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The Fragmentation of Production and the Competitiveness of Nations in the Automotive Sector – A Network Approach

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Abstract

In recent decades the organisation of production has changed, with production and manufacturing activities no longer taking place in a single location, with lower transportation and communication costs leading to production activities geographically spread out into a global value chain. This reorganisation and fragmentation of the production process has led to increased sources of competition at the international level, with many firms from industrialised nations increasing their level of outsourcing and off-shoring of lower value activities to developing countries. Along with the increase in outsourcing activities, many industrialised nations are also now facing increasing competition from developing countries, who are steadily developing capabilities, in which industrialised nations once held a firm competitive advantage. This paper makes use of network analysis of the international trade network to analyse the competitive level of countries in the automotive industry, and to answer the research question of to what extent is the competitiveness level of a country determined by its position within the international trade network. The application of the temporal network autocorrelation model (TNAM) will be used to answer this question, this is an advanced statistical method that provides a highly flexible framework to model the competitiveness of nations embedded in an international trade network.

1. Introduction

Policy makers have long had concerns over the competitiveness of nations, along with specialisation patterns in prominent industries. In recent decades the nature of these concerns has shifted due to the changes in the way production and trade is structured, particularly the dispersion of production across national boundaries (Lall, 2001). Lower transportation and communication costs have led to production activities geographically spread out into global value chains (GVCs), with a rise in the trade in intermediate goods overtaking trade in final goods (Miroudot et al, 2009; Jones et al, 2005; Helg & Tajoli, 2005; Yeats, 2001).

Helpman (2006) noted that the world economy has undergone a transformation in recent decades. One of the most prominent changes, with a number of implications for the competitiveness of nations, is the increased activity of MNEs and changes to their organisational form. These include the increased use of international sourcing strategies in the coordination of their global supply chains (Helpman, 2006), where outsourcing business functions in a disintegrated production process is becoming a defining characteristic of the global economy (Grossman & Helpman, 2005).

The globalisation of industries, increased levels of outsourcing and global production sharing have intensified international competition. International production sharing provides the opportunity for developing nations to participate in GVCs; rather than developing capabilities to manufacture a product in its entirety, nations can focus on specialising in certain business functions or slice of the supply chain. Participation in complex supply chain activities can potentially provide a number of economic benefits, such as facilitating market access and capability-building through learning (Bernhardt & Pollak, 2015; Cattaneo et al, 2013; Pietrobelli & Rabellotti, 2007).

The rise of global supply chains has triggered a number of concerns amongst policy makers from developed countries, where there has been a fear of job losses due to international outsourcing activity (Park et al, 2013). For instance, the fragmentation of production has led to many firms from developed nations to increasingly outsource and offshore lower value activities to emerging economies (Baldwin, 2012). This has provided the opportunity for a number of developing countries to participate in the production process, often acting as key suppliers in the global supply chain. The expansion of GVCs across industries has deepened the level of integration of so called emerging giants (such as China and India) in the international division of labour (Curtis & Ciuriak, 2010). For instance, China has become a dominant player, at the centre of East Asian production networks, often acting as global workshop. This has generated further concerns, as many industrialised nations are now facing increasing competition from emerging economies, who are steadily developing capabilities where industrialised nations once held a strong competitive advantage (BIS, 2010; Linares-Navarro et al, 2014).

These changes are particularly evident in the automotive industry, where emerging economies have become key suppliers in the sector (Amighini & Gorgoni, 2014; Blázquez & González-Díaz, 2015). Along with a shift of production activities to emerging economies in this sector, there has also been an increase of internationalisation activities of automakers from developing nations, enhancing their capabilities through a number of high level acquisitions. The financial crisis provided the opportunity for auto firms from developing nations to acquire distressed auto firms from the West (Sturgeon & Van Biesebroeck, 2011). These acquisitions have been particularly evident from Indian and Chinese firms. For instance, in 2010, Geely, a Chinese firm, acquired Ford's Swedish car maker Volvo in a $1.8 billion deal (The Economist, 2010). And in October 2008 includes India's Tata Motors purchased Jaguar and Land Rover from Ford for $2.3 billion (The Economist, 2008).

Globalisation can have a number of economic benefits, such as a positive impact on productivity (Kowalski & Büge, 2013), yet the short term costs of globalisation and international outsourcing, such as plant closures and job losses, are much more visible (OECD, 2008). Therefore, the increased level of integration of emerging economies in the production process is often associated with a negative public opinion towards globalisation (in Western economies). This subsequently often generates calls for protectionist policy from public figures, where political actors are reluctant to be on the wrong side of public opinion regarding trade and globalisation issues (Winslett, 2016). This is often exacerbated by media portrayals of international trade as a struggle between nations, rather than reconfigurations of supply chains that may actually enhance national competitiveness. This suggests a need for more accurate presentations of these processes.

1.1. Statement of the Problem

Rapid globalisation in past decades and the subsequent reorganisation of production has affected national competitiveness, in terms of how it is viewed, appropriate measurement and the drivers of competitive performance (Biggeri, 2007). For instance, complex international sourcing strategies play an important role within GVCs, where access to intermediate inputs are vital in order to develop an competitive offer of goods (Andersson, 2015). Therefore, access to foreign suppliers can potentially allow for the expansion of exports and to better compete in international markets. This contrasts to the more typical view of national competitiveness, where imports (either intermediate inputs or final goods) are viewed as a source of foreign competition (Cattaneo et al, 2013). However, in order to expand the value added in various stages of production, there is a need to increasingly import a higher level of intermediate inputs. This highlights the need to better explain the performance or competitiveness of a country in a sector characterised by a disintegrated production process.

Given the increased levels of interdependence observed in the organisation of production in the global economy, there is a need for a systemic approach to assess national performance in industries characterised by an internationally fragmented production process. Baldone et al (2007) highlight that the reorganisation of production raises the issue of whether typical measures of comparative advantage and traditional approaches to model the determinants of competitiveness are still suitable. They question whether these indices and statistical approaches are still well equipped to provide a sufficient overview of the realities of national performance in the world today. Therefore, traditional approaches and methodologies used to support decision-making on competitiveness issues are potentially inadequate in the light of the structural changes that characterise production today. The rise of GVCs presents the need for a new perspective to investigate the competitiveness of nations, as GVCs shape the comparative advantages of countries (Amador & Cabral, 2015).

A typical approach when investigating national competitiveness is to examine the profile of a single country, mapping a competitive index for a product or sector (for example Havrila & Gunawardana, 2003; Cooper, 2006). Cattaneo et al (2013) highlight that when investigating trade and competitiveness, the single country level is no longer appropriate; that the nature of trade today is complex, and that there is a need to undertake an analysis at the global level. They emphasise that a systemic perspective is necessary, given production no longer takes place in a single location, a country cannot be competitive in isolation, rather it must develop efficient[1] links with other nations.

1.2. Aims & Objectives

This study aims to present an alternative framework to assess the competitiveness of nations in an industry characterised by a fragmented production process: the automotive sector. The automotive sector represents an industry characterised by a high level of fragmentation and is considered an important sector by policy makers in terms of its contribution to the economy and political value. This paper employs a relational modelling approach to better identify the determinants of competitiveness in a complex, disintegrated global supply chain. This relational approach provides a more systemic method to model national competitiveness, as it allows us to focus on the impact of network effects on international performance; more specifically the impact of a nation developing efficient linkages and having access to foreign suppliers.

It is argued that network analysis can help provide a systemic and global perspective, assuming interdependencies between countries. This paper makes use of a network perspective, analysing the network of disaggregated trade data, which can be used as a proxy for production (Amighini & Gorgoni, 2014). In terms of international trade, a network is defined as a set of nations, linked by directed trade ties.[2] This work makes use of a longitudinal network model in order to assess the competitiveness patterns of nations on the basis of their position in a network of international trade and the competitiveness of trade partners.

Additionally, the disintegration of production has resulted in a shift in the level of analysis used to examine production patterns. As the supply chain is segmented into various functions, where individual components are manufactured in various production sites spread out across the globe, the macro sector approach is no longer suitable (Baldwin & Robert-Nicoud, 2014). Therefore, this paper makes use of the more appropriate product level of analysis, in order to assess the competitiveness of nations in various component groups of the automotive sector.

[1] In this paper, the term "efficient" is applied in line with the GVC literature, as observed in the work of Amador & Cabral (2016), Cattaneo et al (2013) and Werner et al (2014). In these work, efficient linkages describe the effective exchange of intermediate inputs (rather than in economics where the term "efficient" is associated with optimal allocation of resources).

[2] Where a tie from nation *i* to nation *j* would indicate that *i* exports to *j*. These ties may be considered binary, which would simply indicate the presence or absence of a trade tie, or weighted, where the tie captures the value of trade between the two nations.

A number of studies assess the trade competitiveness of countries through comparing global trade shares and export performance indices (such as Ishchukova & Smutka, 2013 examining Russia's agricultural sector and Dieter & Englert, 2007 investigating Germany's timber industry). Although mapping the individual performance patterns of a country is a useful and often insightful task, the approach does have a number of limitations. For instance it does not specifically account for the position of a country in regards to other nations and trading partners (Montalbano & Nenci, 2014). A relational, network approach provides an alternative method to overcome these limits, assuming interdependency between nations, rather than examining performance patterns individually, independent of other countries.

1.3. Contribution & Research Questions

This paper intends to provide a contribution to the literature on international competitiveness, specifically to analyse the competitiveness of nations in a fragmented production process, more specifically the automotive industry.[3] A range of scholars have made attempts to link fragmentation of production to indices capturing the performance of nations (specifically within the GVC framework). However, these are chiefly concerned with comparing indices (such as the revealed comparative advantage) based on export data with world Input-Output (I-O) tables at the aggregate level (Benkovskis & Wörz, 2014; Brakman & Van Marrewijk, 2016; Ceglowski, 2015), rather than addressing the underlying determinants of high performance in a sector characterised by a disintegrated production process.

This paper provides the opportunity to test not only how country characteristics influence the performance of nations, but also how a nation's structural position and linkages to other nations influence its competitive performance in the sector. Kinra & Antai, (2010) highlight a shift in perspectives when considering the topic of competitiveness, with the increasingly popular usage of the structural paradigm to address the competitiveness phenomena.

This paper asks a number of research questions regarding the structure of international trade and the competitiveness of nations in the automotive sector; a sector with high level of political and economic value, therefore investigating competitiveness patterns in this sector is particularly important.

[3] In this paper the terms competitiveness and performance interchangeably; it is beyond the scope of this paper to provide a discussion on whether an assessment of export performance is consistent with the notion of competitiveness.

The automotive industry is considered an example of a global industry, with production sites worldwide, yet a number of features have influenced the geographical structure of the sector and point towards the rise of regional production networks. The high political value of the industry has influenced policy and therefore encouraged automakers to "build where they sell" – encouraging final assembly to take place at the local or regional level (Sturgeon et al, 2009). Furthermore, the varying technological content and types of components involved in production have led to different strategies being employed at different stages of the automotive GVC. For instance, components with high weight to value are often expensive to transport, therefore production of these components is coordinated at the regional level (Athukorala, 2009).

The following research questions arise:

1. To what extent is a country's economic performance in the automotive sector determined by its position in the international trade network?

2. Is the economic performance of a nation in the automotive sector influenced by the performance of its trade partners? Are nations more likely to become competitive if they trade with competitive nations?

3. To what extent does a nation's role at the regional level effect its economic performance in the automotive sector?

The first research question provides the opportunity to assess whether a nation with a particular trading profile is more likely to become competitive. More specifically, this allows us to assess the impact of having access to intermediate inputs through foreign suppliers on a nation's competitive performance in automotive sector. The second question allows us to investigate whether creating efficient linkages to competitive nations affects a country's economic performance in the automotive sector. The third research question considers regional trade patterns in the automotive sector, in particular, whether the position of a nation within its region affects international economic performance in the automotive industry. Given the importance of regional production networks in this sector, this emphasises the need to examine the interplay between the position a country holds in a region and national competitiveness in the automotive sector.

This paper makes use of an advanced network model to answer these research questions; a longitudinal extension of the network autocorrelation model, the Temporal Network Autocorrelation Model (TNAM), which allows us to model the performance of nations on the basis of their position in the international trade network (ITN) and country attributes over time.

This paper builds on the work of Amighini & Gorgoni (2014) and their network analysis of the reorganisation of production in the automotive sector. Amighini & Gorgoni (2014) make use of a descriptive analysis of various component networks characterising the automotive sector to address a number of research questions. They provide an assessment of whether production of each component is more regional or global. They utilise the network approach to identify key nations in the production of each component, specifically the rise of emerging economies as suppliers in the industry and the subsequent changes to the structure of the networks.

This paper utilises the same product classifications outlined by Amighini & Gorgoni (2014) to create four network groups in order to utilise the more appropriate component level perspective when investigating a sector characterised by a fragmented production process. These component groups include Electrical parts, Engines, Rubber and Metal components and Miscellaneous parts. This paper extends the approach by Amighini & Gorgoni (2014) by additionally considering the commodities that characterise final goods production; assembly and distribution of final automotive goods differs from parts and components, as the former is constrained by high political sensitivities and assembly still plays a crucial role in the automotive sector (Túry, 2014). The definition of the final goods product group is taken from Blázquez et al (2013).

The paper proceeds as follows: the next section reviews the literature on international competitiveness, including a survey of competitiveness measures utilised in various studies. This is followed by an overview of the automotive sector. Section four then presents the data utilised in constructing the trade network and the performance indicators. Section five outlines the method and model specification applied in this paper. Section six presents the results of the TNAM and directly addresses the research question of to what extent a nation’s performance or competitiveness depends upon its position in the ITN. The final sections discuss the results and provide a number of concluding comments.

2. Literature Review

The concept of international competitiveness has attracted considerable scholarly attention in past decades. A number of strands of literature have emerged to tackle the complex topic of international competitiveness; ranging from the development of theoretical frameworks (such as the work of Porter, 1990) to a discussion of whether competitiveness is even a relevant concept in a macroeconomic context (Krugman, 1994; Mulatu, 2016).

The review presented in this section covers a number of areas of the literature concerning international competitiveness. Firstly, given that international competitiveness is an elusive concept (Neary, 2006), a survey of various international competitiveness indices, along with subsequent critiques and developments are presented. Secondly, a brief overview of empirical studies assessing the economic performance of nations, (either from a single country or sectoral perspective) is presented. However, it is not the purpose of this paper to provide an exhaustive review of all determinants of national competitiveness in all settings.[4] Rather this part of the review will highlight the key strategies employed in empirical work examining the trade performance of nations, along with work establishing a link between the fragmentation of production and national competitiveness. Thirdly, a stream of literature investigates the rise of emerging economies, in particular the BRIC economies,[5] and whether they pose a threat to the competitiveness of both industrialised and developing nations. Therefore, a brief overview of the international competitiveness literature studying this phenomenon is presented. The review will conclude with an examination of the extant literature employing network analysis to investigate the interplay between the position of countries within the ITN and economic growth.

2.1. Survey of National Competitiveness Measures

Policy makers often make use of international competitiveness indices to benchmark economic performance, where these indices allow them to evaluate inadequacies, in order to reallocate resources to strengthen areas and develop capabilities (Lall, 2001). However, measuring the economic performance and competitiveness of a country is a notoriously difficult task, given the range of contexts in which the term can be applied (Reis & Farole, 2012; Fertő & Hubbard, 2003; Waheeduzzaman & Ryans, 1996). There are a number of definitions of international

[4] See Delbari et al (2015) for a more in depth review of international competitiveness research, along with the most influential works within the subject area.
[5] Brazil, Russia, India and China

competitiveness; at a broader level, this includes the extent to which all citizens experience a satisfactory and growing standard of living (Tyson, 1992). Alternatively, in purely macroeconomic terms, international competitiveness is often regarded as an exchange rate issue (as highlighted by Huggins & Izushi, 2015 and Mulatu, 2016). Furthermore, the term competiveness if often used interchangeably with concepts such productivity and innovation-driven indicators of performance (Carayannis & Grigoroudis, 2014).

