused, recycled and remanufactured in a continuous loop. To move to such a system, significant innovation is required in products, processes and business models, at a variety of stages. At the design and manufacturing stage, product innovation is required to design smaller and lighter products that are less material- and resource-intensive. Further product innovation is required to design products that can be more easily deconstructed, more easily repaired, and from which material inputs can be more easily extracted. Process innovation is needed to divert waste from one industry into others.[44] At the product-use stage, innovation is required to design longer lasting, more durable products that are easier to repair. Business model innovation is required to help incentivise the repair of existing products, and to shift to the types of dematerialised, servitised business models discussed above. At the end of the product-life process, product and business model innovation is required to encourage resource recovery, reuse and recycling.

Although the closed-loop circular economy is still in its infancy, there are practical examples in which companies in the UK are making moves in that direction, benefiting both their sustainability and bottom line. For example, British Sugar now generates a quarter of its revenue from non-core business, based on harnessing waste products from its sugar production. It sells topsoil for landscaping, aggregate for building, animal feeds, chemicals for the cosmetic industry, speciality tomatoes, bioethanol fuels, liquefied CO_2 for soft drinks, and electricity to the national grid. Such activity has increased the company's productivity, improved its revenue, and minimised the waste products that emerge from its operation.[45] Airbnb is an example of maximising the productivity of building space by allowing second incomes to be generated from existing building stock. Of course, these models are not perfect and criticisms abound of Airbnb inflating house prices, and Uber undermining workers' rights,[46] highlighting the need for further business model innovation in this area for this type of distributed platform model to meet the needs of society.

Promotion of the circular economy is occurring across the world through policies from city-scale[47] to regional level.[48] However, there are significant technical and financial challenges that must be overcome in order to move in the direction of a circular economy. Although many companies may be aware of the benefits of moving to closed-loop approaches, many businesses suffer from 'pilot paralysis' – whereby they don't know how to get started or what ideas are scalable.[49] Providing information, advice and best practice can help overcome this step – as can building industry groups that can share experience. The move to a circular economy may conflict with many existing business models – and although transitions to closed-loop structures may bring long-term gains they may disrupt profitability in the short run. Projects with such long-term payback periods are notoriously difficult to implement given current incentives and corporate governance regimes that are based on short-term shareholder value. Information and skills in the area are also generally lacking – and both require further development to introduce the type of transformative change that is required to implement closed-loop systems.

Trend 4:
Changes in the way key inputs into industrial processes are produced

Our final trend focuses on changes in the way that key inputs into many industrial processes are being produced. There are three important sub-trends that are of most interest in this area: changes in how energy is generated and used; changes in types of materials that are becoming commercially available for use; and the increasing amount of resources able to be reused in industrial processes.

Energy generation

One of the greatest potential changes to industry is the way the energy it consumes will be generated. In order to meet its legal commitments under the Climate Change Act, the UK sets out Carbon Budgets, and in the latest version of these, emissions from electricity should fall to approximately 20 per cent of a baseline scenario. Within industry, electricity consumption, petroleum, gas, and solid fuel consumption are required to fall below the baseline in order to meet the budget, with only the use of biofuel in industry increasing.[50] The move to an electricity system with a high level of renewables implies a huge construction of new forms of infrastructure in a relatively short space of time. This will require significant amounts of industrial products, and applying new forms of manufacturing techniques as discussed above to these industrial products could lead to significant developments in the creation of a redistributed, closed-loop manufacturing system in the UK.

The change to a low carbon energy system also implies changes in the forms of energy that many industrial processes use as an input. Developing and adapting technologies to produce standard industrial products using new, low carbon, forms of energy is a huge potential industry globally. Europe has made moves to promote industrial development in this direction through its climate package which includes targets for energy efficiency and renewable energy and the world's largest carbon-trading mechanism, the European Union Emissions Trading System (EU ETS). The effectiveness of the latter of these instruments has been much discussed and studied,[51] with a range of perspectives emerging as to its success. Recent studies have found that the EU ETS has played only a small part in encouraging firms to reduce carbon emissions, but where it has been successful, emissions reductions have worked hand in hand with greater overall efficiency, and even energy-intensive firms have derived some benefits, such as understanding their emissions in greater depth.[52]

The encouragement of innovation in such long-lived processes as energy in industrial systems requires visible, long-term incentives. Creating such long-term incentives has been a fundamental challenge to policy instruments such as the EU ETS, and renewable feed-in tariffs which have been used to incentivise technologies such as small-scale solar photovoltaics. Any industrial strategy must work to create such long-term incentives to ensure that it is both creating an energy system that is long-term fit for purpose for industry, but also an industrial sector that is able to adapt to the changes in the energy system anticipated over the coming decades.

Innovative materials

Other key inputs into industrial processes are also changing, such as significant advances in the field of material science with new innovative materials emerging that are either commercially available or on the cusp of becoming available. Already-known materials such as carbon fibre are becoming more widely used in consumer applications such as road vehicles and sports equipment.[53] Nanomaterials offer even greater potential but are at much earlier stages of development. Graphene is a material that could open new markets and replace existing technologies or materials. It is many times the stronger than steel, but is lightweight, flexible, can conduct both electricity and heat, and is also transparent. Much of the underlying science relating to the development of graphene was conducted at the University of Manchester.[54] Building on this development to develop industrial sectors utilising graphene technology is a huge potential competitive advantage to the UK.

