

Title: UK trading patterns within and between regions in the automotive sector – a network analysis

Abstract

This study provides an analysis of the UK's role in the automotive sector, focusing on the trading relationship of the UK within and between regions. It additionally provides an examination of the countries that hold equivalent trading positions to the UK in various segments of the automotive sector. The results indicate a high level of integration with Europe & Central Asia; outside the region, there appears to be a trend towards sourcing inputs from East Asia & Pacific, along with the Middle East & North Africa acting as an export destination. The equivalence analysis results provide a set of nations that could reposition themselves to gain from the UK's departure from the European Union. Amongst them are traditional key European players in the sector, along with Eastern European nations, which have been developing key strengths within the sector in recent years.

1. Introduction

There has been substantial debate in recent decades over whether production is becoming increasingly regional or global (Baldwin & Lopez-Gonzalez, 2018). Production has undergone a transformation in recent decades, where the process is increasingly fragmented. Products are no longer manufactured entirely in one location, rather the process is fragmented across a wide geographic space (Helg & Tajoli, 2005). This suggests geographic distance is playing a lesser role in the production process. However, there continues to be a high level of regional trade and a proliferation of regional trade agreements. In particular, the question of whether production is regional or global, given the rise of global supply chains and the fragmentation of production, has received increased attention in recent years (Chen & De Lombaerde, 2014; Hernández & Pedersen, 2017; Los, Lankhuizen, & Thissen, 2016; Los, Timmer, & Vries, 2015). For instance, Johnson & Noguera (2017) note that regional supply (or value chains) are more pronounced than global supply chains and can vary substantially by region.

Many argue that this fragmentation of production has increased the importance of regional trade, as it has given rise of regional production networks and value chains (De Backer, De Lombaerde, & Iapadre, 2018; Pomfret & Sourdin, 2018). Extant literature examining the interplay between regionalisation and the fragmentation of production has often focused on the

growing role of East Asia, in particular how China acts as a hub for the region along with the impact of regional agreements such as ASEAN (Andal, 2017; Athukorala, 2011; Zhang, Cui, Li, & Lu, 2018). This paper aims to examine regional production patterns in relation to the UK, given the 2016 Brexit vote, which poses challenges for the UK in the region. The production, investment and trading relationship between the UK and EU members is likely to drastically change, shifting from frictionless trade and access to the EU Single Market to potentially the WTO's Most-Favoured nation rules (Dhingra, Ottaviano, Rappoport, Sampson, & Thomas, 2018; Dhingra, Ottaviano, & Sampson, 2017). We examine the features of production in the automotive sector, with a focus on the European region, and examining the UK's role within this region. The 2016 Brexit vote has altered the UK's position within Europe and can have implications for the position it holds within the automotive sector, a politically important sector that contributes significantly to employment levels. Since the Brexit vote, there have been several studies examining the potential impact, especially on how the UK's withdrawal from free trading agreements and custom arrangements will impact its economic growth (Anderson & Wittwer, 2018; Chang, 2018; Greenaway & Milner, 2019; Hantzsche, Kara, & Young, 2019; Latorre, Oleksyuk, & Yonezawa, 2019; Minford, 2019).

The automotive sector is an example of a sector characterised by both regional and global features (Freyssenet & Lung, 2000), with a substantial political and economic importance. The sector is especially important for European countries; Europe is one the world's main regional production sites, contributing to a high level of total vehicle production (Pavlínek, 2019). Brexit poses a risk to the sector, in terms of manufacturing investment and exports (as noted by Gasiorek, Serwicka and Smith, 2019). Bailey & De Propris (2017) note that since 2010, the UK has been a star performer in the automotive sector, and that its performance in the sector has greatly benefitted from EU membership and access to the single market. Therefore, this study examines how the UK is embedded in the region and wider global trading system in the automotive sector.

We ask a set of central research questions:

1. What role does the UK play within the automotive sector in Europe; more specifically how does it link to other nations in the region and how does it link the region to other regional partitions?

2. What countries hold an equivalent position to the UK in the sector, both within and outside the region? Are there any countries well positioned to potentially take the role of the UK in the region, as it becomes disintegrated from the EU?

In order to address these research questions, a network analysis approach is utilised, analysing a set of International Trade Networks (ITNs) representing different segments of the automotive sector, and examining the role of the UK in these networks.

2. Data and empirical setting

2.1. Data

Various approaches and datasets have emerged to better understand the reorganisation of production in recent decades. In this study, we make use of the approach developed by Yeats (2001); utilising detailed disaggregated trade data on parts and components to examine the organisation of production. The automotive classifications defined by Amighini & Gorgoni (2014) are employed, where they establish a number of products groups. They make use of disaggregated product codes to establish groups representing different segments of the automotive sector; electrical parts, engines and rubber and metal parts. These groups have varying levels of technological content, ranging from the high-tech electrical parts to the low-tech rubber and metal components. These product groupings and their individual codes that make up these product groups are presented in the appendix. These product groupings present a more accurate overview of the automotive sector compared to data at the aggregated macro level.

The International Trade Networks (ITNs) have nodes as countries, where they are linked by international trade ties, directed from the exporter to the importer. A threshold was applied to the network, where only trade ties that were greater than 0.01% of total trade in the product group were retained. This is an established approach in studies of ITNs, as observed in Gorgoni, Amighini, & Smith (2018a) and Smith, Gorgoni, & Cronin (2019). The use of the threshold allows to omit countries and ties from the network that contribute very little to international trade yet impact topological properties of the network. These networks are created for the three product groups (electrical parts, engines and rubber, and metal parts) for 2013 and 2018.¹

¹ The data (the international trade networks) that support the findings of this study are available from the corresponding author upon reasonable request.

2.2. Empirical Setting – Automotive Sector

The automotive sector is an important sector, with large political value; as it is highly visible and contributes significantly to national employment (Sturgeon & Biesebroeck, 2011). The sector is described as global (Dicken, 2003) yet is characterised by several macro-regional production networks (Frigant & Zumpe, 2017); in particular North America, Europe and East Asia. Europe is one of the main production regions for the sector, accounting for a high level of vehicle production and output (Pavlínek, 2019).