A number of scholars even question the relevance of considering competitiveness at the country level; amongst the most vocal is Krugman (1994).[6] Regardless of the scepticisms concerning national competitiveness, it is unlikely that policy makers will disregard issues of competitiveness and benchmarking the economic performance of nations (Fagerberg et al, 2007). They will continue to ask questions such as why do some countries have a better trading performance than others? What policies should be proposed to improve the relative economic performance of a nation?

A range of composite metrics have been developed to capture the competitiveness of nations (see Reis & Farole, 2012 for an overview of these metrics); one of the most widely applied and utilised by policy makers is the Global Competitiveness Index (GCI) developed by the World Economic Forum (WEF, 2015). This is a broad measure which assesses the competitiveness of nations on the basis of twelve pillars comprising of over a hundred individual components including both macroeconomic and micro business aspects. These twelve pillars are split into three groups: (i) basic requirements (such as infrastructure), (ii) efficiency enhancers (such as higher education and technological readiness) and (iii) innovation and sophisticated factors. In the formulating of the GCI for a country, the set of pillars within each group are weighted depending on development levels. Where the pillars and components in the first category will receive a higher weight for countries with lower development levels and the third category will be assigned an increased weight for advanced nations with greater development levels (Dusa, 2014).

The work of Porter (1990) provides the underlying theoretical base for the GCI. Porter (1990) introduces a diamond model, which emphasises four interlinked areas influencing the

[6] See Dunning (1995) and Krugman (1995) for further details regarding the debate on whether it is appropriate to discuss competitiveness at the country level.

competitiveness of a nation[7]: factor conditions, demand conditions, related and supported industries and firm strategy, structure and rivalry. The approach emphasises that to improve the competitive performance of a nation there is a need to support one of the diamond points in an industry, such as through the use of subsidiaries to firms, tax breaks and educational policies.

Although the diamond approach is frequently applied in empirical studies, and has a broad appeal to policy makers, it has been critiqued and extended by a number of scholars. Amongst the most prominent is the work of Rugman & D'Cruz (1993), noting the original model is not applicable to all nations, in particular small, open economies. A set of further limits have also been recognised; amongst them is the level of analysis. Porter (1990) continually shifts between firms, industries and nations when discussing the conceptualisation of national competitiveness, often focusing on the ability of firms and industries in the 'home base' to gain large shares of the global market (Davies & Ellis, 2000). The overlap of conceptual levels with various degrees of disaggregation has resulted in further ambiguity regarding definitions and measurements of competitiveness (Congdon, 1990). A further aspect critiqued is the notion of 'home base', which does not necessarily allow the role of FDI to be included within the analysis. Additionally, the rivalry aspect of the diamond model is also focused on the home base (and is rather difficult to fully measure), neglecting that rivalry also exists at the global level when competing in international markets (Wezel & Lomi, 2003). In a globalised world, in order to fully assess national competitiveness, international features must be incorporated into the analytical framework (Cho et al, 2008).

Regardless of the criticisms of the work of Porter (1990), the GCI metric remains popular amongst policy makers. However, the measure itself is also not without controversy and criticism; in particular, Lall (2001) outlines the deficiencies of the measure, specifically its methodological and quantitative weaknesses. In the context of the reorganisation of production, the ability to remain competitive in a certain function or stage of the production network is a more appropriate level of analysis (Athukorala, 2009). Therefore, the composite GCI's relevance in assessing a nation's performance is somewhat limited. Cinicioglu et al (2012) demonstrate that the composite index developed by the WEF is not an ideal measure in the

[7] Hence referring to the model as a "diamond" with four points.

automotive sector; where they identify only 15 of the 111 components of the measure relevant to the automotive industry.

The Institute for Management Development (IMD) have also developed a competitiveness index, which shares a number of conceptual features with the GCI; it is also composed of a large number of sub-indices based on hard and soft data (IMD, 2012). This leaves the index subject to many of the same criticisms and weaknesses of the GCI; furthermore, it is also limited in term of coverage, where it is only available for 59 countries.[8]

The UN Industrial Development Organization (UNIDO) have developed a composite index to capture to the industrial performance of nations for cross-country analysis, the Competitive Industrial Performance (CIP) index (UNIDO, 2002). The CIP provides a measure to capture the manufacturing *potential* of nations. It is composed of eight sub-indices, which can be grouped into three categories: firstly, capacity to produce and export manufactures, secondly, technological deepening and thirdly, upgrading and world impact. The function of the CIP index is to provide a tool for identifying potential problem areas, acting as a policy aid when assessing the broad features of the economic system (Andreoni, 2013).

Although these single composite measures of competitiveness attract a number of criticisms, especially regarding whether a single aggregate measure can fully capture the notion of competitiveness across sectors, they still remain popular with policy makers. A single aggregated measure is often preferred in benchmarking exercises.

Along with competitiveness indices developed by international organisations, trade-based measures are often applied to assess a nation's economic performance. Trade has long been used as a measure of national economic performance, with an early definition of national competitiveness given by Scott & Lodge (1985:3), describing it as "a country's ability to create, produce, distribute and/or service products in international trade while earning rising returns on its resources". Although the notion of competitiveness is approached as a separate topic in International Business and Economics (IBE), it has its roots in international trade theory.[9]

[8] See Carayannis & Grigoroudis (2014) for a detailed overview of the IMD's measure of competitiveness, the GCI and a number of other competitiveness indicators.
[9] See Kordalska & Olczyk, (2014) for a discussion of the determinants of export performance based on a range of theoretical perspectives and Waheeduzzaman (2011) for an overview of the key conceptual works examining the broad macro aspect of competitiveness.

Although the notion of competitiveness is approached as a separate topic in International Business and Economics (IBE), it has its roots in international trade theory.[10]

The concept of competitiveness has a strong association with theories of specialisation, such as the classic theory of comparative advantage.[11] Comparative advantage refers to when a nation can produce a good in which the opportunity cost of producing the good is lower in comparison to other nations, therefore this theory is applied to explain patterns of specialisation and trade at the sector level (Ricardo, 1891). However, as there has been a rise in trade in intermediate goods, where offshoring business functions is a common practice in the production process, Grossman & Rossi-Hansberg (2006) note there is a need to move away from typical approaches focusing on final goods. In relation to the notion of competitiveness, Cho & Moon (2000) note that the theory of comparative advantage is somewhat incomplete; it is able to highlight differences in productivity levels between countries, but unable to fully explain why these differences exist.

An alternative theory to explain patterns of specialisation that was developed to complement and build on the theory of comparative advantage is the Heckscher – Ohlin (H-O) theory. The H-O theory notes that differences in a nations' factor endowments, such as labour and capital, determine specialisation and trade patterns (Helpman, 2011). However, the empirical evidence supporting the H-O theory is somewhat mixed, suggesting that factor prices alone do not determine international trade and specialisation patterns (Grimwade, 2003). Furthermore, as production has become increasingly fragmented, a finished product is not simply the result of the factor endowments of a single nation, rather all those participating in the production process (including those manufacturing intermediate inputs). When examining the performance and specialisation of nation in specific industries, the fragmentation of production has distorted many aspects of the concept of comparative advantage; emphasising the need to complement these theories with alternative approaches to better understand the competitiveness of nations in disintegrated global supply chains (Baldone et al, 2007).

[10] See Kordalska & Olczyk, (2014) for a discussion of the determinants of export performance based on a range of theoretical perspectives and Waheeduzzaman (2011) for an overview of the key conceptual works examining the broad macro aspect of competitiveness.

[11] Siudek & Zawojska (2014) provide an overview of how the concept of competitiveness links to a number of theoretical frameworks.

Nevertheless, trade-based measures still provide a number of insights into the global performance of nations.

One of the most widely applied measures to capture the trade performance of nations is the Revealed Comparative Advantage (RCA) index, as developed by Balassa (1965). The RCA is a measure which captures the ratio of a nation's export share in a sector compared to the average export share of the sector.

But whilst the RCA captures relative export performance, it can differ greatly from sectoral export performance. Haar (2014) demonstrates that there is a clear discrepancy between the level of exports in a sector and whether a nation holds a comparative advantage; industries where a nation holds a comparative advantage are not necessarily the industries that export large volumes.

Numerous scholars have undertaken research regarding the RCA index, such as its ability to capture the theoretical concept of comparative advantage (Deb & Hauk, 2015) and various transformations applied to improve certain properties of the measure (Amador et al, 2011). For instance, the raw RCA index can be transformed in order to gain an RCA measure with a symmetric distribution in order to ensure the distribution is stable so that values can be compared over time (Laursen, 2015).

Although this measure is frequently applied in empirical studies to assess the competitiveness of a nation, and its performance in a particular sector, there is a need to question the extent to which the RCA is consistent with the notion of competitiveness. The RCA is a relative measurement which captures the performance of a product within a country; whereas the notion of competitiveness (especially in policy terms), requires a cross-country comparison of their performance in a product group (Lafay, 1992). When the RCA is utilised in a cross-country analysis, large differences in the size of nations can result in various issues, such as assigning a higher weighted RCA score to smaller nations.

Furthermore, a number of scholars question whether the RCA is suitable in assessing the performance of nations in a fragmented production process. Amongst them is the assessment of the index by Baldone et al (2007:1762), where they note that the disintegration of production "blurs the concepts of comparative advantage as we know it".

The calculation of the standard measure of RCA based solely on gross exports, has led to a number of scholars questioning the extent to which a single flow measure can provide an assessment of a nation's performance in international trade. Iapadre (2001) provides an overview of a set of net trade indicators and argues that these are more suitable in defining the performance of nations. However, whether net balance measures are appropriate for assessing performance in a sector characterised by a disintegrated production process is debateable, as they assume imports are a negative effect (Guerrieri & Vergara Caffarelli, 2012). On the other hand, importing intermediates for re-processing and further export is a fundamental element of the global supply chain.

One commonly used, simple net trade measure is the normalised trade balance, which is the ratio of the trade balance of a nation (in an industry) to the nation's total trade (in the industry). However, when examining highly disaggregated trade data the use of this measure may be misleading, given high values (i.e. the extreme), may simply indicate a nation which exports very little, yet does not import. This would suggest a high performance in the industry, yet in reality may simply indicate that it is not a key participant in the sector (Andreoni, 2013).

Vollrath (1991) suggests the need to incorporate imports into the calculation of the RCA, and offers an alternative, the Relative Trade Advantage (RTA). The RTA is the revealed export advantage (RCA) minus the revealed import advantage (RMA)[12] of a country. If the RTA is greater than zero, this indicates that a nation has a relative comparative trade advantage, that is a nation is relatively more competitive in the sector in terms of its trade profile. The RTA is not without criticism; as noted by Vollrath (1991), the RTA shares some of the limitations of the RCA measure, in particular that it is sensitive to small (or non-existent) export or import values.

Bojnec & Fertő (2012) highlight the interdependencies between comparative advantage measures and other (typical) country competitiveness measures. They identify a high level of consistency between the RTA and trade competition indices, such as the trade balance, price competitiveness and the unit value of exports.

A further alternative to the RCA is the Lafay Index (Lafay, 1992), which takes into account both export and import trade flows. This alternative measure complements the RCA in terms

[12] The RMA is calculated in the same way as the RCA, but for imports.

of its ability to control for intra-industry trade, by accounting for the difference between export and import flows (the normalised trade balance) in its calculation. Positive Lafay values indicate specialisation whilst a negative value points towards de-specialisation patterns (Zaghini, 2005). This index establishes whether a country has a comparative advantage based on trade balance in the sector weighted by a country's overall trade balance. This measure of trade performance has been utilised in a number of studies, amongst them Ferrarini & Scaramozzino (2015) and Alessandrini et al (2011).

Although the RCA and related measures have their limits, they are still widely applied in policy related works (such as Beltramello et al, 2012; BIS, 2012a), due to their intuitive appeal (in terms of interpretation) and straightforward calculation process.

In the context of a sector characterised by a disintegrated production process, the value of trade balance measures to assess performance (such as those outlined in this section) is debateable. In a fragmented production process, a trade surplus is not necessarily superior to a deficit (Haar, 2014). Where in a fragmented production chain, nations often import a high level of intermediate inputs for further reprocessing and export in order to remain competitive and expand on the value of downstream production stages (Cingolani et al, 2015). This suggests that further work is required to develop a measure to better assess performance in sectors characterised by a fragmented global supply chain.

2.2. National Competitiveness Empirical Studies

In this subsection, there is a focus on trade-based measures, given that composite indices such as those developed by the WEF and IMD are not necessarily suitable in the context of a sector characterised by a fragmented production process. As competitiveness is a complex concept, with numerous definitions and indices, the determinants vary widely depending on the setting and measurements employed (Siudek & Zawojska, 2014).

For instance, Delgado et al (2012) argue that competitiveness (defined at the broader level) is shaped by three key factors: social infrastructure, fiscal policy and microeconomic conditions. By contrast, Kordalska & Olczyk (2014) note that export competitiveness is determined by a range of other country characteristics, including levels of demand (both foreign and domestic), trade openness, investment intensity and labour productivity. This highlights that the perspective and measurement of national competitiveness can impact results regarding key determinants.

An approach frequently observed in the literature empirically examining the topic of national competitiveness is to map an index for a single nation over time for multiple or individual sectors, noting how a country's performance in certain industries have improved or weakened. For example, Gnidchenko & Salnikov (2013) map the competitive position of Russia and Havrila & Gunawardana (2003) examine Australia's textile industry over time. The use of a comparative approach rather than statistical modelling arises from the metrics available, as many are not suitable in cross-country analysis, including the RCA, perhaps the most widely used metric for international competitiveness.

The use of the RCA as a comparative tool to examine the national competitiveness of nations is well documented in a number of industries; amongst them the argo food (Fertő & Hubbard, 2003; Bojnec & Fertő, 2009, 2015; Serin & Civan, 2008; Latruffe, 2010) and textile sectors (Chi et al, 2005; Hanif & Jafri, 2008; Lau et al, 2009).

A potentially more fruitful approach to analysing international competitiveness is consideration of the relationship between international inputs and outputs by industry. Timmer et al (2013) describe how the World Input-Output Database (WIOD) can be utilised in measuring the competitive performance of nations, demonstrating its use in analysing Germany's automotive sector. Timmer et al (2014) recognise the value of the RCA concept, in terms of its direct and clear interpretation, and so make use of the WIOD to calculate a nation's RCA of Global Value Chain incomes. A higher value indicates that a nation has a higher share of GVC income in the sector compared to its overall share of GVC income. A number of studies have built on this approach, with Ceglowski (2015) and Brakman & Van Marrewijk (2016) providing a detailed comparison of RCA measures based on Input-Output (I-O) data to those based on gross exports.

The use of GVC incomes provides a novel way to assess the competitiveness of nations participating in global supply chains; nevertheless, it still has a number of limitations. It is limited to the coverage of the I-O datasets, which considers sectors at a high level of aggregation, along with reduced coverage in terms of nations and years (especially when compared to standard international trade datasets). This limit becomes increasingly prominent when examining a sector such as the automotive industry, where the manufacture of the final product contains parts and components with widely differing technological content and production patterns. In a sector characterised by a fragmented production process, investigating the competitiveness and performance of the business function or product grouping is a more relevant and appropriate level of analysis. Timmer et al (2014) acknowledge that there is still much work to be done in terms of improving I-O data, in particular, a higher level of disaggregation is required to consider the heterogeneous trends characterising national competitiveness in manufacturing industries.

The link between the fragmentation of production and export performance has not been fully addressed in empirical studies (Guerrieri & Vergara Caffarelli, 2012). The work based on WIOD is primarily used to demonstrate the value of alternative metrics and datasets, than to fully assess the determinants of performance in a fragmented sector. Nevertheless, some scholars have analysed competitiveness with a link to the reorganisation of the production process. For instance, Athukorala & Waglé (2014) provide an assessment of the export performance of Georgia, noting that increasing involvement in production sharing allows a nation to specialise in certain slices of the production process and subsequently enhance its export performance; they identify that in the case of Georgia, it has not fully exploited the potential benefits associated with integration into global production networks.

