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Review of trends in manufacturing and global supply chains, and their impact on UK freight

Future of Mobility: Evidence Review

Foresight, Government Office for Science

Review of trends in manufacturing and global supply chains, and their impact on UK freight

Professor D John Mangan

Chair in Marine Transport & Logistics, School of Engineering, Newcastle University.
Visiting Professor, School of Business, Trinity College Dublin

Professor A McKinnon

Chair in Logistics, Kuehne Logistics University, Hamburg
Professor Emeritus, Heriot-Watt University, Edinburgh

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Executive summary

The movement of freight into, around and out of the UK is a derived demand. In order to investigate what future freight flows will look like, it is necessary to understand the drivers of such demand and also how the freight demanded is produced and how it moves from production to consumption. This movement and related activities are commonly referred to as the supply chain. Myriad factors, ranging from manufacturing strategy to geopolitics, dictate what future freight flows might look like.

This review is primarily concerned with how and why freight is produced and moves, and with understanding the influences on future freight flows. Specifically, it looks at trends in manufacturing and, more generally, production (we clarify and differentiate these terms in the review), retail and supply chain. Other, parallel work streams are investigating related areas (for example, transport technologies and automation) which are outside the scope of this review.

Changing patterns in global trade

The review begins by taking a macro perspective and examines changing patterns in global trade which comprises individual freight flows within complex supply chains composed of many nodes and links. We focus particularly on international freight movements in and out of the UK. While domestic freight movements are in scope, this is primarily in the context of their role as the import or export leg of associated international freight movements.

The analysis draws in particular on international seaborne freight movements, which account for over 80% of global trade by volume and more than 70% by value. Tracking international seaborne freight thus gives a good insight into trade patterns and the structure of supply chains. The remaining international freight moves by other modes and these too are considered.

World merchandise trade has grown continuously in recent decades, apart from a decline associated with the global economic slowdown in 2008. UK maritime freight volumes also grew continuously until 2007, then began to decline and are now marginally less than they were over 20 years ago (501m in 1994; 473m in 2016), reflecting a changing traffic profile and, in part, an increased miniaturisation and lightening of freight. Global freight volumes have traditionally been closely correlated with GDP but there is evidence that this link is weakening. The review considers the likely reasons behind this change.

The review also looks at issues of de-globalisation and a growth in reshoring, and considers that their impact on future UK-centric freight flows has been somewhat exaggerated.

We conclude that there are some fundamental underlying shifts in international trade flows underway. Essentially these involve changes in demand and structural changes to international manufacturing networks, including a rise in local-for-local manufacturing. Combining these insights with others evidenced in the review (such as changes in supply chain architectures, de-materialisation and changes in manufacturing) it is our contention

that, while globalisation will continue, global trade flows in volume terms will not continue to grow in the medium term at the same fast pace as seen in recent decades.

Furthermore, we contend that, while international trade will remain at the heart of the UK's economy, UK-centric maritime freight flows are unlikely to rise significantly in the medium term, as changes in efficiencies and materials will offset absolute volume growth. A notable trend is that more products will be transported in containers than has previously been the case. For example, fruit products are increasingly containerised at source rather than shipped in bulk.

The review explains how the physical structures of some global transport networks are gradually changing, with new routes slowly emerging, although these will have only limited impact on the UK. In addition, market disruptors such as Amazon are entering the logistics marketplace and are acquiring their own transport and warehouse assets. New forms of transport are slowly emerging, such as floating ports, truck platooning, increased use of inland dry ports, drones and airships, and, in the longer term, the 'Hyperloop'.

Adding value to products in transit may also become more common in the future, for example 3D printing of products on board ships that act as 'rolling warehouses' and 'floating factories'. This allows products to be customised closer to demand and also cuts down on the need to carry spare parts, for example.

Changes in supply chain architecture

The review looks at how supply chain architectures are changing and evolving, due to drivers such as sustainability pressures and technology advances, as it is the supply chain which dictates how products get to the point of demand. There is a growing complexity inherent in many global supply chains and wide-ranging interdependencies are leading to problems in over-stretched global supply chains. We anticipate that, in 2040, products produced and consumed in the UK will be even more tightly tied into very sophisticated and transparent global supply chains than is the case today. Driven by technology, these supply chains will be 'self-thinking' and will automatically manage demand, movement and supply chain performance.

Changes in manufacturing and retail

The review looks at two key nodes in the supply chain – manufacturing and retail. We consider how these areas are changing and evolving, and what impact this will have on future freight flows. We focus on how the sourcing strategies of UK retailers are evolving; the continued growth and evolution of internet shopping; the growing popularity of 'servitisation' (selling products and services together); the growth in mass customisation; and a shift in production capabilities, driven in particular by the digital revolution. The latter heralds the growth of additive manufacturing (such as 3D printing) and, in turn, the emergence of a 'maker movement' of 'prosumers' who both produce and consume their own products.

The nature of products flowing in and out of the UK in 2040 is likely to be significantly different from today, and product characteristics are likely to vary depending on their stage in the supply chain. Where previously flat-packed products generated significant transport savings, in future we are likely to see products progress through multiple states with resulting transport efficiencies. Product capabilities such as self-healing, auto configuration

and print-on-demand will feature heavily. It is apparent that many of the products envisaged to populate this future world will have higher value:volume ratios than today's products and, accordingly, lower cost sensitivity. Business-to-consumer (B2C) and consumer-to-consumer (C2C) sales will make up an increasing share of product flows.

Conclusions

In our review we conclude that it is difficult to predict exactly what UK manufacturing and freight flows will look like beyond the short term and on a sector-specific basis, given the fact that many analyses of medium-term and long-term trends are qualitative in nature and are at times conflicting. Beyond the short term (five to ten years), it is necessary to build an informed view, based on all the available evidence, as to the likely situation in 2040. This is what we have endeavoured to do.

We conclude our review by identifying 10 key challenges for the UK in the context of trends in manufacturing and global supply chains and their impact on UK freight flows. We identify the opportunities that these challenges present and who can enable such opportunities to be exploited.

In 2040 the UK will still be one of the world's leading trading economies. Many of our predictions are predicated on one key factor: the ability of freight to flow efficiently and cost effectively in and out of the UK. This is an essential attribute for any open, trading economy. At present the UK scores reasonably well on various indices in this regard and can learn from the best performers such as Germany and the Netherlands.

It is critically important that changes to our trading relationships over the coming years do not lead to any erosion in the UK's trade and logistics capabilities. It is important, too, that the UK continues to have ports and airports as 'stops' on the route networks of the global shipping and air freight carriers.

In the past, public provision of port and other transport infrastructure was a key policy concern. In the future, the UK's ability to trade will be more contingent on softer issues, especially logistics decisions by the commercial sector about the structure of their global supply chains (such as where they will locate their hubs and distribution centres; how they will structure their route networks; where manufacturing and value-adding will take place; and how global supply chains will be structured).

In the globally connected economy, transport chokepoints may evolve in the future outside the UK with a knock-on effect into the UK and its ability to trade. A case in point might be congestion at the key continental container transhipment ports, for example. The UK needs a strong, technology-led logistics sector: this will enable our manufacturing and retail sectors to compete on the international stage and also represents an opportunity for export service earnings.

1 Introduction

The movement of freight into, around and out of the UK is a derived demand. This means it is dependent on retailers, manufacturers and others who wish to move freight from one place to another. In order to investigate what future freight flows up to 2040 will look like, it is necessary to understand the drivers of such demand, as well as how the freight demanded is produced and how it moves from production to consumption. The latter movement and related activities are commonly referred to as the supply chain. We discuss the supply chain further in section 3 below.

Myriad factors dictate what future freight flows might look like. They include:

- economic growth and consumer demand,
- industrial competitiveness,
- geopolitics and trading relations,
- regulations and fiscal policy,
- sustainability concerns,
- capabilities of available transport services,
- product composition,
- manufacturing practices and strategies,
- labour/employment issues,
- retail practices and strategies, and
- supply chain architectures.

This review is primarily concerned with how and why freight is produced and moves, and understanding the *influences* on future freight flows. Specifically, then, the review is concerned with trends in manufacturing, retail and supply chain. Other parallel work streams are investigating related areas which are outside the scope of this review such as transport and the sharing economy, and developments in transport technologies and automation.

In order however to understand the *influences* on future freight flows it is first necessary to understand the *drivers* of future freight flows (*who* will demand *what freight* to *flow where* and *why*). Accordingly, this review is structured as follows:

- **Section 2** sets the scene by taking a macro perspective and examines changing patterns in global trade which comprises individual freight flows within complex supply chains composed of many nodes and links.

- **Section 3** looks at how supply chain architectures are evolving. This is important as it is the supply chain which dictates how products get to the point of demand.

- **Section 4** looks at two key nodes in the supply chain – manufacturing and retail. It examines how these are changing and what impact this will have on future freight flows.

- **Section 5** builds on the analysis in the preceding sections and seeks to determine which of these trends will have the greatest impact on, and potential for, the UK. We identify gaps in capability and policy implications.