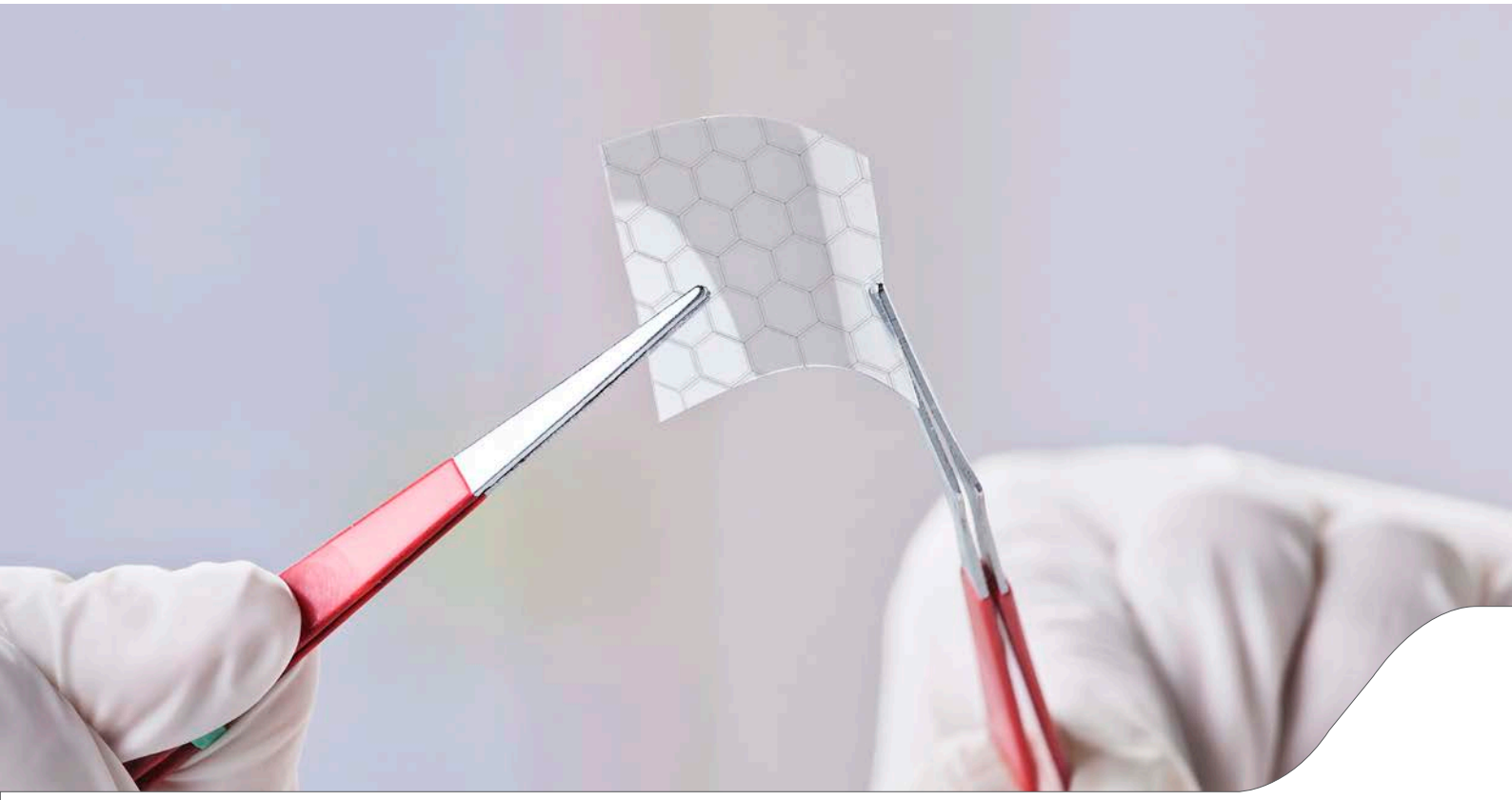
The development of active materials, including materials that can recover or self-heal, is at an earlier stage, but offers tremendous potential to industry, and would also help to move towards a circular economy.[55] There is much basic science being conducted in the area, and partnerships between academia and industry are starting to emerge but much work remains to build commercial industries out of these materials.[56] Given the UK's strength in industrial and academic research and development there is huge potential to build leading industries in this area, if the basic science can be maintained, and innovative commercial applications and business models are developed. Government can assist by supporting the basic science, helping to build partnerships between industry and academia and clarifying the regulatory environment relating to such new materials.[57]

Closed-loop systems

A move towards closed-loop industrial systems may also change dramatically the form of key inputs into industrial processes. Such systems would ensure that resources are utilised many times before they are discarded. Materials would be reused, recycled and remanufactured – and then serve as inputs into industrial processes. This requires changes in not only in what happens to industrial products after use, but also how they are designed and manufactured. The remanufacturing process can add value: rather than downcycling used steel to its lowest value application, such as reinforcing bars, it could be upcycled to higher value tailored components.[58] Integrated business models that undertake both upcycling processes and construction in fields in which the UK is already competitive (such as automotive assembly and aerospace) could help facilitate this process, and increase the value captured by UK industry. This could also provide employment for UK workers whose existing skills may otherwise be wasted (such as the steel workers that would have been affected had Tata Steel pulled out of the UK).