Overall, the various empirical studies highlight the complexity and elusive nature of the competitiveness concept, where features of competitive performance are highly dependent on the context where they are applied (in terms of country and sector), and measurements utilised. Moreover, these studies suggest that there is scope to further explore the link between the fragmentation of production and the competitiveness of nations, especially in cross country analysis.

2.3. The rise of BRICs – a threat to competitiveness?

Although the rise of the emerging economies – more specifically the BRIC nations – is an important topic in the competitiveness debate, it is the rise of China (and to a lesser extent, India) as a dominant player in the global economy that has attracted the most attention (Paul, 2016; Qiu & Zhan, 2016), with many scholars questioning whether it is a threat to the competitive position of both industrialised nations (Vu, 2015) and other emerging economies (Lall et al, 2005; Jenkins & Edwards, 2015).

A number of scholars have dealt with the implications of the rise of China to other developing nations; more specifically its impact for the region (amongst them Lall & Albaladejo, 2004; Greenaway et al, 2008; Amann et al, 2009). Since China's accession to the WTO, it has expanded its export performance in labour intensive goods; this has raised concerns amongst other developing nations with a comparative advantage in these goods (Shafaeddin, 2004). More specifically, does China act as a competitor for other East Asian nations or is it an engine for export growth for its neighbours (Pham et al, 2016)? Nevertheless, this is a question that does not have a clear answer. Several scholars argue that China represents a competitive threat to the export performance of Mexico, along with the Latin American (amongst them Jenkins et al, 2008; Qureshi & Wan, 2008) and the East Asian regions (especially in low tech and resourced based industries); whereas Athukorala (2009) notes that the crowding-out concerns are highly exaggerated.

China's integration into the world economy and improved export performance has led to an increase in interest in the examination of the competitive dynamics of China in a number of sectors (Zhang et al, 2013). The performance of China has been analysed through various perspectives and measurements, such as the RCA (Shafaeddin, 2004; Zhang et al, 2013), the CIP index (Zhao & Zhang, 2007) and the trade balance index (Li et al, 2016). Additionally, a number of sectors have been analysed in further detail, amongst them the wooden furniture industry (Han et al, 2009) and electrical equipment sector (Lu, 2015).

Along with China, a further set of emerging economies have also been discussed, particularly India, focusing on the extent to which they present a challenge to developed economies. Qureshi & Wan (2008) investigate whether China and India act as complementary forces to nations in certain sectors, along with where they are competitors. In their work, they consider nations with a shared RCA in a product to be competitors, noting that China presents a challenge to industrialised nations in medium to high tech products. Montalbano & Nenci (2012, 2014) further analyse RCA patterns to highlight the competitive or complementary nature of the rise of China, India, Brazil and South Africa, noting that amongst these nations, China presents the most prominent challenge to the performance of advanced economies.

2.4. Network Analysis & Economic Growth

There is a great deal of extant literature applying network analysis to analyse the ITN; along with a number of studies examining the economic growth of nations from a relational perspective.

One stream of literature that has highlighted and empirically tested the relationship between the economic performance of nations and the position in the ITN, is work of World System theorists employing Social Network Analysis (SNA) techniques (amongst them Snyder &

Kick, 1979; Breiger, 1981; Nemeth & Smith, 1985; Smith & White, 1992; Mahutga, 2006; Mahutga & Smith, 2011). These works often test whether there is a process of unequal exchange occurring in the world system (or ITN), where nations in the periphery are excluded from the most profitable activities in the global economy, with wealth (or value) concentrated at the core (Lloyd et al, 2009). This stream of literature has highlighted that nations in the core occupy dominant positions, where nations in the periphery typically hold subordinate roles, constrained or dependent on relations with nations at the core.

Clark & Mahutga (2013) extend the world system hypothesis, testing whether a form of unequal exchange occurs across the core-periphery partitions of the global economy. They apply network analysis to test whether a nation's "trade centrality" can be enhanced or improved by trading with highly connected or isolated partners. They note that trade between nations occupying different positions in the ITN and the gains from these exchanges, are a result in differences in bargaining power; where nations in the core hold more favourable bargaining positions. They conclude that nations gain more from trade and have an increased trade centrality when they are involved in unequal exchanges with isolated trade partners.

A variety of studies outside of the world systems literature have utilised network analysis to investigate the link between the topology of economic networks and the performance of nations, such as economic growth and comparative advantage patterns. Amongst them is the approach formulated by Hidalgo et al (2007) examining the complexity of a nation's export basket and patterns of specialisation of certain products within a network perspective. This is operationalised through the creation of a bipartite network linking a nation to a product if it has a comparative advantage in the manufacture of that product (i.e. if the RCA is greater than or equal to 1). The bipartite network is then projected onto two one-mode networks; a country-to-country network, where nations are linked according to shared specialisation, and a product-to-product network, where products are linked when a country is specialised in both products. The latter provides the opportunity to ask research questions regarding the resulting "product space." For instance, this perspective allows the examination of country upgrading opportunities, as nations tend to upgrade to products that require similar specialisation capabilities (Hidalgo & Hausmann, 2009; Kali et al, 2013). However, while providing an insight into product proximity and specialisation patterns, this does not allow for a consideration of the interplay between trade structure and patterns of performance.

Hidalgo & Hausmann (2009) utilise this relational framework to develop an Economic Complexity Index (ECI), building on the work of Hausmann et al (2006). This measure captures the complexity of a country's export profile, examining whether a country has the capabilities to manufacture complex products. A nation that is able to produce more sophisticated goods is better equipped to compete in a range of markets (Hausmann et al, 2014).

The development of these measures has resulted in a stream of literature devoted to examining the relationship between the complexity of a country's export basket and economic growth. This approach has been utilised to examine the patterns of a number of nations, such as China (Jarreau & Poncet, 2012), the Netherlands (Zaccaria et al, 2015) and Turkey (Erkan & Yildirimci, 2015). Further efforts have been made to extend and assess economic complexity metrics (amongst them Mariani et al, 2015; Cristelli et al, 2013; Tacchella et al, 2012, 2013). However, these approaches focus on the aggregate drivers of economic growth, rather than examining the drivers influencing a nation's ability to compete in a specific sector.

This review highlights the value of a relational approach to assess the economic performance of nations, however, there is scope to build on this work, assessing the extent efficient linkages in the ITN effect competitiveness, and the impact of specific network effects.

3. The Context – the Automotive Sector

The automotive sector is considered an important industry by policy makers, because of its significant contribution to employment, along with its high visibility (Sturgeon & Van Biesebroeck, 2011). The sector is considered of substantial importance, especially to industrialised nations; this is most evident in the US, where the auto sector and supporting industries account for a significant level of private sector jobs (Klier & Rubenstein, 2006). In the US, the sector is not only viewed as an important contributor to economic growth, but also represents a source of national pride, where the dominance of US automakers has been a significant feature of the economic landscape in past decades. During the 2007-2008 financial crisis, US automakers General Motors and Chrysler received a $17.4 billion bailout; reflecting the importance of the sector, and the significant potential political consequences of the demise of a major American industry (Financial Times, 2008; Klier & Rubenstein, 2013).

This sentiment is not limited to the US, many European nations also highly value domestically headquartered automakers; this was demonstrated in France, where the sector received a €6 billion bailout to support Renault and Peugeot-Citroen (Financial Times, 2009). Additionally, 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 representative a key challenge for the UK and its performance in the industry (Holweg et al, 2009; BIS, 2013).

The automotive industry is one of the most geographically fragmented sectors and has undergone a number of transformations in recent years (Türkcan & Ates, 2011). The trends and patterns characterising the production process of the automotive industry has been examined by a number of scholars applying a wide range of frameworks. For instance, the GVC framework has been employed to analyse the impact of the 2007-2008 financial crisis on the automotive value chain. Sturgeon & Van Biesebroeck (2010) noted that the financial crisis accelerated the growth and integration of developing nations into the industry, with the rise of emerging economy automakers through a number of significant acquisitions (such as China's Geely and India's Tata Motors). Furthermore, emerging economies are increasingly acting as important suppliers in the sector, with nations such as China and India further integrating into the automotive production network. China is increasingly acting as an important supplier of intermediate inputs to a number of leading automakers, including Japanese and Korean firms (Amighini, 2012).

A further area of study is whether production in this sector is regional or global. The automotive sector is often described as a 'globalised industry', yet production is centred on a number of key regional production blocs (Schlie & Yip, 2000; Domański & Lung, 2009). Pavlínek & Žížalová (2014) note that trade in parts and components (rather than final goods) is heavily centred on regions, especially North America, Southeast Asia and Europe. 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).

4. Data & Measures of Competitiveness

4.1. Data

Empirical fragmentation of production studies frequently utilise highly disaggregated bilateral trade data in order to map production patterns (Ng & Yeats, 1999; Yeats, 2001). This approach is followed in this study, making use of disaggregated trade statistics within the classifications of automotive components defined by Amighini & Gorgoni (2014), but supplementing these with final goods categories. By considering final goods trade networks, the behaviour of nations involved in the final stages of the automotive GVC is captured.

A network of final goods trade in the automotive sector was created based on the definition provided by Blázquez et al (2013), who make use of the gravity model to assess the effect of EU membership and specialisation levels on the integration of nations into the global automotive value chain. This definition was used by Blázquez & González-Díaz (2015) in an empirical network analysis of the automotive sector, examining a trade network of parts and components and a network of final goods. In a descriptive analysis of the networks for 1996 – 2009, they note consistent patterns between the structure of part and components and final goods networks. They identify regional tendencies, along with the networks becoming more integrated over time. In terms of specific nations, they note the rise of emerging economies taking key positions in the networks.

In this study, a boundary is applied to the network, only retaining trade ties which are at least 0.01% of world trade.[13] This is to ensure that only the most relevant ties (and countries) are included in the network, as weaker ties significantly increase network properties, such as reciprocity and density, yet contribute very little in terms of trade value. The networks are defined as a set of countries linked by trade, where the value of the ties indicate the proportion

[13] See appendix for percentage of world trade retained by applying this threshold.

of world trade (therefore the tie value must be at least 0.01). The network data was collected at six time points for each component group (1994, 1998, 2002, 2006, 2010 and 2014).[14]

The data utilised in the construction of the ITNs and the calculation of the competitiveness measures was obtained from UN Comtrade (extracted using WITS) for a range of product codes within the industry, as listed in Appendix A. A range of country characteristics and measures of competitiveness at the product level were collated as described below.

Country characteristics are included: GDP, GDP per capita, regional partition, exchange rates, factor endowments and infrastructure. In this paper, a proxy is defined to capture physical capital factor endowments, utilising a country's electrical power consumption/usage (Kwh per capita). This approach is utilised by Faustino & Leitão (2011) in their study on the determinants of vertical intra-industry trade in the automotive industry; testing whether vertical intra industry trade occurs more frequently amongst nations with different factor endowment profiles.[15] When examining an industry characterised by a highly disintegrated production process, service links play an important role. Service links include communication and transportation infrastructure levels, which capture the extent to which nations can participate in production sharing (Blázquez et al, 2013). Therefore, internet users per one hundred people is utilised to capture infrastructure levels of a country. Service links can also be captured through GDP per capita, where more affluent nations tend to have improved linkages.

4.2. Measures of Competitiveness

Given the complexity and ambiguity of the competitiveness concept at the national level, a single measure cannot be relied on, rather a variety of indices are employed to capture the performance of nations participating in various stages of the automotive sector. In this paper, a combination of standard and relational measures of international competitiveness are used.

The standard measures available include a number of trade based indices such as the RCA, RTA and variants of the normalised trade balance. Further measures are those provided by international organisations, such as the GCI and CIP metrics. In the context of the reorganisation of production, many of these indices become unsuitable, and lose much of their

[14] Descriptive statistics and visualisations of these networks are not provided here, rather these can be found in the works of Amighini & Gorgoni (2014) and Blázquez & González-Díaz (2015).
[15] This proxy for physical capital endowments is applied in a number of studies, amongst them Zhang et al (2005) and Hoan Thanh Phan & Young Ji Jeong (2014).

intuitive value. As noted by Baldone et al (2007), the fragmentation of production lessens the explanatory power of the RCA index. The RTA and other normalised balance measures experience a number of limitations in a sector characterised by a disintegrated production process, as they do not allow to capture the interplay between import performance (such as sourcing intermediate inputs) and the competitiveness of nations. For instance, the RTA is the revealed export advantage (RCA) minus the revealed import advantage (RMA), where the RMA is considered as measure of foreign competitiveness. Yet the RMA is often applied to reflect production sharing patterns, where holding a RMA points towards a nation specialising in assembly operations (Kim, 2002).

The GCI is not necessarily appropriate in capturing the manufacturing performance of nations, especially in a complex supply chain; as the composite index only provides a broad measure, not necessarily suitable to capture the performance of nations in the automotive sector (Cinicioglu et al, 2012).

The composite metric utilised in this study is the CIP; this measure captures the manufacturing potential of nations, therefore provides a more suitable index to capture the competitiveness of nations in an industry characterised by a fragmented production chain. Furthermore, this measure provides an alternative to those based solely on international trade data.

Grodzicki (2014) suggests that global interdependencies have made standard indices based on international trade data (such as the RCA) less appropriate. These interdependencies suggest that a relational measure of competitiveness may be more suitable when examining a fragmented production process. Network analysis provides a number of alternatives in assessing the performance of nations; providing a relational approach to capture the various roles of countries in the ITN.

A number of network measures provide a suitable representation of the competitiveness of a nation in the ITN, in particular centrality measures. Centrality measures capture the extent to which an actor holds a prominent position in the network (Borgatti et al, 2013), so provide a natural indicator of performance. Weighted out-degree centrality provides a measure of export performance in the sector, Magerman et al (2013) using this as a measure of international competitiveness. Out-degree centrality is a count of the number of ties an actor sends in the network, whereas in-degree centrality is a count of the number of ties an actor receives

(Freeman, 1978). In the context of the ITN, out-degree and in-degree centrality reflects the number of export and import ties of a nation respectively. Weighted out- (in-) degree centrality provides both a measure of the number of export (import) partners of a nation, as well as the contribution of these export (import) ties to total trade in the industry.[16]

A further index that can capture the performance of a nation is the hub score; this term has been discussed both in the network context and as an economic concept. In the economic context, the term hub is often used when describing the rise of China in the global economy, noting that it has emerged as a manufacturing 'hub'. Furthermore, Ferrarini (2013) notes that vertical trade is chiefly centred on a selection of hubs in the world economy: USA, Germany, Japan and China. The term hub has also been applied to capture the interdependence of a nation in the world or regional markets (Chen & De Lombaerde, 2014; Suder et al, 2015).

In network terms, an actor is considered a hub if it has a large number of outgoing ties pointed towards actors with high in degree scores. In terms of the ITN, a hub refers to a nation that exports to central and important markets; where a hub can be thought of as a 'factory of the world' (Deguchi et al, 2014).

A potential issue with using a network measure of competitiveness in a model that investigates whether performance is impacted by the position of a nation in a network is the potential correlation between network metrics, especially centrality measures. Centrality measures may be correlated, as they are all derived from the same adjacency matrix representing the network. However, Valente et al (2008:6) demonstrate that although these measures are correlated to an extent, this varies vastly from case to case, reflecting that centrality measures are "distinct, yet conceptually related".

In this paper we employ a number of measures of international competitiveness; these each present a slightly different interpretation of competitiveness. These measures include hub scores, weighted out-degree centrality (export performance), and the CIP index.

[16] See Opsahl et al (2010) for the formulation of weighted out and in degree centrality measures employed in this paper.

