MIDLANDS ENGINE

Observatory

MIDLANDS ENGINE SUPPLY RESEARCH REPORT
ADVANCED MANUFACTURING SUPPLY CHAINS

MARCH 2021

BIRMINGHAM CITY University
Centre for Brexit Studies

The resilience of advanced manufacturing supply chains across the Midlands

Sector 'Deep Dive' Report for the Midlands Engine Observatory by

Alex de Ruyter, David Hearne and Ian Henry

MIDLANDS ENGINE

Acknowledgements:

The Authors would like to thank the Midlands Engine for the funding support to undertake the research contained in this report.

60 Second Overview

The Midlands Engine is the region with the highest proportion of manufacturing employment in the UK and contains several advanced manufacturing clusters, notably in automotive, aerospace and medical technologies. Previous analysis has suggested that these coexist in a complex industrial geography, with suppliers involved in more than one sector. The pandemic poses a significant and potentially existential threat to the operation of some of these supply chains, which has been compounded by a major change in the UK's trading relationship with the EU. Several of the sectors in which the Midlands specialises face particularly acute challenges from the UK's exit of the EU Single Market and Customs Union post-Brexit.

As such, this report outlines findings and policy recommendations arising out of a review of secondary data and 12 interviews with senior managers in companies involved in the automotive, aerospace, medical technology sectors. In doing so, this work enhances our understanding of what policy interventions would have the most beneficial impact on this complex web of suppliers. The analysis includes results from the proprietary Brexit impact assessment model of AutoAnalysis, which has been used by the Department for Business Energy and Industrial Strategy in government and by a number of major industry players and companies in the financial sector.

Our findings indicate that key issues remain around skillsets and access to talent, cost reduction for exports and facilitating trade, in addition to measures to facilitate a shift to a green economy. The imposition of new non-tariff trade barriers has proved particularly challenging to smaller firms. The findings clearly demonstrate the importance of diversification in terms of both product markets and products for upstream suppliers.

Contents

Executive Summary

This sector 'deep dive' report on Advanced Manufacturing in the Midlands sought to assess the supply chain resilience of firms in these sectors in the face of the twin challenges of Brexit and Covid-19. A mixed-methods approach of desktop research, propriety analysis from specialist research input and qualitative data from 12 interviews with senior managers was used to assess the challenges facing the automotive, aerospace and medical technologies sectors (and their suppliers and service providers). These analyses and findings are detailed in the subsequent sections of this report but below we outline the key findings and policy recommendations arising from our research.

Research findings

Both Brexit and the Covid-19 pandemic have posed challenges for businesses in the advanced manufacturing sectors in the Midlands. The impact of both events has been heterogeneous with respondents having adapted in a variety of ways and experiencing quite different outcomes. In terms of pandemic response, there has naturally been a limit to what businesses have been able to do. However, certain commonalities stand out. Our research has highlighted the nature of these and given some insights into potential strategies to overcome them.

Common themes

Respondents shared concerns around skills gaps and potential difficulties in attracting skilled and technical personnel. Likewise, a desire to see improved infrastructure was almost universal, although respondents differed in terms of what they stressed. The initial disruption incurred by Covid-19 heavily affected all manufacturers. Since then, diversification has proved to be key, both in terms of products (perhaps unsurprisingly, the market for medical technologies has experienced a very different pandemic to aerospace) but also in terms of markets.

Those able to take advantage of demand in East Asia (where demand has been much more buoyant) have suffered less.. The situation in Europe (including the UK) has been consistently challenging, whilst that in North America has been changeable but overall lies somewhere between the European and East Asian experience (at least economically). For some companies their exposure to these markets has been "indirect" – i.e. they supply a UK firm which itself sells into certain markets (both export and domestic).

This echoes the more general findings of the academic literature on business robustness and resilience, emphasising the importance of investment in "related variety"[1]. However, this research also highlights the importance of diverse (export) markets and capital investment. Ensuring that firms have the incentives to undertake said diversification and investment and maintain cash flow is clearly of importance, as is an understanding of best practice elsewhere around the globe.

Diverse experiences

In terms of Brexit specifically, the impact has been much more heterogeneous, with a clear gap between our smaller and larger respondents. Some problems related to initial difficulties, of getting used to the new customs regimes:

"…*when* [the supplier] *came to deliver, which was the first week in January, they hadn't got the paperwork and I suddenly realised that yes, it was their responsibility, and they had to get all their papers correct. So, we received that material yesterday. So that's six weeks late. So, I'm not pleased…*

[1] Related variety specifically relates to the relatively modern concept in the economic geography literature that whilst regions benefit from producing a variety of goods and services, inter-industry knowledge spill-overs typically arise when that variety is amongst goods and services that are closely related.

And we're talking 40,000 pounds worth of materials. So, for a small company, such as ourselves, 40,000 pounds, being late is not good news" (Participant 5).

"*…certainly getting sales and product to our customers has slowed down. Because what's been happening is some of the carriers have been held up either at the port or individual mainland EU country's borders, and held for maybe, you know, an extra week or 10 days*" (Participant 9).

However, some problems are clearly much more long-term in nature and there are concerns about the introduction of documenting rules-of-origin compliance for the automotive sector post-2022 as well as the introduction of more stringent import-checks. Although the report makes several recommendations for government, including enhanced but targeted infrastructure investment. Recommendations for firms centre on the twin challenges of upskilling and product innovation. In both cases, a closer relationship with the third sector (including universities, FE institutions and others) is important. This will enable enhanced knowledge exchange involving sectors that typically rarely collaborate, alongside working with the public sector where appropriate in ensuring close alignment with strategic economic plans and rapid planning approvals. There are significant actions that can be taken by government (both national and local) to facilitate business growth including tax incentives, improved access to finance and assistance in complying with the new trading relationship. Product delays and lost business are serious challenges for smaller exporters, as is an increase in shipping costs and costs around customs compliance. In contrast, larger firms that have been able to draw on international experience elsewhere have found the transition to the new UK-EU relationship much smoother.

Moving forward

The pandemic has exposed the fragility of the region's supply chains. This research has underscored the importance of diversification, broadly defined – and many forward-looking businesses are already responding by branching out into new products and markets. The challenge for government and other stakeholders is to create an environment that facilitates similar actions more broadly. As such, upskilling of existing workforces, help to mirror best practice elsewhere, interaction between different stakeholder groups (including higher education, the private sector and others) are all important.

This underscores the importance of major "anchor firms" around which innovative smaller firms tend to cluster, which is particularly visible in the West Midlands automotive sector and the East Midlands aerospace sector. Improved transport links and a stable system of technical and academic education will enable these clusters of excellence to grow and thrive, driving productivity growth across the region, which has the highest proportion of manufacturing employment in the UK, and the rest of the country.

Policy Recommendations

- Targeted infrastructure investment in the following areas:
    - Improving inter-urban link transport, especially East-West links within the Midlands Engine in order to benefit fully from agglomeration and cluster effects.
    - Improving intra-urban transport, facilitating access to talent.
    - Addressing "pinch points" between the Midlands and key ports, notably Bristol, on the A14 between the Midlands and Felixstowe, the A34 to Southampton and routes to Liverpool. This has renewed importance post-Brexit considering shifts in firms' transport and logistics strategies.

- Enabling and facilitating forward-looking opportunities in mobility, especially around programming, vehicle connectivity (vehicle-to-X and X-to-vehicle) and electronics. To do so, it is importance to maximally leverage existing expertise in the region, so as to:

    - Facilitate and incentivise (even) greater collaboration between universities, other academic institutions and private companies.
    - Continue and strengthen existing programmes to address key STEM skills-gaps
    - Facilitating a greater shift to life-long learning and flexible, bespoke modular delivery working in tandem with manufacturers. This is likely to build on the *Help to Grow* scheme and existing KTP frameworks.

- Work to protect existing National Strategic Assets[2], particularly large "anchor firms", around which an innovation ecosystem has grown up. A collaborative approach between local government, central government, the private sector and HEIs is needed – the so-called "triple helix". Hence, delivering on electrification in the vehicle sector and decarbonisation in aerospace and ensuring the supply-chain ecosystem around these is paramount. This will involve close cooperation with major anchor-firms in order to understand what demand for upstream products is likely to be sustained.

- Further enhance and facilitate access to finance for start-up and scale-up firms. There are barriers in terms of time and information around existing (non-Covid19) schemes.

- Firms across advanced manufacturing face challenges in pivoting profitably to a low-carbon future. In automotive, the presence of substantial domestic battery manufacturing is key. Given the importance of proximity for agglomeration economies, there is a strong case for situating at least one such facility in the Midlands.

- Recognising the unique challenges for firms in the aerospace manufacturing sector and providing targeted support in order to protect the country and region's world-class skillset.

[2] We define a National Strategic Asset as a firm that engages in substantial R&D/design/engineering with significant spill-over effects. Firms of this nature typically are in tradable sectors, account for a non-trivial proportion of the regional economy (GVA) and are usually "high-tech". E.G. Rolls Royce, JLR, Airbus, ARM, AstraZeneca, GSK.

Introduction

On 1st January 2021, the UK found itself outside of the EU's Single Market and Customs Union. Coming more than four years after a (52%) majority voted to leave the EU, it is fair to say that the process has been more complex than many had initially envisaged. Moreover, 2020 saw the emergence and spread of Covid-19, the worst pandemic the world has seen in a century, with over 2.8 million deaths to date (April 5th 2021) world-wide and over 126,000 deaths in the UK.[3] Governments around the world have had to impose dramatic measures to arrest or contain the spread of a novel coronavirus.

The implications for supply chains in advanced manufacturing will undoubtedly be profound given both the ongoing pandemic and the emergence of new non-tariff barriers to trade between Great Britain (GB), Northern Ireland (NI) and the EU in the form of customs, new and extended SPS checks and other checks on the movement of goods, and the end of Freedom of Movement of people. As the region with the highest proportion of manufacturing employment in the UK, the Midlands is particularly exposed to these shifts. At present, the question of how the region's supply chains are coping and how the situation is likely to evolve in the coming months and years remains open. Whilst there is a substantial academic literature investigating regional resilience (Bailey and Turok, 2016; Kitsos, Carrascal-Incera, & Ortega-Argilés, 2019; Rocchetta and Mina, 2019) the present combination of events is unprecedented, and we have only very limited understanding of the implications of these shifts as they are played out on the ground.

The present research begins to address this gap in our knowledge utilising a combination of secondary data analysis, detailed sectoral information, including proprietary modelling (see Henry (2020) for details); and primary interview data. We find that whilst there are substantial strengths in advanced manufacturing across the Midlands with particular clusters of excellence, substantial supply-chain vulnerabilities remain.

The document is structured as follows. We begin by giving an overview of advanced manufacturing in the Midlands using a variety of secondary data sources. This demonstrates both that the region is closely connected with international supply chains (particularly in Europe) and that there are real gaps in our knowledge based on aggregate data. We note issues around accurate classification of businesses, which particularly affect smaller firms. Firms manufacturing medical equipment and those serving multiple sectors find greater difficulties with accurate classification than others. This is then followed by a Brexit impact assessment pertaining to the most important manufacturing sector in the Midlands; that of automotive. We then introduce our primary interview data which seeks to provide indicative evidence of the state of play with manufacturers in the Midlands in terms of supply chain resilience in the face of Covid-19 and Brexit. Finally, we conclude with a series of policy recommendations for national and regional government.