The focus of this review is primarily international freight movements in and out of the UK. Domestic freight movements are examined primarily in their role as the import/export leg of associated international freight movements. While all transport modes are within the scope of the review, the analysis focuses in particular on international seaborne freight movements. The most recent United Nations Conference on Trade and Development (UNCTAD) *Review of Maritime Transport 2017* notes that over 80% of global trade by volume and more than 70% by value is carried on board ships and handled by seaports worldwide.[1] As discussed in section 3 below, it has been contended that maritime containerisation has been more of a driver of globalisation than all trade agreements in the past 50 years taken together. Tracking international seaborne freight thus gives a good insight into both trade patterns and the structure of supply chains. The remaining international freight moves by air, road, rail and pipeline, and these too are considered.

Manufacturing and production: a definition

Before progressing further with our analysis and discussion, it is important to understand and distinguish two terms that are often used interchangeably – *manufacturing* and *production*.

Manufacturing is generally defined as the actual physical activity of converting raw materials into tangible products such as computer chips or t-shirts. As well as physically manufacturing such products, other related activities, such as testing, packaging and distribution, are also often undertaken in many manufacturing processes. Many products are not manufactured in factories from raw materials but are instead assembled from components which are in turn produced by other manufacturers.

Many traditional manufacturers have evolved from focusing on just manufacturing in factories to a wider set of activities associated with the generation of products. Increasingly, many manufacturing processes also incorporate the addition of services (this is known as *servitisation* and is discussed further in section 3 below) and the application of various materials and information technologies to the manufacturing process.

Generally, the term *manufacturing* is used in the sense of an active verb and to refer only to the process for the physical generation of a tangible product in a factory, while *production* is used in the sense of a noun to refer to the wider set of activities (including, but not limited to, manufacturing) necessary for the generation of such products.

A good example of the distinction between manufacturing and production is in the context of ‘lean’ (discussed further in section 4 below). Generally, the term *lean production* has taken over from the original term *lean manufacturing. Lean production* implies the application of lean principles to all activities relating to the generation of products, not simply the reduction of waste in the physical manufacturing process (which would be referred to as lean manufacturing).

While the terms of reference for this study specify manufacturing, it is important that the analysis also considers production. Moving beyond manufacturing and production takes us to the concepts of logistics and the supply chain. Both will be defined in section 3 below.

[1] It is difficult to get valid and reliable global mode share estimates. Martinez et al (2014), for example, give a freight volume estimate for maritime at 85%.

2 The macro perspective: changing patterns in global trade

Martinez et al (2014) note that international trade has grown rapidly in the post-war era with trade volume growing 27-fold between 1950 and 2007 – three times faster than world GDP growth.

Changes in freight volumes

Our starting point for an analysis of global and UK trade patterns is Figure 1, which shows the growth of world merchandise trade and associated measures since 1975. It illustrates how the volume of world seaborne trade has increased alongside world merchandise trade.

Figure 2 charts the UK's maritime freight traffic flows since 1994. Overall traffic volumes grew up until 2007. They then began to decline and are now marginally less than they were over 20 years ago (501m tonnes in 1994; 473m tonnes in 2016)[2], reflecting a changing traffic profile and increased miniaturisation and lightening of freight.

Liquid bulk (such as liquefied gas and oil) has been declining since 2000 and the share of imports has been increasing. Dry bulk (ores, coal, and agricultural products) has been reasonably steady since 1994; as with liquid bulk the share of imports is increasing. Unitised cargo volumes (via container (LoLo) or Roll-on/Roll-off (RoRo)) have steadily increased over this time. A slight dip post 2007 has reversed and unitised volumes are now at the highest level since 1994. The share of imports has also slightly increased.

Share of imports

Other general cargo (containers less than 20 feet, forestry products, iron and steel products) – the smallest category of UK maritime freight traffic – is the only category in which the share of imports has slightly decreased. Overall, the share of imports across all types of maritime freight traffic combined has risen: in 1990 it was 57% and by 2015 it had risen to 63%.

Such 'directional imbalances' (with imports dominating) pose challenges for the shipping lines, which typically have surplus available capacity on UK outbound legs (this is especially pronounced in the unitised trades).

Domestic traffic (movements within port areas and to offshore platforms, along the coast, and between ports in Northern Ireland and Great Britain) and traffic along inland waterways (especially along the River Thames) also play a reasonably significant role in the context of overall UK maritime freight movements.

[2] Note that these figures refer to the UK's 53 major ports (those that handle more than 1 million tonnes annually). More than 100 minor ports handle a further 11 million tonnes.

Maritime and air transport volumes compared

Maritime transport is of course not the only mode for the transport of freight in and out of the UK. According to the Department for Transport (2015), UK ports in 2015 handled a total of 13.5 million freight units (16% of these were domestic) while the Channel Tunnel rail link carried 1.5 million freight units (in contrast, 2.9 million freight units travelled by sea between the UK and France). In the same year, approximately 2.4 million tonnes of air freight and mail was handled at UK airports (Eurostat). This compares with 497 million tonnes of freight handled at UK seaports. While the volume of air freight is minuscule in comparison to the volume of sea freight, it is important to highlight that such air freight typically comprises much higher-value freight. It has been estimated (York Aviation, 2015) that, by value, air freight accounts for around 40% of UK imports and exports.

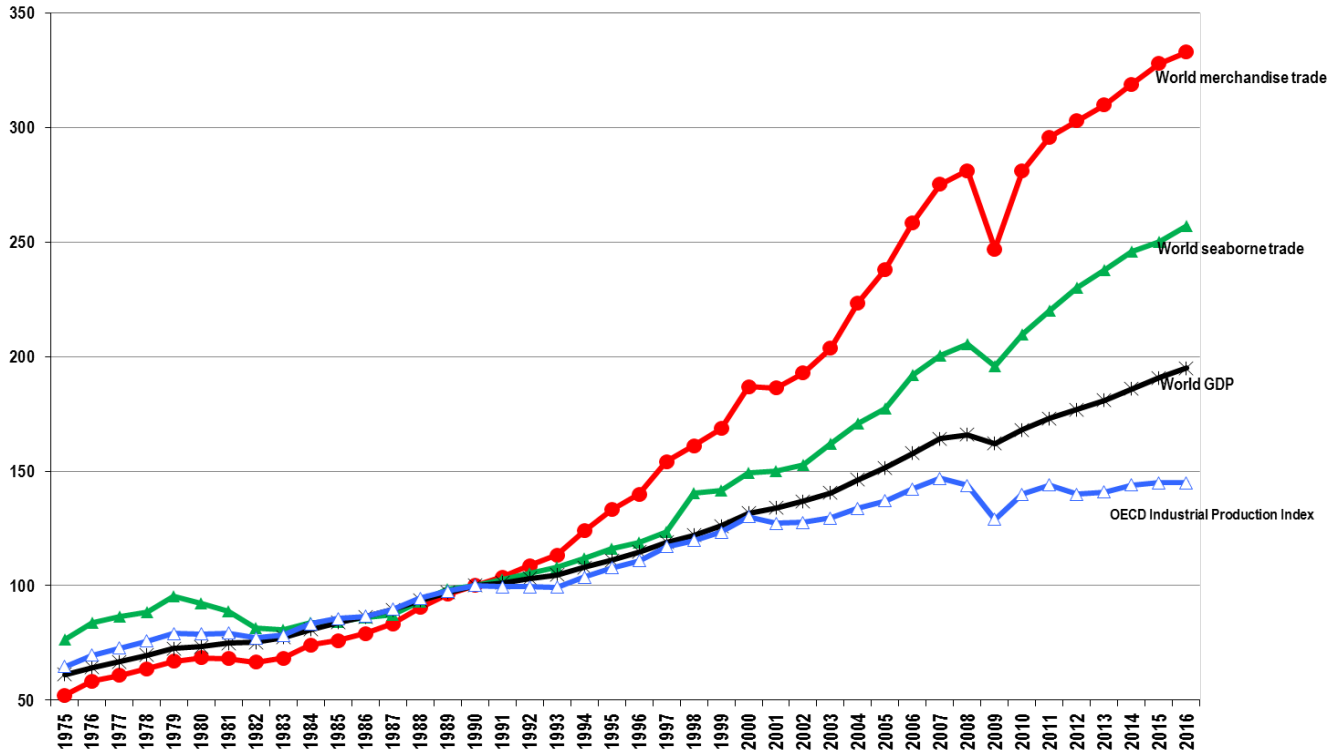

Figure 1 Indexed growth of world merchandise trade, and associated measures, since 1975 (1990 = 100)

Source: UNCTAD *Review of Maritime Transport 2017* – with sincere thanks to Hassiba Benamara from UNCTAD's Trade Facilitation Section for providing this excellent diagram.