5. Methodology & Model Specification

5.1. Temporal Network Autocorrelation Model (TNAM)

An advanced network model is used to address the research questions presented in section one: the Temporal Network Autocorrelation Model (TNAM). Autocorrelation models have been frequently applied in Social Network Analysis (SNA), chiefly to model social influence and contagion patterns, with Fujimoto et al (2011:231) describing them as the "workhorse" for empirically testing for network effects on actor behaviour.

The autocorrelation model was first developed and applied to detect the presence of spatial autocorrelation, and its impact on a dependent variable (see Cliff & Ord, 1972).[17] In SNA, the autocorrelation model has primarily been applied to answer research questions concerning social influence, where the network captures the extent to which the behaviour of an alter impacts the behaviour of an ego (Leenders, 2002).

The model is applied by considering a weight matrix, W (the network), where w_{ij} reflects a tie between *i* and *j*, where the weight captures the extent to which actor *j* (the alter) influences the behaviour or performance of actor *i* (the ego). Leenders (2002) provides a detailed overview of the potential specifications of the weight matrix, chiefly in the social influence context.

The network autocorrelation model has been applied in a number of empirical settings, including academic performance (Vitale et al, 2016), the political sciences (Franzese & Hays, 2007; Franzese et al, 2012) and numerous social influence studies (amongst them Ibarra & Andrews, 1993; Fujimoto & Valente, 2012; Geng et al, 2015). Furthermore, the statistical power of autocorrelation model has been examined by a number of scholars; specifically dealing with potential estimation bias issues (Mizruchi & Neuman, 2008; Neuman & Mizruchi, 2010; Wang et al, 2014).

A number of alternatives to autocorrelation models exist to model attributes based on network structure. For instance, Robins et al (2001) introduce a social influence model based on the Exponential Random Graph Model (ERGM) family of models; this was more recently extended by Daraganova & Robins (2013) as the Auto Logistic Actor Attribute Model

[17] Variants of the network autocorrelation model have been developed in a number of subject areas, such as spatial econometrics, spatial statistics, along with SNA; although there is a level of overlap amongst these approaches, they have chiefly been developed in isolation (Hays et al, 2010).

(ALAAM). ALAAMs predict whether a node will possess a (binary) attribute based on the (binary) network structure. Within this model various local configurations are specified to investigate how patterns of ties may be associated with an attribute. Configurations include network positions, capturing the levels of activity in the network of nodes with the attribute, along with network attribute configurations, which capture the dependence between nodes with the attribute, such as contagion effects.

Tranmer et al (2014) present a Multiple Membership Multiple Classification Model, which shares a number of conceptual aspects with the network autocorrelation model, yet chiefly deals with estimating the level of variation in the outcome variable. Tranmer et al (2016) apply this model to a multilevel network of emergency departments (sub-units) embedded in hospitals (organisations) and patient transfer ties amongst them, in order to assess the variation of emergency department waiting times (sub-unit performance).

The network autocorrelation model has experienced a number of improvements and extensions in recent years. Leifeld et al (2014) developed a longitudinal extension: the TNAM. The TNAM provides a generalisation of the ALAAM, potentially for multiple time steps and any kind of outcome distribution. The model allows the researcher to capture a number of structural effects and how these impact the dependent variable. For instance, the centrality of actors; this allows us to test whether actors in the network occupying a more central position are more likely to have an increased dependent variable (such as performance).

The TNAM is one of the most comprehensive models available to investigate the performance of an actor in a network. The performance of an actor *i* is conditional on a wide range of variables, including actor covariates, the performance of other actors (at both current and previous time points), and the previous performance of actor *i*.

The model predicts the performance of an actor as a function of a number of dependencies, therefore the predicted performance of actor *i* may take the following form:

$$P\left(y_i^t \middle| A^{t-D,\dots,t}, X^{t-D,\dots,t}, Y^{t-D,\dots,t-1}, Y_{j\neq i}^t, \theta\right) = \; g^{-1}\left(\left[A^{t-D,\dots,t}, X^{t-D,\dots,t}, Y^{t-D,\dots,t-1}, Y_{j\neq i}^t\right]\beta\right)$$

Where:

- D is the temporal dependence with an upper bound of $D\epsilon\{0,1,\dots,T-1\}$
- $A^{t-D,\dots,t}$ which refers to current and/or recent networks

- $X^{t-D,\ldots,t}$ which refers to current and/or recent covariates
- $Y^{t-D,\ldots,t-1}$ which refers to current and/or recent actor performance (while $Y_{j\neq i}^{t}$)
- g^{-1} is the mean function appropriate to the edge distribution

5.2. Model Specification

The TNAM presents a highly flexible model to predict the attributes of actors embedded in a network, where a number of parameters can be specified. Table 1 outlines the parameters which can be included in the model along with their interpretation. The effects that can be specified in the TNAM include exogenous effects (as can be included in a standard regression model), attribute similarity effects and network effects, which can all be applied as predictors of performance.

Table 1 TNAM Effects

Term	Economic Interpretation
Covariate (Such as GDP, GDP per capita, exchange rate, infrastructure level)	This term captures whether a nation with a certain characteristic has a high performance level. For instance, are nations with a higher GDP more competitive?
Lagged Competitiveness Measure	This term captures whether the previous performance of a nation influences its current performance.
Netlag	This term captures whether the performance of a nation is affected by the performance of its trading partners.
Attribute Similarity	This term creates a similarity matrix based on an attribute. It captures whether two nations similar in one dimension (regional belonging) are more or less likely to be similar in another (competitive performance).
E-I Index	It captures the impact on performance of a nation having a regional or global trading profile.
Brokerage Role by Regional Partition (Coordinator, Gatekeeper, Representative, Liaison, Consultant)	These terms capture whether holding a certain role within and between regional partitions increases the likelihood a nation will become competitive.
Out-degree Centrality	This captures whether nations with a high export level perform better.
In-degree Centrality	This captures whether nations with a high import level perform better.
Structural Similarity	The term captures the extent to which structurally similar nations in the ITN have similar performance levels.

A set of network effects are included in the model to address the first research question, more specifically these are the centrality measures. Where the in-degree and out-degree centrality capture whether a nation's import and export performance respectively, influences competitiveness levels.

An additional network effect is structural similarity, where a positive and significant effect would indicate that nations that hold structurally equivalent positions in the ITN are more likely to have similar performance levels.

In order to address directly address the second research question a netlag parameter is specified. The netlag parameter captures how much direct trading partners influence the performance of nations in the automotive sector.[18] Where a positive and significant parameter would indicate that if a nation trades with competitive nations, it is more likely to become competitive. The netlag parameter not only allows us to test the impact of the performance of trade partners, it also allows us to operationalise and test the unequal exchange hypothesis proposed by Clark & Mahutga (2013). Where a negative and significant effect may indicate a mechanism of unequal exchange, where trading with less competitive nations increases the likelihood a nation will become competitive.

In order to address the third research question, a set of regional level terms are included in the model specification; Kordalska & Olczyk (2014) note that export competitiveness is influenced by spatial effects, that the performance of neighbouring countries will affect export growth. The first is the regional similarity term (based on the attribute similarity effect); this allows to assess whether nations in the same region are more likely to share performance levels. Bahar et al (2014) argue nations in the same region share an 'export basket'; therefore, the use of the regional similarity parameter will allow us to test whether they also share performance levels. A positive and significant term would indicate shared performance, pointing towards nations acting as a complementary force to neighbouring countries. Whereas a negative and significant would indicate that there is an uneven distribution of performance within regional partitions.

Additionally, we include an effect to capture whether a nation with a regional or global trading profile is more likely to become competitive. This effect is the External – Internal (E-I) Index, a relational measure that assesses whether a nation's trade is mostly intra-regional or global. The index is based on the regional partitions, and assesses the number of trade ties a nation has inside and outside the partition (the external and internal ties)[19]. The index gives a value between -1 and 1, where a negative value indicates a country has an intra-regional trading profile, whilst a positive value indicates a country has a global trading profile. When specified in the TNAM, a negative and significant effect would indicate that nations with a more regional

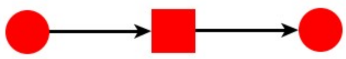
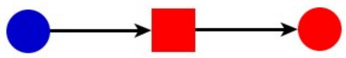
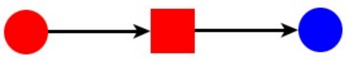
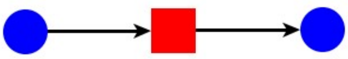
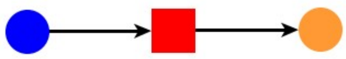
[18] Within the modelling framework the terms weightlag and netlag are applied to capture the effect of the performance of direct partners for weighted and binary networks respectively. The terminology originates for the spatial autoregressive modelling literature, where the term spatial lag is used to capture the effect of spatial autocorrelation (LeSage, 2008). For comparative purposes, we use the term netlag to refer to both the weighted and binary parameters.

[19] The E-I Index is defined as $\frac{E-I}{E+I}$ where is E is the number of external ties, and I is the number of internal ties (Krackhardt & Stern, 1988).

trading tendency are more likely to become competitive in the automotive industry. Although typically a network measure, it is possible to compute at the node level (Everett & Borgatti, 2012); in this paper we compute it at the country level.

Furthermore, we include a set of parameters to assess whether the role a nation plays within and between regions has an effect on its competitiveness levels, making use of the approach applied by Amighini & Gorgoni (2014). They make use of the Gould & Fernandez (1989) brokerage roles to distinguish the roles played by nations linking the various regional partitions. There are five brokerage roles (coordinator, gatekeeper, representative, consultant and liaison), indicating different positions a country may hold in the ITN. We include these five roles in the TNAM to test whether holding a certain brokerage role at the regional level increases the likelihood of a nation becoming competitive in the automotive industry. Table 2 presents a description of these five brokerage roles in the context of the ITN, along with a set of visualisations.

Table 2 Description of 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.

Note: In the visualisation, the broker is indicated by a square, other nations by a circle. The different colours indicate regional partitions, where the same colour would indicate both countries belong to the same regional partition.

A nation is considered a coordinator if it imports and exports to nations in the same regional grouping, coordinating trade at the regional level. The gatekeeper role captures the case when a country imports from a different region, then exports these goods to countries in own region.

For instance, it would capture the transit role of the Netherlands, where it imports large volumes globally to redistribute them across Europe. The representative role indicates where a nation imports from countries in its own region, then exports to countries in another regional partition. Consultants act as external players, linking to a region (not their own), importing and exporting with this region. Liaisons link nations from different regions; indicating that the nation holds a stronger position in the global production network (over regional production sites). The consultant and liaison roles have the weakest link to international trade in terms of their interpretation. They are included for consistency and to ensure full use of the complete set available, rather than using only a partial implementation of brokerage roles. Although it could be argued that the consultant role may reflect some form of offshoring or outsourcing tendencies; for instance, it potentially captures the case where a European nation exports to China for an assembly function, then China exports back to Europe, acting as a supplier. On the other hand, when utilised in the model, it is difficult to distinguish between this tendency (as we do not focus on specific nations or regions) or whether we are simply observing inter regional trade, such as the case where the US trades with Europe[20].

A range of exogenous effects are included: GDP, GDP per capita, exchange rates, infrastructure levels and capital factor endowments. The GDP and GDP per capita terms allow us to assess whether large and affluent nations are more likely to hold competitive positions in the automotive sector, and to control for size and income effects. Exchange rates are included to control for cost competitiveness. When considering a fragmented production process, it is important to acknowledge that exchange rates may have a different impact, as various types of trade react differently to exchange rate movements (Cingolani et al, 2015).

In this study we make use of time lagged variables to capture the lagged influence of position in the production network on competitiveness; allowing us to further consider how holding an integrated position enhances performance over time. For instance, addressing whether an emerging economy that further integrates into the production network benefits from the change

[20] The network metrics (such as brokerage role, E-I index) are calculated using UCINET (Borgatti et al, 2002) and the weighted out degree centrality outcome variable is calculated using the tnet R package (Opsahl, 2009).

in its position in the ITN. The time points are every four years, rather than using the year-to-year changes, as a longer period of time allows to better capture the full effects of holding a certain position in a production network[21].

The terms outlined in this section allow us to assess the impact of previous relational effects and country covariates on current performance, where the TNAM is implemented as part of the xergm package in R (Leifeld et al, 2014).

5.3. Robustness Checks – Addressing Endogeneity

An issue that emerges from this modelling approach (and the specification of a number of network effects) to assess the competitiveness of nations is the endogeneity issue. As noted by Boehmke et al (2016:124) this problem predominantly arises in network studies as a result of "using measures of one feature of the international system to explain another." Therefore, to alleviate the endogeneity issue in this study, we employ the approach outlined by Boehmke et al (2016). More specifically, we make use of an Instrumental Variable (IV) two stage estimator approach[22]. The underlying concept associated with this technique is that endogeneity is stripped from the variables in question by substituting them with a set of suitable instruments. We follow the strategy outlined by Boehmke et al (2016), where we make use of a *Instrumented Network* in our estimation. In the two step estimator procedure, an instrumented network is utilised instead of a direct IV. This approach involves, firstly, simulating the ITN[23], in order to create the Instrumented Network. This Instrumented Network is then used to construct the relational effects specified in the model, acting as IVs in the estimation process.

When simulating the ITN to create the Instrumented Network, we make use of Temporal Exponential Random Graph Model (TERGM), as developed by Hanneke et al (2010)[24]. This network based approach allows us to simulate a better set of instruments to be used in the estimation, as it captures the increasingly interdependent nature of the global economy as it is today. However, the network simulated by the TERGM is a binary network. Therefore, we present the results of three estimations for each product group (for each competitiveness index):

[21] Furthermore, the use of lagged variables also helps deal with the problem of endogeneity, which concerns whether a network position (import performance, regional integration) improves competitiveness.
[22] Kali et al (2007) and Clark & Mahutga (2013) both make use of Instrumental Variable approaches during robustness checks to deal with potential endogeneity issues. It is also a technique frequently applied in the political sciences (Sovey & Green, 2011).
[23]Boehmke et al (2016) make use of the gravity model to simulate the ITN.
[24] See the Appendix B for further details on the TERGM, and its use in simulating the Instrumented Network.

Weighted Network, Binary Network and the Instrumented Network, where the final estimation acts as a robustness check. The use of both the weighted and binary model allows us to examine whether any substantial differences emerge when accounting for weighted ties; for instance, is it only the value (or volume) of trade that shapes competitiveness (as identified by the weighted network model), or is it also the underlying distribution of trade ties (as identified by the binary model)?

In the estimation process a time step must be dropped; when simulating the network, the TERGM estimation is conditioned on the covariates of the previous time point, where for the first observed ITN there are no previous covariates. Therefore, the estimation starts at t=1998, where the estimation is conditioned on the 1994 country covariates; as a result, simulated networks based on the TERGM are only available from 1998. For consistency across models, the TNAM is implemented from 1998 to 2014.

6. Results

6.1. Weighted Out Degree Centrality (Export Performance)

When considering the important players in the ITN, most descriptive studies make use of some variant of out degree centrality (Amighini & Gorgoni, 2014; Reyes et al, 2014; Fagiolo et al, 2008). Where out degree centrality captures the number of export ties a country has, the weighted out degree measure goes a step further, accounting for the value of the ties, and assesses the contribution of the export ties of a nation to world trade. Therefore, it makes sense to make use of weighted out degree centrality to measure the sectoral performance of a country. Table 3 presents the results of the TNAM using weighted out degree centrality as a measure of export performance.

Across product groups and models, a number of parameters are consistently non-significant; these include the majority of country covariates, the E-I index and the structural similarity effect. On the other hand, previous performance has a consistent positive and significant effect across component categories. A parameter with mixed results across models is the impact of import performance (as indicated by in degree centrality). The results suggest that high level of imports (in terms of trade value) have a negative and significant association with competitiveness. Yet the number of import partners does not have a significant effect, as indicated by the results of the binary model across product groups.