[3] https://covid19.who.int/

Secondary data analysis and Brexit/Covid-19 impact assessment

In this section we examine aggregate trends and issues facing the sector in the Midlands. We open this discussion by trying to assess just exactly what is meant by 'advanced manufacturing' before moving on to assess the wider supply chain for automotive and aerospace. This is then followed by a sector 'deep dive' on automotive, an industry of particular importance to the region, to assess firms' exposure to Brexit.

Advanced manufacturing across the Midlands

There is little consensus over what constitutes "advanced manufacturing" in practice. Some of the UK's census data refer to industries under SIC codes 26-30[4] as "high tech", with those in 23-25[5] labelled as "low tech". Nevertheless, whilst SIC codes provide an essential framework within which to classify products and industries, these definitions can sometimes fail to capture the full complexities of modern manufacturing and company structure. Much metals manufacture and processing today involves complex processes. To give a trite example – the processing of nuclear fuel is, according to this definition, "low tech". By contrast, although ostensibly "high tech", the production of circuit boards or compact discs is today highly commoditised and relatively low-value.

In this regard, two things become apparent. Firstly, there is a clear and obvious need to avoid being excessively specific from a definitional perspective. Previous work in the area (De Ruyter et al., 2020) has pointed to the challenges faced in this regard, with many firms acting as suppliers to a number of different high-value sectors. Secondly, the nature of advanced manufacturing is subject to significant shifts over time that are difficult to predict: the commoditisation of Printed Circuit Board and Compact Disc manufacture (and the growing obsolescence of the latter as a result of technological shifts) suggests caution in the construction of industrial strategies.

We take a broad but selective view of advanced manufacturing, concentrating on a handful of sectors – specifically automotive, aerospace, medical technologies and associated metal fabricators and industrial service providers in the supply chain. In so doing, however, we are not prescriptive regarding firm classification: manufacturers of metal products supplying an automotive company are intrinsic parts of the advanced manufacturing supply chain, notwithstanding the fact that they themselves are not part of the automotive sector. We also take a particularly close interest in firms that supply multiple sectors (for example, manufacturers of metals supplying both automotive and aerospace) or who have the clear potential to do so. Multiple clients across different sectors have clear benefits in terms of business resilience to shocks and could also have productivity benefits, although the latter is uncertain and likely to depend on the nature of firm diversification (Chang, Fernando, Srinivasan, & Tripathy, 2013).

As Figure 1 demonstrates, the automotive sector makes heavy use of inputs from other industries. These include both the obvious – metal fabrication and plastics[6], for example – and those that are less clear on first inspection, such as financial services, chemicals and "other services" (often

---

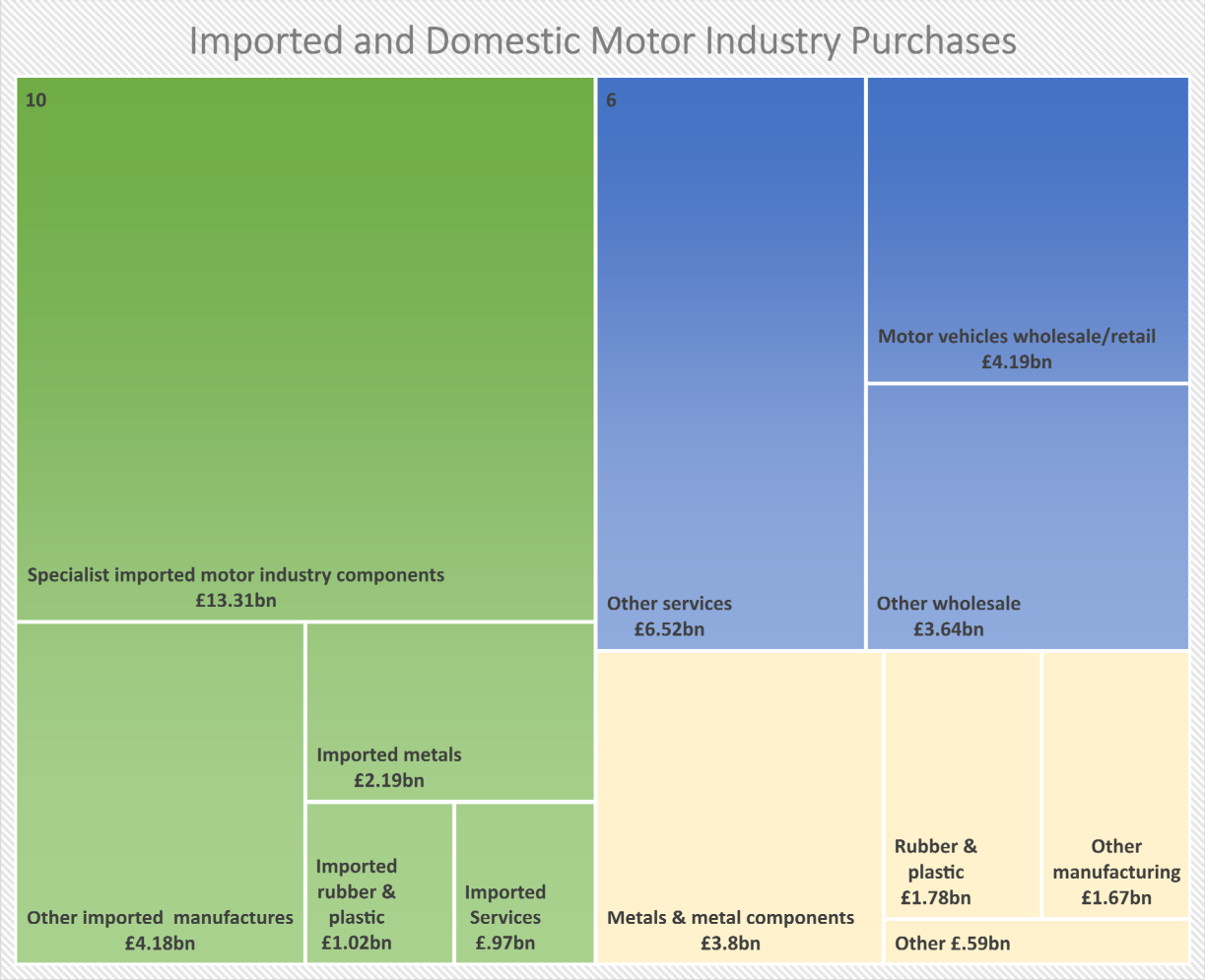
[4] 26 = manufacture of computer, electronic & optical products,
27 = manufacture of electrical equipment,
28 = manufacture of machinery & equipment,
29 = manufacture of motor vehicles,
30 = manufacture of other transport equipment.

[5] 23 = manufacture of "other" non-metallic mineral products (typically glass, ceramics and building products)
24 = manufacture of basic metals
25 = manufacture of fabricated metal products

[6] Plastics as a category includes rubber.

professional services such as accountancy and specialist external engineering firms). Also visible is the dependence on imports of specialist automotive parts and components. Despite admirable efforts to deepen the UK's supply base, in many cases necessary inputs are not produced (and cannot easily be produced) in the UK. The local automotive industry relies upon imported gearboxes, for example. There is some scope for re-shoring from locations outside Europe, although in practice this is likely to be quite limited. Documentation and paperwork costs will also rise from 2022 due to implementation of the new trading agreement (Her Majesty's Government and European Union, 2020).

Figure 1: The Wider Supply Chain for Manufacturers in the Motor Vehicle Sector



Source: Office for National Statistics (2020b)[7]

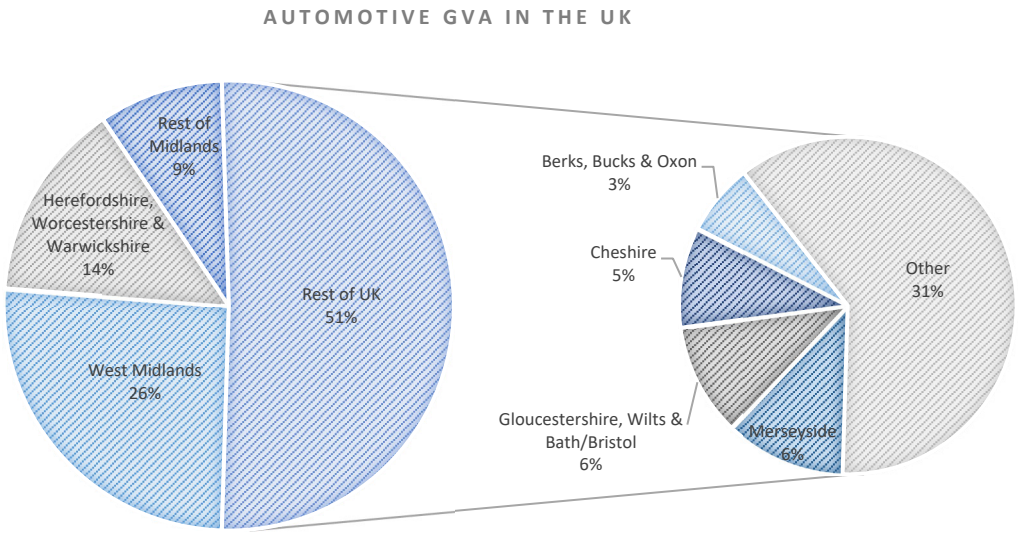
Despite the presence of large manufacturing facilities across the UK, the value-added by the automotive sector is remarkably spatially concentrated (Figure 2). The Midlands is responsible for around half of the UK's total automotive GVA. Moreover, since the most recent data relate to 2018, if anything this pattern is set to become even more extreme with the closure of Honda's Swindon plant and Ford's engine factory in Bridgend. Of the major automotive manufacturing regions outside

[7] The chart shows inputs into the motor vehicle manufacturing industry. Imported components appear on the left in green, whilst domestic services are in blue and domestic manufactures in yellow. Note the preponderance of specialist components in imported items, many of which cannot be sourced domestically.

of the Midlands, a large proportion are proximate to the region (e.g., Cheshire, Oxfordshire and Merseyside), demonstrating that the functional economic geography of the automotive cluster extends beyond the Midlands Engine boundaries.

There are likely to be several reasons for this. A substantial portion of total value-added is captured by suppliers. It is this fact that lies behind both the insight that gross exports are a poor measure of where the value is added by those exports, both in terms of location (the ratio of value-added to gross exports is highly heterogeneous across sets of bilateral trade partners) and sectors (Johnson, 2014). As a result, work has focussed on understanding how to trace the industrial contributions to value-added in gross exports, typically via input-output analysis (Los, Timmer, & de Vries, 2016).

Figure 2: The UK's automotive Gross Value Added by region



Data relate to 2018. Source: Office for National Statistics (2019b)

However, this problem is equally apparent when related to the sale of individual products. The value-added captured by final assembly in many industrial processes is considerably smaller than might be anticipated. Thus, whilst the North East of England captures just 15.2% of its total turnover in the automotive industry in value added, the Midlands captures 23.4% (Office for National Statistics, 2020c) and this is partly due to the depth of the supply chain in the latter relative to the former. The West Midlands in particular boasts significant supply of parts and components in the automotive sector, with major component manufacturers (e.g. GKN Driveline[8] and ZF). In the case of the automotive industry, there is likely to be another factor at play: specifically, the value added by design and engineering relative to the value added by assembly.