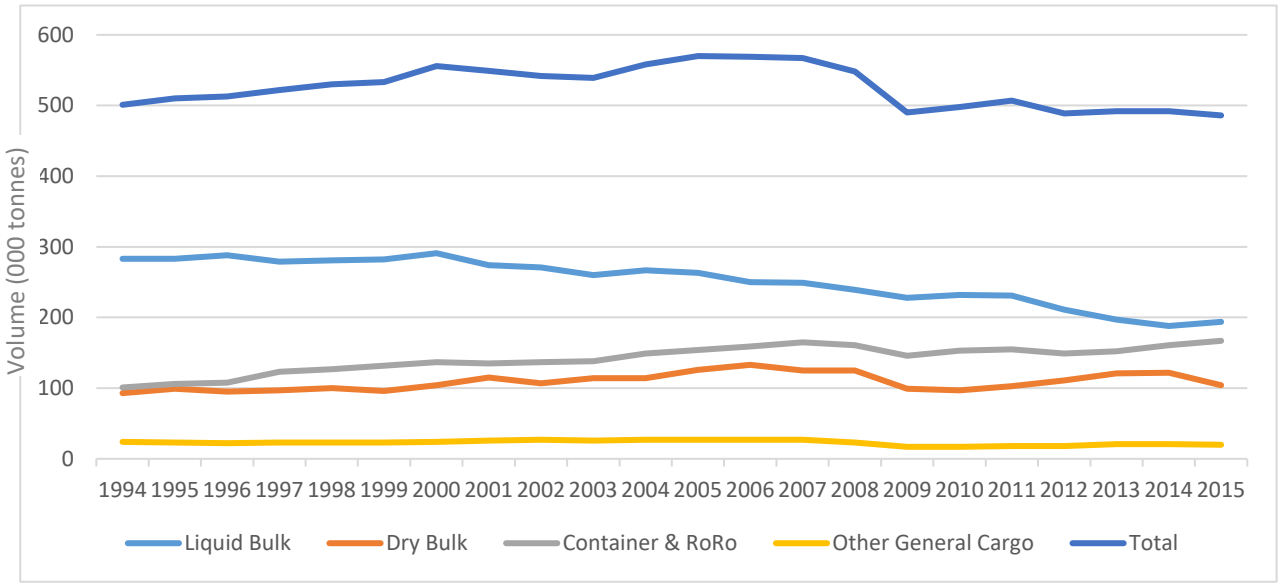

Figure 2 – UK Major Port Freight Traffic by year (volumes in '000 tonnes)

Source: UK Department for Transport Statistics.

The relationships between GDP, trade and transport

A simplistic – but incorrect – analysis would be to disaggregate these various datasets and extrapolate out to 2040 in order to predict future UK-centric merchandise trade flows. This is to assume that the current drivers of freight demand continue and that there is a continued link between GDP, trade and transport, which may no longer be the case.

Forecasting future freight flows has traditionally been predicated on an established link between changes in GDP and concomitant changes in trade. That link has however been questioned in recent years. One relatively straightforward reason for this is the increasing role of services as a component of GDP – thus rising GDP (due to services growth) would not be associated only with merchandise trade growth. UNCTAD's *Review of Maritime Transport 2014* (UNCTAD, 2014, p3) noted that:

> *'Growth in GDP, merchandise trade and seaborne shipments are interlinked and continue to move in tandem … trade can generally grow faster or slower than GDP, although since the 1990s it has tended to grow about twice as fast …. As merchandise trade expanded at nearly the same rate as GDP (in 2013) the validity of the established historical ratio between GDP and trade is being questioned.'*

Figure 3 illustrates a time series ratio for world merchandise trade volume growth to world real GDP growth. In a similar vein to the observations by UNCTAD on the trade-GDP relationship outlined above, the World Trade Organisation (WTO, 2017a) has observed that:

> *'Historically, the volume of world merchandise trade has tended to grow about 1.5 times faster than world output, although in the 1990s it grew more than twice as fast. However, since the financial crisis, the ratio of trade growth to GDP growth has fallen to around 1:1. Last year marked the first time since 2001 that this ratio has dropped below 1, to a ratio of 0.6:1 … The ratio is expected to partly recover in 2017, but it remains a cause for concern.'*

It did in fact appear to recover; the most recent projection (WTO, 2017b) for trade growth to GDP growth is 1.3:1 for 2017.

It seems then that the link between trade and GDP may be, at least in part, weakening and is not particularly consistent. Hence extrapolating the trendlines in Figures 1 and 2 to get an insight into future freight flows is not particularly valid.

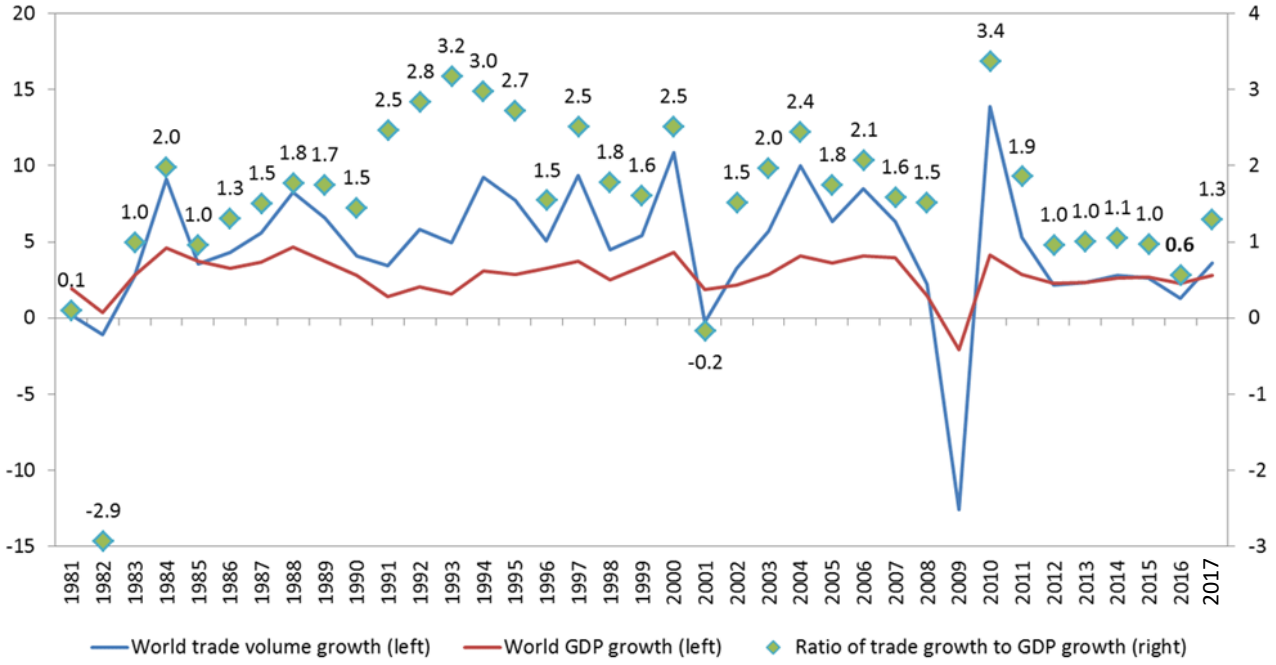

Figure 3 - Ratio of world merchandise trade volume growth to world real GDP growth (1981-2016*)*

Source: World Trade Organisation https://www.wto.org/english/news_e/pres17_e/pr800_e.htm

It is worthwhile investigating the relationship between GDP and trade a little further, as it may generate insights on the possible nature of future product flows. According to United Nations (2017):

> *'Diminished expansion of international global value chains (GVCs) has also significantly subdued trade flows. GVCs expanded substantially during the 1990s and 2000s, driven by 'efficiency-seeking' foreign direct investment to establish International Systems of Integrated Production (ISIP) in sectors such as automobiles, electronics and apparel.'*

Typically, such systems comprise the product brand owner – for example, Ford, Nike or Dell – which is underpinned by a tiered network of interlinked suppliers spread around the globe. The next section on supply chain architecture explores this topic in more detail.

The expansion of GVCs led to a boom in international trade flows in the 1990s and early 2000s but has noticeably decelerated in the last decade.

Constantinescu et al (2015) have analysed the relationship between trade and GDP in the past four decades. As well as the increasingly important role of services in global trade, they suggest another reason:

> *'[The] explanation lies primarily in changes in international vertical specialisation, most notably in the United States and China. The long-run trade elasticity increased during the 1990s as production fragmented internationally into global supply chains and decreased in the 2000s as this process decelerated.'*

They observe that such structural changes were ongoing and independent of the most recent global financial crisis. They add that other extraneous factors could also have had a bearing, for example, rising wages in certain developing countries and the shale gas revolution in the United States.

The changes in vertical specialisation suggest, in some countries at least, a substitution of domestic inputs for foreign inputs, with companies using more locally/regionally produced intermediate goods as production inputs rather than sourcing these from afar. This is evidenced by data from Constantinescu et al (2015), which show a decline in manufacturing imports as a share of GDP for both the United States and China. Similarly, they illustrate a slowdown in the growth of the ratio of foreign value added to domestic value added in world gross exports, which indicates that global supply chains are expanding at a slower pace.

These trends should not be construed as the end of globalisation, Constantinescu et al (2015) note that increased domestic sourcing could be due to a growing domestic supplier base arising from foreign direct investment from overseas firms. Similarly, as in-country transport links improve in countries such as China, this in turn leads to a lowering of the costs associated with local sourcing.

The future of globalisation

A key concern in any consideration of future trade patterns is the current prevalence of anti-globalisation rhetoric and associated political developments. Such rhetoric is 'thick in the air' (The Economist, 2016) and there is a rise in 'nationalism, protectionism, isolation' (Financial Times, 2016). Two recent conference papers dealt comprehensively with these issues in a supply chain context: see Grant et al (2017) and Mangan (2017). It is generally accepted that a turning away from globalisation was flagged as far back as the early 2000s by the sociologist Walden Bello (2004) in his classic text, *Deglobalisation: ideas for a new world economy*. So, is globalisation an 'inexorable and unstoppable force'? Dicken (2015, p37) answers 'not inevitably … as the period between 1919 to 1939 shows'. He however notes that today the situation is very different: 'the interconnections within the global economy are now much deeper – and faster – than in the past'.