When considering the export performance of nations in the electrical automotive components production network, the results (for the most part) are consistent across the weighted and binary realisations of the networks and are robust (as indicated by the TNAM results for the instrumented network estimation). In terms of the covariates, there is only one notably result to mention, the negative and significant GDP per capita result. This highlights the rise of emerging economies in this slice of the automotive GVC, and in the broader electronics supply chain (Sturgeon & Kawakami, 2010).

The role a nation holds within and between regional partitions significantly influences whether a country is a competitive exporter of electrical automotive components. Nations holding representative and consultant roles have a negative and significant association with competitiveness. Therefore, acting as an external player to a regional partition or as a global distributor does not increase the likelihood of becoming a competitive exporter.

The consultant result is not unexpected, given this component group is characterised by strong regionalisation patterns (as identified by Amighini & Gorgoni, 2014), acting as an external player to a region could be considered a redundant position.

A number of brokerage roles have a positive and significant association with competitive export performance; the coordinator and liaison roles. The coordinator role highlights that integration into the regional production network increases the likelihood of becoming a competitive exporter of electrical parts.

For electrical automotive components, the netlag parameter is also positive and significant; this indicates that developing efficient trade ties with other competitive nations increases the likelihood of becoming a competitive exporter.

The results of the TNAM highlight that the association between competitive export performance of engines and position in the ITN shares a number of features with the other component groups in the automotive sector, such as the import performance and previous competitive performance results. Similar to electrical parts, there is a positive and significant netlag result for engines, this suggests that developing efficient linkages to competitive exporters increases the likelihood of holding a competitive position.

The brokerage roles a nation holds within and between regions has a significant impact on engine export performance. The gatekeeper and liaison roles have a positive association, whereas the consultant and coordinator roles (yet only in the binary realisations of the ITN) have a negative association. This highlights the importance of acting as a regional supplier, rather than at the centre of the regional production network.

Table 3 TNAM Results for Weighted Out Degree Centrality

WO (Weighted Outdegree Centrality - Export Performance)	Electrical Weighted	Electrical Binary	Electrical IN	Engine Weighted	Engine Binary	Engine IN	Miscellaneous Weighted	Miscellaneous Binary	Miscellaneous IN	Rubber & Metal Weighted	Rubber & Metal Binary	Rubber & Metal IN	Final Weighted	Final Binary	Final IN
(Intercept)	0.7601	0.7805	0.6861	-0.8372 **	-0.8592 **	-0.8589 **	-0.1472	-0.1406	-0.0558	-0.0076	0.1863	0.2321	2.6368 ***	2.0011 ***	2.1034 ***
	(0.5178)	(0.5363)	(0.5054)	(0.2795)	(0.2801)	(0.2849)	(0.2671)	(0.2674)	(0.2634)	(0.2270)	(0.2320)	(0.2219)	(0.2447)	(0.2381)	(0.2381)
time	0.0005	0.0427	0.0480	-0.0162	-0.0111	-0.0139	-0.0082	0.0029	0.0069	-0.0130	0.0056	-0.0129	0.0295	-0.0208	0.0022
	(0.0409)	(0.0419)	(0.0431)	(0.0350)	(0.0354)	(0.0349)	(0.0280)	(0.0285)	(0.0290)	(0.0194)	(0.0190)	(0.0186)	(0.0194)	(0.0212)	(0.0210)
GDP	0.0485	0.0216	0.0215	0.0063	0.0007	0.0054	-0.0137	-0.0275	-0.0293 *	0.0070	-0.0054	-0.0007	-0.1078 ***	-0.0738 ***	-0.0796 ***
	(0.0296)	(0.0302)	(0.0275)	(0.0101)	(0.0103)	(0.0099)	(0.0136)	(0.0142)	(0.0136)	(0.0122)	(0.0123)	(0.0126)	(0.0153)	(0.0141)	(0.0141)
GDP per capita	-0.1777 *	-0.1667 *	-0.1524 *	-0.0095	-0.0067	-0.0108	-0.0109	-0.0079	-0.0104	-0.0572 *	-0.0480	-0.0702 *	-0.0334	-0.0459	-0.0481
	(0.0698)	(0.0706)	(0.0659)	(0.0149)	(0.0150)	(0.0147)	(0.0169)	(0.0170)	(0.0172)	(0.0278)	(0.0277)	(0.0303)	(0.0354)	(0.0324)	(0.0339)
Exchange Rates	-0.0117	-0.0055	-0.0067	0.0047	0.0078	0.0030	-0.0313	-0.0119	-0.0065	-0.0165	-0.0113	-0.0074	-0.0131	-0.0091	-0.0082
	(0.0220)	(0.0223)	(0.0207)	(0.0120)	(0.0120)	(0.0117)	(0.0256)	(0.0254)	(0.0253)	(0.0103)	(0.0101)	(0.0107)	(0.0115)	(0.0107)	(0.0109)
Electric Consumption	-0.0086	0.0041	0.0105	-0.0086	-0.0092	-0.0179	-0.0337	-0.0263	-0.0286	-0.0274	-0.0331	-0.0274	-0.0559 *	-0.0510 *	-0.0483 *
	(0.0513)	(0.0528)	(0.0498)	(0.0287)	(0.0287)	(0.0282)	(0.0290)	(0.0288)	(0.0289)	(0.0214)	(0.0212)	(0.0219)	(0.0244)	(0.0243)	(0.0245)
Internet Users	0.0273	-0.0046	-0.0024	0.0112	0.0030	0.0062	0.0192	0.0120	0.0133	0.0301 *	0.0215	0.0396 *	0.0276	0.0486 **	0.0432 *
	(0.0306)	(0.0315)	(0.0308)	(0.0237)	(0.0238)	(0.0243)	(0.0210)	(0.0212)	(0.0215)	(0.0141)	(0.0144)	(0.0158)	(0.0145)	(0.0163)	(0.0185)
E-I Index	0.0376	0.0247	0.0192	-0.0265	-0.0364	-0.0518	-0.0096	-0.0186	0.0211	0.0078	0.0162	0.0604	0.0209	0.0176	0.0120
	(0.0699)	(0.0735)	(0.0775)	(0.0595)	(0.0593)	(0.0720)	(0.0559)	(0.0556)	(0.0650)	(0.0365)	(0.0370)	(0.0351)	(0.0366)	(0.0394)	(0.0345)
Gatekeeper	0.0047	0.0040	0.0043	0.0096 **	0.0063	0.0143 ***	0.0060 **	0.0059 *	0.0087 **	0.0060 *	0.0030	-0.0066 **	0.0020	0.0018	0.0029
	(0.0031)	(0.0034)	(0.0039)	(0.0032)	(0.0035)	(0.0036)	(0.0022)	(0.0023)	(0.0027)	(0.0026)	(0.0026)	(0.0023)	(0.0016)	(0.0018)	(0.0017)
Coordinator	0.0119 ***	0.0059	0.0086 **	-0.0000	-0.0059 *	-0.0108 ***	-0.0004	-0.0051 *	-0.0075 ***	-0.0113	-0.0080	0.0305 ***	0.0013	-0.0000	0.0037 **
	(0.0028)	(0.0032)	(0.0031)	(0.0033)	(0.0026)	(0.0027)	(0.0024)	(0.0020)	(0.0020)	(0.0077)	(0.0078)	(0.0072)	(0.0015)	(0.0015)	(0.0013)
Representative	-0.0112 ***	-0.0097 ***	-0.0156 ***	-0.0012	0.0019	0.0023	0.0040 *	0.0061 ***	0.0023	-0.0008	-0.0033	-0.0003	0.0054 ***	0.0017	-0.0032 **
	(0.0024)	(0.0025)	(0.0024)	(0.0021)	(0.0020)	(0.0021)	(0.0018)	(0.0016)	(0.0017)	(0.0027)	(0.0027)	(0.0017)	(0.0011)	(0.0011)	(0.0012)
Liaison	0.0109 ***	0.0122 ***	0.0062 ***	0.0131 ***	0.0098 **	0.0097 ***	0.0005	-0.0047 *	0.0048 *	-0.0003	-0.0029	0.0002	0.0078 ***	0.0043 ***	-0.0021 *
	(0.0028)	(0.0029)	(0.0017)	(0.0038)	(0.0034)	(0.0023)	(0.0025)	(0.0022)	(0.0021)	(0.0022)	(0.0021)	(0.0011)	(0.0011)	(0.0011)	(0.0010)
Consultant	-0.0168	-0.0591 ***	-0.0197 *	-0.0473 **	-0.0479 **	-0.0467 ***	0.0132	0.0266 *	-0.0424 ***	0.0022	0.0082	0.0014	-0.0318 ***	-0.0187 **	0.0169 ***
	(0.0181)	(0.0163)	(0.0083)	(0.0169)	(0.0163)	(0.0098)	(0.0118)	(0.0115)	(0.0093)	(0.0056)	(0.0055)	(0.0033)	(0.0056)	(0.0060)	(0.0051)
WO Lag 1	0.8051 ***	0.8401 ***	0.8911 ***	0.7930 ***	0.8649 ***	0.8982 ***	0.7431 ***	0.8291 ***	0.9385 ***	0.9316 ***	0.9489 ***	0.9030 ***	0.4851 ***	0.8968 ***	0.9503 ***
	(0.0387)	(0.0348)	(0.0289)	(0.0559)	(0.0263)	(0.0249)	(0.0418)	(0.0277)	(0.0274)	(0.0456)	(0.0289)	(0.0155)	(0.0549)	(0.0229)	(0.0211)
Netlag	0.0137 ***	0.9226 *	1.0846 ***	0.0129 *	0.4620 *	0.5464 *	0.0176 ***	0.5989 **	0.5616 **	0.0066	0.5271 ***	-0.1970	0.0664 ***	0.0217	-0.0438
	(0.0041)	(0.3705)	(0.3172)	(0.0051)	(0.2232)	(0.2229)	(0.0042)	(0.1879)	(0.1898)	(0.0056)	(0.1462)	(0.1109)	(0.0079)	(0.1594)	(0.1531)
Regional Similarity	-0.0138 **	-0.0106 *	-0.0111 *	-0.0019	-0.0005	-0.0005	-0.0002	0.0019	0.0016	0.0001	-0.0003	0.0006	-0.0012	-0.0012	-0.0009
	(0.0046)	(0.0049)	(0.0045)	(0.0018)	(0.0018)	(0.0018)	(0.0019)	(0.0020)	(0.0019)	(0.0017)	(0.0016)	(0.0017)	(0.0022)	(0.0019)	(0.0018)
Indegree Centrality	-0.2307 ***	-0.0116	-0.0184	-0.0603 *	0.0058	-0.0014	-0.0979 **	-0.0088	-0.0054	-0.1266 ***	-0.0061	-0.0012	-0.0570 **	0.0037	0.0056
	(0.0421)	(0.0159)	(0.0134)	(0.0266)	(0.0120)	(0.0116)	(0.0330)	(0.0103)	(0.0101)	(0.0264)	(0.0058)	(0.0037)	(0.0197)	(0.0070)	(0.0066)
Strucutral Similarity	0.0013	0.0031	0.0002	0.0008	-0.0002	0.0005	0.0009	0.0017	0.0012	0.0001	-0.0010	-0.0013	0.0003	-0.0004	-0.0030
	(0.0017)	(0.0038)	(0.0043)	(0.0013)	(0.0031)	(0.0035)	(0.0011)	(0.0030)	(0.0035)	(0.0008)	(0.0016)	(0.0008)	(0.0008)	(0.0016)	(0.0022)
Log Likelihood	-581.8117	-594.7364	-583.0832	-360.4869	-356.7187	-352.8578	-312.0405	-310.7993	-316.0304	-289.6644	-292.259	-283.4825	-289.5935	-311.8568	-309.0341
Num. groups: node	124	124	124	92	92	92	105	105	105	147	147	147	140	140	140

Note: ****p < 0.001, **p < 0.01, *p < 0.05:*
Weighted – Weighted ITN Model
Binary – Binary ITN Model
IN – Instrumented Network Model

The negative coordinator result is not unexpected in the engines production network, where Amighini & Gorgoni (2014) identify that the engines ITN does not have a clear regional structure, therefore holding an integrated role in a weakly structured regional production network is unlikely to enhance performance.

When assessing the export performance of nations in the miscellaneous components production network, the effect of import performance and past performance are consistent with the other product groups. However, the brokerage results differ from the other segments of the automotive GVC, and must be interpreted with caution; especially paying careful attention to the results from the instrumented network model. There is a positive and significant gatekeeper parameter across the three models, which suggests that acting as a regional supplier of miscellaneous components increases the likelihood of becoming a competitive exporter.

Furthermore, there is a negative coordinator role result, suggesting that integration into the regional production network is not associated with a competitive export performance; this perhaps reflects the decline in the levels of regionalisation in this product group over time (as identified by Amighini & Gorgoni, 2014).

The liaison and consultant roles are significant at the 5% level in the binary model, however, the sign switches in the instrumented network model (which acts as a robustness check). This indicates, whilst significant, these results are not necessarily robust. A possible explanation for this is that amongst the five brokerage roles, these two have the weakest interpretation in the context of international trade. The representative role shares some of these concerns; although positive and significant in the weighted and binary models, this significance falls away in the instrumented network model.

Although there are a number of features associated with a competitive export performance of rubber and metal parts that are shared with the other product groups (such as import patterns and previous performance), it exhibits a number of substantial differences.

Firstly, the role a nation plays at the regional level does not have a robust and significant association with a competitive export performance of rubber and metal parts. Secondly, the netlag result is not significant (although positive and significant for the binary realisation, it is not a robust result, as indicated by the instrumented network model). This suggests that developing efficient linkages in this low tech slice of the automotive value chain is not significantly associated with a competitive export performance.

The competitive export performance of the latter stage of the automotive GVC is characterised by a number of aspects are unique to the final goods category. The results indicate the role a nation holds within and between regions and the association with competitive performance must be interpreted with caution. Although there are a number of significant parameters across the weighted and binary network models, these results are not necessarily robust, as indicated by the instrumented network model. More specifically, these are the representative, liaison and consultant roles. The issues arising from the liaison and consultant role are (again) potentially a result of the lack of explanatory power of these role in the context of the ITN.

The netlag parameter is only positive and significant in the weighted realisation of the ITN and non-significant elsewhere. This suggests in the case of final goods, only strong ties with competitive nations will impact the competitive export performance of countries.

6.2. Hub

The hub score indicates whether a nation is characterised as a factory of the world. The application of the TNAM in this case allows us to investigate whether or not a country is a global producer of automotive parts. Table 4 indicates the results for the TNAM for the hub score; where across all models for each product group, past hub performance has a positive and significant effect on current performance levels.

A number of features have a significant association with whether a country is a factory of the world for electrical automotive components. The brokerage role results indicate that taking into account trade value levels impacts whether holding a certain role increases the likelihood of becoming a hub. For instance, acting as a regional supplier is positive and significant (at the 5% level), yet the significance disappears for the binary realisation of the production network. Furthermore, the liaison and consultant roles do not exhibit consistent results across models, highlighting the issues regarding the inclusion of brokerage roles which lack a strong interpretation in the ITN context.

The coordinator role is positive and significant, suggesting that integration at the regional level has a positive impact on performance (this also reflects the high levels of regionalisation observed in this component group).

In this product category, establishing efficient linkages with factories of the world is not significantly associated with hub levels (as indicated by the netlag parameter). The export performance results (out degree centrality) indicate that it is not only the value of exports, but also the underlying binary distribution that determines whether a nation is more likely to become a factory of the world for electrical automotive components.

A number of features have a significant association with hub levels in the engine product group. The brokerage roles in this product group must be interpreted with care; whilst the gatekeeper and coordinator roles are significantly positive and negative respectively, this significance drops off in the instrumented network estimation.