Regional production clusters in the automotive industry do not only help facilitate production in geographical terms, but also serve markets with shared preferences, allowing the clusters to specialise in the customisation of vehicles to meet regional needs. A number of features can influence the need for passenger vehicles to be customised to fit the needs of a certain market. Income levels of markets impact preferences; consumers from high income nations have higher expectations, such as more advanced and sophisticated features. Furthermore, vehicles must follow market standards and regulations, customising the production accordingly; these features are often shared at the regional level, such as European standards (Humphrey & Memedovic, 2003).

Given the importance of the sector, and Europe's prominent position in the sector; it is salient to examine the role of the UK in the sector, and how it links the European production network to other geographic regions. In the UK the automotive sector is also of strategic value, where it employs around 129,000 people, accounting for 5.2% of manufacturing employment (BIS, 2013). Furthermore, the UK is home to a number of niche engine manufacturers, reflecting a notable strength in the sector. However, a lack of a strong domestic supply chain and access to tier one suppliers represents a key challenge for the UK and its performance in the industry (BIS, 2013; Holweg, Davies, & Podpolny, 2009).

3. Methods

This paper makes use of network analysis to understand and examine the UK's role in the automotive sector. Network analysis techniques have been frequently used to examine characteristics of international trade, (De Benedictis & Tajoli, 2011; Gorgoni, Amighini, & Smith, 2018b; Kali & Reyes, 2007), investment (Metulini, Riccaboni, Sgrignoli, & Zhu, 2017)

and value added (Amador & Cabral, 2017). A network perspective has also been utilised to investigate regional trade patterns in the global economy (De Lombaerde, Iapadre, McCranie, & Tajoli, 2018; Seno-Alday, 2019; Zhu, Cerina, Chessa, Caldarelli, & Riccaboni, 2014). The use of network analysis allows for a more detailed examination of the UK's position in the trade system in the automotive sector, rather than examinations of aggregate levels of regional and global trade (Iapadre & Tajoli, 2014, 2017). A number of studies examine regional trade patterns by focusing on the proliferation of regional trade agreements. Reyes, Wooster, & Shirrell (2014) find that RTAs have contributed to regionalised patterns emerging, yet these have been offset by other factors, such as the growth in trade in Southeast Asia & Pacific. On the other hand, Piccardi & Tajoli (2015) find that Preferential Trade Agreements (PTAs) are only weakly associated with the ITN structure. Sopranzetti (2018) utilised a network approach and finds that countries that are more connected to trade agreements benefit by exporting more than those that are more isolated. This has clear implication for the UK as it is set to distance itself from the regions' free trade arrangements.

Following the approach developed by Amighini & Gorgoni (2014), and subsequently applied by Gorgoni et al. (2018a); we make use of the Gould & Fernandez (1989) brokerage roles to examine how a country links its region to other regional partitions. These capture different roles a country plays within and between regional partitions; providing insights on other features of regionalisation in the global economy. The coordinator role occurs when a country links together countries belong to its regional partition, therefore the country playing this role tightens regional production networks. Countries holding a gatekeeper role act as suppliers of imported inputs for their region. The representative role on the other hand captures when a country acts as an exporter for the region. The consultant role is when a country acts as an external player to a regional production network. The liaison role is a global trading configuration, where a country links to countries belong to different regional partitions. These roles are presented in further detailed in table 1, with a visualisation of the role and economic interpretation.

This approach is complemented with a structural equivalence analysis to address the second research question. Structural equivalence is where actors are connected to the exact same actors in the network (Wasserman & Faust, 1994). This approach has been utilised to examine patterns of international trade (Hafner-Burton, Kahler, & Montgomery, 2009; Nemeth & Smith, 1985; Tong & Lifset, 2007), where equivalent countries import and export with the exact same countries. This approach will therefore allow us to identify countries which held an

equivalent position to the UK in 2013 and 2018, how this has changed over time, and what countries are potentially in a position to benefit from the reduced competition from the UK in the sector.

4. Results

Table 2 provides the number of countries in each regional partition. Table 3 presents a set of descriptive network metrics for each component group, including density, reciprocity, out degree centralisation, in degree centralisation and regional assortativity. Density is a measure of network connectivity; it is the ratio of observed to all possible ties in the network. Reciprocity captures the extent to which there are two-way ties in the network, where two countries both import and export from one another. In degree and out degree centrality refers to the number of ties an entity receives and sends respectively in a network. Centralisation captures the spread of these degree centrality scores in a network; therefore, in the case of the international trade network, it can be used to examine the distribution of trade ties. A high out (in) degree centralisation indicates that export (import) ties are concentrated in a handful of countries in the network, whilst a low score would suggest that they are spread evenly throughout the network (Borgatti, Everett, & Johnson, 2018). Regional assortativity captures the correlation of regional partition membership between connected countries in the network. A positive score would point towards intra-regional trade, whilst a negative inter-regional.

Table 3 indicates that the network metrics remained constant over the time period across the three product groups. The in degree centralisation is consistently low, and the out degree centralisation is high. This indicates that the import trade ties are evenly distributed across countries in each network. The export ties on the other hand are concentrated in a small handful of countries in each product group across time. This points to a hierarchical division of labour in the three product groups over time. The regional assortativity is positive in all product groups indicating a tendency for regional homophily (or regional trade).

Figures 1 and 2 are visualisations of the ITN for electrical parts for 2013 and 2018 respectively. The countries are represented by their national flags, the country size is the export performance of each country. The edges represent the trade ties between countries, and size is the value of the trade tie between countries. The number of countries in the electrical parts network has decreased over time, with a drop in the number of countries from Middle East & North Africa and Latin America & Caribbean, as observed in Table 2.

Insert Figure 1 about here.

Insert Figure 2 about here.