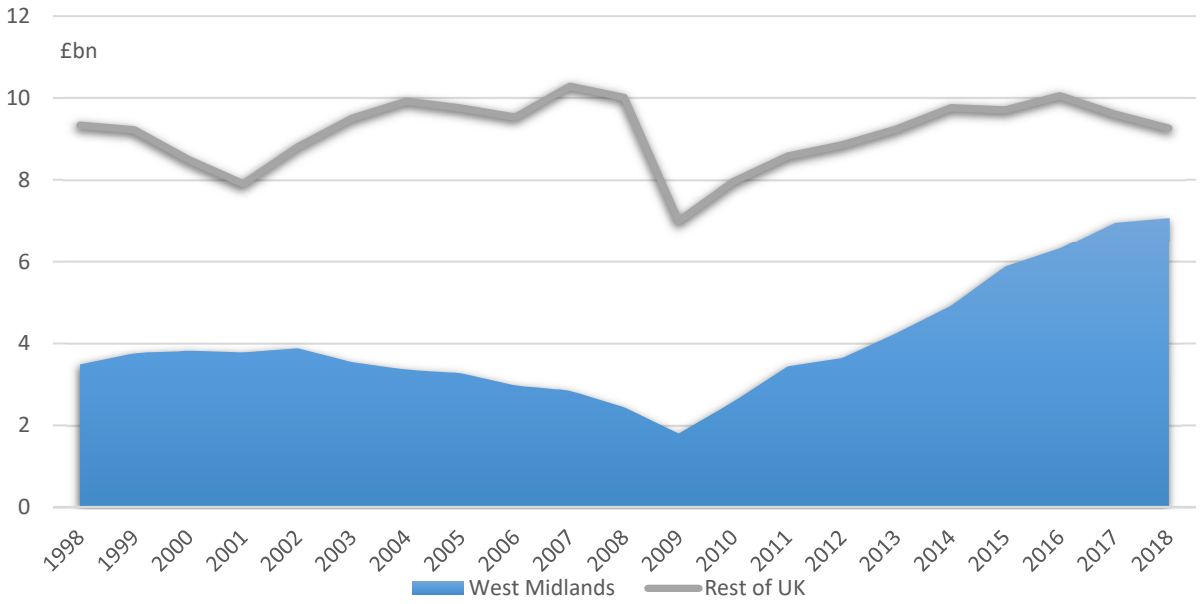
Whilst this phenomenon is well documented with regards to trade in high value consumer electronics (Xing and Detert, 2011), it equally applies to subnational variations in production in many other sectors. Whilst a substantial number of vehicles are manufactured in the East Midlands

[8] Current concerns surround the continued viability of GKN notwithstanding, with talk of a 'rescue plan' in the offing – see https://www.birminghammail.co.uk/news/midlands-news/union-rescue-plan-save-gkn-19810711

(overwhelmingly by Toyota at Burnaston), very little of the R&D or engineering for those vehicles is carried out in the region[9].

In contrast, by far the largest vehicle manufacturer in the West Midlands – Jaguar Land Rover – carries out the overwhelming majority of the design and engineering for its models in the region, including those assembled elsewhere[10]. The same is true of a number of niche vehicle manufacturers that sell few vehicles but whose combined turnover and value added is relatively substantial (Aston Martin, Dennis-Eagle, Morgan and LEVC amongst others). Rapid growth (particularly of JLR, the production volumes of which approximately doubled between 2008 and 2016[11],) has seen the region steadily increase its share of the UK's automotive value-added during the period of recovery from the 2008-09 global financial crisis. Indeed, Figure 3 below illustrates starkly both the period of retrenchment, which saw the closure of several manufacturing plants in the region (MG Rover, Peugeot and LDV), and subsequent dramatic recovery.

Figure 3: Automotive Value Added by Region (Constant Prices)



Source: Office for National Statistics (2019b)

However, as noted in previous figures, the presence of major manufacturing and engineering expertise in large firms has significant impacts on suppliers in the region and further afield. Moreover, proximity clearly matters for suppliers. This is obvious from Figure 4, showing the concentration of GVA in the fabricated metalworking sector. Whilst this is significantly more diffuse than either the automotive or aerospace sectors, it nevertheless remains spatially concentrated. We cannot know what proportion of concentration of GVA in the fabricated metalworking sector is

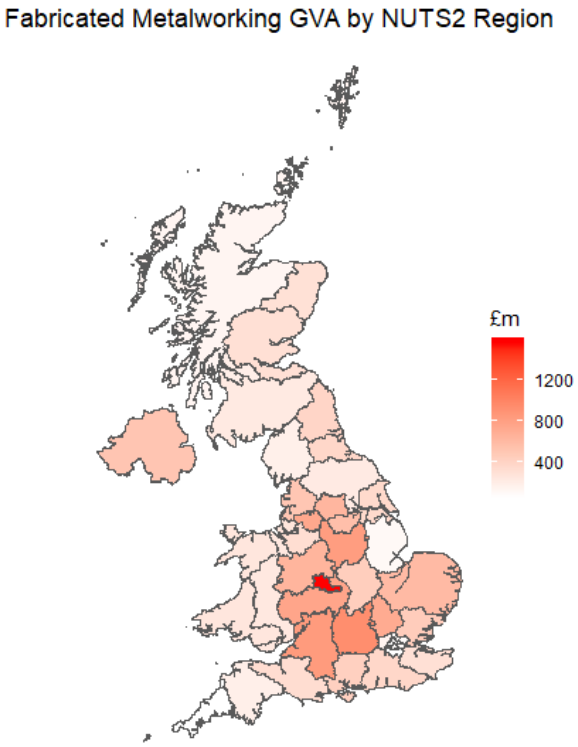
[9] Also noteworthy is the fact that Toyota engine production takes place outside the region, whilst engineering for all the engines in UK made Toyotas is done in Japan.

[10] This stands in sharp contrast to Nissan in the North East, whose engineering typically takes place outside the region. Nissan's UK technical centre is located near Bedford and it employs a small design studio in London, although the bulk of its design and engineering activities take place outside the UK entirely in Japan.

[11] Although they have fallen somewhat since owing to the opening of its plant in Slovakia, several models being in the declining phase of their model cycles and poor sales of Jaguar saloons.

linked to the proximate automotive and aerospace industries, but it is telling that the value of metal fabrication is extremely high in the West Midlands metropolitan area where it exists in close proximity to an automotive industry that is a heavy user of fabricated metal products.

Figure 4:



Data relate to 2018. Source: Office for National Statistics (2019b)

The available data suggest that the spatial pattern of output in the aerospace sector is quite different. Official statistics for subnational output (GVA) are only available down to 2-digit SIC codes. Aerospace falls under SIC division 30 – a catchall for the manufacture of all non-road vehicles. However, it is possible to infer a substantial amount from a combination of national data, the Annual Business Survey and local knowledge.

Nationally, aerospace (industry group 30.3) accounts for 77.4% of total GVA in division 30 (Office for National Statistics, 2020a) with the overwhelming majority of the remainder being accounted for by the manufacture of ships and boats. The Annual Business Survey (Office for National Statistics, 2020c) indicates that the value of this is very modest in both the East and West Midlands (about 1.8% of the UK total).

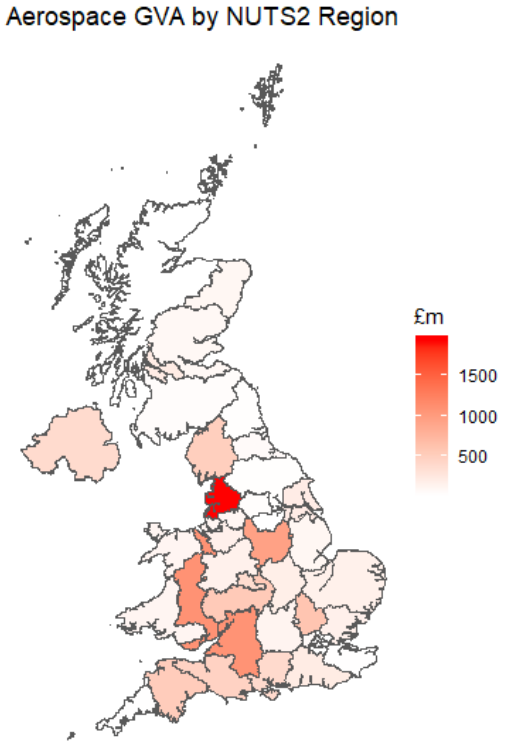
Approximately 20%-25% of all UK shipbuilding GVA takes place in the devolved nations (predominantly Scotland around the Clyde), with around half of the English total located in the South West. A significant portion (although by no means all) of this relates to defence, with substantial activities across the region, but particularly in Dorset and Devon (with some activity in Cornwall).

Given this geographic spread, we can be confident that, excepting these areas, the overwhelming majority of GVA captured in Figure 5 relates to the aerospace industry. The extreme concentration of activity in Lancashire reflects the presence of major military aviation production capacity (particularly BAE Systems), although the area also has a smaller civil aerospace manufacturing sector (e.g. Rolls-Royce in Barnoldswick). In terms of civil aerospace manufacturing, three regions emerge

as particular concentrations of GVA. East Wales and the South West of England (particularly around Bristol) have clusters of world-class excellence centred on Airbus, whilst Derbyshire & Nottinghamshire exhibit a high-value cluster linked to the position of Rolls Royce in Derby.

In this regard, it is important to note that, as in the case of the automotive sector, many of the supply chains involved in aerospace have a pan-Midlands dimension. Thus, Moog, UTC Aerospace and Collins Aerospace all have a presence in Wolverhampton in the West Midlands, even though only a very small proportion of the UK's total value added in the aerospace manufacturing industry is generated there, as inferred in Figure 5. The area of Herefordshire, Worcestershire and Warwickshire is also significant. Since many aerospace products are "dual use" in both civil and military aviation, the sector (particularly exports) is heavily regulated.

Figure 5:



Data relate to 2018. Source: Office for National Statistics (2019b)

An alternative way of representing the spatial spread of the sector is via the use of location quotients. We can produce these for employment within local authorities. A location quotient of greater than one indicates that the sector accounts for a greater proportion of employment in the region than in the UK as a whole. Within the Midlands, the spread of employment is highly uneven across local authorities as can be seen in Table 1 below:

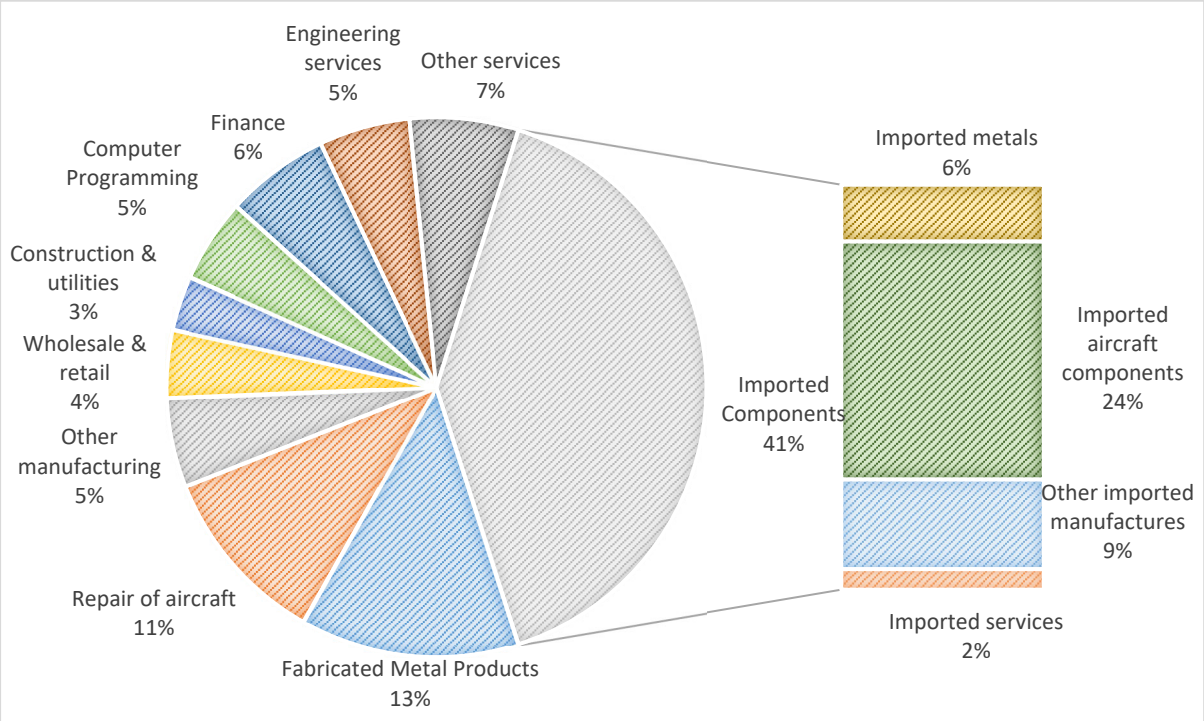
Table 1: Aerospace manufacturing in the Midlands (by location quotient)

Local Authority	*Location Quotient*
Derby	37.8
Wolverhampton	3.6
Nottinghamshire	2.4
Coventry	1.4

Leicestershire	1.2
Worcestershire	1.1
Lincolnshire	1.1
Shropshire	0.8
Dudley	0.8
Warwickshire	0.6

As is the case for the automotive sector, the aerospace manufacturing industry draws heavily on a number of other manufacturing subsectors, particularly metal fabrication, as well as a number of services, including finance/insurance and programming. The wider supply chain for aerospace in the Midlands is depicted in Figure 6.