The out degree result indicates exporting high volumes (yet not necessarily to a high number of markets) increases the likelihood of becoming a hub. This highlights the importance of serving a small selection of key markets to improve competitiveness levels in the production of engines. The in degree centrality parameter is positive and significant (at the 5% level) for the weighted network estimation. This suggests having access to large volumes of intermediate inputs (yet not importing from a range of nations) increases the likelihood of becoming a global factory.

When examining whether a nation is a global producer of miscellaneous components, taking into account the value of exchanges amongst countries has a substantial impact on the modelling results. For instance, a number of parameters are significant when modelling the binary realisation of the network, yet are non-significant for the weighted case. These include the E-I index, representative and coordinator roles. The positive E-I index and negative coordinator results suggest that establishing global (binary) trading ties, (rather than regional), increases the likelihood of becoming a factory of the world in this segment of the value chain. The positive representative role suggests that acting as a global distributor (within binary production networks) has an association with acting as a global factory.

The gatekeeper role is only significant in the weighted network, suggesting acting as a regional supplier points towards an association with competitive producer performance (yet not in a substantially significant manner).

The liaison and consultant results exhibit issues, regarding significance patterns across models, more specifically in the instrumented network model (the robustness check).

Table 4 TNAM Results for Hub

HUB	Electrical Weighted	Electrical Binary	Electrical IN	Engine Weighted	Engine Binary	Engine IN	Miscellaneous Weighted	Miscellaneous Binary	Miscellaneous IN	Rubber & Metal Weighted	Rubber & Metal Binary	Rubber & Metal IN	Final Weighted	Final Binary	Final IN
(Intercept)	-0.0177	-0.0261	-0.0299	-0.0102	0.0021	-0.0120	-0.0172	-0.0166	-0.0199	-0.0261	-0.0107	-0.0115	0.0015	0.0021	0.0001
	(0.0170)	(0.0173)	(0.0178)	(0.0190)	(0.0199)	(0.0192)	(0.0156)	(0.0203)	(0.0189)	(0.0135)	(0.0137)	(0.0140)	(0.0077)	(0.0083)	(0.0080)
time	0.0009	0.0005	-0.0003	-0.0034	-0.0064	-0.0028	-0.0022	-0.0004	0.0010	-0.0023	-0.0029 *	-0.0032 *	-0.0020 *	-0.0019 *	-0.0014
	(0.0020)	(0.0020)	(0.0020)	(0.0035)	(0.0037)	(0.0038)	(0.0033)	(0.0039)	(0.0037)	(0.0014)	(0.0014)	(0.0015)	(0.0008)	(0.0008)	(0.0008)
GDP	0.0011	0.0008	0.0008	0.0000	0.0001	0.0002	0.0009	0.0009	0.0009	0.0018 **	0.0013	0.0023 **	-0.0003	-0.0003	-0.0004
	(0.0008)	(0.0008)	(0.0008)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0010)	(0.0009)	(0.0007)	(0.0007)	(0.0008)	(0.0004)	(0.0004)	(0.0004)
GDP per capita	-0.0033	-0.0024	-0.0024	0.0001	0.0000	-0.0001	-0.0006	-0.0004	-0.0005	-0.0036 *	-0.0030	-0.0052 **	-0.0004	-0.0004	0.0000
	(0.0020)	(0.0020)	(0.0020)	(0.0010)	(0.0011)	(0.0010)	(0.0011)	(0.0014)	(0.0013)	(0.0016)	(0.0016)	(0.0019)	(0.0009)	(0.0009)	(0.0009)
Exchange Rates	-0.0003	-0.0005	-0.0003	0.0005	0.0005	0.0001	-0.0002	-0.0005	-0.0002	-0.0007	-0.0005	-0.0004	0.0000	-0.0000	0.0002
	(0.0006)	(0.0006)	(0.0006)	(0.0008)	(0.0009)	(0.0008)	(0.0014)	(0.0020)	(0.0018)	(0.0006)	(0.0005)	(0.0006)	(0.0003)	(0.0003)	(0.0003)
Electric Consumption	0.0012	0.0009	0.0009	-0.0007	-0.0006	-0.0012	-0.0013	-0.0011	-0.0009	-0.0008	-0.0010	-0.0010	-0.0007	-0.0007	-0.0007
	(0.0018)	(0.0018)	(0.0018)	(0.0020)	(0.0021)	(0.0020)	(0.0017)	(0.0022)	(0.0020)	(0.0013)	(0.0012)	(0.0014)	(0.0007)	(0.0007)	(0.0007)
Internet Users	-0.0000	-0.0003	-0.0001	-0.0000	0.0013	0.0015	0.0002	0.0011	0.0006	0.0016	0.0017	0.0034 **	0.0007	0.0007	0.0003
	(0.0014)	(0.0014)	(0.0014)	(0.0016)	(0.0018)	(0.0016)	(0.0013)	(0.0017)	(0.0015)	(0.0010)	(0.0010)	(0.0011)	(0.0005)	(0.0006)	(0.0006)
E-I Index	0.0006	0.0001	0.0003	0.0010	0.0044	0.0052	0.0028	0.0082 *	0.0121 **	0.0001	0.0016	0.0054 *	0.0000	0.0000	0.0002
	(0.0028)	(0.0028)	(0.0035)	(0.0036)	(0.0039)	(0.0045)	(0.0027)	(0.0037)	(0.0042)	(0.0025)	(0.0025)	(0.0026)	(0.0011)	(0.0012)	(0.0011)
Gatekeeper	0.0003 *	0.0003	0.0002	0.0010 ***	0.0009 **	0.0003	0.0003 *	0.0002	0.0003	0.0001	-0.0001	-0.0007 ***	0.0002 **	0.0001 *	0.0002 ***
	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0003)	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)
Coordinator	-0.0003 *	-0.0004 **	-0.0003 *	-0.0008 ***	-0.0005 *	-0.0001	-0.0003	-0.0003 *	-0.0008 ***	-0.0008	0.0009	0.0033 ***	0.0000	0.0000	0.0002 ***
	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0006)	(0.0006)	(0.0005)	(0.0001)	(0.0000)	(0.0000)
Representative	-0.0000	0.0000	-0.0001	-0.0001	-0.0000	0.0002	-0.0001	0.0004 **	0.0006 ***	-0.0001	-0.0005 *	-0.0001	-0.0000	-0.0000	-0.0001 **
	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0001)	(0.0000)	(0.0000)	(0.0000)
Liaison	-0.0001	-0.0004 **	0.0002	-0.0004	-0.0002	-0.0012 ***	-0.0010 ***	-0.0007 ***	0.0006 ***	-0.0002	-0.0002	0.0001	0.0001	0.0001	0.0000
	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0000)	(0.0000)	(0.0000)
Consultant	0.0006	0.0017 *	-0.0013 **	-0.0015	-0.0020	0.0015 *	0.0036 ***	0.0032 **	-0.0052 ***	0.0003	0.0008 *	0.0001	-0.0007 **	-0.0004	0.0002
	(0.0009)	(0.0008)	(0.0004)	(0.0012)	(0.0012)	(0.0007)	(0.0008)	(0.0010)	(0.0007)	(0.0004)	(0.0004)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
HUB Lag 1	0.6157 ***	0.7873 ***	0.8370 ***	0.9065 ***	1.0977 ***	1.2176 ***	0.7938 ***	0.8608 ***	0.9793 ***	0.5737 ***	0.7724 ***	0.8505 ***	0.9339 ***	0.9439 ***	0.9643 ***
	(0.0467)	(0.0245)	(0.0241)	(0.0558)	(0.0493)	(0.0477)	(0.0387)	(0.0335)	(0.0364)	(0.0468)	(0.0223)	(0.0199)	(0.0195)	(0.0118)	(0.0116)
Netlag	-0.0049	-0.0148	0.0100	-0.0004	-0.0002	0.0103	0.0278 ***	0.0171	0.0110	0.0172 **	-0.0195	-0.0136	0.0413 ***	0.0032	0.0236 ***
	(0.0054)	(0.0144)	(0.0168)	(0.0046)	(0.0105)	(0.0112)	(0.0039)	(0.0105)	(0.0104)	(0.0065)	(0.0129)	(0.0103)	(0.0093)	(0.0067)	(0.0064)
Regional Similarity	-0.0050	0.0005	0.0033	0.0002	-0.0026	0.0060	-0.0032	-0.0082	-0.0097	0.0021	0.0000	0.0001	0.0009	0.0012	0.0010
	(0.0036)	(0.0039)	(0.0042)	(0.0055)	(0.0059)	(0.0064)	(0.0046)	(0.0055)	(0.0051)	(0.0031)	(0.0030)	(0.0034)	(0.0029)	(0.0032)	(0.0031)
Outdegree Centrlaity	0.0116 ***	0.0024 ***	0.0022 ***	0.0111 ***	0.0014	-0.0001	0.0147 ***	0.0005	0.0021 **	0.0239 ***	0.0022 ***	-0.0003	0.0003	0.0001	-0.0006 **
	(0.0022)	(0.0005)	(0.0006)	(0.0024)	(0.0008)	(0.0009)	(0.0025)	(0.0007)	(0.0008)	(0.0041)	(0.0003)	(0.0003)	(0.0012)	(0.0002)	(0.0002)
Indegree Centrality	-0.0023	-0.0010	-0.0009	0.0049 *	0.0002	0.0011	-0.0040 *	0.0000	-0.0008	-0.0061 ***	-0.0007 *	-0.0003	-0.0027 **	-0.0002	-0.0001
	(0.0018)	(0.0005)	(0.0005)	(0.0020)	(0.0009)	(0.0008)	(0.0017)	(0.0008)	(0.0007)	(0.0017)	(0.0003)	(0.0003)	(0.0008)	(0.0002)	(0.0002)
Strucutral Similarity	0.0005	-0.0012	-0.0028	-0.0052	-0.0112	-0.0422 **	-0.0004	-0.0064	-0.0094	-0.0002	-0.0031	-0.0039	0.0020	0.0004	0.0002
	(0.0041)	(0.0059)	(0.0074)	(0.0049)	(0.0096)	(0.0162)	(0.0031)	(0.0075)	(0.0074)	(0.0018)	(0.0029)	(0.0021)	(0.0018)	(0.0018)	(0.0028)
Log Likelihood	882.4247	884.1335	876.2701	582.3697	558.6814	583.9831	777.5556	700.1239	725.4517	1248.3292	1240.2302	1244.2525	1552.5902	1538.4025	1549.1817
Num. groups: node	124	124	124	92	92	92	105	105	105	147	147	147	140	140	140

****p < 0.001, **p < 0.01, *p < 0.05*

Note:

- *Weighted – Weighted ITN Model*
- *Binary – Binary ITN Model*
- *IN – Instrumented Network Model*

Again, a potential explanation for the lack of consistency of these results in this product group, is that these roles lack a clear interpretation in the ITN setting.

The netlag parameter is positive and significant in the weighted model, this suggests that the strength of ties matter when examining how efficient linkages with competitive nations impact performance. In this case, establishing strong trading relations with factories of the world increases the likelihood of becoming a hub for miscellaneous components.

The out degree centrality results highlight that the volume of exports, and to a lesser extent, the number of trade partners is positively associated with global producer performance. The in degree centrality results are negative and significant, suggesting that assess to foreign intermediate inputs is not necessarily associated with becoming a factory of the world.

When examining what determines whether a nation is more likely to become a factory of the world for rubber and metal parts, there are a number of notable country covariates results that require comment. In particular, there is a tendency for larger emerging economies to be global producers in this slice of the automotive GVC; reflecting the rise of emerging economies in participating in low tech segments of the automotive supply chain.

In the case of rubber and metal parts, brokerage roles do not appear to have a significant association with hub performance levels. The netlag parameter is positive and significant, yet only for the weighted network. Therefore, in a similar manner to the miscellaneous components group, only developing strong efficient ties to factories of the world increases the likelihood of becoming a global producer of rubber and metal parts.

The centrality results point towards a positive and significant export performance and negative and significant import performance. However, this significance disappears in the instrumented network estimation.

In the case of the latter stages of the automotive GVC, the hub score reflects whether a nation is a global assembler of final automotive goods. The role a nation plays within and between regions influences whether it is a global assembler. For instance, there is a positive and significant gatekeeper effect, this suggests that distributing final automotive goods at the regional level is positively associated with a competitive performance.

The consultant role is negative and significant, yet only for the weighted network. However, this still highlights that acting as an external player to a region could be considered a redundant position in a sector characterised by regional trading patterns.

The netlag parameter is positive and significant, indicating that establishing efficient linkages to global assemblers increases the likelihood of becoming a factory of the world in the final stages of the automotive GVC. The import performance (as represented by in degree centrality) is negative and significant, yet this significance drops off in the binary realisations of the ITNs. This result is not unexpected, given global assemblers are in a better position to serve the domestic market, so are less reliant on imports of additional final goods.

6.3. Competitive Industrial Performance (CIP)

The CIP provides a measure of manufacturing potential, derived from a number of indices in its formulation, including manufacturing value added. The use of this measure allows us to assess the impact of a country's position in different stages of the automotive GVC on its industrial competitiveness. Furthermore, this index provides a measure of competitiveness that is external to the international system being modelled (the ITN), contrasting to the hub and weighted out degree measures of performance.

There a number of country covariates consistent across all models and groups; this is not unexpected given the CIP measure is external to the ITN, so the country covariates will influence the CIP in a similar manner across categories. There is a tendency for smaller, affluent countries with improved service links (as indicated by the internet users variable) to have a significant association with high CIP levels. Furthermore, there is a negative and significant factor endowments effect (as reflected by the electrical consumption variable). Previous CIP levels are consistently positive and significant across models and product categories. However, the effect of the position a nation holds within production networks varies across component groups.

The association between position in the ITN and CIP levels differ between the weighted and binary realisations of the network for electrical automotive components, especially in regards to the brokerage roles. For instance, in the weighted case, there is a positive and significant liaison role and negative and significant representative role. Whereas in the binary case, only the coordinator role is negative and significant. Although, the weighted and binary results are not entirely consistent, they both point towards an association between increased CIP level and holding a global position in the production network. This contrasts to the results of the weighted out degree and hub measures, where an integrated position at the regional level has a positive impact on performance.

The netlag variable indicates mixed results, only significant for the binary network (yet not robustly so). Therefore, developing efficient electrical parts trade linkages to competitive nations does not significantly shape CIP levels.

The in degree centrality results indicate that having access to large volumes of foreign intermediate inputs increase the likelihood of holding a competitive industrial performance; yet the number of import partners is not significantly associated with CIP levels. In this segment of the value chain, nations holding equivalent positions in the ITN are more likely to hold equivalent CIP levels. These results further highlight the differences between measuring performance using a composite metric and trade based indices of competitiveness (as the tendency in the trade based measures is for a negative in degree parameter).

In the production of engines, the role a nation plays within and between regions does not have a significant association with CIP scores. Similar to the electrical parts group, the netlag parameter exhibits mixed results; highlighting the ambiguity between CIP levels and establishing efficient linkages to competitive nations in this segment of the automotive GVC.

Contrasting to electrical automotive parts, the in degree centrality parameter is negative and significant for the weighted network (yet non-significant for the binary realisation). This suggests that in order to enhance manufacturing potential there is a need to develop the capabilities of domestic suppliers in this high tech slice of the automotive supply chain.

In the miscellaneous production network, the regional brokerage roles do not have a substantially significant association with the CIP of nations. The representative role is positive and significant, yet this significance disappears in the instrumental network estimation. The same pattern is also observed in the positive netlag and negative out degree centrality parameters.