In both the field of materials and energy there is a shift towards an increasingly bioeconomy. New biobased alternatives to plastic are emerging, such as purely plant-based polyethylene terephthalate (PET), with companies such as Pepsi and Coca-Cola leading the way.[59] Biomass energy sources are being promoted around the world, and both pure biomass electricity plants and co-fired plants where biomass and fossil fuels are used in combination are an increasingly important part of the energy mix, along with increasing amounts of biodiesel used in transportation. Potentially such moves can form key parts of a future circular economy, with waste products from one industry (such as waste wood products) used in another (such as energy) or even waste from one product used to create another in the same industry (sugar molasses in soft-drink manufacture used to make biobased plastics). There are major potential problems to overcome: developing supply chains; the potential social and environmental issues such as diverting crops from food to energy; and avoiding encouraging monoculture ecosystems in place of natural forests. However, the bioeconomy can form a crucial and growing part of any future, sustainable and productive industrial sector.

The inputs used by industry to produce its products in the next few decades are likely to shift dramatically. This creates both opportunities for new business development, but also risks to existing business practice. Creating a flexible strategic environment in which new materials, energy systems and technologies can appear, and helping to facilitate the provision of skills, opportunities, information, infrastructure and a suitable fiscal environment should be the key aims of industrial strategy.



Recommendations

Each of the four identified trends will shape UK and global industry over the coming decades. Each offers challenges and opportunities for the development of world-leading, economically powerful, socially equitable and environmentally sustainable industry in the UK. Seven recommendations for policies and strategic interventions are synthesised here to provide a list of key priorities for consideration.

1. Define a primary goal, such as improving productivity within a sustainable, inclusive economy, and provide a long-term timeframe, sufficient to guide major investments; build a strategy to meet that goal.

As discussed in the first section, there are many potential primary objectives for any industrial strategy, and many timeframes that the strategy can be concerned with. Outlining these clearly is vital, helping any industrial strategy, helping to build stability and predictability for industry. The primary objective could be improvements in key indicators, or could be focused on the achievement of a socially important mission-oriented innovation, which can trigger subsidiary improvements in innovation, investment and productivity.

2. Focus on sectors that provide strategically important functions and assist them to develop innovative products, functions, and business models; use them to help build UK expertise for export to the rest of the world.

The UK has a number of high-performing industrial sectors such as automotive construction, aerospace, space, biotechnology, and software development. The focus here should not be on industrial products (such as primary steel) but the final functions that are demanded by consumers (such as housing). This would allow the UK's industrial strategy to help foster export-ready industrial sectors, as well as those that can solve key domestic social issues.

A focus on service outcomes allows greater policy flexibility. Without specifying 'winning' manufacturing sectors in advance, support can be given to the creation of a range of novel, innovative industrial products that could deliver transformative and sustainable change in the UK, such as moves to redistributed and circular business models. Work should be undertaken to understand the key barriers and policies needed in each sector. It would allow the industrial strategy to adapt to the changing pattern of demand of future societies, and also to the changing way that industrial products can meet that demand.

3. Focus on innovations in business practice, new business strategies and new business models, as well as innovation in science and technologies.

A critical success of the previous industrial strategy was protected funding for basic science and research and development, which should be maintained to ensure the UK protects its advantages in areas such as innovative new materials and biotechnology. This is especially critical if, as a result of Brexit, EU funding streams are not accessible. But any new industrial strategy must take a wider view and encourage innovation in business practice, new strategies and models across all sectors.

In each of the four trends innovation is required, as much as basic technological R&D, for the UK to build industry that can compete internationally and deliver economic, environmental and social benefits. The development of closed-loop industrial practices, a redistributed manufacturing sector, a dematerialised, servitised economy and one in which renewable energy generation, resource reuse, recycling and remanufacturing are commonplace, requires transformational change in business practice, much more than it requires transformational technological change.

Helping to ensure such change should be a crucial part of the UK's next industrial strategy, utilising policies such as the creation of institutions to pilot initiatives and demonstrate activities, fiscal incentives to encourage new practice to be disseminated, and amendments to public procurement. Such support needs to explicitly engage with how to help businesses transition from out-of-date business models to new approaches.

4. Build greater linkages between government, industry and other key stakeholders to help foster growth of different sectors, but keep an arms length from companies to avoid picking winners.

One of the recent key success stories of UK industrial strategy has been improved productivity in the automotive sector. A key part of that success was the establishment of the Automotive Council to strengthen co-operation between the UK government and the sector.[60]

By focusing on the issues of technology, supply chains, and business environment and skills, government has been able to tailor its support for the sector in the most efficient manner. Extending this type of collaboration to other key strategic areas could allow the types of productivity gains seen in the automotive sector to roll out across the economy. This style of collaboration involves creating broader intersectoral networks involving industry, government (both central and local), trade unions, financial institutions and technical and academic institutions – mirroring similar structures in Germany.[61] Creating these networks is not a short-term endeavour – it requires years of work building closer collaboration with such stakeholders. However, such networks could help to bring different, non-market considerations to British industry that could foster a culture of longer term innovation and economic, environmental and social improvements.