From Figures 1 and 2 we observe for electrical parts that there is a core-periphery structure, with a set of dominant countries at the centre of the network, and a set of less connected countries on the periphery. The UK is at the centre of the network, yet is playing a lesser role, especially compared to China, USA and Germany.

Figures 3 and 4 show the ITNs for trade in engines; we observe that the UK has a stronger position in this network (compared to electrical parts), and this has remained consistent during the time period. From the visualisation and table 2, we observe that there are less countries involved in the trade of engines compared to the other products groups. With the exception of Europe & Central Asia and North America, there are fewer countries from all other regions participating in the engines trade network (compared to the other component groups).

Insert Figure 3 about here.

Insert Figure 4 about here.

Figures 5 and 6 provide a visualisation of the rubber and metal parts networks for 2013 and 2018; in this product grouping the UK appears to be playing a lesser role compared to the electrical parts and engines component product groups. Similar to electrical parts, these networks appear to exhibit a core-periphery structure; which is also indicated by the

centralisation results in table 3. This suggests exports are increasingly concentrated in a small handful of countries. The visualisations, along with table 2, indicate that the dominant regions are Europe & Central Asia and East Asia & Pacific. Since 2013, there has been a drop in the number of countries from Latin America & Caribbean and the Middle East & North Africa participating in trade of these low tech components in the automotive sector.

Insert Figure 5 about here.

Insert Figure 6 about here.

4.1. Gould-Fernandez Analysis

Figure 7 shows a count of the number of times the UK plays each Gould-Fernandez (GF) role for 2013 and 2018. Across the three product groups, we observe that the UK rarely holds consultant or liaison positions. The most salient roles it holds linking regions are coordinator, gatekeeper, and representative roles; these all require a link to Europe & Central Asia, highlighting the importance of regional integration for the UK in the automotive sector.

Insert Figure 7 about here.

The coordinator role is an important role for the UK; Brexit poses a risk to the position the UK holds, as it is unlikely to remain a coordinator for the region when it is no longer benefitting from frictionless trade. This points to a need for a reorientation of the UK's trade, shifting towards consultant and liaison roles in the sector; potentially through new FTAs (with partners such as the USA or India).

The results of the consultant role will not be presented, given the UK's minor role acting as a consultant, as shown by Figure 7.

Table 4 shows that the UK plays a specific coordinator role in the ITN across product groups; linking together a specific set of European nations. In particular, it acts as a coordinator, deepening regional production sharing with Ireland; this role is potentially at risk as a result of the 2016 Brexit vote. Ireland is more reliant on UK trade than other EU members, as it represents a major source of intermediate inputs for Irish firms (Arriola et al., 2018). Table 4 also presents a close coordinator relationship with Denmark across product groups in the automotive sector. Smith, Hermansen, & Malthé-Thagaard (2019) provide a detailed examination of the potential impact of Brexit on Denmark, stating that Brexit threatens the strong bilateral trading and investment relationship between the two nations. They note that Denmark's exports to the UK in transport equipment are likely to experience between a 20 and 25 percent decline from current levels.

The representative role is when the UK imports from Europe & Central Asia, for export to other regional partitions. Table 5 indicates the top regional destinations for these exports. For electrical parts, the UK is consistently acting as a supplier of European components to the Middle East & North Africa. The electrical parts results contrast to engines and rubber and metal parts, where we observe a tendency towards exporting these components to East Asia & Pacific. An explanation for this is that the region has a strong competitive advantage in the related electronics value chain, therefore is unlikely to source inputs and components from the UK (Sturgeon & Kawakami, 2010).

Table 6 illustrates that across product groups, and especially in the engines component, the UK is consistently importing from Central and Eastern European nations, such as Slovenia, Slovak Republic and Hungary, in the two timepoints. Pavlínek, Domański, & Guzik (2009) identify that these nations have exported high levels of automotive goods (particularly engines) since the 1990s, therefore it appears that the UK sources inputs from these nations for processing and further export outside of the region. Table 6 also indicates the countries which are most frequently the destination for UK exports in its representative role. The UK consistently acts as a representative for Europe & Central Asia in its exports to Canada and Australia; reflecting that the UK consistently supplies automotive exports to these Commonwealth nations. After the UK leaves the EU, the trading relationships between Australia and Canada may change, as firms in these countries may choose to source automotive goods from other players, better integrated in the European market. A further point to note, is that the UK often acts as a supplier of European imports to countries in the Middle East & North Africa, where in some cases there is a consistent trading relationship between the UK and United Arab Emirates.

In 2013, there are a set of countries that the UK consistently exports to in its representative role, across product groups, however, by 2018, we observe distinct differences between the various segments of the automotive production chain. We observe that the individual countries that the UK exported to in its representative role were from a wide variety of regions. For electrical parts there appears to be consistency from 2013 to 2018, with only the UK reducing exports to Chile and Egypt and increasing those to Japan in its representative role. It is important to note in electrical parts, the UK experienced a decline in the number of times it held this role in this segment of the automotive sector, as indicated by figure 7.

On the other hand, in the engine category, we witness substantial changes during the time period. In 2013, the export destinations in the UK's representative role are comparable to the electrical parts segment; whereas by 2018, there is a shift towards supplying South American nations (Brazil and Chile) along with nations in Southeast Asia, (Malaysia and Thailand), although not the key dominant players in the region (such as China).

Similar to engine, the export destinations of rubber and metal parts from the UK in its representative role has changed from 2013 to 2018. In 2013, the UK supplied rubber and metal inputs from Europe & Central Asia to some of the dominant players in the automotive industry, such as Japan and China. However, by 2018, the UK is no longer a key supplier for these countries, however, it does act as a supplier to India, an emerging giant in the automotive industry (Sturgeon & Biesebroeck, 2011).