Figure 6: The Wider Supply Chain for Manufacturers in the Aerospace Sector



Source: (Office for National Statistics, 2020b)

Aerospace imports and exports are extremely lumpy and exhibit large variations from year to year. This is particularly true for exports to individual destinations. That said, certain patterns are clear from trade data. In 2019, the UK exported in excess of £14.4bn of aerospace products, running a large trade surplus in this sector (Her Majesty's Revenue and Customs, 2020). A majority of these exports were to the EU (£8.7bn) and the overwhelming majority were parts and components for aircraft (£12.7bn, of which £8.2bn was to the EU) pointing to the degree of integration in supply chains. The sector's value-added has grown rapidly over the past few years, growing by 47.1% since 2007 (pre-financial crisis) compared with growth of 15.4% in the economy as a whole (Office for National Statistics, 2020a), although by far the most rapid growth over this period has come from Wales, with output growth in the Midlands something of a tale of two halves – growth being slow but from a high base in the East Midlands with the converse being true in the West Midlands (Office for National Statistics, 2019b).

The aerospace sector is heavily regulated, having operated under the oversight of the European Aviation Safety Agency pre-Brexit and now the UK Civil Aviation Authority. The UK-EU agreement includes provisions for co-operation and mutual recognition such that, although the prior regulatory framework is not replicated (and with notable new restrictions on airlines and others) manufacturers face relative continuity. Users and manufacturers of complex chemicals involved in aerospace manufacture (for example the chemicals used in coating metals) face some additional challenges involved with regulatory duplication.

Then there are challenges in ascertaining which region imports are destined for, as regional data on imports and exports are only available for quite broad definitions.[12] Thus, it is impossible to distinguish between imports of entire vehicles and parts and components (whether for use during vehicle manufacture or as aftermarket parts). For aerospace, the problem is even more severe since data only exist for "other transport equipment" (i.e., not road vehicles), which encompasses an array of high value goods including trains and rolling stock, boats, aircraft and parts thereof. Worse, since imports are frequently registered by the importer they can get wrongly assigned to regions. We cannot distinguish, therefore, between an aircraft imported for use at East Midlands Airport and parts and components to be used by Rolls-Royce in the assembly of a Trent engine.

In contrast to the manufacturing of advanced transport equipment, comparable data are less readily available for the manufacture of advanced medical equipment. As became clear during early 2020 with shortages (anticipated and real) of key equipment, the UK lacks some of the manufacturing capacity in this area relative to some of its peers. In contrast, the country has a large and well-developed pharmaceuticals sector. A total of 5,500 people work in the manufacture of medical and dental instruments and supplies in the Midlands, of which a large majority are in the West Midlands (Office for National Statistics, 2019a). One of the challenges here is classification.

Consider the high-profile example of Smiths Group plc. A provider of specialist medical equipment, Smiths shot to fame during 2020 due to their pivotal role in the UK's "ventilator challenge"[13] during the first 'wave' of the pandemic caused by the novel coronavirus (SARS-COV2). Ventilators are a quintessential example of manufactured medical products. Yet both of Smiths' registrations at Companies House (one for the head office of Smiths Group plc. and the other for Smiths Medical Group ltd.) classify it under SIC code 70100, namely "activities of head offices". In contrast, Breas Medical Ltd. who are also manufacturers of ventilators (headquartered at Stratford-upon-Avon in the West Midlands), are registered under SIC 32500 – "manufacture of medical and dental instruments and supplies". Whilst the classification used by the Inter-Departmental Business Register (IDBR) need not be the same as that of Companies House, this nevertheless highlights the likelihood of misclassification, particularly of smaller businesses.

In this vein, it is noteworthy that the Office for Life Sciences (2020) finds significantly greater levels of employment in the Medical Technology sector than the Office for National Statistics (2019a) – 17,700 across the Midlands when digital health is included, although the wider "life sciences" sector employs 32,570. This, too, is likely to mismeasure the sector, since at least some of the businesses concerned specialise primarily in logistics and distribution (an often-underappreciated specialism but outside the core manufacturing sector). That being noted, it is possible to estimate approximate

[12] Specifically 2-digit Standard International Trade Classification (SITC) commodity codes, unlike national data which are available at a much more granular level (8-digit Harmonised System (HS) commodity code).
[13] At a point where it was feared that the UK would "run out" of ventilators to treat sick patients, a consortium of manufacturers stepped in to begin rapid domestic manufacturing of these complex medical devices. As an existing manufacturer of ventilators, the design and expertise of Smiths proved integral to this effort.

numbers in manufacturing by using the publicly available source data (Office for Life Sciences, 2020) and interpolating. Linear interpolation suggests that companies based in the region might employ approximately 22,800 in manufacturing within the life sciences sector, with a lower bound of 15,335. Naturally, not all of that employment will actually be in the Midlands since larger companies in particular tend to have multiple sites, including outside of the UK. Nevertheless, that does give some evidence on the sector's extent and importance in the Midlands Engine region.

In summary, the automotive sector is of particular importance to the Midlands, comprising almost 21% of the region's entire manufacturing sector (without including those in metal manufacture, rubber, plastics and chemicals who supply into the region's automotive industry). However, we also see significant presence in aerospace (directly worth more than 5% of the region's manufacturing sector) and medical technologies. We now consider a more detailed assessment of the impact of Brexit and Covid-19 on the automotive sector, using the proprietary model developed by AutoAnalysis. However, note that many of these issues (for example the current shortage of semiconductors[14]) will equally impact on other advanced manufacturing sectors.

Sector deep-dive: automotive

This section is divided into three subsections. The first considers the value of various facets of the automotive sector in the Midlands. The second considers the impact of Covid-19 and its knock-on effects to the production of semiconductors, which in turn has disrupted supply to the automotive sector. Finally, this is followed by an assessment of the impact of Brexit on UK vehicle production, and finally we seek to assess whether continued automotive production in the UK is "at risk". We draw on the AutoAnalysis Brexit Impact Assessment model (Henry, 2020) as used by the Department of Business, Energy and Industrial Strategy and a number of industry and financial sector players. The model allows users to calculate the impact of tariffs on imported components, exported components, imported cars and vans, exported cars and vans according to the geography of sourcing or destination of parts and finished vehicles. These calculations can be done at an industry level, a regional level, a company level, a plant level or individual vehicle model level. It allows users to vary tariff rates, sourcing geographies and production volumes to see what the impact of individual factors or a combination of factors might have.

The model takes vehicle production volumes, proprietary data on the value of purchasing expenditure on components by the car companies, the geography of sourcing of these components (e.g., whether the parts come from UK, Europe, China or other countries) and the factory gate value of the vehicles produced in the UK to produce a variety of data outputs. For this report, the model has been used to calculate the value of vehicle manufacturing in the Midlands area, based on Jaguar Land Rover and Toyota; these companies account for the overwhelming majority of the automotive manufacturing sector in the region and close to 100% of the passenger car business in the region (there is some specialist car production and also commercial vehicle production but to all intents, JLR and Toyota represent over 90% of the value of the sector).

We have based our value calculations on 2019 vehicle production volumes because 2020 numbers were greatly distorted by the impact of Covid19, which saw UK production fall below 1 million, at approximately 972,000 units. Although 2019 was to some extent affected by Brexit issues, it is nonetheless a reasonable guide as to a typical year's production volume for the industry, and a guide also to the potential level to which the UK automotive industry *could* return to post-Brexit. In this vein, 2017 and 2018 were part of the previous boom in the sector, and not really representative of

[14] https://www.autoexpress.co.uk/jaguar/354814/jaguar-land-rover-shuts-two-factories-due-semiconductor-shortage

either an average year in the past, and certainly not a guide as to the potential for the UK going forward.

Just over 1.36 million cars and vans were made in the UK in 2019. Of these, just over 447,000 (or 33% of UK production) were made by JLR and Toyota. This total includes vehicles made in the JLR factory at Halewood on Merseyside; we need to include Halewood production in our calculations because a) the engines used in vehicles produced at Halewood are made in Wolverhampton and b) around two-thirds of the value of the components used in these vehicles were made or assembled into subsystems in the Midlands area. As such, we have a major example here of how the functional economic geography of a regional industrial cluster is not necessarily coterminous with the political construct of a (NUTS1) region.

To emphasise, the AutoAnalysis model uses *confidential company, factory and vehicle-specific data* and hence is subject to significant non-disclosure. A dummy table of data for a theoretical model is shown below for reference:

Vehicle company	**Vehicle Model**	**2019 production**						
Company X	Model Y	200,000						
Spend per vehicle (Bill of Materials, BOM value)	**UK %**	**EU %**	**Other Europe %**	**US %**	**Japan%**	**China %**	**RoW %**	**Total £**
17,500	20.0%	55.0%	4.0%	1.0%	10.0%	5.0%	5.0%	100.0%
£ spend per country/region	3,500	9,625	700	175	1,750	875	875	17,500

The value of the automotive manufacturing sector in the Midlands

The model has data as per the table above for each car or van made in the UK by vehicle companies making over 50,000 vehicles a year and by adding the data for relevant JLR and Toyota models together, it generates the following overall values for the automotive manufacturing sector in the Midlands:

- **Annual expenditure on components** for vehicles made by JLR and Toyota amounts to approx. **£10.2bn**; this represents **nearly 43% of expenditure on parts by the UK's volume vehicle companies:**
    - The JLR/Toyota spend ratio of 43% is higher than the 33% of UK car and van production which these companies represent because of the relatively high value of JLR models, especially when compared to the bulk of vehicles made in the UK
- 49% of this £10.2bn is spent at tier 1 suppliers in the UK, i.e., £4.58bn
- Moreover, 30% of the spend by JLR and Toyota is estimated as being spent at suppliers in the Midlands, i.e., £3.03bn
- Around 40% of the spend in the Midlands is then spent outside the UK on tier 2 or 3 imported parts or raw materials, meaning that **the net spend in the Midlands by JLR and Toyota is approximately £1.82bn**

- In addition, we can add the value of business with Midlands suppliers by other UK vehicle manufacturers: the net value of this spend, after taking into account expenditure by Midlands suppliers on imported parts and raw materials, is a further £1.125bn
- In total therefore, we calculate the net value of UK vehicles companies' expenditure with Midlands suppliers to be close to **£3bn** in a typical year. This is a significant element in the total value of the region's economy.