The creation of an Industrial Strategy Commission to guide and develop the new strategy, comprising business, trade unions, local authorities, central government and academic institutions may be one method of starting to build such networks.[62]

Another success story of previous government industrial policy has been the creation of sectoral specific Catapult Centres with funding drawn from the private and public sectors. They can provide value by demonstrating best practice, helping basic science reach markets, and developing new businesses. They could include a focus on innovation of new business models and systems, and either the development of new centres focusing on the Circular Economy, Redistributed Manufacturing or Dematerialisation, or the rolling out of a strategic priority of such trends across all centres.

Focusing on key strategic areas, via mission-oriented innovation, could potentially help promote transformational business, as could involving a broad spectrum of stakeholders in the governance of such centres to avoid capture by particular business interests.

5. Create greater incentives for businesses to invest in long-term productive developments.

A large part of the struggling productivity challenge that the UK is encountering is an ingrained culture of short-termism within UK business.[63] This phenomenon has eroded incentives to invest in long-term technological development and breakthrough research and development. It also reduces the incentives to undertake the types of transformational change that might bring long-term gains at the cost of short-term profit, such as through development of closed-loop industrial systems.

There are numerous causes of short-termism,[64] but one of the most important is the nature of ownership of British business and the fiscal and corporate governance regimes that business faces.[65] The encouragement of more long-term investors into equity markets, through changes to taxation regimes (such as the tapering of Capital Gains Tax over time), changes to reporting requirements to move away from short-term quarterly reports to multi-year reporting structures that discuss long-term strategy, goals and investment.

The inclusion of long-term governance as the key component of executive and non-executive pay could ensure that bonuses are incentive-compatible with long-term investment decisions rather than short-term profit. All measures that could be revenue-neutral but encourage the emergence of a culture of long-termism – allowing UK businesses to adapt to the global trends discussed above.

6. Seek to match demand and supply of highly skilled labour by looking at the future prospects for the economy and acting where needed to boost demand as well as supply.

Much focus has been put on a lack of skills in the UK economy, and the need to improve training and educational attainment. The lack of skills may be a key limiting factor in a number of sectors (especially software development, biotechnology and engineering).

This challenge may be amplified depending on the final Brexit package. Whatever the final negotiated agreement it is essential that key sectors are able to source the skills they require to grow and expand.

There are a number of important changes in the pipeline for skills through changes to the funding environment for academic institutions and an increasing focus on competition between universities. This environment needs to be suitably tailored to ensure that universities can deliver the types and quantities of skills needed not for the economy of today, but for the economy of the future. Many educational institutions focus on meeting the needs of the recent past, rather than the near future, or the potential future. Improving linkages between trainers and educators and industry will be one way of addressing this.

Although the supply of skills is an important issue, so is the demand for skills. Overall, the UK economy has a huge problem with a mismatch of qualifications and apparent under-utilisation of skills.[66] The UK also has one of the highest levels of demand in the OECD for low-skilled workers.[67] As the Porter report

Recommendations (cont.)

highlighted, the UK has a choice between a high-skilled, high-value economy, and a low-skilled, low-value economy. It seems that the UK is on a path towards the latter, rather than the former. Although employment is increasing, much of it is in low-paid and low-skilled jobs. This type of low-skilled employment is fundamentally different to the low-skilled work of previous generations – it is often insecure and perceived as low status. It often offers few opportunities for personal or career development, looking regions and populations into low-skill, low-value traps.

Increasing the number of highly skilled individuals may not be sufficient to overcome this trend. What is more important is to create the demand for these individuals, and allow supply to work to meet that demand. Training engineers to work in closed-loop industrial systems is of no value if no business is willing to work towards closed-loop systems. However, there is a value in such training if it is anticipated that the economy will travel in that direction. The challenge is anticipating what the future demand for skills is and building a suitable training environment accordingly.

7. Co-ordinate all significant policy instruments, including procurement, infrastructure development and planning, to meet the needs of the strategy. Procurement particularly has particular under realised value as a policy delivery tool.

The government has a wide variety of tools at its disposal to help drive forward the other recommendations, and it should use them to help craft a holistic and effective industrial strategy.

For example, government has a critical role in using its own central procurement, actions and policies to jump start demand for highly skilled individuals, and show proof of concept to industry that trends such as dematerialisation, closed-loop systems and redistributed manufacturing are feasible, profitable and sustainable.

Government's vital role in infrastructure development can bring huge twin benefits. The construction of new infrastructure would help to facilitate industrial growth in line with all four of the above identified trends. Ensuring that the construction of such infrastructure (through regulatory reform and public procurement rules) happens in a way that also reinforces the positive benefits of such trends and helps to move the UK towards a redistributed, dematerialised, circular economy, could be a win-win. The potential for collaborative action in this area is evidenced by the work of the Green Construction Board (GCB), now part of the Construction Leadership Council. For example, the HMT Infrastructure Carbon review, developed by the GCB, has ministerial support and commitment from leaders of large infrastructure organisations, and identifies actions to reduce carbon and cost in infrastructure by aligning the value chain to release the value of lower carbon solutions.