Table 7 indicates the main regions the UK imports from in its gatekeeper role; we observe across product groups, inputs were chiefly sourced from East Asia & Pacific for further export to Europe & Central Asia. East Asia & Pacific is a region that acts as both a source of inputs and destination of exports for the UK, (as indicated in table 5), where it is the top region for both the UK's gatekeeper and representative roles; this reflects the importance of the region to the UK's international trade profile in the automotive sector. If the UK is to reposition itself, moving from the European regional production networks, these results indicate it needs to establish a closer trading relationship with countries from East Asia & Pacific. This also highlights the importance of the region in the wider automotive sector, where it is at the centre of various global supply chain configurations (Andal, 2017; Plummer, 2007).

Table 8 presents the top countries where the UK sources inputs for further processing and export into Europe & Central Asia. When examining the individual countries some differences begin to emerge between product groups in the automotive sector. However, the results

emphasise the close relationship between Ireland and Denmark with the UK, as they are consistent destinations for UK exports within the region.

For electrical parts, there has been substantial changes in where the UK sources parts for further export to the region; with the exception of Hong Kong, which remains a constant supplier of these parts. In 2013, it sourced from countries playing a key role in the wider electronics value chain, such as South Korea, along with traditional key players in the automotive sector, such as Japan and the USA. In 2018, the UK has shifted towards sourcing from countries with lower development levels, such as Mexico, Thailand, and Indonesia, which are not part of the strong East Asia and Pacific electronic value chain. Similar to the representative role, there has been a shift towards creating a stronger relationship to India.

In 2013, for engines, the UK chiefly sourced from the traditional dominant countries in the sector, the USA and Japan, along with Mexico and China. In 2018, it appears that the UK's inputs from China for further export to Europe & Central Asia were surpassed by South Korea and Australia. The UK plays a consistent role in acting as a gatekeeper for inputs from the USA and Mexico to be distributed in the region. The top destinations for these UK engine exports in Europe & Central Asia, appears to have remained constant between 2013 and 2018, with Ireland, Denmark, the Netherlands, and a selection of Eastern European nations remaining as key destinations of UK engine exports. However, figure 7 indicates that the UK's role as a gatekeeper for engines is substantially lower than other brokerage roles in this segment of the automotive sector, in particular when compared to the representative and coordinator roles.

Table 8 indicates for rubber and metal parts, these low tech components are chiefly sourced from a set of developing nations in Asia; these patterns have remained constant from 2013 to 2018. The destination of these low tech components in Europe & Central Asia is similar to the other segments of the automotive value chain, which indicates that the UK has close relationships with a specific set of countries in the region. Following its departure from the EU, the UK will have to reposition itself, either to attempt to maintain these relationships, or find alternative trading partners, focusing on the countries it trades with in its alternative roles.

Table 9 presents the regions the UK acts as a liaison for in the various trade networks at 2013 and 2018. The liaison roles the UK holds reflect its position at the global level, as trade ties in the liaison role are outside Europe & Central Asia and are not intra-regional. Table 9 suggests that the UK plays a key role linking East Asia & Pacific and Middle East & North African countries with the rest of the world. North America is not a top region in the product groups in

either 2013 or 2018. This suggests that for the automotive sector, establishing an FTA with the USA would not be particularly beneficial to the UK, rather there should be a strategy to reposition trade towards establishing agreements with regions where the UK already holds an important position. Although, when examining the results presented in table 9, it is important to note that the UK only plays a minor liaison role, especially when compared to alternative GF roles, as indicated by figure 7.

4.2. Structural Equivalence Analysis

The structural equivalence analysis provides the set of countries that hold an equivalent position to the UK in the ITNs in the automotive sector. The countries are potentially in a position to gain from the Brexit vote, where firms may choose to invest in these nations that benefit from frictionless trade in the region, and move from the UK. At the country level, these nations may undertake a reorientation of policy to gain and improve their training position, especially as Brexit could result in these countries facing less competition from the UK in the sector.

Table 10 shows the results from the structural equivalence analysis for the three product groups. For electrical parts, there has been little change from 2013 to 2018, whereas in the case of engines and rubber and metal parts, there appears to have been an increase in the number of nations holding an equivalent training position to the UK from 2013 to 2018.

The results from the GF analysis highlighted the close trading relationship between Ireland and Denmark with the UK. Whilst the results from table 10 indicate that they do not hold equivalent positions to the UK, it provides a set of equivalent nations that may replace the UK, especially if they foster close relationships to Ireland and Denmark. These finding is in line with the work of Arriola et al. (2018); they note that the investment gains towards Ireland as a result of Brexit are only likely to be modest.

Table 10 indicates that the UK holds an equivalent position to many countries in Europe & Central Asia, and only a brief equivalence to the USA in rubber and metal parts in 2013. This table highlights the difficulties that Brexit poses for the UK's automotive sector, where there are limited opportunities across segments to reposition itself and easily emulate a nation's role outside Europe & Central Asia.

On the other hand, table 10 indicates the countries which could potentially substantially benefit from the UK's exit from the EU, taking the UK's role, along with reduced competition from

the UK. In electrical parts, by 2018 Hungary held an equivalent position to the UK; and Timmer, Los, Stehrer, & De Vries (2013) and Cieřlik, Biegańska, & Środa-Murawska (2019) have noted that Hungary holds a specialisation in the production of electronics, so may potentially be able to build on these strengths, and develop its advantages in the automotive sector.

For engines, where the UK (currently) has some competitive advantages in engine production, the number of nations holding an equivalent role to the UK has grown since 2013, with a number of key countries, such as France and Italy joining a set of nations consistently equivalent to the UK in engine production. This suggests that there are a number of key opportunities for the UK engine producers to relocate their production to the EU post-Brexit; either to nations with a history of success in the automotive sector (such as France), or those developing engine production capabilities, where there is the opportunity to benefit from reduced costs.

In the low tech segment of rubber and metal parts, the UK held an equivalent position to the USA in 2013; therefore this suggests that the UK could look to the USA's current position, and how it could reposition itself to once again hold an equivalent position to a leading nation in the automotive sector. During 2013, the UK also held an equivalent position to Germany, another traditional major player in the sector. In this segment of the automotive sector, there are several countries from Eastern Europe that are positioned to replace the UK; building on strengths in the production of low tech goods (Adăscăliței & Guga, 2018; Pavlínek, 2002).