Table 5 TNAM Results for CIP

CIP	Electrical Weighted	Electrical Binary	Electrical IN	Engine Weighted	Engine Binary	Engine IN	Miscellaneous Weighted	Miscellaneous Binary	Miscellaneous IN	Rubber & Metal Weighted	Rubber & Metal Binary	Rubber & Metal IN	Final Weighted	Final Binary	Final IN
(Intercept)	0.2247 ***	0.2281 ***	0.2193 ***	0.1839 ***	0.2034 ***	0.2050 ***	0.1841 ***	0.1903 ***	0.2100 ***	0.2179 ***	0.2303 ***	0.2217 ***	0.2238 ***	0.2260 ***	0.2235 ***
	(0.0146)	(0.0139)	(0.0139)	(0.0189)	(0.0191)	(0.0187)	(0.0163)	(0.0157)	(0.0157)	(0.0214)	(0.0209)	(0.0212)	(0.0142)	(0.0142)	(0.0138)
time	-0.0006	-0.0005	-0.0019	-0.0001	-0.0006	-0.0013	-0.0004	0.0003	-0.0001	0.0004	0.0011	0.0009	0.0009	0.0006	0.0004
	(0.0010)	(0.0010)	(0.0011)	(0.0011)	(0.0012)	(0.0012)	(0.0010)	(0.0010)	(0.0011)	(0.0008)	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0009)
GDP	-0.0125 ***	-0.0131 ***	-0.0124 ***	-0.0096 ***	-0.0103 ***	-0.0105 ***	-0.0101 ***	-0.0107 ***	-0.0115 ***	-0.0107 ***	-0.0110 ***	-0.0109 ***	-0.0096 ***	-0.0100 ***	-0.0095 ***
	(0.0011)	(0.0011)	(0.0011)	(0.0008)	(0.0008)	(0.0008)	(0.0008)	(0.0007)	(0.0007)	(0.0008)	(0.0008)	(0.0009)	(0.0009)	(0.0009)	(0.0009)
GDP per capita	0.0060 *	0.0058 *	0.0045	0.0019 ***	0.0020 ***	0.0021 ***	0.0022 ***	0.0024 ***	0.0024 ***	0.0056 **	0.0048 **	0.0029	0.0015	0.0014	-0.0001
	(0.0025)	(0.0024)	(0.0025)	(0.0004)	(0.0005)	(0.0005)	(0.0006)	(0.0006)	(0.0006)	(0.0018)	(0.0018)	(0.0019)	(0.0020)	(0.0021)	(0.0021)
Exchange Rates	0.0002	0.0001	-0.0005	0.0007	0.0008	0.0001	-0.0015	-0.0005	-0.0014	0.0001	0.0001	-0.0000	-0.0001	-0.0001	-0.0000
	(0.0006)	(0.0006)	(0.0006)	(0.0008)	(0.0008)	(0.0008)	(0.0010)	(0.0010)	(0.0011)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
Electric Consumption	-0.0037 **	-0.0037 **	-0.0036 **	-0.0038 **	-0.0040 **	-0.0041 **	-0.0034 **	-0.0040 **	-0.0035 **	-0.0044 ***	-0.0057 ***	-0.0046 ***	-0.0046 ***	-0.0049 ***	-0.0044 ***
	(0.0012)	(0.0011)	(0.0011)	(0.0013)	(0.0013)	(0.0013)	(0.0013)	(0.0013)	(0.0013)	(0.0010)	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Internet Users	0.0021 ***	0.0022 ***	0.0026 ***	0.0027 ***	0.0030 ***	0.0026 **	0.0025 ***	0.0021 **	0.0023 **	0.0019 ***	0.0018 **	0.0031 ***	0.0023 ***	0.0025 ***	0.0036 ***
	(0.0006)	(0.0006)	(0.0006)	(0.0008)	(0.0008)	(0.0008)	(0.0007)	(0.0007)	(0.0007)	(0.0005)	(0.0006)	(0.0007)	(0.0006)	(0.0006)	(0.0007)
E-I Index	0.0007	0.0003	-0.0011	0.0011	0.0011	0.0006	0.0016	0.0015	0.0015	0.0015	0.0017	-0.0017	0.0018	0.0021	0.0010
	(0.0015)	(0.0015)	(0.0015)	(0.0020)	(0.0020)	(0.0022)	(0.0022)	(0.0021)	(0.0023)	(0.0013)	(0.0013)	(0.0014)	(0.0015)	(0.0016)	(0.0013)
Gatekeeper	0.0001	0.0000	0.0003 ***	-0.0001	-0.0001	-0.0002	0.0000	0.0001	-0.0003 **	0.0001	0.0001	-0.0000	-0.0001	-0.0001	0.0000
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Coordinator	0.0001	-0.0002 **	-0.0002 ***	0.0001	-0.0000	-0.0002 *	-0.0001	-0.0002 *	0.0001	-0.0005	-0.0002	0.0001	0.0000	0.0001	0.0000
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.0003)	(0.0003)	(0.0001)	(0.0001)	(0.0001)
Representative	-0.0002 **	-0.0001	0.0000	-0.0001	-0.0000	0.0001	0.0003 ***	0.0004 ***	-0.0000	0.0000	-0.0001	0.0001	-0.0001 *	-0.0001 *	-0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0000)	(0.0000)	(0.0000)
Liaison	0.0002 **	0.0000	0.0001	0.0003 *	0.0002	-0.0001	-0.0000	-0.0001	0.0003 **	-0.0001	-0.0001	-0.0001	0.0000	0.0000	-0.0001
	(0.0001)	(0.0001)	(0.0000)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Consultant	-0.0006	0.0000	-0.0003	0.0000	-0.0001	0.0003	0.0003	0.0007	-0.0005	0.0004 *	0.0006 **	0.0000	0.0002	0.0003	0.0007 ***
	(0.0004)	(0.0003)	(0.0002)	(0.0005)	(0.0005)	(0.0002)	(0.0004)	(0.0004)	(0.0003)	(0.0002)	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0002)
CIP Lag 1	0.7707 ***	0.7588 ***	0.8236 ***	0.7823 ***	0.7740 ***	0.8138 ***	0.7775 ***	0.7627 ***	0.8557 ***	0.7115 ***	0.7884 ***	0.8549 ***	0.7264 ***	0.7889 ***	0.8316 ***
	(0.0348)	(0.0334)	(0.0282)	(0.0396)	(0.0406)	(0.0353)	(0.0401)	(0.0365)	(0.0344)	(0.0337)	(0.0301)	(0.0240)	(0.0374)	(0.0338)	(0.0294)
Netlag	-0.0045	0.0868 ***	0.0408	0.0235 **	0.0417	-0.0913 **	0.0273 **	0.1877 ***	0.0227	0.0271 ***	0.0820 ***	0.0239 **	0.0092	0.0743 **	0.0334
	(0.0061)	(0.0241)	(0.0227)	(0.0077)	(0.0414)	(0.0335)	(0.0103)	(0.0356)	(0.0346)	(0.0067)	(0.0186)	(0.0088)	(0.0056)	(0.0266)	(0.0279)
Regional Similarity	-0.0024	-0.0015	-0.0007	-0.0044 *	-0.0045 *	-0.0044 *	-0.0020	-0.0013	-0.0018	-0.0039	-0.0037	-0.0021	-0.0044 **	-0.0034 *	-0.0033 *
	(0.0015)	(0.0014)	(0.0014)	(0.0021)	(0.0021)	(0.0021)	(0.0017)	(0.0016)	(0.0017)	(0.0021)	(0.0020)	(0.0021)	(0.0014)	(0.0014)	(0.0013)
Outdegree Centrlaity	0.0049	0.0005	0.0001	-0.0046	-0.0001	0.0028 **	-0.0083 *	-0.0035 ***	-0.0001	-0.0044	-0.0005	-0.0003	0.0025	-0.0007	-0.0004
	(0.0028)	(0.0006)	(0.0005)	(0.0037)	(0.0009)	(0.0009)	(0.0038)	(0.0008)	(0.0009)	(0.0029)	(0.0003)	(0.0002)	(0.0033)	(0.0004)	(0.0006)
Indegree Centrality	0.0027 *	0.0006	0.0000	-0.0036 **	-0.0004	0.0004	-0.0006	0.0005	-0.0003	-0.0003	-0.0005	-0.0000	0.0013	-0.0003	-0.0004
	(0.0011)	(0.0004)	(0.0003)	(0.0013)	(0.0005)	(0.0004)	(0.0017)	(0.0004)	(0.0003)	(0.0020)	(0.0003)	(0.0002)	(0.0010)	(0.0003)	(0.0003)
Strucutral Similarity	0.0004 *	0.0003	0.0010 **	-0.0001	-0.0002	0.0008	0.0003	0.0002	0.0011	-0.0002	-0.0002	-0.0005	0.0002	0.0002	-0.0010 **
	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0005)	(0.0005)	(0.0003)	(0.0004)	(0.0006)	(0.0002)	(0.0003)	(0.0003)	(0.0002)	(0.0003)	(0.0004)
Log Likelihood	1187.2538	1200.8351	1193.7104	810.907	800.4548	801.0614	967.6525	976.3959	961.7902	1461.6411	1456.3577	1434.3308	1362.7772	1355.144	1361.6585
Num. groups: node	124	124	124	92	92	92	105	105	105	147	147	147	140	140	140

****p < 0.001, **p < 0.01, *p < 0.05*
Note:

- *Weighted – Weighted ITN Model*
- *Binary – Binary ITN Model*
- *IN – Instrumented Network Model*

Unlike the other competitiveness measures or product groups, the consultant role is positive and significant in the CIP rubber and metal components category; however, this significance drops off in the robustness check (as indicated by the instrumented network results). The netlag term is positive and significant for rubber and metal parts; this indicates that developing efficient trade ties to nations with high industrial competitive levels has the potential to enhance the CIP.

In a similar manner to the other low tech categories in the automotive sector (miscellaneous components and rubber and metal parts), only a single brokerage role (representative) is significant for final goods, and this significance does not hold in the instrumented network estimation. The regional similarity parameter is negative and significant, indicating that within the final assembly production network, CIP levels are unevenly distributed within regions.

A potential explanation for the lack of significance of the relational effects in the miscellaneous components, rubber and metal parts and final assembly production network is due to the formulation of the CIP. The CIP is partly derived from the participation in high and medium tech industries, therefore, it is not a surprise that the position of a nation in segments of the GVC with lower technological content lack a significant association with CIP levels.

7. Discussion of Results

The results from the TNAMs for the various measures of country performance highlight the clear differences between the competitiveness measures and their determinants, especially when comparing the aggregate CIP measure with the trade based performance indices, where high levels of disparity are observed.

Across the product groups and different measures of competitiveness measures, there appears to be a consistent negative (and in some case, significant) regional similarity effect. This indicates there is not a tendency for shared performance in regions, perhaps indicating the presence of a dominant player, suggesting a crowding out effect at the regional level. On the other hand, given the high level of integration and intra-regional trade in the sector, this may indicate that nations source from others in the region, yet specialise in different functions to their neighbours in order to better exploit their comparative advantages (Bahar et al, 2014).

Furthermore, the rise of emerging economies in the production process has led to growing number of policy concerns. For instance, China’s increasing integration in the electronics sector has led to many emerging markets (such as Latin American and East Asian nations) expressing concerns, often viewing China as a threat to export performance (Athukorala, 2009). Although electrical components are characterised as high tech products, not all nations trading these goods are involved in innovation driven activities. China has become increasing integrated into the electronics value chain (Pham et al, 2016), yet it is not directly involved in high value adding functions, rather it acts as an assembly centre in the production network (Athukorala, 2009). This suggests that in the electrical automotive parts sector, high performing nations (based on trade measures of competitiveness) act as processing centres. The positive netlag parameter in the export performance model then highlights that trading with these centres that provide essential functions, allow nations to improve their own export performance and production capabilities. This suggests that in this sector, there may be a dominant player at the regional level (as indicated by the negative regional similarity parameter), yet does not necessarily indicate a process of crowding out.

Along with the threat of emerging giants to developing nations, a number of additional competitiveness concerns have been expressed by nations in the world economy. In order for nations to formulate suitable policy, there is a need to better understand the structure of the global supply chain, and their position within various functions (Altenburg, 2007). In particular, the results highlight there is a need to be aware of the performance of trading partners; where in order to achieve an optimal position in the automotive supply chain there is a need to establish efficient linkages to competitive partners. This is especially important for nations with low development levels, in order to ensure they do not become trapped in low value, subordinate exchanges in the global economy.

With respect to the controls, a low level of significance was observed in the models, for instance, exchange rates did not significantly shape competitiveness levels. Athukorala & Menon (2010) along with Avsar & Turkcan (2013) note that global production sharing tends to weaken the link between the effect of exchange rate movements on trade volumes, (and therefore trade competitiveness levels).

Physical capital factor endowment levels do not play a significant role in shaping the performance of nations in this sector (with the exception of the CIP case). One possible explanation is that fragmented production process has led to exports not only containing the factor endowments of the exporter, but also the endowments of the nations from which the country imports intermediate inputs (Beltramello et al, 2012).

The results across models and competitiveness measures point towards a negative impact of import performance (in terms of trade volumes). This suggests that in order to become a competitive player in various segments of the automotive GVC, there is a need to have access to domestic suppliers. Therefore, a potential policy implication could be to improve and develop the internal supply chain, and implement a set of polices to enhance the capabilities of domestic suppliers. Furthermore, access to intermediate inputs (either sourced domestically or internationally) allows for OEMs[25] and contract manufacturers to enter the local industry. In the UK, the nation is seen to hold notable advantages in the production of engines. However, in order to expand and develop in this segment, there is a need to overcome key weaknesses, specifically the state of the current internal supply chain and the availability of domestic suppliers (BIS, 2013). A higher number of domestic suppliers may also increase levels of integration of these contract manufacturers into the global supply chain, rather than becoming dependent on local plants (as often observed in engines production in the UK, as noted by Holweg et al, 2009) A shift to niches within a business function, such as a specific area of component production, allows a nation to increase value captured, acting as a key supplier to manufacturers operating in the broader component group.

The regional brokerage roles provide some insights regarding the degree of power that a nation processes, despite not necessarily belonging to the core, and how this interacts with the notion of competitiveness. The role a nation plays within and between regions has a significant effect on the likelihood of becoming competitive, yet varies across product groups and performance measures. The brokerage roles a nation possesses has a significant effect on competitiveness in terms of export performance (out degree centrality) and hub levels, yet does not play a significant role in determining CIP levels. The results vary in terms of whether brokerage roles are significant and the sign of the effect. The consultant role should be interpreted with caution, as it could highlight the importance of intra-regional trade, where acting as an external player to a region may simply be a redundant role. The results highlight that acting as a gatekeeper (or in some cases a representative) has a positive association with competitive performance; this emphasises that when investigating national competitiveness in a sector, there is need to take into account not only the role a nation plays within a region, but also how it links regional partitions.

[25] Original Equipment Manufacturers; which have become increasing integrated into the automotive production process over recent years.

The netlag results are consistently positive, and in most cases significant, indicating that establishing efficient trade relationships with competitive countries has a positive impact on national performance. It also highlights, that contrasting to the findings of Clark & Mahutga (2013), there is not a process of unequal exchange occurring in the automotive ITNs.

Overall, when examining the competitiveness of nations in the production of automotive parts exports matter – not just the gross value, but also their distribution. Furthermore, when considering export performance of individual component groups, regional patterns and position play a significant role.

8. Concluding Comments

This paper aimed to address a number of research questions regarding the competitiveness of nations in order to present a step towards understanding the determinants of national performance in the automotive industry. It aimed to address whether a country's performance in the sector was determined by its position in ITNs and the performance of trading partners, along with its position at the regional level. This paper made use of a TNAM, applied to a range of ITNs at the more appropriate product level, to address these questions. The extent to which relational effects and the position of a nation in the trade networks vary by component groups, (which differ by technological content), and also vary depending on the measure of competitiveness employed.

The results from the TNAM indicate a number of patterns involving the performance of nations in the automotive sector. Firstly, they highlight that the way competitiveness is measured and defined matters, as various definitions suggest increased performance is determined by almost contradictory processes. For instance, the determinants of a nation as key player in the sector by weighted out degree centrality clearly differs from what determines whether a nation has increased CIP levels.