Investment in research and development, if targeted holistically to incorporate business practice as well as pure science, can help boost innovation in technology and business practice. Working together with key sectors can improve the targeting of this investment.

Building a planning framework that considers the overall trends discussed here, working with sectoral institutions, focusing on key strategic sectors, and helping to build both supply and demand for skills, will help the government to develop the overall strategic vision that should be encapsulated in its new industrial strategy.

Ensuring that all these tools work together is crucial, and each policy being clear and consistent is vital in order to deliver wide consensus not only in the overall strategy but also in the implementation process.

Case study: house building

A focus on re-formation of the housing sector could serve as a landmark area for the UK's industrial strategy – helping to boost growth of technology enablers, provide proof of concept, and boost demand for skills that in turn engenders an increase in the supply of such skills. All of the previous recommendations could help address the issues in the housing sector via mission-oriented investment.

There is a huge issue in the UK at present with insufficient provision of accommodation required at an affordable level. Much work needs to be done to ensure that such a fundamental service is provided to the population in an appropriate, sustainable and economically efficient manner. The building sector globally uses almost half of the total flow of all raw materials, so improving the resource efficiency of the sector can have huge implications for the sustainability of the economy as a whole.

Focusing on the changing nature of demand (such as increasing demand for single occupant housing, or new smart housing), rather than just constructing new houses, will allow innovative solutions to the problem. The traditional model of firms constructing housing for sale to individuals in the private market is not working. The traditional rental sector is also failing to provide affordable suitable accommodation. New business models are required to provide these accommodation services, and these need to be innovated and incentivised, along with technological solutions (such as modular housing such as those offered by new firms such as Hivehaus) to help solve the problem.

Such issues have wider implications, as the personal retirement model in the UK is designed on the basis of home ownership at affordable levels. As mortgages take longer to pay off and home ownership decreases, the current models of pension schemes are unlikely to provide sufficient income to cover housing costs.

The formation of a Housing Council to create innovative solutions between government, industry and other key stakeholders, and either the creation of a Housing Catapult centre, or expanded scope for existing centres (such as the Future Cities Centre) would help innovative technologies and business models to emerge, and help government and industry to work together to find shared solutions to key challenges.

Changing the way that new housing projects are funded, and allowing local government to invest long term in new social housing, could help reduce short-termism in the sector. Reforming tax incentives and planning reforms to incentivise construction firms to construct housing using reuseable components could help to demonstrate the benefits of moves to a circular economy – providing learning opportunities for both the technical and business model challenges. It would boost demand for skills in this area, fostering supply and help start the development of internationally competitive business in this area. Interesting models are starting to emerge, such as the partnership between Warrington-based housing association Your Housing Group and renewable energy firm WElink to develop both solar-powered 'flatpack' houses and the factories to build more such developments. Such business models should be fostered and studied to enable wider roll out across the country.

If successful, industrial strategy could help reduce housing costs, freeing up large amounts of capital amongst those most likely to engage in entrepreneurial activity (the young people who are currently devoting almost all of their income to rent); help boost technological and business development in line with industrial trends that are likely to define the next few decades; and potentially create a globally leading industry. If the UK has to construct large numbers of new houses, why not do so in a fashion that will maximise long-term economic, environmental and social benefits and build industrial growth in the process?

References

[1] In this paper we define industry broadly, to include traditional industrial production as well as new forms of industry in sectors such as communications and information technology.

[2] Harari, D. (2016). Briefing Paper Number 05795, Regional and local economic growth statistics. House of Commons Library.

[3] Labour Productivity: Apr to June 2016. (2016). London: Office for National Statistics. Retrieved 17 January 2017, from https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/bulletins/labourproductivity/aprtojune2016

[4] The situation is different for manufacturing which remains well below its 2008 productivity level, and services which have surpassed 2008 levels after initial falls.

[5] For more information see Mazzacuto, M. & Penna, C. (2015) *Mission-Oriented Finance for Innovation.* Policy Network and Rowman & Littlefield International

[6] Labour Productivity: Apr to June 2016. (2016). London: Office for National Statistics. Retrieved 17 January 2017, from https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/bulletins/labourproductivity/aprtojune2016

[7] For further detail on the importance of linking long-term strategic visions to short-term policy making see: University of Cambridge Institute for Sustainability Leadership (CISL) (2016). November). *Future Proofing: building sustainable plans for long-term economies*. Cambridge, UK: The Prince of Wales's Corporate Leaders Group.

[8] Westlake, S., Rae, J., & Marston, L. (2016). *Getting it right this time: four ideas for a better industrial strategy.* [Web log post.] Nesta. Retrieved 18 January 2017, from http://www.nesta.org.uk/blog/getting-it-right-time-four-ideas-better-industrial-strategy

[9] Porter, M. & Ketels, C. (2003). UK Competitiveness: moving to the next stage. DTI Economics Paper. Retrieved from http://www.hbs.edu/faculty/Publication%20Files/file14771_83b42e5a-7e88-49be-9d33-2fc7585a87d9.pdf

[10] Orange, R. (2016). Waste not want not: Sweden to give tax breaks for repairs. *The Guardian.* Retrieved 18 January 2017, from https://www.theguardian.com/world/2016/sep/19/waste-not-want-not-sweden-tax-breaks-repairs

[11] Germany's Frauhofer-Gesellschaft is the leading organisation for applied research in Europe and has over 60 research institutes and units across Germany. Its focus is on applied science and developing that science for use in industry.