5. Discussion & Conclusion

This study posed two research questions: firstly, what role does the UK play within the automotive sector in Europe; more specifically how does it link to other nations in the region and how does it link the region to other regional partitions? The second question is, what countries hold an equivalent position to the UK in the sector, both within and outside the region? Are there any countries well positioned to potentially take the role of the UK in the region, as it becomes disintegrated from the EU? The study provided a network analysis of the automotive sector to address these questions, examining various segments with varying level of technological content. The implications of these results are increasingly important given the 2016 Brexit vote.

To address the first research question, a Gould-Fernandez brokerage analysis was employed to various segments of the automotive sector. The results from figure 7 providing a count of the various GF roles the UK holds in the different segments of the automotive sector, highlights the similarities and differences between these segments. The UK rarely plays a consultant role in the automotive sector, this result is consistent across component groups. The liaison role, where a country links together nations from different regional partitions, appears to be more important in the electrical parts segment. This role is associated with global trading patterns, rather than integration into a regional production network. The UK's liaison role in the electrical parts segment is associated with trade ties to nations from East Asia & Pacific. This reflects the strength of the East Asia value chain. The gatekeeper role, where the UK imports from another region for export to Europe & Central Asia, is most prevalent in the low tech rubber and metal segment. The representative role, where the UK sources imports from the region for export outside the region is key in the engines segment. The UK holds a competitive advantage in the production of engines; the importance of the representative role suggests it is embedded in the regional value chain for its competitive production of engines for export elsewhere. This suggests that Brexit and a subsequent disintegration from the region, as a result of restricted access to the single market, poses a substantial threat to the UK in this segment of the automotive sector. The UK holds a coordinator role, reflecting regional embeddedness, across segments of the automotive sector, yet this is chiefly observed in the low tech rubber and metal components grouping.

The additional GF analysis highlighted the regions and individual countries the UK imported and exported to in its various brokerage roles. This analysis highlighted the close relationship between the UK, Denmark, and Ireland, which is likely to be disrupted as a result of Brexit (Arriola et al., 2018; Smith et al., 2019). The GF analysis pointed towards an increase in the level of imports sourced from East Asia & Pacific across segments of the automotive sector, (regardless of the technological content of the product group). The region that chiefly acts a destination for UK exports, outside of Europe & Central Asia, is the Middle East & North Africa. These results indicate that if the UK is to reposition itself in the industry (post-Brexit), there may be a need to enable access to imports from East Asia & Pacific and ease export to the Middle East & North Africa. This suggests the UK should target trade agreements with nations in these areas in order to shift from being embedded in regional production (reliant on integration into the European production network, which may prove difficult) to a better position within the wider automotive global value chain.

To tackle the second research question, a structural equivalence analysis was undertaken. This highlighted the nations that hold equivalent positions to the UK in the various segments of the automotive sector, pointing towards a number of countries that could benefit from the UK's exit from the European Union. In particular, several Eastern European nations hold equivalent positions to the UK across segments in the automotive sector, representing an opportunity for these nations to strengthen existing capabilities that have been developing in more recent years (Cieřlik et al., 2019; Pavlínek, 2019), especially if they foster closer relations to European nations that the UK has close trading relationships with in the sector (such as Ireland and Denmark).

Further potential policy implications (for both the UK and EU nations) are highlighted by the GF and structural equivalence analysis presented in this paper. The GF analysis has highlighted that the UK has important ties to commonwealth nations (such as Australia and Canada); many suggest fostering agreements with these nations as a potential strategy post-Brexit. However, the GF analysis indicates that the UK links to commonwealth nations are chiefly in a representative role, acting as a supplier for the EU to commonwealth nations. This indicates that the UK's relationship with commonwealth nations is a result of integration with the EU in the modern economy, rather than historical ties. In line with the work of Hearne, De Ruyter, & Davies (2019), the commonwealth nations might not represent a solution to replace EU trade (especially in the automotive sector). They note that the UK's embeddedness in the EU over the past four decades has strengthened the relationship between commonwealth nations and the EU, where it seems unlikely that the UK will displace the EU in these trading relationships in the future.

The structural equivalence analysis highlights that there are very limited opportunities for the UK to emulate countries outside the EU, in order to successfully reposition itself away from EU trading arrangements. Therefore, this highlights that from a policy perspective, there is a need for the UK to go beyond developing FTAs, rather there is a need to develop industrial policy (Bailey, Driffield, & Kispeter, 2019). Industrial policy in the automotive sector could focus on developing skills and domestic resources (such as an internal supply chain) in order to remain an attractive investment; this is especially important for UK automotive clusters (such as Oxford and Hams Hall) to survive and thrive.

The results of the GF analysis, in particular the strong coordinator role played by the UK in the various segments of the automotive sector, reflects the highly connected nature of the UK and

EU's trading relationship in the sector (in line with the findings of Giammetti, 2020 and Giammetti, Russo, & Gallegati, 2020). This suggests that a desirable policy outcome (for both the EU and UK), would be to partially maintain this close trading relationship in the sector. This would allow for a reduction of disruptions to the just in time supply chains that characterise the automotive sector in Europe.

There are a variety of avenues for future research to better understand the UK's role within the sector, and how it may potentially be disrupted by Brexit, or other political or economic factors. There is potential to expand on this work through an investigation of the processes and mechanisms that give rise to these (brokerage) trade roles and whether they are associated with a comparative advantage in the sector. Future work could examine the role the UK plays in the region by utilising input-output datasets, such as those described by Timmer, Dietzenbacher, Los, Stehrer, & De Vries, 2015), which have frequently been used to map Global Value Chains (GVCs) (Amador & Cabral, 2016), and to examine where the UK sits along the GVC, and any Regional Value Chains (RVCs).