A clear outcome of this study is that there is a need to better define competitiveness; one alternative proposed here is through the use of relational measures (such as the hub score). In the light of the fragmentation of production, further research needs to be undertaken providing a descriptive comparison of the various competitiveness measures and country rankings. For instance, comparing the competitiveness ranks of nations based on their position in the ITN at the component level, with RCA of GVC incomes based on corresponding I-O data.

The TNAM results answer the first two research questions; the impact of position in the ITN and performance of trading partners on competitiveness varies depending on the measure of competitiveness. In terms of sectoral export performance (out degree centrality) and whether a nation is a factory of the world (hub level), the position in the ITN and performance of trading partners has a significant effect. With respect to the CIP results, it is important to emphasise that when considering competitive patterns, we should not disregard the ITN structure, rather for the CIP, only examining the trade networks of medium to high tech products is significantly associated with the CIP score. For low tech production, the CIP is less susceptible to structural influences; that the position of a nation in low tech ITNs does not significantly shape performance levels.

The third research question asks whether regional patterns shape performance in the automotive sector. In terms of the hub and export level performance measures, brokerage roles have a significant effect, yet vary across product groups. This indicates that regional patterns matter in shaping the performance of nations in the automotive sector, yet the specific determinants at the regional level vary depending on how performance is captured.

Therefore, given the importance of regional effect, there is a need for policy makers to continue to create and sustain efficient linkages within regional production networks, in order to ensure that there is sufficient access to suppliers and intermediate inputs at the regional level. In the automotive sector, this refers to ensuring there is access to specialised inputs and services.

When examining the modelling results, specifically the binary and instrumented network models, we are able to assess whether the conclusions still hold after the robustness checks. For the majority of cases, these results hold, where magnitudes and significance levels are relatively similar; however, certain results appear to exhibit robustness issues. These issues chiefly involved the brokerage roles, especially the liaison and consultant roles, which lack explanatory power in the ITN context. Even though the effects of regional position on performance seem plausible, endogeneity concerns cannot be entirely ruled out. Nevertheless, given the high level of models and measures applied, the majority of findings are consistent with the main results when examining the robustness checks presented by the instrumented network estimation. Nonetheless, these issues point towards a need to better understand the link between regionalisation activity and international competitiveness in a sector characterised by a fragmented production process.

In terms of measuring country competitiveness, relational indices provide a clearer measure of sector performance, as they are easily interpreted and allow for cross country comparisons. Furthermore, unlike measure such as, RTA, RCA and the Lafay index, network measures of trade performance are not sensitive to small or non-existent export or import values; as the lack of ties would simply indicate a lower performance. Unlike the CIP, the relational measures also allow for a comparison between sectors of different technological content.

The results indicate that in order to increase a nations' position in a sector the product level or business function is more appropriate, as the determinants of national performance vastly differ amongst the products groups. The product categories vary in terms of technological content and value added to the economy. From a policy maker perspective, any attempts to upgrade to a higher value product group in the automotive GVC, should involve identifying their current position in the product group, along with the ideal position for the product (for example becoming a regional supplier of engines). Furthermore, policy makers should not disregard their position in lower value activities, rather there is a need to be aware of the position in these component groups, and specifically who acts as a supplier to them, and the performance of these suppliers.

In concluding, the main limitations of this study must be acknowledged. For instance, it is important to acknowledge when assessing country performance, it is at the firm level where the source of the competitiveness of nations lies. The performance of firms creates economic value and ultimately contributes to national competitiveness (Bhawsar & Chattopadhyay, 2015). Therefore, this suggests that a further avenue for future research would include employing a measurement of competitiveness that links the micro firm level with the macro country level that is appropriate to be utilised in a study that takes the more appropriate task or business function perspective.

Overall, the TNAM provides a flexible approach to assess how both actor covariates and network effects impact the outcome variable, and demonstrate that network effects play a role in determining the competitiveness of a nations, along with the impact of the competitive levels of trading partners.

Appendix

Appendix A - Data & Network Threshold

Table 6 International Trade Product Codes (SITC Rev. 3)

Electrical Parts	
SITC Rev. 3 Code	Code Description
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	
SITC Rev. 3 Code	Code Description
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
Miscellaneous Components	
SITC Rev. 3 Code	Code Description
7841	Chassis fitted with engines, for the motor vehicles of groups 722, 781
78421	Bodies (including cabs), for the motor vehicles of group 781
78425	Bodies (including cabs), for the motor vehicles of groups 722, 782
78431	Bumpers and parts thereof, of the motor vehicles of groups 722, 781, 782
78432	Other parts and accessories of bodies (including cabs)
78433	Brakes and servo brakes and parts thereof, of the motor vehicles of group
78434	Gearboxes of the motor vehicles of groups 722, 781, 782 and 783
78435	Drive-axles with differential, whether or not provided with other transmission
78436	Non-driving axles and parts thereof, of the motor vehicles of groups 722
78439	Other parts and accessories of the motor vehicles of groups 722, 781, 782
82112	Seats of a kind used for motor vehicles
Rubber & Metal Parts	
SITC Rev. 3 Code	Code Description
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
Final Automotive Goods	
SITC Rev. 3 Code	Code Description
781	Motor cars and other motor vehicles principally designed for the transport of persons
782	Motor vehicles for the transport of goods and special-purpose motor vehicles
783	Other road motor vehicles
722	Tractors
74411	Self-propelled trucks powered by an electric motor, fitted with lifting or handling equipment

Table 7 Percentage of world trade retained by 0.01% threshold

Product Group	1994	1998	2002	2006	2010	2014
Electrical Components	92.76	92.22	91.30	91.89	91.14	94.00
Engines	95.50	95.73	95.44	94.87	94.19	95.15
Rubber & Metal Parts	92.89	92.42	91.86	91.78	91.66	93.16
Miscellaneous Components	95.07	94.8	94.79	94.08	93.7	94.75
Final Goods	95.48	95.41	95.31	94.53	93.94	95.05

Appendix B - Simulation of ITNs

The Temporal ERGM (TERGM) is utilised to construct the instrumented network to be used in the TNAM estimation. This firstly involved estimating the temporal model, then making use of the TERGM estimation to simulate the set of instrumented networks. Hanneke et al (2010) outline the specification of a TERGM for networks in discrete time, where at time t, the network has an ERGM distribution where the network statistics (or model parameters) specified in the model include both configurations of the network at time t, and configurations at previous time points, such as delayed reciprocity (Desmarais and Cranmer, 2012b). The configurations (or model parameters) specified in the model and their interpretation are outlined in table 8. Table 9 presents the estimation results from the models used to simulate the ITNs

Table 8 TERGM Network Configurations

Effect	Economic Interpretation
Edges	This terms captures the baseline propensity for ties to be form in the network.
Activity Spread (GWODEGREE)	This term captures the extent to which (binary) export ties are evenly distributed in the network, or a concentrated in a handful of nations.
Popularity Spread (GWIDEGREE)	This term captures the extent to which (binary) import ties are evenly distributed in the network, or a concentrated in a handful of nations.
GWESP	This coefficient captures the tendency for triadic closure in the network, and therefore captures the tendency for hierarchical trading patterns in the network.
GWDSP	This term captures the extent to which nations are indirectly ties, trading with the same set of nations.
Mutual	This captures the extent to which trade ties between two nations are reciprocated.
Delayed Reciprocity	This captures the propensity for a one way trade relationship at t-1 to become a reciprocated trading tie at time t.
Stability (Memory)	This term captures the persistence of edges (and non-edges) from one time point to another.
Mutual (attribute)	This captures the extent to which there are reciprocated trade ties amongst nations with a certain attribute. For instance, Mutual Region would capture the extent to which trade ties are reciprocated within the same regional partition.
Nodematch	This captures the propensity for trade between two nations with the same characteristic. For instance, Nodematch Region would capture whether there is a tendency for intra-regional trade.
Nodeofactor/Nodeifactor	This captures the propensity for a nation with a certain attribute to export/ import.
Nodeocov/Nodeicov	This captures the propensity for a nation with a certain continuous characteristic to export – for instance, are larger nations more likely to export/import?
Absdiff (attribute)	This captures the propensity for a tie to form on the basis of the difference between the (continuous) attributes of two nations. For example, a positive and significant GDP parameter indicates nations of different sizes are more likely to trade.

Table 9 Estimation of the TERGM Results

	ELECTRICAL	ENGINES	MISCELLANEOUS	RUBBER & METAL	FINAL
Edges	-2.72 *	-0.37	-0.35	-0.32	-2.23 *
	[-3.02;-2.34]	[-1.44;0.47]	[-1.33;0.19]	[-3.14;0.40]	[-2.59;-1.92]
Mutual	0.31 *	0.67 *	1.35 *	1.55 *	-0.1
	[0.04;0.54]	[0.16;0.97]	[0.97; 1.72]	[1.16; 1.74]	[-0.26;0.09]
Popularity Spread	-1.34	-2.58 *	-1.58 *	-1.17 *	-0.06
	[-2.05;0.27]	[-3.16;-1.95]	[-1.90;-1.17]	[-1.88;-0.95]	[-0.21;0.31]
Activity Spread	-1.69 *	-2.48 *	-2.24 *	-3.86 *	-1.94 *
	[-2.01;-1.20]	[-2.68;-2.19]	[-2.95;-1.88]	[-4.25;-3.11]	[-2.33;-1.38]
GWESP	0.71 *	0.37 *	0.54 *	1.06 *	0.73 *
	[0.61;0.76]	[0.19;0.54]	[0.45;0.60]	[0.91; 1.14]	[0.70;0.78]
GWDSP	-0.04 *	0	0.01	-0.11 *	0.01 *
	[-0.06;-0.01]	[-0.01;0.01]	[-0.01;0.02]	[-0.13;-0.08]	[0.00;0.02]
Nodeofactor South Asia	0.1	0.25	0.81	0	0.81 *
	[-0.43;0.66]	[-0.68; 1.14]	[-0.03; 1.43]	[-0.16;0.18]	[0.51; 1.00]
Nodeofactor Middle East & North Africa	0.40 *	0.11	0.42	0.13 *	-0.11
	[0.21;0.49]	[-0.30;0.54]	[-0.09;0.87]	[0.02;0.23]	[-1.01;0.54]
Nodeofactor Latin America & Caribbean	-0.23	-0.44	0.44	0.01	-0.28
	[-0.54;0.02]	[-1.10;0.16]	[-0.09;0.87]	[-0.54;0.28]	[-0.89;0.10]
Nodeofactor North America	-0.74	-2.54 *	0.58	-2.26 *	0.5
	[-1.60;0.09]	[-3.13;-2.05]	[-0.29; 1.26]	[-10.26;-1.47]	[-0.44; 1.19]
Nodeofactor East Asia & Pacific	0.99 *	0.29	0.71 *	-0.13	1.02 *
	[0.57; 1.46]	[-0.21;0.82]	[0.38; 1.01]	[-0.22;0.09]	[0.50; 1.46]
Nodeofactor Europe & Central Asia	0.07	0.07	0.71 *	-0.07	-0.39
	[-0.17;0.36]	[-0.44;0.66]	[0.20; 1.25]	[-0.27;0.13]	[-1.06;0.06]
Nodeifactor South Asia	-0.08	-0.24	-0.12	-1.54 *	-0.15
	[-1.19;0.15]	[-0.76;0.88]	[-0.65; 1.21]	[-1.72;-1.25]	[-0.70;0.34]
Nodeifactor Middle East & North Africa	-0.18 *	-0.4	-0.26	-0.63 *	0.26 *
	[-0.81;-0.09]	[-0.88;0.63]	[-1.00;0.95]	[-0.85;-0.46]	[0.11;0.45]
Nodeifactor Latin America & Caribbean	-0.28 *	-0.26	-0.07	-0.61 *	-0.13
	[-0.79;-0.15]	[-0.75;0.81]	[-0.56; 1.11]	[-0.77;-0.41]	[-0.40;0.19]
Nodeifactor North America	-0.51 *	-0.31	0.09	-1.20 *	0.4
	[-1.06;-0.23]	[-1.29;0.90]	[-0.44; 1.39]	[-1.53;-0.46]	[-0.41; 1.03]
Nodeifactor East Asia & Pacific	-0.99 *	-0.88	-0.35	-0.69 *	-0.71 *
	[-1.60;-0.75]	[-1.34;0.19]	[-1.22; 1.05]	[-1.08;-0.52]	[-1.30;-0.19]
Nodeifactor Europe & Central Asia	-0.48 *	-0.71	-0.26	-0.46 *	-0.72 *
	[-0.70;-0.32]	[-1.21;0.27]	[-0.97; 1.10]	[-0.68;-0.24]	[-0.99;-0.42]
Node Match Region	1.32 *	1.24 *	0.56 *	0.21 *	1.30 *
	[1.16; 1.54]	[1.00; 1.50]	[0.12; 1.08]	[0.03;0.74]	[1.06; 1.55]
Nodematch High Income Nation	0.06	-0.09	0.04	-0.22	0.17
	[-0.10;0.15]	[-0.31;0.06]	[-0.11;0.13]	[-0.27;0.04]	[-0.05;0.34]
Nodeofactor High Income Nation	0.25	-0.08	-0.17	-0.05	0.19
	[-0.07;0.41]	[-0.21;0.13]	[-0.30;0.12]	[-0.29;0.39]	[-0.03;0.50]
Nodeifactor High Income Nation	0.18 *	-0.28 *	-0.09	-0.35	-0.02
	[0.01;0.37]	[-0.41;-0.15]	[-0.29;0.14]	[-0.48;0.11]	[-0.19;0.35]
Nodeocov GDP	1.25 *	1.34 *	0.21 *	1.33 *	0.04
	[1.01; 2.06]	[0.90; 1.99]	[0.00;0.44]	[1.07; 1.59]	[-1.09;0.51]
Nodeicov GDP	1.00 *	1.00 *	0.14	1.27 *	0.04
	[0.72; 1.86]	[0.59; 1.64]	[-0.12;0.36]	[0.97; 1.51]	[-0.36;0.54]
Nodeocov GDP per capita	-0.56 *	-0.03	0.08	-0.09 *	0
	[-0.76;-0.42]	[-0.35;0.20]	[-0.09;0.25]	[-0.20;-0.05]	[-0.00;0.00]
Nodeicov GDP per capita	0.02	-0.09	0.01	0.41 *	0
	[-0.13;0.13]	[-0.36;0.25]	[-0.09;0.19]	[0.34;0.45]	[-0.00;0.00]
Absdiff GDP	-0.82 *	-0.75 *	-0.18	-0.91 *	0.15
	[-1.67;-0.53]	[-1.44;-0.24]	[-0.40;0.03]	[-1.15;-0.63]	[-0.50;0.75]
Absdiff GDP per capita	-0.22 *	-0.14 *	0.05	-0.26 *	0
	[-0.34;-0.14]	[-0.38;-0.02]	[-0.13;0.16]	[-0.38;-0.11]	[-0.00;0.00]
Mutual Region	0.37 *	0.41 *	0.11	-0.1	0.84 *
	[0.05;0.74]	[0.02;0.87]	[-0.22;0.56]	[-0.31;0.08]	[0.50; 1.16]
Mutual High Income Nation	-0.02	-0.02	0.1	0.05	-0.38 *
	[-0.33;0.28]	[-0.28;0.24]	[-0.33;0.51]	[-0.11;0.22]	[-0.55;-0.25]
Delayed Reciprocity	0.42 *	1.25 *	1.67 *	-2.51	-1.33 *
	[0.13;0.75]	[0.48; 3.26]	[0.67; 4.81]	[-2.68;0.12]	[-1.53;-0.26]
Memory/Stability	1.56 *	3.09 *	4.20 *	2.33	3.61 *
	[1.47; 1.69]	[3.01; 3.30]	[4.06; 4.38]	[-0.21; 3.20]	[3.52; 3.82]

*Significant parameters are indicated by * where zero is outside the confidence interval*

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