The reality is that countries still need to trade with each other given their relative comparative advantages and thus the influence of deglobalisation should not be overestimated. New trade agreements – such as those that will follow on from Brexit; the European Union–Canada Comprehensive Economic and Trade Agreement, which is likely to come into force in 2017–2021; and the (currently stalled) Transatlantic Trade and Investment Partnership – will influence future trade patterns and may also lead to new, niche trades. However, certain other developments may dampen global trade: a significant and current example is that of the rebalancing of the Chinese economy towards domestic demand.

The long-term outlook for global trade

UNCTAD's most recent *Review of Maritime Transport 2018* projects that world seaborne trade volumes will expand at a compound annual growth rate of 3.8% in the five years to 2023. It predicts that containerised trade and major dry bulk commodities trade will experience the fastest growth. The UNCTAD review also very usefully collates relevant forecasts from a range of sources (see Table 1), all of which suggest a positive outlook for seaborne trade, although most do not project forward very far.

There are few extant forecasts of global trade beyond 2030, with most interested parties only forecasting ahead by a few years. There are, however, some notable exceptions. Fontagné et al (2014) at the OECD predict that international trade will quadruple by 2050. While this increase is significant, it is not as extensive as the 27-fold international trade increase seen between 1950 and 2007.

Martinez et al (2014) analyse this projected trade increase further, especially in the context of both CO_2 emissions and global freight patterns. They note that the projected growth of freight volume is far from uniform around the world, being significantly stronger in maritime routes and inland connections in Asia. Reflecting the shift of the economic centre of gravity towards Asia, they observe that the North Pacific corridor is expected to surpass the North Atlantic as the main world freight corridor. Significant growth is projected to take place especially in intra-Asian volumes and intra-African freight volumes.

Other entities, such as energy companies and financial services companies, have also attempted to forecast further into the future. HSBC and Oxford Economics, for example, have produced a forecast for UK trade to 2030. While acknowledging the inherent difficulties associated with forecasting, especially for the UK at this time given the uncertainties surrounding changing international relations, it nonetheless attempts to forecast future trade flows. Its key assertions are that both goods imports and exports will continue to grow. Key export categories will be chemicals, transport equipment and machinery, with little change predicted in the top export destinations (in descending order: USA, Germany, China, Ireland and France). Machinery, other manufactures and chemicals show the largest import growth potential, again with little predicted change in the top countries of import origin (in descending order: Germany, China, USA, France, Ireland).

While global merchandise trade continues to grow, and regardless of the oscillations in the relationship between GDP growth and trade growth, it is clear that there are some fundamental underlying shifts in international trade flows underway Essentially these revolve around changes in demand and structural changes to international manufacturing networks. Combining this insight with others evidenced in subsequent sections of this review (such as changes in supply chain architectures, de-materialisation and changes in manufacturing) it is our contention that while globalisation will continue, global trade flows in volume terms will not continue to grow in the medium term at the same fast pace as seen in recent decades. Furthermore we contend that, while international trade will remain at the heart of the UK's economy, UK-centric maritime freight flows are unlikely to rise significantly in the medium term, as efficiencies and materials changes are likely to offset any absolute volume growth.

Projecting organisation	Growth rates	Years	Seaborne trade flows	Source
Lloyd's List Intelligence	3.1 4.6 3.6 2.5	2017-2026 2017-2026 2017-2026 2017-2026	Seaborne trade volume Containerised trade volume Dry bulk Liquid bulk	*Lloyd's List Intelligence research, 2017*
Clarksons Research Services	3.4 5.2 4.9 2.6 2.4	2018 2018 2019 2018 2018	Seaborne trade volume Containerised trade volume Containerised trade volume Dry bulk Liquid bulk	*Seaborne Trade Monitor, May 2018* *Container Intelligence Monthly, 2018* *Container Intelligence Monthly, 2018* *Dry Bulk Trade Outlook, 2018* *Seaborne Trade Monitor, 2018*
Drewry Maritime Research	4.5	2018	Containerised trade volume	*Container Forecaster, Quarter 1, 2018*
Maritime Strategies International	3.7 4.5 4.5	2017 2018 2019	Containerised trade volume Containerised trade volume Containerised trade volume	*Dynamar B.V., Dynaliners Monthly, May 2017*
McKinsey	3.0	2017	Containerised trade volume	*Dynamar B.V., Dynaliners Monthly, May 2017*
IHG Markit	By a factor of 2.7	2016-2030	Seaborne trade value	*IHS Market Research, 2016*
UNCTAD	4.0 5.2 6.4 1.8 2.8	2018 2018 2018 2018 2018	Seaborne trade volume Dry bulk Containerised trade volume Crude oil Refined petroleum products and gas	*Review of Maritime Transport, 2018*
UNCTAD	3.8 4.9 6.0 1.7 2.6	2018-2022 2018-2022 2018-2022 2018-2022 2018-2022	Seaborne trade volume Dry bulk Containerised trade volume Crude oil Refined petroleum products and gas	*Review of Maritime Transport, 2018*

Table 1 – Projected seaborne trade developments, 2016-2026 (UNCTAD *Review of Maritime Transport 2018*, p16)

The growth in world population – predicted to increase to around 10.1 billion by 2100 (Dicken, 2015, p341) – will undoubtedly feed some global trade growth. Increased urbanisation and the rise of megacities, combined with rising living standards in some developing countries (as national incomes rise, the demand for imported consumer goods such as higher protein food products should also rise), will lead to new trade patterns. Changes in the structure of trade flows driven by demographics may be just as significant as any volume growth.

Analysis of the various influences on international freight flows is likely to yield insights as good as (or indeed even better than) any quantitative trade forecasts of UK-centric trade

flows. The next section in this review thus considers how changes in supply chain architecture are impacting international freight flows.

3 Changes in supply chain architecture

The origins of the supply chain concept (see Figure 4) can be traced to the early 1980s when several disparate trends and developments led to increased interest in the coordination of product (and associated services) flows from source to point of consumption. One of the best definitions of the supply chain is that by Martin Christopher, Emeritus Professor of Marketing and Logistics at Cranfield School of Management (Christopher, 2011), who defines the supply chain as:

> '*the network of organisations that are involved, through upstream (supplier end of the supply chain) and downstream (customer end of the supply chain) linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer.*'

Note that the terms 'supply chain' and 'logistics' are not the same, although they are often incorrectly used interchangeably. Logistics is primarily concerned with materials flows (getting the right product to the right customer at the right cost), whereas the supply chain is a much wider, inter-company, boundary-spanning concept that involves flows such as information and materials. For more on the distinction between the concepts, see Chapter 1 in Mangan and Lalwani (2016).

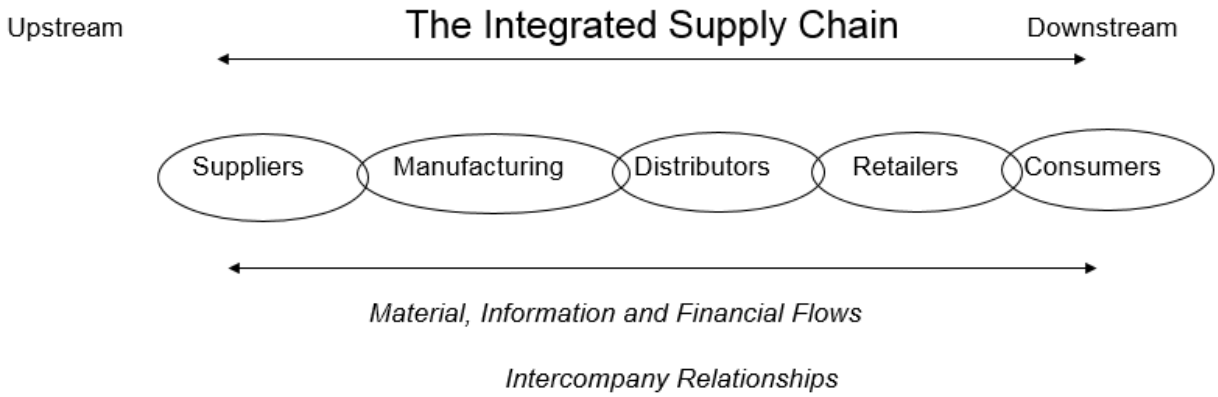

Figure 4 – The Integrated Supply Chain (Mangan and Lalwani, 2016, p11)

Today, many supply chains are stretched around the world with individual nodes chasing low cost and other comparative advantages. These supply chains underpin global commerce. The website open.sourcemap.com illustrates many examples of such global supply chains with insightful interactive visualisations. One of the most commonly observed illustrations of a stretched global supply chain is that of the iPhone. While the product is designed and marketed in the US, the various components are sourced from a range of overseas suppliers, and the phone is then assembled by Foxconn in China.