6. Appendix

Table A 1 Component groups and SITC codes

Electrical Parts	
<u>SITC Rev. 3 Code</u>	<u>Code Description</u>
76211-76212	Radio-broadcast receivers not capable of operating without an external source
77812	Electric accumulators (storage batteries)
77823	Sealed-beam lamp units
Engines & Parts	
<u>SITC Rev. 3 Code</u>	<u>Code Description</u>
71321-71322	Reciprocating internal combustion piston engines for propelling vehicles
71323	Compression ignition internal combustion piston engines (diesel or semi-diesel)
77831	Electrical ignition or starting equipment of a kind used for spark ignition
77833	Parts of the equipment of heading 778.31
77834	Electrical lighting or signalling equipment
Rubber & Metal Parts	
<u>SITC Rev. 3 Code</u>	<u>Code Description</u>
6251-62551	Tyres, pneumatic, new, of a kind used on motor cars (including station wagon)
62559	Tyres, pneumatic, new, other
62591	Inner tubes
62592	Retreaded tyres
62593	Used pneumatic tyres
62594	Solid or cushion tyres, interchangeable tyre treads and tyre flaps
69915	Other mountings, fittings and similar articles suitable for motor vehicle
69961	Anchors, grapnels and parts thereof, of iron or steel

7. References

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8. Tables

Table 1 Gould-Fernandez Brokerage Roles

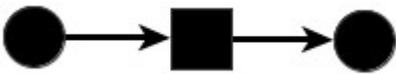
Brokerage Role	Visualisation	Description
Coordinator		Coordinators link countries in the same region, deepening region production sharing.
Gatekeeper		Gatekeepers import from other regions and then distribute exports in their own region, therefore acting as a regional supplier.
Representative		Representatives import from their own region and export outside the region. These nations act as global distributors for their region.
Consultant		Consultants link countries from the same region, where they act as external players to regional production networks.
Liaison		Countries acting as Liaisons link countries from different regional partitions.

Table 2 Number of countries in each regional partition in each network

	Electrical Parts		Engines		Rubber & Metal	
	2013	2018	2013	2018	2013	2018
East Asia & Pacific	14	13	13	13	17	16
Europe & Central Asia	34	37	32	32	40	44
Latin America & Caribbean	19	12	10	10	20	13
Middle East & North Africa	18	10	12	6	15	8
North America	2	2	2	2	2	2
South Asia	5	4	2	2	5	4
Sub-Saharan Africa	15	12	5	3	17	12
Total	107	90	76	68	116	99

Table 3 Descriptive network statistics

	Electrical Parts		Engines		Rubber & Metal	
	2013	2018	2013	2018	2013	2018
Density	0.07	0.09	0.10	0.12	0.07	0.09
Reciprocity	0.43	0.38	0.54	0.54	0.38	0.42
In Degree Centralisation	0.23	0.28	0.29	0.38	0.25	0.29
Out Degree Centralisation	0.69	0.70	0.55	0.58	0.68	0.75
Regional Assortativity	0.27	0.22	0.21	0.20	0.24	0.24

Table 4 UK Coordinator Results

Product Group	2013			2018		
Electrical Parts	Ireland, Slovenia, Belgium	Switzerland, Turkey,		Ireland, Denmark, Slovak Republic	Turkey, Switzerland,	
Engines	Belarus, Netherlands, Portugal	Denmark, Ireland,		Denmark, Belarus, Ireland, Belgium, Romania		
Rubber & Metal	Ireland, Luxemburg, Serbia, Sweden	Denmark, Greece,		Ireland, Denmark, Serbia, Belgium, Russia	Greece,	

Table 5 UK Representative – Top Region UK exports to in Representative role

Product Group	2013	2018
Electrical Parts	Middle East & North Africa	Middle East & North Africa
Engines	Middle East & North Africa	East Asia & Pacific
Rubber & Metal	North America	East Asia & Pacific

Table 6 UK Representative – Top countries the UK trades with in Representative role

	2013				2018			
	Top countries UK imports from		Top countries UK exports to		Top countries UK imports from		Top countries UK exports to	
Electrical Parts	Denmark, Slovenia, Bulgaria, Ireland, Portugal	Slovak	Chile, Saudi Arabia, Egypt, United Emirates	Canada, Saudi Arabia, Australia, Arab	Bulgaria, Slovak Republic, Belgium, Ireland, Portugal	Slovak Republic, Czech Republic, Poland	Saudi Arabia, Canada, Australia, United Arab Emirates, Japan	
Engines	Portugal, Republic, Denmark, Slovenia, Netherlands	Slovak	United Emirates, Australia, Canada, India	Arab	Slovenia, Hungary, Slovak Republic	Belgium, Poland	Chile, Malaysia, Brazil, Canada, Australia, Thailand	
Rubber & Metal	Serbia, Luxemburg, Portugal, Hungary, Republic, Slovenia	Slovak	Canada, Arab South Africa, Brazil, China	United Emirates, Japan	Serbia, Slovak Republic, Ireland, Turkey, Portugal	Belgium, Republic, Russia, Hungary	India, Australia, United Arab Emirates, Canada, South Korea	

Table 7 UK Gatekeeper – Top Region UK imports from in Gatekeeper role

Product Group	2013	2018
Electrical Parts	East Asia & Pacific	East Asia & Pacific
Engines	Latin America & Caribbean	East Asia & Pacific
Rubber & Metal	East Asia & Pacific	East Asia & Pacific

Table 8 UK Gatekeeper – Top countries the UK trades with in Gatekeeper role

	2013				2018			
	Top countries UK imports from		Top countries UK exports to		Top countries UK imports from		Top countries UK exports to	
Electrical Parts	Hong Kong, Indonesia, Vietnam, Thailand, Korea, Japan	Kong, South USA,	Ireland, Switzerland, Poland, Sweden	Turkey,	Hong Kong, India, Mexico, Thailand, Indonesia		Denmark, Ireland, Sweden, Switzerland, Poland, Turkey	
Engines	Mexico, USA, China	Japan,	Ireland, Denmark, Belarus, Netherlands, Sweden, Turkey, Romania	Austria,	South Korea, Japan, Mexico, Australia, USA		Ireland, Denmark, Belarus, Romania, Netherlands, Russia	
Rubber & Metal	Philippines, Lanka, Indonesia, Thailand	Sri Lanka, Brazil,	Ireland, Switzerland, Denmark, Sweden	Greece,	Philippines, Vietnam, Lanka, Thailand	Sri Lanka, Indonesia,	Ireland, Slovenia, Greece, Denmark, Austria	