In terms of output at the factory gate, the combined value of the JLR and Toyota cars made in the Midlands (including allowance for the Midlands' value of the vehicles made at JLR's Halewood factory) is **just over £14.6bn**, or 44% of the of the value of UK vehicle production as measured at the factory gate. This clearly highlights both the absolute value of the sector to the region and of the region's automotive sector to the industry as a whole. In producing 33% of the volume output of vehicles in the UK, the region generates 44% of the factory gate value of total UK vehicle production. As such, this again this highlights the higher value per unit of the vehicles made in the region versus the UK as a whole.

Moreover, the Society of Motor Manufacturers and Trades (SMMT), the trade association for the industry, estimates that the total automotive manufacturing sector in the UK, including commercial vehicles, off-highway vehicles, engines and components exported abroad and for spare parts is close to £80bn. This reflects the value of JLR production to the region and reinforces the argument that JLR should be considered as a 'National Strategic Asset' in terms of attendant regional (and national) resilience strategies – and moreover makes the case for continuation of an explicit industrial (sector-based) strategy that builds on - and fine-tunes - the current focus on competitiveness, tax breaks and Freeports. This is something which regional authorities need to protect and build on, especially as JLR moves into electric vehicles.

Securing a battery factory for the region would involve understanding and supporting JLR's needs and plans in detail. JLR's future EV build volumes could justify a large scale battery manufacturing facility (a so-called "gigafactory"), making cells and assembling complete battery packs. However, it is also possible that the company would prefer to source cells from the EU and assemble them in-house (whether at Castle Bromwich or elsewhere). The current trend within the industry is for cell production and pack assembly to move 'in house'.

In any event, assembly of battery packs will require a supporting supply chain capable of delivering a range of other components, such as cases, covers, bracketry, supporting parts, cabling and so forth. There is no reason why such parts cannot be sourced in the UK and within the Midlands area specifically; the crucial thing is to engage with JLR and other automotive manufacturers in order to understand what local and regional bodies can do to attract additional suppliers or help those in the region with relevant skills become accredited or approved suppliers if they do not have such status already.

Covid-19 and semiconductors

Covid-19 has severely impacted on vehicle production across the world, with Europe and the UK being particularly affected. All vehicle assembly plants were closed for part of March, and most of April and May. Some plants (e.g., Castle Bromwich) remained closed beyond this timeframe, whilst some smaller manufacturers restarted production somewhat more quickly. By the end of June, the majority of factories were back in production, although the ramp-up rates varied substantially across the region. Whilst plants are generally "back to normal" by this point, that baseline of normality looks significantly different to the pre-Covid19 period.

Social distancing and other Covid-19-compliance measures mean that some production efficiencies have been lost and it is generally acknowledged by industry insiders that effective capacity has been reduced by between 5% and 10%, although achieving a standard way of measuring has not been established. Even now there are occasional lost shifts due to Covid-19-related labour shortages caused by large numbers of assembly line staff needing to self-isolate or supply delays caused by specific Covid19 outbreaks, such as the one that led to the closure of the German border with the Czech Republic in February. This led to some problems at a number of German plants as suppliers could not deliver to the vehicle plants. Problems in specific locations can lead to disruptions at specific vehicle plants; for example, the closure of the Channel Tunnel and sea routes in late 2020 led to some production stoppages at Toyota plants in both the UK and France.

In addition, the automotive industry as a whole has had to deal with shortages of semi-conductors which have been the subject of supply constraints, particularly those manufactured in Taiwan, which possesses a non-trivial portion of global semiconductor manufacturing. In mid-2020 many European and North American vehicle plants cut production forecasts and signalled to suppliers that their deliveries would be correspondingly reduced. In turn, systems suppliers reduced orders with their suppliers, including semiconductor suppliers that saw reduced incoming orders from the automotive sector. This occurred simultaneously with a dramatic escalation of semiconductor demand from the tech sector as phone and computer demand mushroomed as home-working and home-schooling grew around the globe. Semiconductor manufacturers naturally reallocated supply to these sectors. When automotive demand rebounded, the supply was therefore already committed elsewhere. The resulting shortages are closely analogous to the widely acknowledged “bullwhip effect” (Costantino, Di Gravio, Shaban, & Tronci, 2013) leading to widespread reports in late 2020 and throughout much of 2021, stating that vehicle companies would be reducing production in certain locations owing to chip shortages.

The industry consensus is that in Q1 and Q2 of 2021 firms will lose up to 10-12% of planned production but that this should be recoverable later in the year, although the situation remains extremely fluid and lost production could prove larger than this. The Taiwanese Government has directed key semiconductor suppliers who dominate the global market – particularly Taiwan Semiconductor Manufacturing Company (TSMC) – to boost supply to the automotive industry. Some semiconductor manufacturers, or tier 1 businesses who have relied on third party suppliers, have decided to boost their own production in Europe – Bosch and Infineon are two of the most important European operations to do this. More could follow. There is however a fear that shortages could return later in the year (especially the knock-on impact of the recent Suez Canal disruption will continue to affect supply chains for some time to come) while a third wave of Covid19 is also a major fear. Both of these (semiconductor shortages and the pandemic) combined could have a major impact on vehicle production later in 2021 and possibly beyond; another Covid-19 wave could well tip many companies – which have to date survived through government backing via furlough or similar schemes elsewhere in Europe – into becoming insolvent when these schemes come to an end. There is a serious fear of latent unemployment becoming real later in 2021 and in turn hitting demand for “big ticket” items such as new cars.

UK automotive production potential post-Brexit

Finally, now that the UK-EU Trade and Cooperation Agreement (TCA) has been ratified by the European Parliament, the UK automotive industry ought to be able to plan for the future in a more stable environment than it has operated in since 2016. But instability predominates, primarily due to Covid-19 and the associated shortage of semiconductors. In addition, with political tensions between

the UK and EU over Northern Ireland and, to some extent, the distribution of vaccines for Covid-19, uncertainty remains over the broad structures within which the automotive industry operates.

In 2020, UK automotive production fell below 1 million units for the first time since the 2008-09 recession. AutoAnalysis' central forecast in March is that 2021 should see a recovery in UK production to just over 1.13 million, up 16.7% on 2020. This will be in response to pent-up demand being met when the dealerships open across Europe and an imminent boost to production from the new Qashqai and the new Range Rover in October. However, the risk of a renewed wave of Covid-19 and semiconductor shortages lasting well into 2021 could impact both new car demand and the ability of the industry to produce vehicles; a severe Covid-19 outbreak across Europe and semiconductor shortages extending into the second half of 2021 could see UK vehicle production falling below last year's levels. The situation is very fluid. If events turn out better than this, we could see that over the next few years, total UK production might climb towards 1.3 million – assuming that Ellesmere Port wins the next Astra; that MINI volumes are maintained; and that the new JLR models planned proceed on time. Furthermore, this is despite the closure of the Honda factory in Swindon from July of this year.

Moreover, there is a substantial risk of demand shocks (both positive and negative) due to public health restrictions and the associated economic conditions. Equally, on a more positive note, there is also the possibility of new models being allocated to the UK (unlikely though this may seem at present given the uncertainties surrounding Ellesmere Port and the somewhat fractious relationship between the UK government and the European Commission).

Ultimately, in the event of a serious Covid-19 third wave across Europe and sustained semiconductor shortages through 2021, then production this year could remain below 1m and then settle around the 1 million level going forward. A more optimistic view, especially now that the TCA has been ratified, with Covid-19 controlled, and the semiconductor shortage overcome, could see more models allocated to UK car plants with production climbing towards 1.4m a year. In summary, the central forecast provided by AutoAnalysis is that the UK should increase to approximately 1.28 million units by 2026; but in the event of both Covid-19 and semiconductor shortages resulting in long-term operational problems production will likely only reach a maximum of 1.09 million in 2026 and could well be lower than this. A "realistic" optimistic scenario however, with some new model boost would see the UK reaching just over 1.38 million by 2026.

In considering implications for the Midlands, Toyota should remain broadly consistent in terms of its production volume and new model cycle plans (although this is dependent on the UK Government's legislative position around hybrid vehicles); a new Corolla should hopefully be confirmed around 2024 and go into production around 2026, sustaining that element of the regional economy through to the early 2030s. At JLR, meanwhile, change is underway. Starting in 2025, the Jaguar brand will switch to an all-electric range to be made in Solihull, with an expected maximum eventual volume of approximately 60,000 units a year, well below past ambitions of 150,000 or more per year. Castle Bromwich will stop car production although its long-term use remains to be confirmed. Land Rover/Range Rover will launch its first all-electric vehicle in 2024 and will add more EVs in the years ahead, but it will continue to make internal combustion engine and hybrid powered vehicles well into the 2030s. JLR will also likely produce a narrower range of models in Solihull, and while production volumes may go down, the value of this production will probably rise as EV prices will likely be higher than existing petrol or diesel vehicles for some time to come due to the costs of batteries (at present around 40% of total vehicle cost for some electric vehicles).

Summary

The previous sections have provided a comprehensive secondary data analysis at the macro- and meso- level for advanced manufacturing sectors in the Midlands. However, gaps remain in our understanding at the micro level of how advanced manufacturing businesses in the region are responding to the twin challenges of Brexit and Covid-19. Specifically, we have considerably less knowledge of the impact further up the supply chain, most notably above tier-one suppliers. Whilst the issues facing companies in terms of adjusting to the new trading regime with its range of customs and security checks, the factors shaping business preparedness will necessarily be different and vary in terms of size, exposure to EU trade, supply chain fragilities and whether they already trade outside of the EU.

In turn, this will impose different constraints on business in terms of procurement, operations, customer communications, HR issues and regulatory and compliance issues going forward. Hence, the following section explores these issues further, drawing on primary data generated via semi-structured interviews with managers in the denoted advanced manufacturing sectors.

Methodology: Primary Data Collection

Given the focus of the study on advanced manufacturing businesses, a case study research strategy was adopted. Accordingly, in addition to the desktop analysis described above, a total of 12 semi-structured interviews of approximately 30-60 minutes duration were undertaken with senior managers in the automotive, aerospace, medical technologies sectors and attendant suppliers and industrial service providers. These individuals consisted of a mix of functional areas (procurement, operations, finance etc.) but the key criterion for interview selection was that these people in some sense "owned" the issues of Brexit and Covid-19 in their organisation. In conducting the interviews, we specifically sought a mix of respondents across different tiers of the supply chain, ranging from key Vehicle Manufacturers (VMs) through to smaller tier 2 and tier 3 firms. Key summary statistics pertaining to respondents (sector, supply tier, size of the business etc.) are detailed in Table 1.

Questions centred on the preparations for Brexit, where information on Brexit was sourced, supply chain responses to the pandemic and any attendant HR, regulatory and compliance issues (e.g., kite-marking) arising thereof. Additionally, more general questions were asked to explore the utility of several potential government interventions such as physical and digital infrastructure expenditure, tackling skills gaps, grants for R&D or changes in the tax system. Interview participants were provided with prior information about the purpose of the research to ensure fully-informed consent, and the interviews were conducted in accordance with the strict ethical tenets of voluntary participation, anonymity, confidentiality and non-disclosure where requested. The interviews were recorded online via secure digital recording platforms (MS Teams) and transcribed using the services of a research assistant. Data was kept on secure servers and all personal identifiers were destroyed upon the conclusion of the research.