The concept of global supply chains is elucidated by Rivoli in her book *The Travels of a T-Shirt in the Global Economy* (2009) which showed how goods can be made cheaply in one part of the world and then transported for sale in markets thousands of miles away. Similarly, Jephson and Morgen (2014) show how apples and oranges can be transported around the world for just a few cents each.

Such international transportation is enabled especially by maritime containerisation which, by virtue of its economies of scale and operating efficiencies, allows unit transport costs to be reduced to a minimum. For example, a single 40-foot shipping container can carry 5,000 pairs of jeans from Asia to Europe at a cost of just 35 pence per pair.[3] It has in fact been contended that containerisation has been more of a driver of globalisation than all trade agreements in the past 50 years taken together (The Economist, 2013). Various other reports have also highlighted the important role played by containerisation in countries' economic development (see, for example, Maersk, 2017). While supply chain management (SCM) started to become popular in the 1980s, its origins likely lie in the advent of maritime containerisation a few decades earlier in the 1950s.

Key trends in supply chain management

SCM, and its underpinning logistics capabilities, has become a remarkable and exciting discipline that shapes world trade and for many countries allows living standards to rise[4]. It is not an exaggeration to say that it has allowed companies to deliver fabulous products and services to customers – and create profitability for businesses. Gartner (www.gartner.com) each year produces a list of the top 25 supply chains, generated from an analysis of various input metrics (a mix of publicly available quantitative data plus peer opinion data). The top performers in 2017 were: Apple, P&G, Amazon, Unilever, McDonalds, Inditex (Zara) and Cisco.

The following are some of the key trends in SCM today:

Changes in the competitive landscape

The competitive landscape is increasingly dictated by supply chains – rather than individual firms or products – competing. This applies across a variety of disparate industry sectors (for example, retail and automotive). Horizontal collaboration (also known as 'coopetition' - cooperating with competitors to leverage supply chain advantages) is becoming more prevalent.

Many companies are providing not just products but also value-adding services (described as 'servitisation' by Baines and Lightfoot, 2013) – for example, remote monitoring of equipment – as part of their end-to-end supply chain offering.

Widespread consolidation among companies is evident across many industry sectors with fewer, larger companies dominating (see, for example, the evolving structure of the pharmaceutical sector).

[3] In 2010 the BBC tracked a single shipping container around the world for a year (http://news.bbc.co.uk/1/hi/business/7600180.stm), giving an insight into the nature of global supply chain management.
[4] A feature captured in the advertising of the container line Yang Min (http://www.yangming.com/).

Design for supply chain efficiency

Design is moving beyond just the product and into the wider supply chain. This is known as design for supply chain efficiency (DFSCE). Many companies are now using the supply chain to innovate and add value. There is a growing emphasis on using the supply chain to facilitate responsiveness and mass customisation. Section 4 below will consider advances in manufacturing and discuss mass customisation in more detail. It is clear that 3D and 4D printing have the potential to radically alter flows through supply chains.

Stretched global supply chains

Increasingly, supply chains are stretched around the world with nodes focused on specific activities in different countries. Revenue management (including taxes and exchange rates) is a key focus. Often contract manufacturers (for example, Foxconn) produce the actual product, while the original equipment manufacturers (for example, Nike) focus on brand and supply chain. Ongoing work on trade facilitation, especially concerning more widespread use of 'single window' centralised online procedures for customs and border compliance, by the WTO, UNCTAD and others is lowering barriers to cross-border trade and reducing costs.

Reshoring

Offshoring (moving production to lower cost locations) has been the norm in many supply chains, although there are now examples of companies nearshoring[5] and reshoring[6] some activities that had previously been offshored. One highly publicised example (Mirabella, 2016) is that of clothing manufacturer Under Armour, which opened a new manufacturing and design facility in the US. Other companies, including Adidas and Reebok, have done likewise. A common feature of such facilities appears to be that they are used for limited production runs to test process designs and customer demand.

Two points are particularly apposite with regard to reshoring:

- Many processes that are reshored have become more highly automated thus they do not necessarily lead to significant employment gains. Chick et al (2014), for example, showed how some European manufacturers are enjoying relative advantage and renewed success.

- The relative wage advantage of heretofore low-cost countries is declining, rendering them less competitive for low-cost manufacturing. Furthermore, as their national income increases, their demand for imported consumer goods rises. For further insights on the topic of offshoring, see Gray et al (2017), Ketokivi et al (2017) and, specifically in the context of China, Das and N'Diaye (2013).

Manenti (2016) cites two conflicting reports on the prevalence of reshoring – one by A.T. Kearney, which focused on import data, suggests that reshoring as a trend is overhyped and 'officially dead', while a report by Boston Consulting Group, which used surveys of companies' reshoring plans, suggested that reshoring is alive and kicking.

[5] Nearshoring is the practice of transferring a business operation to a nearby country, especially in preference to a more distant one.
[6] Reshoring (also known as backshoring) is the act of reintroducing domestic manufacturing to a country. It is the reverse process of offshoring.

The reality is likely more nuanced between these two extremes and, in practice, what we are observing is a rise in what has come to be known as 'local-for-local manufacturing' – that is, moving manufacturing closer to demand (which does not necessarily mean bringing it back to the home country). Key drivers behind this strategy include marketing (branding products as made in the local market) and reducing lead times and supply chain risk (discussed below). This strategy is consistent with the emerging trade patterns (more domestic and intra-regional trade, emergence of new and niche trades, and changes driven by structural changes in manufacturing networks) discussed in section 2. It does not imply a widespread shift to deglobalisation: as stated in section 2, there are deep interconnections across the global economy which will ensure globalisation continues. Advances in technology (discussed further in the next section) are a key enabler of local-for-local manufacturing and, in turn, such manufacturers may generate other new global freight flows (for example, raw materials for 3D printing processes).

Supply chain risks

It was noted above that many supply chains are stretched around the world – some however are becoming *too stretched*; wide-ranging interdependencies are adding potentially too much complexity to many supply chains. This can be seen in the knock-on effects of extreme weather events on global manufacturing systems. For example, the impact of the Icelandic volcano ash cloud in 2010 led to stoppages on car production lines thousands of miles away. More recently, Hurricane Maria caused shortages of certain pharmaceuticals produced in Puerto Rico for the global market.

Rising energy costs are having an increasing impact and there is a growing awareness of supply chain risk management (SCRM). For more information on supply chain risk management, see Simchi-Levi et al (2014).

Environmental impact

Awareness of environmental impact is also growing: interest in carbon footprinting in the supply chain is becoming more prevalent and there is an increasing acceptance that the environmental impact of logistics must be addressed. Some companies are setting particularly ambitious targets. DHL, for example, aims to cut its logistics-related emissions to zero by 2050 (Dynamic briefing: Supply chain and transport, World Economic Forum / Professor Alan McKinnon, December 2017).

The impact of new technology

Technology and the internet of things are having a pervasive and growing influence on logistics systems and supply chains. The Trend Radar from DHL (2016) provides particularly useful insights into the impact of a wide range of technologies on logistics and SCM. Applications range from smart transport, drone deliveries, radio-frequency identification (RFID), data analytics and blockchain. As the supply chain becomes more digitalised in an age where the customer is "'always on', the potential exists for supply chains to become personalised, automated and localised (PAL). The supply chain of the future will be 'self-thinking' – by leveraging the combined capabilities of data analytics, artificial intelligence and automated materials handling, products will be automatically replenished. There are, however, downsides associated with some of these technology developments, such as cyber security concerns in the area of smart shipping.

Changing global transport routes

The physical structure of some global transport networks is gradually changing. New routes are slowly emerging, including:

- The Northern Sea routes, although their potential is currently constrained by various factors such as seasonality, technology and insurance. See Melia et al, 2017, and Humpert, 2016.
- China's 'One Belt, One Road' initiative which builds on massive investment in connected transport infrastructure across 60+ countries – in essence, seeking to revive the ancient Silk Road trading routes (McKinsey, 2016). There was much fanfare to herald the arrival in early 2017 of China's first direct freight train to the UK (ITV News, 2017) with The Economist (2017) predicting that new rail routes between China and Europe will change trade patterns.
- The suggested Nicaragua Canal, funded by a Chinese billionaire (Daley, 2016).
- The International North–South Transport Corridor (India, the Russian Federation and Central Asia).
- The Quality for Infrastructure Partnership, Japan (see UNCTAD).

Changes in the global logistics marketplace

As markets change and the logistics industry develops, it is notable that other 'non-traditional' actors, such as Amazon are entering the logistics marketplace and acquiring their own transport and warehouse assets (Weise, 2016). Other emerging market disruptors include logistics service providers such as Flexport. Built around the sophisticated use of online technologies, these companies are unlike traditional logistics service providers in that they have no physical logistics assets of their own. New forms of transport are also emerging, such as floating ports; truck platooning; increased use of inland dry ports (these are typically rail connected hubs many miles inland from the seaport); drones and airships; and, in the longer term, the 'Hyperloop'.

The future of supply chains

Following the preceding discussion, it is reasonable to assert that supply chains over the next 20 years will have some of the following characteristics:

- Driven by regulation and a demand for more transparency, and facilitated by technology (especially blockchain), there will be full visibility of products, which will flow seamlessly and autonomously between nodes.
- Demand will be customer-designed and led, and supply chains will have 'self-thinking capabilities'.
- The carbon intensity of logistics activity will be significantly reduced and more energy efficient than it is today. Where relative differences in carbon intensity exist (between factories in different countries, for example), these will become a more important locational differentiator.