Table 9 UK Liaison Results

Product Group	2013				2018			
	UK Imports from		UK Exports to		UK Imports from		UK Exports to	
Electrical Parts	East Asia & Pacific		Middle East & North Africa		East Asia & Pacific		Middle East & North Africa	
Engines	Latin America & Caribbean		Middle East & North Africa		East Asia & Pacific		Latin America & Caribbean	
Rubber & Metal	East Asia & Pacific		Middle East & North Africa		South Asia		Middle East & North Africa	

Table 10 Structural Equivalence Results

Product Group	2013	2018
Electrical Parts	Austria, Belgium, Czech Republic, Italy, Netherlands, Poland, Portugal, Spain, Sweden	Austria, Belgium, Czech Republic, France, Hungary, Italy, Netherlands, Poland, Spain, Sweden
Engines	Austria, Belgium, Czech Republic, Hungary, Italy, Netherlands, Slovak Republic	Austria, Czech Republic, France, Hungary, Italy, Poland, Romania, Slovak Republic, Slovenia, South Korea, Spain, Turkey
Rubber & Metal	Czech Republic, France, Germany, Italy, Poland, Spain, Turkey, USA	Belgium, Czech Republic, France, Hungary, Italy, Netherlands, Poland, Portugal, Romania, Russia, Slovak Republic, Spain, Turkey