Table 1: Respondent Profiles – key information

Date of interview	Pseudonym	Sector	Location	Size of enterprise (approx. # employees)
Feb 9th	Participant 1	Automotive	Derbyshire	2000
Feb 9th	Participant 2	Metal fabricator	Black Country	500
Feb 10th	Participant 3	Industrial Service Provider	Birmingham	5
Feb 10th	Participant 4	Metal fabricator	Black Country	150
Feb 11th	Participant 5	Metal fabricator	Black Country	100
Feb 11th	Participant 6	Metal fabricator	Black Country	100
Feb 17th	Participant 7	Machine tools	Black Country	100
Mar 15th	Participant 8	Jewellery	Birmingham	50
Mar 16th	Participant 9	Metal fabricator	Black Country	100
Mar 16th	Participant 10	Med Tech	Birmingham	600
Mar 16th	Participant 11	Industrial Automation	Birmingham	100
Mar 26th	Participant 12	Metal fabricator	Derbyshire/ Worcestershire	1300

The sample is unfortunately rather skewed towards the West Midlands, due to a disappointing lack of responses from aerospace industry firms (this is compounded by concerns around disclosure in defence contracting significant in the aerospace sector). Of automotive, aerospace and med-tech employment in the East Midlands, almost 2/3 is in aerospace. The East Midlands accounts for 80% of the Midlands' aerospace employment. Of all aerospace employment in the East Midlands, at least 2/3 is accounted for by a single firm (Rolls-Royce) with whom we were unable to secure an interview. In contrast, over 85% of automotive employment and almost ¾ of med-tech employment is in the West Midlands.

Much the same pattern (a West Midlands skew) is visible in some of the key metalworking sectors that make up tier-2 and tier-3 suppliers (e.g. forging, stamping & powder metallurgy). The major exception to this rule is businesses whose main function is “machining” (SIC 25620). However, this covers a huge multitude of different business types, most of which would not be classified as “advanced manufacturing”. The East-West skew is therefore an unwanted side-effect of the skew in the industrial mix.

However, one of the important findings was that it is challenging to accurately categorise suppliers. One respondents, for example, supplied both parts to the automotive sector and parts for whole body scanners.

In the sections that follow, we detail the findings of the research in accordance with the themes denoted above. Given the relatively small size of the interview sample, the findings should be considered as indicative rather than being necessarily representative, so a modicum of caution is necessary in terms of generalising the findings.

Findings

Expectations in the lead-up to a Trade Agreement

In the lead-up to the attainment of the UK-EU Trade and Cooperation Agreement, all of our respondents said that they had undertaken scenario planning and considered a No Deal outcome with the imposition of a tariff regime to be the worst-case scenario. However, preparations for exiting the Single Market and Customs Union had been hampered by what they regarded as a lack of transparency and clear information from the Government and its civil service. Even those respondents from businesses that undertook substantial trade outside of the EU, and hence were already familiar with customs checks and the Incoterms that govern international trade thought that Brexit would impose additional disruption to them:

"*The bit I was most worried about was around the uncertainty which drives lack of confidence in terms of buying, forecasting and it was that which was quite damaging for our business over multiple attempts of leaving the EU, and second that we were quite confident that if there was a deal it would be short term to medium term adjustments, not necessarily by us, but more our supply chain and customers that probably will give us the most pain. And all those things came true…*" (Participant 4).

Accordingly, we now turn to the implementation of the TCA and its immediate impact on our respondents. We focus on supply chain, trade and HR issues.

The immediate impact of exiting the Single Market and Customs Union

Supply Chain and Logistics

Evident from some of our respondents was that the disruption to supply chains triggered by exiting the Single Market and Customs Union had resulted in lost orders from European customers that in turn had triggered plant shutdowns and hence workforce redundancies; for instance, this respondent who had been forced to close a site in Worcestershire:

"*Germany stopped ordering as they always do in August… That is not unusual. But then there was nothing in September either. And October, so, and then they want you to do a price reduction. And we were already talking to them about the price increase. So, we parted company, which was very sad, because we've been working for them for 25 years or so and closed the site down… this major company was taking around about 20% of our turnover, actually at that site. So yes, that site was taken away by problems with Brexit*" (Participant 5).

"*Everyone's capturing their cost and pushing it back down the supply chain. So yeah, you know, roughly speaking, a 20% increase in in freight charges-ish. But I do think that's short term. I think it will be an increase, but not as much as that once things have settled down*" (Participant 4).

Thus, one of the key impacts of Brexit has been to force changes in the nature of supply chain and logistics linkages. Some of these will take months (due to the challenges of sourcing alternative suppliers and distributors, with contracts varying in time length) as companies re-evaluate the efficacy of utilising particular transport routes and modes. In a similar fashion, manufacturers based in the Midlands will re-examine the costs and benefits of producing and sourcing locally as opposed to elsewhere in the EU as the new trading relationship becomes embedded. However, even prior to exiting the Single Market and Customs Union, there was evidence that OEMs were effecting changes to logistics in terms of importing parts and components to the UK:

"*Our inbound logistics began to change for European-sourced parts before Brexit; we used to bring in 100% of European sourced parts through the Tunnel, but it is now 70%. We use Portbury, Felixstowe and 1 or 2 others on the east coast will be added later this year. The new ports receive parts on*

containers or unaccompanied trailers. There are fewer European trucks coming over now" (Participant 1).

These shifts in turn will have implications for regional transport infrastructure policy in terms of upgrading regional trunk road and rail networks; a theme we return to in the policy discussion section.

In terms of supply chain resilience, what was noticeable from our sample was that the metal fabricator firms tended to supply more than one sector – for example, Participant 4, who stated that their firm supplied 10 industry sectors, with automotive, construction/plumbing, medical and telecoms being the biggest. This is important in the sense that having a diverse range of customers lessens the exposure to adverse developments in any individual sector, and points to the clear benefits of supply chain diversification for suppliers caught out in the event of an OEM plant closure (as has been evidenced in the demise of MG Rover at Longbridge in 2005 and Honda at Swindon this year, for example).

HR and Skills

Turning to personnel issues, skills gaps in design and engineering were particularly prevalent in all sectors examined. Historically these gaps had been filled by recourse to a readily available skilled European workforce at competitive wage rates. At the aggregate (UK) level, there is significant variation in terms of sectoral and business dependency on EU workers. In general, approximately 12% of the UK's manufacturing workforce were EU nationals (Office for National Statistics, 2020). There is some evidence that the proportion in the Midlands is somewhat higher than this (Office for National Statistics, 2019), although sample sizes requires caution. What is incontrovertible is the heavy dependence of certain subsectors on EU nationals, although this appears to be concentrated amongst low-skilled workers in the food & drink industry, where around one third of the workforce are EEA nationals (Migration Advisory Committee, 2018). Insofar as we have aggregate evidence for the automotive, aerospace and medical technology sectors, the available evidence suggests that the figure is similar to manufacturing as a whole (ibid.), albeit with substantial inter-firm variation.

Of course, relatively low overall employment numbers can conceal extremely high dependency for certain critical functions in roles that are difficult to fill. Engineering and technical expertise is at a particular premium and measures will need to be put in place urgently to address this shortage moving forward (particularly via upskilling). Nationally, there is some evidence that EU migrant labour tends to be more concentrated in larger firms within our sectors of interest, a finding that appears to be replicated in the Midlands (De Ruyter et al., 2020). In this context, Participant 10, who worked for a Med Tech firm that supplied abdominal procedure materials for hospitals, commented that over 80% of their workforce were from the EU, and that this had occurred since accession of Central and Eastern European states into the EU in 2004. They were acutely aware of this dependency but thought that they had enacted policies to maintain a stable workforce:

"*…because we seem to have grown the contacts who the agencies that we use, have good contracts for that demographic group. And of course, we've got multiple family members - say one family with multiple members that work for us as well. So, it seems to be that once you get a job, you can put other members of your family forward*…."

Not that this had dissuaded them from pursuing strategies to reduce this latent HR dependency:

"*We did have probably 6% of staff who have considered that they needed to go back, you know, with the skills they built up over here. And they wanted to move back, so we lost a huge amount of people.*

We also employ about 300 temps, purely because of the demand, so we've tried to introduce a lot more automation…"

Moving on to the impact of employment law, one of the key arguments around Brexit (at least in terms of its progenitors) was the purported EU-instigated barrier to greater labour flexibility under the auspices of the Maastricht Social Chapter (e.g., the Working Time Directive, Temporary Agency Workers' Directive), a point argued on successively by David Cameron and Boris Johnson (Gomez Arana, Rowe, de Ruyter, Semmens-Wheeler, & Hill, 2019). Indeed, key members of Cabinet such as Home Secretary, Priti Patel; Foreign Secretary Dominic Raab; International Trade Secretary Liz Truss, and Business Secretary Kwasi Kwarteng, hold strongly pro-deregulation views, as espoused in their 2012 treatise, '*Britannia Unchained…*'[15]. However, our research (and that of others[16]) suggests that there is little manifest desire from employers to pursue greater labour flexibility post-Brexit:

"*It would be lovely to rehash all the employment laws, and we were all affected in an adverse way by some of the extremes of the European Community that we've had to comply with. But we've got a workforce and they've been used to this regime now, since 1973. And they would be most upset if the laws were changed by this country, or indeed this company within this country, to favour the employer, as opposed to the employee*" (Participant 5).

Moreover:

"*…my concern is that all the good workers' rights laws that have come in* [from the EU] - *I read a lot of stories to say that the* [UK] *Government at the moment is suggesting that they're probably going to change those or relax them, you know, more to the benefit of business. I would say this would be quite a step back – and I say this, even as a businessperson running a business….*"

When prompted further on why they thought this –

"*Well, I think that the EU did quite a lot for the people who actually in the main voted for Brexit, which I think is ironic. It is very ironic…. I do think there's going to be some significant changes, which will affect the working class of this country, which I think is a sore shame. It really is. But there you go, that's my biggest concern*" (Participant 4).

Our findings on HR matters thus suggest there is very little if any appetite amongst manufacturers for further labour market "deregulation" and that their personnel concerns largely stemmed more around the issues of workforce/succession planning and ensuring adequate skills retention and development thereof. We now turn to the key issue of new trade barriers in the form of customs and other border checks.

Customs and Border Checks

The UK-EU Trade and Cooperation Agreement (TCA) has led to the creation of a new customs declaration regime and an accompanying range of border checks for UK-EU trade (including trade of certain products into Northern Ireland, which is subject to the Withdrawal Agreement protocol that keeps it within the EU Single Market and Customs Union for goods, in effect). Invariably, this has resulted in delays to the transit of goods and additional costs in trading with the EU. The UK Government views these as "teething problems" and that current hiccups should diminish as firms become more adept and understanding of the new procedures. However, the costs of completing a

[15] Kwarteng, K., Patel, P., Raab, D., Skidmore, C., & Truss, E. (2012). '*Britannia unchained: global lessons for growth and prosperity'.* Basingstoke: Palgrave Macmillan.
[16] Thomas, D. (2021). City of London bosses warn against post-Brexit deregulation. *Financial Times*. https://www.ft.com/content/1a2c7e3d-2bd9-4f9c-90c1-0732df98488e

customs declaration for every consignment of traded produce represent a permanent increase in the cost of doing business, and moreover the impact on Just-in-Time supply chains of the time still needed to conduct border checks, as evidenced from our interviews:

"*I mean, the cost is one thing but it's the time really… usually these goods are required before we can send them, there's a lot of people in a rush for them. By the time we've made them and dispatched, the company very often are sort of desperate for them to get out the door. So we do, because we're doing branding work they tend to be the things that are quite often just decided late on, and are almost the last item to go onto the assembly … So, anything that builds time delay into the system is going to be an issue*" (Participant 6).