- Enhanced supply chain transparency will allow for both reduced fraud and increased awareness around corporate social responsibility issues (for example, supply chain slavery).
- Location will be less relevant in the context of production competitiveness, although there is likely to be increased intra-regional trade as well as a rise in local-for-local manufacturing.
- Product composition will change (see section 4) and the difference between products and services will be increasingly blurred.
- New routes will slowly emerge, as will new service providers and physical transport technologies. Ways of procuring transport and logistics services will change, too, with the sharing economy concept coming to the fore (think Uber for freight).

In 2040, products produced and consumed in the UK will be even more tightly tied to very sophisticated and transparent global supply chains than they are today. Driven by technology, these supply chains will automatically manage demand, movement and supply chain performance.

4 Changes in manufacturing and retail

Manufacturing

The previous sections have pointed to the growth of services as a component of GDP and to a rise in servitisation (combining products and services). Notwithstanding these trends, there is still an obvious demand for physical, tangible products and here, too, some trends are evident. The preceding section on supply chain architectures discussed issues around manufacturing location (offshoring, reshoring, local-for-local, for example). This section will now review other pertinent trends.

From craft production to lean production

To set the context, it is appropriate to consider briefly how manufacturing has evolved over the past 100+ years. Womack et al (1991) delineate the evolution of manufacturing as having moved from the pre-industrial revolution 'craft production' phase to 'mass production'. Mass production came to prominence in the early decades of the 20th century and was based on the ideas of scientific management, which in turn were based on the economic principles set out by Adam Smith in 1776. Then followed the 'lean production' phase, which has its roots in the post-World War II Japanese car production sector and has subsequently been widely embraced in Western manufacturing.

Lean production today is widely practised beyond the manufacturing process, including in many services settings such as banks and hospitals. It has evolved into a management philosophy with a set of guiding principles and a raft of tools and techniques, all focused on improving efficiency and eliminating waste in processes. Just-in-time inventory replenishment is a key cornerstone of lean. Womack et al foresaw (in 1991) the next phase of manufacturing as the 'mass customisation' phase (discussed further below).

Current manufacturing practices

Global manufacturing practices today comprise elements of mass production, lean production and mass customisation, and these production strategies are not mutually exclusive. Two parameters are key in all production strategies – product variety (giving the customer choice) and output volume (thus leveraging production economies of scale). The various production strategies are based on varying combinations of these parameters. Many generic products are now produced in factories that employ sophisticated and cost-effective mass production techniques and that have also embraced the full gamut of lean tools and techniques. Ferdows and Thurnheer (2011) introduced the idea of 'factory fitness' to describe those successful manufacturers who evidence excellence in production built on a common set of core capabilities. Automation and the use of robots in production (a topic covered in a parallel evidence review), together with the use of sophisticated production planning and optimisation techniques[7] across the supply chain, are now fairly standard. Indeed, it is widely asserted that there few extra cost savings and efficiencies remain to be exploited today in manufacturing activities and that any savings and efficiencies that are to be gained are in the wider supply chain (as discussed in section 3).

Mass customisation

Mass customisation is more than just a production technique. It is aligned with supply chain strategy, specifically the idea of the agile supply chain (Christopher, 2011). In essence, mass customisation involves *customisation* into various different finished products of what are often largely *mass*-produced products (Mangan and Lalwani, 2016, p64). Even when different product configurations contain a majority of shared components and features, the customer will usually focus on the dissimilar features among the similar products, hence the strategy's market appeal.

Mass customisation makes use of a production philosophy known as postponement, which involves reconfiguring processes and standardising especially the early stages of production so as to allow postponement of the final product customisation. Other names for this approach are 'delayed product configuration', 'delayed product differentiation' and 'late-stage customisation'. Many manufacturers are now realising the benefits of producing products on what have come to be known as common or shared platforms. In a postponed production system, ideally the final value-adding activities in the supply chain are delayed until customer orders are received. The automobile manufacturing industry has been a keen user of mass customisation as has the consumer electronics sector (Dell was one of the earliest adapters of the strategy). While mass customisation has now been embraced in a diverse array of other sectors from customised foods (for example, M&Ms and Mymuesli) to clothing, many companies and sectors have yet to fully leverage its potential. The key attribute of mass customisation is that it allows the customer to receive exactly what they want at little or no extra cost.

The impact of new technologies

According to OECD (2016), a new production revolution is occurring due to a confluence of technologies, including digital technologies, new materials and new processes such as synthetic biology. The nature of manufactured products is changing, with developments in

[7] For an insight into optimisation applications in the supply chain, see: https://www.youtube.com/watch?v=ncwsr1Of6Cw.

materials science and decarbonisation and a shift to lighter products with a higher value/volume ratio and lower transport cost sensitivity. Some products of course have been completely dematerialised (for example, music CDs replaced by Spotify). More widespread, however, is the trend towards servitisation (combining products and services), which is discussed above.

Aligned with the growth in mass customisation is a shift in production capabilities driven in particular by the digital revolution. Direct digital manufacturing (DDM) allows manufacturers to produce parts directly from a computer-aided design (CAD) file, thus eliminating time lags and investment in tooling, and lowering required production lot sizes. This represents a shift in focus from economies of scale to economies of scope. DDM takes advantage of additive manufacturing technologies such as 3D and 4D printing (the latter embeds a transformation capability into the product – for example, heating the product will alter its shape). Aligning this capability with mass customisation has heralded the era of the 'maker movement', in which the consumer becomes part of product design and production. For example, customers can invest in their own 3D printers and 'manufacture' their required products on demand. Consumers thus become 'prosumers' who both produce and consume their own products. Adidas is one example of a company that is using additive manufacturing technology to allow it to reshore some processes to Europe.

Views differ about the relative impact of additive manufacturing on the supply chain. A report by PwC concluded that as much as 37% of the ocean container business was at risk due to the growth of additive manufacturing. In contrast, DHL estimates that only 2-4% of their Asia-Europe container traffic is at risk (Robertson, 2017). A report by ING (2017) suggested that widespread adoption of 3D printing could wipe out almost a quarter of world trade by 2060, yet a report from the World Economic Forum (2017) presents an opposing view. Figure 5 illustrates an analysis by PwC showing the suitability of different products and industry sectors for 3D printing.

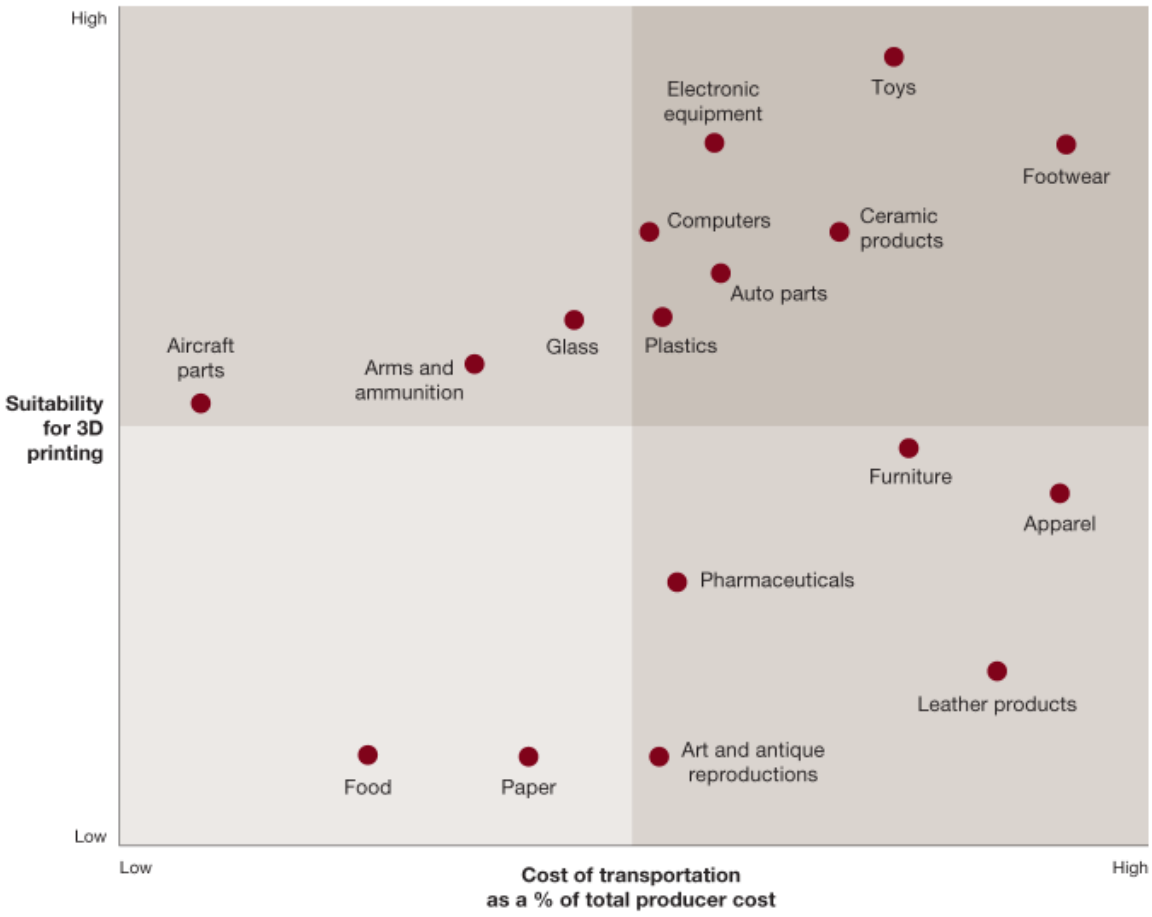

Figure 5 – Suitability for 3D printing

(Source: www.strategyand.pwc.com/trends/2015-commercial-transportation-trends)

Adding value to products in transit may also become more common in the future. For example, 3D printing of products can take place on board ships that act as 'rolling warehouses' and 'floating factories'. This allows products to be customised closer to demand and also cuts down on the need to carry spare parts and other products that may not be needed.