[12] For more information see: BMUB, I. (2016). German Resource Efficiency Programme (ProgRess). Germany: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. Retrieved 18 January 2017, from http://www.bmub.bund.de/en/topics/economy-products-resources-tourism/resource-efficiency/german-resource-efficiency-programme/overview/

[13] Japan has recently released its latest version of this strategy, see: Government of Japan. (2016). *Japan Revitalisation Strategy 2016 – Toward the 4th Industrial Revolution.* Government of Japan. Retrieved from http://www.kantei.go.jp/jp/singi/keizaisaisei/pdf/2016_hombun1_e.pdf

[14] Masui, A. (2016) Development of care robots growing in aging Japan, *The Japan Times.* Retrieved 17 January 2017, from http://www.japantimes.co.jp/news/2016/01/27/national/social-issues/development-care-robots-growing-aging-japan/#.WH4yHlWLTmE

[15] Wells, P.E. & Xenias, D. (2015) From 'freedom of the open road' to 'cocooning': Understanding resistance to change in personal private automobility, *Environmental Innovation and Societal Transitions* Volume 16 September 2105), p106-119.

[16] The dependency ratio is a measure showing the number of dependents, aged 0-14 and 65+, to the total population aged 15-64.

[17] For an analysis of the situation in North America, see: 2015 State Of The Smart Home Report – Icontrol Networks. (2015). Icontrol Networks. [Web log post.] Retrieved 17 January 2017, from https://www.icontrol.com/blog/2015-state-of-the-smart-home-report/

[18] Walker, S. & Roashan, R. (2016). Wearable Technology Report – 2016. IHS Technology. Retrieved from https://technology.ihs.com/581573/wearable-technology-report-2016

[19] Hive is a company owned by Centrica offering technology allowing consumers to adjust their heating via a smartphone.

[20] Collins, B. (2015). Inside Intelligent Textiles: making smart materials for the military. Alphr. Retrieved 17 January 2017, from http://www.alphr.com/business/1001575/inside-intelligent-textiles-making-smart-materials-for-the-military

[21] Department for Business, Innovation and Skills.(2012). Benchmarking UK competitiveness in the global economy. London: Department for Business, Innovation and Skills.

[22] Accenture. (2015). The Rise of Robo-Advice: Changing the Concept of Wealth Management. Accenture. Retrieved from https://www.accenture.com/_acnmedia/PDF-2/Accenture-Wealth-Management-Rise-of-Robo-Advice.pdf

[23] Thomsen, C. (2004). Automation and Robotics – Practical Technology Solutions for the Pharmacy. The Thomsen Group Inc. Retrieved from http://thethomsengroup.com/TTGI%20Pages/Articles%20Studies%20&%20Presentations/2005%20Business%20Briefings.pdf

[24] For a discussion of these barriers see: European Commission. (2017). Advancing the Internet of Things in Europe. Brussels: European Commission. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/ PDF/?uri=CELEX:52016SC0110&from=EN

[25] Hollinger, P. (2015). UK satellite sector reaches for the stars. *Financial Times*. Retrieved 17 January 2017, from https://www.ft.com/content/89fefcfe-ffdb-11e4-abd5-00144feabdc0

[26] Space IGS. (2014). Space Innovation and Growth Strategy 2014-2030: Space Growth Action Plan. Space IGS. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/298362/igs-action-plan.pdf

[27] For an update of the activities of the Satellite Applications Catapult see: Satellite Applications Catapult (2015), Annual Report 2014-2015.pdf

[28] Hollinger, P. (2015). UK satellite sector reaches for the stars. *Financial Times*. Retrieved 17 January 2017, from https://www.ft.com/content/89fefcfe-ffdb-11e4-abd5-00144feabdc0

[29] Space IGS. (2014). Space Innovation and Growth Strategy 2014-2030: Space Growth Action Plan. Space IGS. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/298362/igs-action-plan.pdf

[30] Schumacher, E.F. (1973) *Small is beautiful; a study of economics as if people mattered*. London: Blond and Briggs.