Rules of Origin stipulations could prove to be particularly complex for firms to deal with, as they require a product to be wholly obtained in the UK or EU and to have undergone substantial value-added in either the UK or EU or both in order to secure a zero tariff.[17] These can be quite complex when numerous parts and components go into a finished product and as such in some cases can be specific to individual products. For example, an engine made in the UK which has 30% non-originated content will satisfy rules of origin requirements if it is used to make a car in the UK or EU (ibid.). It is not surprising then that Rules of Origin strictures were deemed to be problematic (or potentially problematic for automotive, given the current 12-month grace period) and time-consuming to follow, by all our participants, for example that of Participant 1, from a major OEM in the region:

"*As far as we can tell right now, we can cope with current and future rules as set out in the agreement, but our international tax and customs teams are going through the fine print. There is a lot of work going to be involved in proving what we know from experience is the case to the satisfaction of the rules of origin protocols*".

These issues have been compounded by delays in the construction of necessary customs infrastructure and recruitment of personnel. With some 10,000 customs officers employed by the UK Border Agency, key industry stakeholders have argued that this is insufficient, and that another 40,000 are needed to cope with additional customs transactions (which will increase further once import checks on EU goods received are phased in between September 2021 and January 2022).[18] Given the hold-ups and increased costs that have arisen because of the imposition of these new requirements, it comes as no surprise that in the latest Manufacturing Barometer survey of UK manufacturing SMEs, two thirds of respondents reported "negative price changes" in their supply chain as having arisen because of Brexit.[19]

That the imposition of new procedures to trading with the EU seemed "one-sided" (in that the EU had immediately imposed customs and other checks on UK exports but that the UK was adopting a phased-in approach) was not lost on our respondents, with one (Participant 3, an Industrial Service Provider) commenting that "[m]*any UK firms were expecting the French ports to adopt the same light-touch approach to check as the UK was doing for imports*" and that it was something of a rude shock to find that this was not the case. That the same approach was adopted across all EU countries only further reinforced perceptions of 'unfairness' – e.g., that of Participant 2, who commented that "[a]*ll EU countries are as bureaucratic as each other. It doesn't matter if you go through France or*

[17] https://commonslibrary.parliament.uk/new-customs-rules-for-trade-with-the-eu/

[18] https://trans.info/lt/uk-government-rebukes-rha-claims-and-says-50-000-customs-officers-is-not-a-target-221563

[19] https://www.swmas.co.uk/sites/default/files/Q3%202020%20Manufacturing%20Barometer%20-%20National%20report.pdf

Belgium or Holland". On top of this came disruptions due to Covid-19, as outlined in the next section.

The impact of Covid-19

All respondents indicated that Covid-19 had caused disruptions to their operations, though this varied across sectors. Covid-19 had impacted in several ways, from causing shortages of raw materials and parts, to directly impacting on productivity through worker illness and consequent absence. The impact of Covid-19 was also felt in terms of changes to work practices, with the impact of spatial distancing and working from home for white-collar employees having an impact on numbers on the plant floor. However, these disruptions had been felt to be greater for smaller operators:

"*Some things are flying through no issues, the larger consignments of materials and products going out, no problems they're going through OK. So, it's mainly the smaller consignments and other problems, and… we've seen a number of customers change their terms, which hasn't been a big issue, but they don't want to be responsible for collection anymore*" (Participant 4).

However, Covid-19, whilst extreme in its impact, was regarded by all our respondents as a passing challenge, and whilst a number of our respondents had utilised the Government's Furlough scheme during demand downtimes, all had seen a subsequent recovery.

Looking Forward

Hence, in considering the longer-term implications of Brexit and Covid-19, our respondents painted a mixed picture. Some felt that the current situation indeed was simply that of constituting 'teething problems' – whilst others (e.g., Participant 11) argued that the imposition of new trade checks was only pressing if one's products had a tight transit schedule to reach final markets (as with that of fresh produce for example):

"*We are confident that it will settle down and delays have been in terms of hours and an occasional lost shift, may be a day or so, but not weeks and months of sustained disruption to manufacturing... Brexit has not been as much as of a disaster as it could have been but that is partly because of our own preparation and flexibility, and hard work by our logistics people*." (Participant 2).

That said, there was concern expressed over the prospective impact of any regulatory divergence going forward. For example, the introduction of the new UK Conformity Assessed (UKCA) Kite-mark for product labelling to meet agreed regulatory requirements in terms of health, safety and environmental impacts to replace the current EU CE-mark was seen to be particularly problematic in this regard by a couple of our respondents:

"*So, we've got a big spike of activity going on now where every product and of course, because of our multiple locations…. We've got to get all the existing product portfolio UKCA marked. And then there's a few complications around Ireland, which is a pain in the butt* …." (Participant 12).

In this context, the UK Government could seek to pursue regulatory divergence in certain areas, which could entail different standards to secure UKCA as opposed to the CE kite-mark. The obvious implication here is that manufacturers supplying both the EU and UK would comply with the higher benchmark, as it would make little sense to pursue separate product lines. Thus, whilst the two kite-marks would initially have identical requirements, the prospect of a future ratchetting up of EU regulations would result in additional requirements (and hence costs) to be met to secure the CE Mark. To emphasise, with the UK's exit from the Single Market, the status of UK-based 'notified bodies' is no longer valid in the EU, so advanced manufacturers who have had to rely on

independent notified bodies to assess their products (e.g., that of gas boilers) will now have to send these to a notified body based in the EU for testing, which will further impose significant additional costs on local businesses.

Further complications to product labelling and packaging arise with the status of *Authorised Economic Operators* (AEOs) – that is, for those feeding into an EU supply chain in terms of who is the "manufacturer" or "importer" or "distributor" so as to demonstrate compliance. What Brexit has done, then, is to shift the status of EU-based *distributors* to that of *importers* if a product of theirs in question comes from the UK (the same also applies in reverse for UKCA), with the attendant implication that legal requirements are far more onerous on an importer. These include the need to ensure that the manufacturer has taken all steps to ensure that product compliance with all relevant EU standards, including providing the requisite documentation and having the importer's details shown on the product or its packaging.[20]

That said, beyond the above, it was difficult to identify any particular regulatory issues or challenges facing our respondents; in part, because the future trajectory of regulatory change is uncertain. The one exception here is in terms of future measures to combat climate change; for example, the phasing out of internal combustion engines in passenger vehicles by 2030, or other zero-emissions requirements on fabricated metal products – a point not lost on vehicle manufacturers and metal fabricators alike:

" *… move on to 2022 and if I'm being frank and honest with you, Brexit and Covid-19 are really unhelpful distractions for us as a company, as we've got a topic called climate change on the horizon. So, the products that we generate 100% of revenue and profit from today are likely to be banned in this decade, so that should be what we're concentrating our minds and efforts on … these short-term challenges are seriously a distraction from us really focusing on those challenge*" (Participant 12).

Accordingly, we now move on to consider the implications of our findings for regional and industrial policy.

[20] https://www.twobirds.com/en/news/articles/2016/uk/brexit-product-compliance-and-liability-implications

Policy recommendations

The findings of our research suggest that the combination of Covid-19 and Brexit represents a substantial change in operating procedures for companies in advanced manufacturing sectors in the Midlands. Businesses are still seeking optimal modes of working and re-examining supply chain configurations given the new context and our interview evidence has demonstrated that for some, this has been particularly stressful. In this context, for some our respondents, there was nothing else that Government could do if they were unable or unwilling to reverse the imposition of post-Brexit trade barriers:

"*I can't see that. I think the infrastructure that we have is good. We know exactly how-to bring steel in from the Continent…. we have no issues with any of the people that we work with, they know what they're doing. If we can just return to pre-Brexit days, in terms of bureaucracy, then that would solve all the problems - there's no other problem we need help with*" (Participant 5).

As such, whilst this has undoubtedly posed certain strategic and operational challenges, the political decisions regarding the UK's future trading relationship with the EU have now been taken and Covid-19 is likely to have a continual (if diminishing) presence in our lives for some time to come. The challenge now is to deliver the optimal outcome for the Midlands in the new context.

Hence, our research findings suggest a clear need to focus on the "big picture" and longer-term strategic goals. For the Midlands, this implies a focus on mobility and certain life-science technologies as areas for strategic intervention. The region has longstanding strengths in mobility, contributing almost 50% of the UK's automotive value-added and a substantial portion of its manufacture of civil aviation equipment. However, a large portion of this high-value activity is tied to a small number of very large firms who act as "anchors". JLR and Toyota account for around 44% of the factory-gate value of UK automotive output.

JLR contributes disproportionately to the sector's GVA because most of its R&D, design and engineering takes place in the Midlands. In contrast, despite its importance, Nissan undertakes very little of this high-value non-manufacturing activity near Sunderland (the same arguably also applies to Toyota at Burnaston and BMW at Hams Hall). Rolls-Royce performs a similar "anchor" role in the aerospace industry cluster around Derby. The area boasts a large number of smaller "upstream" suppliers, related to both its manufacturing history and the presence of large firms. There are related historic strengths in terms of research, both within private companies (such as MIRA) and across a number of Higher Education Institutions. Moving forward to build on these historic strengths requires ongoing innovation and this is likely to particularly relate to computer programming (notably AI, communications and security) and electronics in vehicle (not just automotive) subsystems.

As such, there are particular forward-looking opportunities in mobility. These especially relate to connectivity, vehicles (vehicle-to-X and X-to-vehicle), and electrics. In order to build on these, there is a clear need to better leverage existing research in the region. As such, government support is needed to:

- Facilitate and incentivise (even) greater collaboration between universities, other academic institutions and private companies. This might take the form of an enhanced and expanded KTP programme; industry sponsorship for basic research; more degree apprenticeships; academic placements in industry and other knowledge-exchange mechanisms to enhance the commercialisation of basic research. There are substantial lessons to be learnt from the United States, Germany, Taiwan and South Korea in this area. Well-known examples include

the collaboration of Intel Labs with academic institutions across North America and TSMC's "University Research Centers Program".

- Further enhance and facilitate access to finance for start-up and scale-up firms. Access to finance displays marked spatial inequalities and Central Government needs to provide additional funding for start-up businesses to augment the capabilities of the newly-established British Business Bank. There are barriers in terms of time and information around existing (non-Covid19) schemes. Whilst funding would be sourced from the UK Government, these schemes should be administered locally (where there will be a greater familiarity of local priorities).
- Potential interventions to explore how best to facilitate greater venture capital (VC) funding to the region are urgently needed. This is a key ingredient behind the success of the US tech industry, and whilst that particular ecosystem took decades to emerge, it does point to a clear needed direction of travel. Access to VC finance (and equity finance more generally) is extremely spatially unbalanced within the UK (Wilson, Kacer, & Wright, 2019), posing challenges to "levelling up" the regions

To reiterate, in terms of the above recommendations, understanding the supply-chain demands of vehicle electrification and decarbonisation in aviation will be crucial, whether that involves the addition of new battery capacity or facilitating the use of batteries sourced elsewhere in UK manufactured vehicles. In any event, establishing and nurturing an entire supply chain ecosystem will allow the region to best take advantage of the coming technological shifts.