9. Figures

Figure 1 Electrical Parts ITN 2013

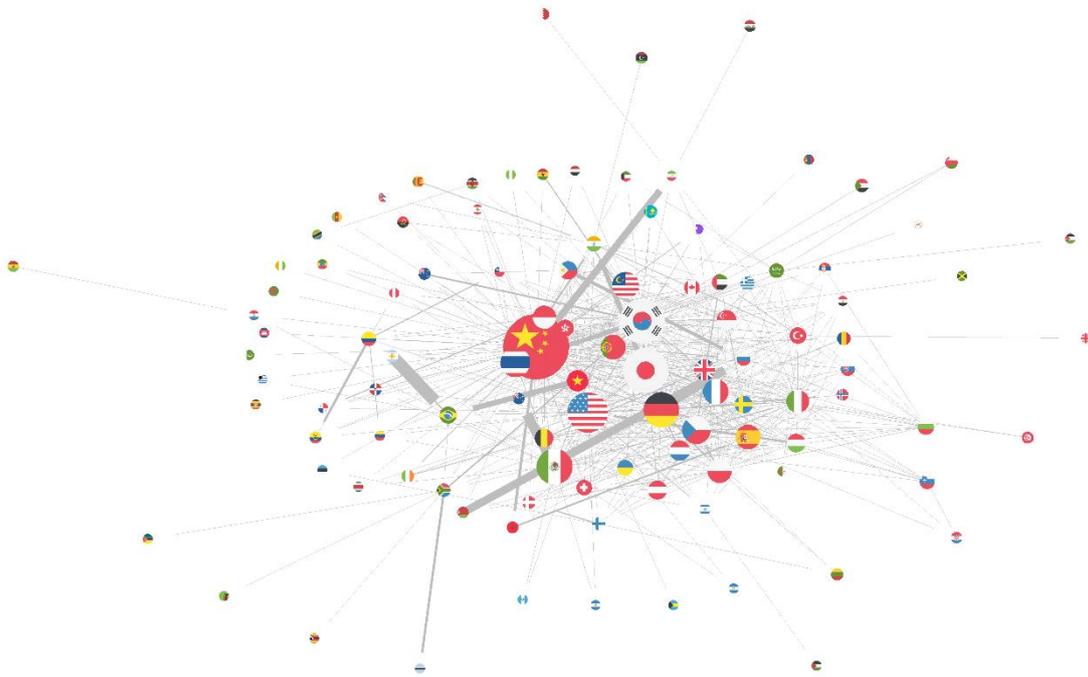


Figure 2 Electrical Parts ITN 2018

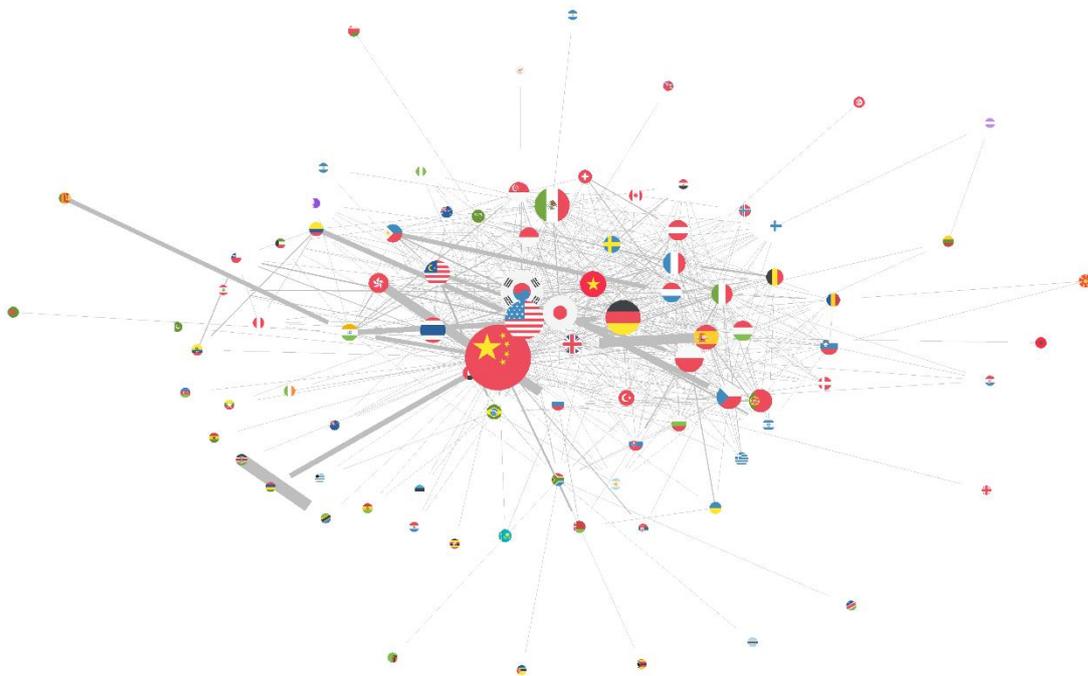


Figure 3 Engines ITN 2013



Figure 4 Engines ITN 2018

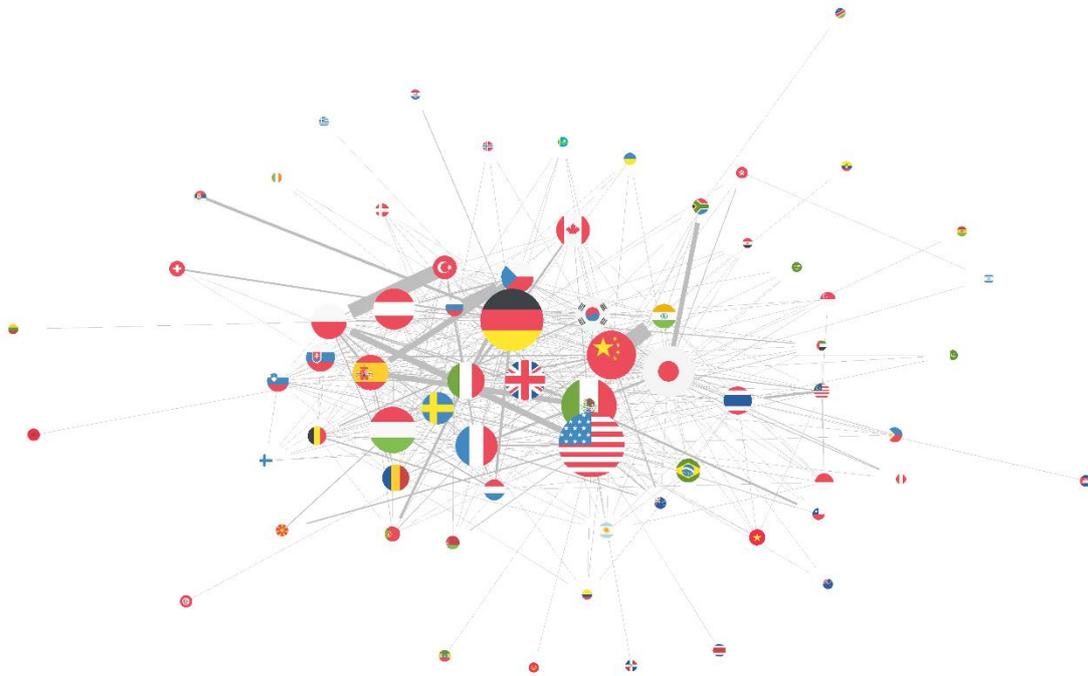


Figure 5 Rubber & Metal ITN 2013



Figure 6 Rubber & Metal ITN 2018

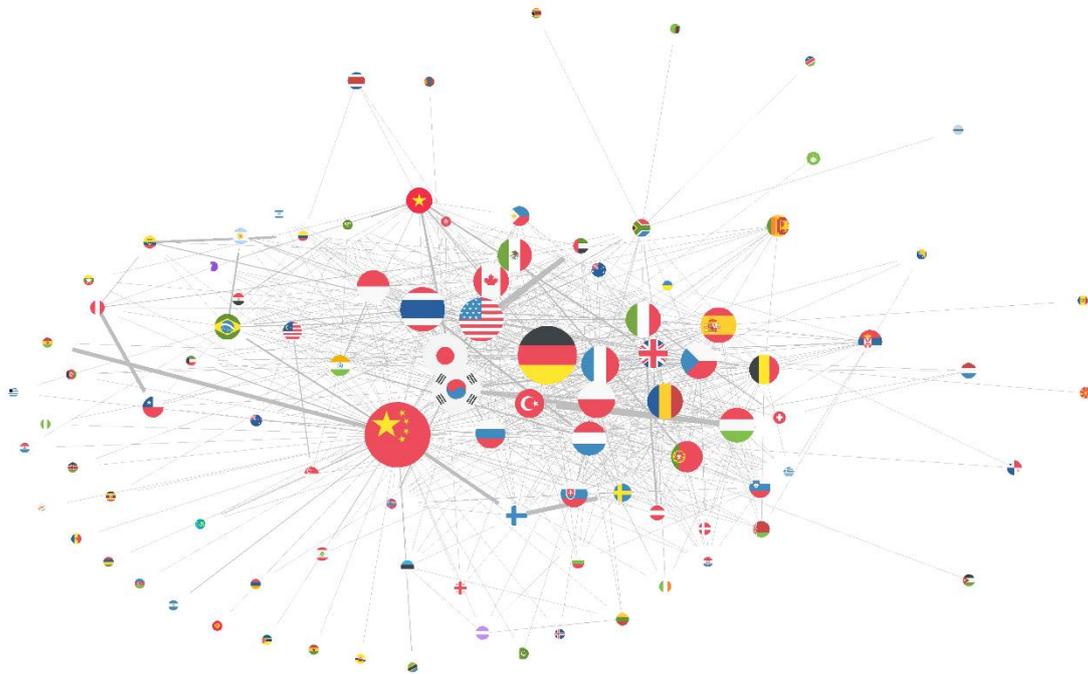


Figure 7 UK GF Roles for 2013 & 2018