[31] Andy Neely, Head of the Institute of Manufacturing at the University of Cambridge, defines servitisation as: "the innovation of organisation's capabilities and processes to better create mutual value through a shift from selling product to selling Product-Service Systems." See: Neely, A. (2013). What is Servitization? [Web log post.] Retrieved from http://andyneely.blogspot.co.uk/2013/11/what-is-servitization.html

[32] World Wide Fund for Nature. (2017). Green game-changers: Insights for mainstreaming business innovation. Gland, Switzerland: World Wide Fund for Nature. Retrieved from http://assets.wwf.org.uk/downloads/1121_1_wwf_greengamechange_aw_web__2_.pdf

[33] Wosskow, D. (2014). Unlocking the sharing economy: An independent review. London: Department for Business, Innovation and Skills. Retrieved January 17, 2017, from the Department for Business, Innovation and Skills website: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/378291/bis-14-1227-unlocking-the-sharing-economy-an-independent-review.pdf

[34] Power by the Hour is a trade-mark of Rolls-Royce plc and was actually coined by the Bristol Siddeley firm in the 1960s. For more information see: Smith, D. (2013). Power-by-the-hour: the role of technology in reshaping business strategy at Rolls-Royce. *Technology Analysis & Strategic Management*, 25(8), 987-1007. http://dx.doi.org/10.1080/09537325.2013.823147

[35] Kim, S., Cohen, M., & Netessine, S. (2007). Performance Contracting in After-Sales Service Supply Chains. *Management Science*, 53(12), 1843-1858. http://dx.doi.org/10.1287/mnsc.1070.0741

[36] Wosskow, D. (2014). Unlocking the sharing economy: An independent review. London: Department for Business, Innovation and Skills. Retrieved January 17, 2017, from Department for Business, Innovation and Skills website: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/378291/bis-14-1227-unlocking-the-sharing-economy-an-independent-review.pdf

[37] We define the decentralisation of manufacturing as being where the production of a product is spread out over a geographic area rather than concentrated in one large factory.

[38] For more information see Pearson, H., Noble, G., & Hawkins, J. (2013). Re-Distributed Manufacturing Workshop Report. Engineering and Physical Sciences Research Council. Retrieved from https://www.epsrc.ac.uk/newsevents/pubs/re-distributed-manufacturing-workshop-report/

[39] See, for example, in the aerospace industry: Sevenson, B. (2017). GE Considers 3D Printing Turbine Blades for Next Generation Boeing 777X's GE9X Engines. 3DPrint.com. Retrieved 18 January 2017, from https://3dprint.com/11266/3d-printed-lpt-ge9x-777x/

[40] For a greater discussion, see: Pearson, H., Noble, G., & Hawkins, J. (2013). Re-Distributed Manufacturing Workshop Report. Engineering and Physical Sciences Research Council. Retrieved from https://www.epsrc.ac.uk/newsevents/pubs/re-distributed-manufacturing-workshop-report/.

[41] Foresight. (2013). The Future of Manufacturing: A new era of opportunity and challenge for the UK Summary Report. London: The Government Office for Science. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/255923/13-810-future-manufacturing-summary-report.pdf

[42] Stahel, W. (2016). The circular economy, *Nature*, 531(7595). 435-438. http://dx.doi.org/10.1038/531435a
An alternative definition is from the European Commission: "the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised". European Commission. (2015). *Closing the loop - An EU action plan for the Circular Economy*. Brussels: European Commission. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614

[43] Accenture in 2015 predicted that a global move to a circular economy could add an extra US$4–5 trillion in extra economy output by 2030. Lacy, P., & Rutqvist, J. (2015). *Waste to wealth: the circular economy advantage*. New York: Palgrave Macmillan.

[44] This is known as industrial symbiosis. Previous attempts have been undertaken to promote this in the UK through the National Industrial Symbiosis Programme.

[45] Short, S., Bocken, N., Barlow, C., & Chertow, M. (2014). From Refining Sugar to Growing Tomatoes. *Journal of Industrial Ecology*, 18(5), 603-618. Retrieved from http://dx.doi.org/10.1111/jiec.12171

[46] See the criticism of Airbnb in San Francisco as reported Trefny, B. (2014). Critics Blame Airbnb for San Francisco's Housing Problems. National Public Radio. Retrieved 18 January 2017, from http://www.npr.org/2014/08/11/338830807/critics-blame-airbnb-for-san-francisco-s-housing-problems
See also coverage of the recent legal case in the UK concerning Uber's classification of their drivers as self-employed, for example O'Connor, S., Croft, J., & Murgia, M. (2017). Uber drivers win UK legal battle for workers' rights. *Financial Times*. Retrieved 18 January 2017, from https://www.ft.com/content/a0bb02b2-9d0a-11e6-a6e4-8b8e77dd083a (subscription required)

[47] For example London has a circular economy roadmap and recently hired a team to engage with SMEs across the city to help them evaluate opportunities to go circular. Other cities are also showing interest through the CE100 scheme.

[48] For example the EU has developed a circular economy strategy and a resource efficiency roadmap. The G7 has also developed an alliance on resource efficiency.

References (cont.)

[49] Lacy, P., & Rutqvist, J. (2015). *Waste to Wealth – the circular economy advantage*, New York: Palgrave Macmillan.