There are attendant implications for the nature of the education and training system for HE and FE institutions within the Midlands; with more emphasis needed on addressing key STEM skills-gaps; but also in facilitating a greater shift to life-long learning and flexible, bespoke modular delivery working in tandem with manufacturers. The current *Help to Grow* scheme announced in the March 2021 budget featuring Small Business Charter (SBC)-registered HE institutions[21] is a good starting point but more needs to be done to embed bespoke working with manufacturers into the core business of HEIs. This was not lost on our respondents:

"*I think some of the way of the German model, educating the whole way up and down accompany the whole way up and down the workforce, is something we should take on board. I think we're doing our bit here and lots of other companies are doing it with apprenticeships and people coming into business. But unless we're making the decision makers aware of the ROI and all the other benefits of technology, it doesn't help*" (Participant 11).

In the automotive sector in particular, the presence of substantial price-competitive battery manufacturing capabilities with agreed customers is crucial in order to retain vehicle manufacturing and expertise. If this is lost, it is unlikely to ever return to the region (in contrast with, e.g., retail). This is true even if in the medium-longer term battery production is commoditised.

Hence, geographical proximity matters, particularly if the region is to maximise 'spill-over' effects and enhance agglomeration. Effective proximity is also a function of transport time and cost. East-West links in the Midlands are poor. There are additionally transport bottlenecks in the peri-urban fringes of major conurbations in both the East and West Midlands. The findings of our interview research indicate that companies have re-routed their logistics in terms of ports for imported parts;

[21] https://smallbusinesscharter.org/help-to-grow-management/

for example, away from Dover to the Midlands towards more use of east coast ports, with attendant implications for road and rail infrastructure (see below).

Specific targeted assistance is needed for the aerospace industry in two main areas:

- Overcoming a large fall in orders in the short-medium term due to Covid19.
- Pivoting towards a low-carbon (and, eventually, zero-carbon) future. Again, this is likely to involve a "triple helix" of cooperation between the public, private and not-profit sectors, especially tertiary education.

Turning to infrastructure, certain transport infrastructure will require upgrading as trade flows change post-Brexit, as evidenced from our interview respondents. This includes the road and rail network to Bristol, the East of England (especially the A14 to Felixstowe) and the port of Southampton (both rail and road links – particularly the A34). There is also a desire to see enhanced links between the East and West Midlands, which at present all-too-often are separate (distinct) clusters of excellence in spite of their geographical proximity. The majority of our respondents were supportive of such measures, particularly those who had struggled with the bottlenecks on the Dover-Calais route.

In summary, there are significant challenges related to importing and (particularly) exporting to and from the EU. Whilst the situation is likely to improve over time, some of this additional trade friction is likely to prove permanent. There are ways in which the government can alleviate some of these challenges, although they will take time to implement, and all relate to decision-making at a national level. Going forward, the challenge will be to ensure that the necessary innovation takes place to enable the UK to compete as a base for high-value, high-productivity industries:

"*I'm part of a couple … manufacturing groups working with the CBI, you know, 'how do we restore the manufacturing sector in in the UK?', and my feedback to them is that I don't foresee the UK in the future being the location where big companies like* [XXXX] *make high volume and low cost, but what I do see the role of UK manufacturing sector being is the innovators and the early adopters*" (Participant 12).

Key Policy Recommendations

As such, the key policy recommendations arising from our work are:

- Targeted infrastructure investment in the following areas:
    - Improving inter-urban link transport, especially East-West links within the Midlands Engine to benefit fully from agglomeration and cluster effects.
    - Improving intra-urban transport, facilitating access to talent.
    - Addressing "pinch points" between the Midlands and key ports, notably Bristol, on the A14 between the Midlands and Felixstowe, the A34 to Southampton and routes to Liverpool. This has renewed importance post-Brexit considering shifts in firms' transport and logistics strategies.
- Enabling and facilitating forward-looking opportunities in mobility, especially around programming, vehicle connectivity (vehicle-to-X and X-to-vehicle) and electronics. In order to do so, it is importance to maximally leverage existing expertise in the region, so as to:

    - Facilitate and incentivise (even) greater collaboration between universities, other academic institutions and private companies.
    - Continue and strengthen existing programmes to address key STEM skills-gaps.
    - Facilitating a greater shift to life-long learning and flexible, bespoke modular delivery working in tandem with manufacturers. This is likely to build on the *Help to Grow* scheme and existing KTP frameworks.

- Work to protect our existing National Strategic Assets, particularly large "anchor firms", around which an innovation ecosystem has grown up. A collaborative approach between local government, central government, the private sector and HEIs is needed – the so-called "triple helix".

- Further enhance and facilitate access to finance for start-up and scale-up firms. There are barriers in terms of time and information around existing (non-Covid19) schemes.

- Firms across advanced manufacturing face challenges in pivoting profitably to a low-carbon future. In automotive, the presence of substantial domestic battery manufacturing is key. Given the importance of proximity for agglomeration economies, there is a strong case for situating at least one such facility in the Midlands.

- Recognising the unique challenges for firms in the aerospace manufacturing sector and providing targeted support in order to protect the country and region's world-class skillset.

Conclusions

This sector 'deep dive' report on advanced manufacturing in the Midlands has sought to understand the impact of Brexit and Covid-19 on business continuity and resilience, with a view to providing an evidence base to inform regional and industrial policy. As such, the importance of advanced manufacturing is underscored in this report. Several key themes have emerged, particularly around skillsets and access to talent, cost reduction for exports and facilitating trade. The imposition of new non-tariff barriers has proved challenging to smaller firms, although much less so for larger ones.

Finally, the research clearly demonstrates the critical importance of diversification in terms of both product markets and products for upstream suppliers. Understanding how best to leverage and support this moving forward will be key. The sector in the Midlands has a bright future ahead of it, providing it can fully protect its existing assets and leverage its expertise. As such, further work could be undertaken to work with firms and other regional stakeholders to develop strategies to upskill and promote product innovation. This could initially take the form of a series of roundtable discussions with key employers in the region (and potential investors in the region) around what they would need from the region to maintain or increase their activity in the Midlands.

Bibliography

Chang, H., Fernando, G. D., Srinivasan, D., & Tripathy, A. (2013). A Re-Examination of Diversification and Firm Productivity. *Journal of Management Accounting Research, 25*(1), pp. 99-118. doi:10.2308/jmar-50397 Retrieved from https://doi.org/10.2308/jmar-50397

Costantino, F., Di Gravio, G., Shaban, A., & Tronci, M. (2013). Exploring the Bullwhip Effect and Inventory Stability in a Seasonal Supply Chain. *International Journal of Engineering Business Management, 5*, p 23. doi:10.5772/56833 Retrieved from https://journals.sagepub.com/doi/abs/10.5772/56833

De Ruyter, A., Bailey, D., Henry, I., Hearne, D., Li, D., Shishank, S., & Eade, R. (2020). *Regional Transport - a supply chain mapping exercise and Brexit exposure check of automotive, aerospace and rail value dependency in the WMCA region*. https://bcuassets.blob.core.windows.net/docs/centre-for-brexit-studies-supply-chain-mapping-exercise-findings-and-results-132248711958081123.pdf

Gomez Arana, A., Rowe, J., de Ruyter, A., Semmens-Wheeler, R., & Hill, K. (2019). Brexit: 'Revolt' against the 'elites' or Trojan horse for more deregulation? *The Economic and Labour Relations Review, 30*(4), pp. 498-512. doi:10.1177/1035304619881271 Retrieved from https://journals.sagepub.com/doi/abs/10.1177/1035304619881271

Henry, I. (2020). There may be trouble ahead...: Leaving the EU with no deal would increase the automotive industry's costs significantly. In D. Bailey, J. Mair, A. De Ruyter & N. Fowler (Eds.), *Camageddon: Brexit & Beyond for UK Auto*. Goring: Bite-Sized Books.

Her Majesty's Government, & European Union. (2020). *TRADE AND COOPERATION AGREEMENT BETWEEN THE EUROPEAN UNION AND THE EUROPEAN ATOMIC ENERGY COMMUNITY, OF THE ONE PART, AND THE UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND, OF THE OTHER PART*. London: Her Majesty's Stationary Office Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/948119/EU-UK_Trade_and_Cooperation_Agreement_24.12.2020.pdf.

Her Majesty's Revenue and Customs. (2020). *UK Overseas Trade Statistics: Interactive Tables* [Data set]. Retrieved 20th January 2020, from https://www.uktradeinfo.com/trade-data/rts-custom-table/

Johnson, R. C. (2014). Five Facts about Value-Added Exports and Implications for Macroeconomics and Trade Research. *Journal of Economic Perspectives, 28*(2), pp. 119-142. doi:10.1257/jep.28.2.119 Retrieved from https://www.aeaweb.org/articles?id=10.1257/jep.28.2.119

Los, B., Timmer, M. P., & de Vries, G. J. (2016). Tracing Value-Added and Double Counting in Gross Exports: Comment. *American Economic Review, 106*(7), pp. 1958-1966. doi:doi: 10.1257/aer.20140883 Retrieved from http://www.aeaweb.org/articles?id=10.1257/aer.20140883

Office for Life Sciences. (2020). Bioscience and health technology sector statistics 2019. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910590/Bioscience_and_Health_Technology_Statistics_2019.pdf

Office for National Statistics. (2019a). Business Register and Employment Survey. Retrieved from https://www.nomisweb.co.uk/query/construct/summary.asp?mode=construct&version=0&dataset=189

Office for National Statistics. (2019b). Regional gross domestic product all NUTS level regions. Retrieved from

https://www.ons.gov.uk/economy/grossdomesticproductgdp/bulletins/regionaleconomicactivitybygrossdomesticproductuk/1998to2018/relateddata

Office for National Statistics. (2020a). GDP quarterly national accounts, UK: July to September 2020. Retrieved Date Accessed, 2020 from https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/ukgdpolowlevelaggregates.

Office for National Statistics. (2020b). Input-output supply and use tables. Retrieved from https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetables

Office for National Statistics. (2020c). Non-financial business economy, UK regional results: Sections A to S. Retrieved from https://www.ons.gov.uk/businessindustryandtrade/business/businessservices/datasets/uknonfinancialbusinesseconomyannualbusinesssurveyregionalresultssectionsas

Wilson, N., Kacer, M., & Wright, M. (2019). *Equity Finance and the UK Regions: Understanding Regional Variations in the Supply and Demand of Equity and Growth Finance for Business*. London: HMSO. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/821902/sme-equity-finance-regions-research-2019-012.pdf

Xing, Y., & Detert, N. (2011). How the iPhone Widens the United States Trade Deficit with the People's Republic of China: Zeitschrift für internationale Wirtshaftsbeziehungen. *Aussenwirtschaft, 66*(3), pp. 339-350,352. Retrieved from https://search.proquest.com/scholarly-journals/how-iphone-widens-united-states-trade-deficit/docview/920284829/se-2?accountid=10749

http://BE6RG4TF5U.search.serialssolutions.com?ctx_ver=Z39.88-2004&ctx_enc=info:ofi/enc:UTF-8&rfr_id=info:sid/ProQ%3Aabiglobal&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&rft.genre=article&rft.jtitle=Aussenwirtschaft&rft.atitle=How+the+iPhone+Widens+the+United+States+Trade+Deficit+with+the+People%27s+Republic+of+China%3A+Zeitschrift+f%26uuml%3Br+internationale+Wirtshaftsbeziehungen&rft.au=Xing%2C+Yuqing%3BDetert%2C+Neal&rft.aulast=Xing&rft.aufirst=Yuqing&rft.date=2011-09-01&rft.volume=66&rft.issue=3&rft.spage=339&rft.isbn=&rft.btitle=&rft.title=Aussenwirtschaft&rft.issn=00048216&rft_id=info:doi/

MIDLANDS ENGINE

Observatory