The nature of UK exports and supply chains

While the various aforementioned trends are fascinating, the important question is what impact they will have on UK manufacturing and the associated supply chains. It is likely that these trends will have a significant impact given the composition of the UK's export product mix. It is, however, difficult to quantify this impact; we will return to this issue in the concluding section below.

Table 2 details the UK's top exports by *value* (in the context of manufacturing trends the top exports by *volume* are less relevant as these are typically bulk products such as petroleum, ores, metal scrap and organic chemicals). Food, beverages and tobacco are not a top export commodity by value, although they represented the highest share (16%) of UK manufacturing output in 2016. The next highest were transport equipment (which

includes the automotive industry) at 15% and the manufacture of metals and metal products at 12% (Rhodes, 2017). This is likely due to the fact that many UK-manufactured food, beverage and tobacco products are consumed in the domestic market rather than exported. In addition, they are relatively low value when compared against other export commodities.

	UK → EU countries	**UK → Non-EU countries**
Export	Motor vehicles	Precious metals
	Mineral fuels	Mechanical appliances
	Mechanical appliances	Motor vehicles
	Electronic equipment	Pharmaceutical products
	Pharmaceutical products	Electronic equipment

Table 2 – Top UK export commodities (by value), December 2016 (Source: HMRC Statistics).

The supply chains for motor vehicles, mechanical appliances, electronic products and other sectors such as aerospace comprise a mix of assembly plants in the UK, densely networked on a just-in-time basis, with component suppliers located in continental Europe and further afield. Due to the high value of the various products that flow through these supply chains, any initiatives that serve to reduce non-value-adding time are eagerly embraced. Finished products are exported from the UK to countries all over the world and time to market is a key success factor. Food, beverage and tobacco exports are largely shipped to market in packaged form, predominantly by container and truck, with some air freight for higher-value specialities. For the pharmaceutical sector, inbound materials usually move in bulk to the UK manufacturing sites, with the high value finished products shipped to market by a mix of maritime container, road and air.

The future of UK manufacturing

The priorities set by the UK's research councils give a good insight into the future of UK manufacturing. The topics that the Engineering and Physical Sciences Research Council (2017) has targeted for research funding include:

- 21st century products: such products might be 'smart' and/or multi-functional or they might enable or enhance well-being. Products that are unimaginable today may be enabled by new technologies, for example, quantum technologies, or they could come from new and advanced materials that are then incorporated into components.
- Rapid manufacture: integrating the manufacturing process into the discovery, design, development and scale-up of new products.
- Digital manufacturing and intelligent factories.
- Sustainability and resilience.
- Making industrial systems become more effective at creating and capturing value at a variety of scales (for example, alternative machine tools, cellular manufacturing, self-healing tools, systems that self-build).
- Alternative supply chains, business models, mass customisation.

the world in 2067 ?
The German home appliance manufacturer BSH asked seven visionaries around the world what they think an ordinary day may look like in 2067. While each forecast differed, all agreed that technology will decisively shape our daily lives and data will play an essential role. It is interesting from a product flows perspective to look at the kinds of products predicted to be part of our future daily lives. Examples ranged from food capsules, self-repairing clothes and even detergents made from the kitchen's waste. Product capabilities such as self-healing, auto configuration and print-on-demand feature heavily. It is apparent that many of the products envisaged to populate this future world will have higher (than today) value/volume ratios and accordingly lower transport cost sensitivity. This represents an opportunity for the UK, given its focus on research and development and new product development, and its capabilities in automated and high value manufacturing.

Retail

Over the past few decades the dominant trends in retail logistics have occurred at a national level rather than internationally (Fernie et al, 2010). This has been particularly so in the UK given its island status. Large retailers supplying the UK need to hold inventory locally to be able to provide competitive order lead times to customers and so tend to develop separate logistics systems for the British market. These systems nevertheless connect with international transport networks and, as the degree of import penetration has greatly increased over the past few decades, UK-based retailers have become ever more dependent on global supply chains. This is one of the important aspects of the internationalisation of retailing that is considered in this section.

Trends in UK retail

The UK retail system is characterised by a high concentration of sales in a small number of major retailers and tight retailer control over the movement of supplies into their shops

(see, for example, Mesic (2015) and McKinnon (1996)). Multiple retailers gain this control by channelling supplies through distribution centres (DCs) that they either operate themselves or outsource to logistics service providers working on their behalf. This makes retail logistics in the UK relatively efficient by international standards. It also makes it easier for foreign manufacturers to penetrate the UK market as they can sell to these retailers directly, rather than via several tiers of wholesaling as found in countries with more fragmented retail sectors. They can also gain wide market exposure by delivering their products in bulk to the DCs of a few multiple retailers. Over the past two decades the proportion of multiple retailers' supplies channelled through DCs has, in most cases, reached 95-100% and stabilised at that level. This has continued to make the UK retail market logistically accessible both to imported and domestically produced goods. In the meantime, several other developments have occurred, as follows.

UK retail chains have globally extended both their sourcing and logistics operations

They typically buy goods free on board (FOB), which means taking ownership of them at a port in the source country and assuming responsibility for the inbound transport operation (McKinnon, 2014). Some extend their reach even further into foreign port hinterlands to consolidate container loads and, in some cases, order-pick for their UK shops.

Major UK-based retailers account for a large proportion of containerised imports in the UK and so are particularly subject to trends in the deep-sea container business such as slow steaming, the formation of alliances and increase in vessel size. Largely in response to the international re-orientation of retail supply chains, the concept of port-centric logistics (PCL) has been strongly advocated in the UK over the past twenty years. Mangan et al (2008) defined PCL as 'the provision of distribution and other value-adding logistics services at a port'. The distinguishing feature of PCL is that containers are destuffed at the port and their contents stored and handled at a new generation of large DCs located at the port. Deliveries are then made directly from port-based distribution parks to retail outlets. It was argued around 2012-14 that the UK was on the eve of a major shift to PCL with the imminent opening of the new London Gateway container port in the Thames estuary. This was portrayed as a 'game-changer': a purpose-built maritime logistics hub combining a major container port and an adjoining 230 hectare distribution park (Ward, 2012). Over the past four years, however, London Gateway has not attracted the expected number of shipping services or logistics property developments, casting doubt on the longer-term impact of PCL on UK retailers' international supply chains. Others have also questioned the prospects for PCL in the UK (Monios & Wilmsmeier, 2012).

The internationalisation of retailing has resulted in many foreign retail chains, such as IKEA, Aldi, H&M and Zara, entering the UK market

This has been in line with UK government policy to promote foreign retail investment in the UK. Most of these foreign entrants, like their British counterparts, rely heavily on distribution centres and have created substantial demand for logistics property in strategic locations around the UK. They too are well integrated into global supply chains though in the grocery sector, chains such as Aldi, Lidl and Netto now source much of their produce locally. Despite government efforts to get British retailers to internationalise, there has been little reverse movement of UK retailers into foreign markets. Only Marks & Spencer and Tesco have had significant presence in other countries and in both cases this has been receding in recent years (Deloitte, 2017).

The UK has become a world leader in online retailing in terms of both its share of total retail sales and average per capita expenditure on online shopping.
Business-to-consumer (B2C) ecommerce generated global sales of $1.92 trillion in 2016 and this figure is forecast to rise to $4 trillion by 2020, when it will represent 14.6% of total retail sales (Emarketer, 2016). The UK is at the vanguard of this global mega-trend that is transforming retail logistics. Most of this transformation is occurring within countries, particularly at the urban level where deliveries to homes and local collection points are replacing conventional shopping trips by car or public transport. In addition to the so-called 'pure players' such as Amazon and Ocado, traditional store-based retailers have diversified into internet shopping and in some cases developed an 'omnichannel' capability. This allows them to co-ordinate the inventory, handling and transport requirements of their shop-based and online networks. The online networks plug into international supply chains similar to those supplying conventional shops.

Online retailing will have a much greater impact on the UK's international freight transport links when consumers order more of their goods directly from foreign suppliers. The level of cross-border B2C ecommerce is still low, constrained by relatively high transport costs, longer delivery times, concern about payment methods and administrative procedures (Lennane, 2018). According to Guo and Xuey (2016), it has however been growing at around 23% per annum and this is expected to continue at least until 2020. In 2017, between 20 and 25% of global B2C ecommerce was cross-border. This proportion is expected to rise as trade facilitation and the globalisation of online platforms, such as those of Amazon, Alibaba and JD.com, make it easier both for traders and consumers to enter this market. These online mega-retailers are also developing a physical logistics capability which will increasingly enable them to fulfil orders internationally. The geographical impact of this trend is well illustrated in a report by Barclays (2017) which shows how the average distances over which people shop for goods has increased exponentially over the past few decades from 15.6 miles in 1955 to 6,281 miles in 2015.