[50] Climate Change Committee. (2016). CCC fifth carbon budget: central scenario data. London: Climate Change Committee. Retrieved from https://www.theccc.org.uk/publication/fifth-carbon-budget-dataset/

[51] For a review of the experience of innovation in the EU ETS see: Laing, T., Sato, M., Grubb, M., & Comberti, C. (2014). The effects and side-effects of the EU emissions trading scheme. *Wiley Interdisciplinary Reviews: Climate Change*, 5(4), 509-519. http://dx.doi.org/10.1002/wcc.283

See also Rogge, K. & Hoffmann, V. (2010). The impact of the EU ETS on the sectoral innovation system for power generation technologies – Findings for Germany. *Energy Policy*, 38(12), 7639-7652. http://dx.doi.org/10.1016/j.enpol.2010.07.047

[52] University of Cambridge Institute for Sustainability Leadership CISL. (2015). *10 years of carbon pricing in Europe*. Cambridge, UK. Retrieved from http://www.cisl.cam.ac.uk/publications/low-carbon-transformation-publications/10-years-of-carbon-pricing-in-europe

[53] *ORNL Review:* Carbon-Fiber Composites for Cars. (2017). Knoxville, Tennessee: Oak Ridge National Laboratory Review. Retrieved 18 January 2017, from http://web.ornl.gov/info/ornlreview/v33_3_00/carbon.htm

[54] Geim, A. & Novoselov, K. (2007). The rise of graphene. *Nature Materials*, 6(3), 183-191. http://dx.doi.org/10.1038/nmat1849

[55] For an example see the discussion on Active Disassembly by the Ellen Macarthur Foundation: Techniques for rapid, non-destructive disassembly. Ellen Macarthur Foundation. Retrieved 18 January 2017, from https://www.ellenmacarthurfoundation.org/case-studies/techniques-for-rapid-non-destructive-disassembly

[56] For more information see the recent Special Issue of the *Smart Materials and Structures Journal* in this area.

[57] Azoula, D. & Buonsante, V. (2012). High time to act on nanomaterials. Friends of the Earth Germany. Retrieved from http://www.ciel.org/Publications/Nanopatch_EU_Nov2012.pdf

[58] Allwood, J. (2016). *A bright future for UK steel.* Cambridge: University of Cambridge. Retrieved from https://www.cam.ac.uk/system/files/a_bright_future_for_uk_steel_2.pdf

[59] Sidel. (2017). A Green Future for Plastic. Retrieved 18 January 2017, from http://www.sidel.com/about-sidel/media/inline-magazine/a-green-future-for-plastic

[60] Automotive Council UK. (2013). Driving success – a strategy for growth and sustainability in the UK automotive sector. London: Department for Business, Innovation and Skills.

[61] For a more detailed discussion see: Hancke, B. & Coulter, S. (2013). The German manufacturing sector unpacked: institutions, policies and future trajectories. Future of manufacturing project: Evidence paper, 13. Foresight. London: Government Office for Science.

[62] Ansell, M. (2016). Three things we hope the chancellor says in the Autumn Statement (and two we hope he doesn't). *Times Higher Education (THE)*. [Web log Post.] Retrieved 18 January 2017, from https://www.timeshighereducation.com/blog/three-things-we-hope-chancellor-says-autumn-statement-and-two-we-hope-he-doesnt

[63] Cox, G. (2013). Overcoming Short-termism within British Business: The key to sustained economic growth. London: The Labour Party. Retrieved from http://www.policyforum.labour.org.uk/uploads/editor/files/Overcoming_Short-termism.pdf

[64] See ibid for a full review of these causes.

[65] Department for Business, Innovation & Skills. (2012). The Kay Review of UK Equity Markets and Long-Term Decision Making. Final Report. London:Department for Business, Innovation and Skills. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/253454/bis-12-917-kay-review-of-equity-markets-final-report.pdf

For more information on how investors can help foster a long-term perspective see University of Cambridge Institute for Sustainability Leadership CISL. (2016). *Taking the long view: A toolkit for long-term, sustainable investment mandates.* Cambridge, UK

[66] Mayhew, K. & Keep, E. (2014). Industrial strategy and the future of skills policy. London: Chartered Institute of Personnel and Development. Retrieved from https://www.cipd.co.uk/Images/industrial-strategy-and-the-future-of-skills-policy_2014_tcm18-10247.pdf

[67] OECD (2013), *OECD Skills Outlook 2013: First Results from the Survey of Adult Skills,* OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789264204256-en

UNIVERSITY OF CAMBRIDGE
INSTITUTE FOR SUSTAINABILITY LEADERSHIP

Cambridge insight, policy influence, business impact

The University of Cambridge Institute for Sustainability Leadership (CISL) brings together business, government and academia to find solutions to critical sustainability challenges.

Capitalising on the world-class, multidisciplinary strengths of the University of Cambridge, CISL deepens leaders' insight and understanding through its executive programmes; builds deep, strategic engagement with leadership companies; and creates opportunities for collaborative enquiry and action through its business platforms.

Over 25 years, we have developed a leadership network with more than 7,000 alumni from leading global organisations and an expert team of Fellows, Senior Associates and staff.

HRH The Prince of Wales is the Patron of CISL and has inspired and supported many of our initiatives.

Head Office
1 Trumpington Street
Cambridge, CB2 1QA
United Kingdom
T: +44 (0)1223 768850
E: info@cisl.cam.ac.uk

EU Office
The Periclès Building
Rue de la Science 23
B-1040 Brussels, Belgium
T: +32 (0) 2 894 93 19
E: info.eu@cisl.cam.ac.uk

South Africa
PO Box 313
Cape Town 8000
South Africa
T: +27 83 491 8369
E: info.sa@cisl.cam.ac.uk

Design: adrenalinecreative.co.uk

www.corporateleadersgroup.com