The UK's very high level of online retail penetration is not only on the consumption side. The country also has a huge number of online traders, many of which export their products. The Department for International Trade (2014) estimated that 228,000 UK-based online retailers exported to the rest of the EU, with on average more than half their sales to customers in other EU countries (Willis Towers Watson, 2017). The future trading relationship with the EU and how smoothly goods move through the borders, will also shape the flow of goods to and from the UK.

The future of manufacturing and retail

Following the preceding discussions on both manufacturing and retail it is reasonable to assert that future manufacturing and retail systems will have some of the following characteristics:

- Production will largely be consumer led with direct digital manufacturing and additive manufacturing capabilities at the fore. Many products, some not even conceived today, will have intelligent capabilities.
- More sectors (for example, medical devices) will exploit technology-enabled mass customisation. A key marketing concern will be to avoid 'consumer overload' (burdening the consumer with too much choice).
- Time compression in production and delivery, and product life cycles, will be more important.

- As noted above in the context of the wider supply chain, manufacturing will be less carbon-intensive and more energy efficient than is the case today, while concepts such as closed loop manufacturing and the circular economy will become the norm.
- Product characteristics will be decoupled from transport requirements. A good example is how liquefied natural gas is transported. Natural gas is usually transported by pipelines, this restricts the number of end users. However, as a liquid it has a higher density, and can be transported via tankers, adding to its flexibility.
- As noted above, product composition will change and the difference between products and services will become increasingly blurred.
- The retail sector will continue as a key driver of product flows in and out of the UK, however reengineering of the sector will be inevitable as international relationships and trends change. Beyond this, and looking ahead to 2040, internet shopping is likely to continue to grow over traditional 'bricks-and-mortar' shopping.

The nature of products flowing in and out of the UK in 2040 is likely to be significantly different from today. Product characteristics are likely to vary depending upon the stage in the supply chain. Where previously flat-packed products generated significant transport savings, in future we are likely to see products progress through multiple states with resulting transport efficiencies.

5 Conclusions: opportunities and challenges for the UK

We noted in section 4 above that it is difficult to quantify the impact of the various trends discussed in this review on UK manufacturing and freight flows, or on a sector-specific basis. Other than some of the studies considered in section 2 concerning global trade flows, many of the analyses of future trends are more qualitative in nature. Deloitte (2015) for example provides an interesting (but not quantified) framework to show how different global industry sectors are likely to be affected by various regulatory, digitisation and other trends. Some of the relevant studies considered in this review come to conflicting conclusions – for example those cited above on the relative impact of additive manufacturing on the supply chain. Beyond the short term (5 – 10 years), it is necessary to build an informed view based on all the available evidence outlined in this review.

We are of the view by 2040 the UK will still be one of the world's leading trading economies. Services and servitisation will make up an increasing share of economic output, while manufacturing will be increasingly digitised (Department for Business, Energy and Industrial Strategy, 2017). Globalisation will continue, but global trade flows in volume terms will not continue to grow in the medium term at the same fast pace as in recent decades. Furthermore, we contend that UK-centric maritime freight flows are unlikely to rise significantly in the medium term, as efficiencies and materials changes are likely to offset any absolute volume growth. In 2040, products produced and consumed in the UK will be even more tightly tied into very sophisticated and transparent global supply chains than is the case today. Driven by technology, these supply chains will automatically manage demand, movement and supply chain performance. The nature of products flowing in and out of the UK in 2040 is likely to be significantly different from today and product characteristics are likely to vary depending on the stage in the supply chain.

Business-to-consumer (B2C) and consumer-to-consumer (C2C) sales will make up an increasing share of product flows.

Much of the foregoing discussion and analysis is predicated on one key factor: the ability of freight to flow efficiently and cost effectively in and out of the UK. This is an essential attribute for any open, trading economy. According to UNCTAD, countries' access to world markets depends largely on their transport connectivity, in particular regular shipping services for the import and export of manufactured goods. Its liner shipping connectivity index (UNCTADstat) captures different countries' levels of integration into global liner shipping networks. In 2017 the UK had the tenth highest score of the dozens of countries in the index. While other European countries (Belgium, Germany and the Netherlands) had slightly higher scores, the UK's score indicates a relatively good level of connectivity, which is to the benefit of the UK's exporters and importers. It is critically important that changes to our trading relationships over the coming years do not lead to any erosion in the UK's trade and logistics capabilities. In addition, it is valuable to look to the 'best in class' performers (as evidenced via the aforementioned index) such as Germany and the Netherlands to see what lessons the UK can learn. Germany sets an excellent example: many of the world's largest logistics and freight forwarding companies are based there (indeed, DHL's key research and development facility is located in Germany); Hamburg, the country's biggest port, has adapted well to changes in the maritime sector despite being quite far upstream river port; most transAsian rail routes terminate in Germany (mostly in Duisburg); logistics is strongly promoted at federal and regional levels as a major industry; and skill levels in logistics are high, partly because of the country's excellent apprenticeship schemes. The Netherlands comes a close second for similar reasons.

It is important that the UK continues to have ports and airports as 'stops' on the route networks of the global shipping and air freight carriers. This is important for policy makers to consider as new trading relationships evolve or are implemented. Where in the past public provision of port and other transport infrastructure was a key policy concern, in the future the UK's ability to trade will be more contingent on softer issues, especially logistics decisions by the commercial sector (such as where they will locate their hubs and distribution centres; how they will structure their route networks; where manufacturing and value-adding will take place; and how global supply chains will be structured). Transport chokepoints – apart from some motorway congestion at times – are not a major brake on the UK economy. However, in the globally connected economy, chokepoints may evolve outside the UK but that have a knock-on effect on the UK and its ability to trade. A case in point might be congestion at the key Belgian and Dutch container transhipment ports. Some international ports develop inland or 'dry' ports to capture more traffic from the wider hinterland. Similarly, some countries invest in overseas transport infrastructure to facilitate their import and export freight flows: one example is China's acquisition of port assets in Greece to facilitate Europe-China freight flows. Similarly, the UK logistics sector may need to look at strategic investments in, and alliances with, logistics infrastructure in continental Europe – in effect, developing strategic logistics corridors in and out of the UK. The UK needs a strong logistics sector to underpin the growth and success of its world class retail sector. As well as supporting domestic activity, a vibrant technology-led logistics sector represents an opportunity for export service earnings. Table 3 summarises what we believe are the 10 key challenges for the UK in the context of trends in manufacturing and global supply chains, and their impact on UK freight flows.

Challenge	Opportunity/solution	Enablers
1. Develop logistics and port infrastructure that reflects and can handle the changing nature of products flows.	A national logistics policy, along the lines of existing national transport and ports policies.	Government in conjunction with the interested stakeholders (ports sector, logistics service providers).
2. Fundamental underlying shifts in international freight flows are underway. Changes in the structure of these freight flows may be just as significant as any volume growth.	Opportunity for the UK to exploit new market opportunities. Technology advances mean that products no longer necessarily move in bulk in their final state. This can lead to enhanced logistics efficiencies (for example, inputs for late-stage 3D printing and mass customisation).	UK industry and its representative bodies.
3. Digitise manufacturing and exploit servitisation opportunities.	Growth of more efficient, more profitable UK manufacturing output. Manufacturers can diversify to also provide services. Proliferation of intelligent products generates new market opportunities.	Government and industry.
4. Leverage opportunities presented by additive manufacturing and associated technologies such as auto configuration.	New market opportunities, growth of a 'prosumer' sector, and rise of local-for-local manufacturing.	Government and industry stakeholders to showcase and promote uptake of pertinent technologies.
5. Development of self-thinking supply chain capabilities. Emergence of Blockchain applications across the supply chain.	Reduced logistics costs, enhanced logistics efficiency, improved transparency and visibility of freight flows.	Technology sector service providers.
6. Reduce the carbon intensity of logistics activity and increase energy efficiency.	More sustainable logistics solutions are usually also associated with a reduction in logistics costs and an opportunity to differentiate from competitors.	Government sustainability targets, NGO and stakeholder influence, innovative manufacturers and logistics service providers.
7. Changing retail patterns.	Opportunity to develop omnichannel logistics solutions to support changing retail patterns – but reducing barriers to trade will be important.	Government trade facilitation arrangements.
8. Ensure that the UK remains a calling point on global container line networks.	This has a direct impact on export and import costs and efficiencies.	Proactive marketing and engagement by the UK ports sector.
9. Mitigate the impact on the UK of overseas transport chokepoints.	Invest in, and form alliances with, dry ports in continental Europe. Develop strategic logistics corridors in and out of the UK.	Port operators and logistics service providers with nodes / interests in the UK – facilitated by agreements between the UK and partner countries.
10. New forms of logistics service provision.	Opportunity for both existing and new (and non-traditional) market entrants to offer logistics services.	Logistics service providers and other private sector interests.

Table 3 – Challenges and opportunities for the UK

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