Title: How does the behaviour of the core differ from the periphery? – an international trade network analysis

Abstract

World systems theory proposes that global trade is stratified into hierarchical groups, a tightly connected core, and a weakly connected periphery. The theory suggests that this hierarchical structure contributes to power imbalances in the global economy and the organisation of the international division of labour. This paper employs a complex network model, an Exponential Random Graph Model (ERGM), to a set of international trade models to examine how the export patterns of the core differ from the periphery. The analysis highlights that many of the processes underpinning the formation of trade ties are consistent across product groups. The key differences between the high- and low-tech groups are import patterns. The difference between export activity of the core and periphery is also more pronounced for low tech compared to high tech. The differences between the export activity of the core and periphery are, that in the low-tech case, larger nations in the periphery are more likely to export, whilst in the core it is smaller nations (up to a point) that are likely to export these low-tech goods. In both the case of the high tech and low tech, less affluent nations in the core were more likely to export.

Keywords: World Systems, Network Analysis, International Trade, Core-periphery, Gravity Model

1. Introduction

The world systems theoretical framework proposed by Wallerstein (1974) seeks to explain economic development, more specifically the dynamics of the capitalist global economy to inform on the economic division of labour between core and periphery regions. World systems theory has links to dependency theory, in particular the power imbalance in global trade between rich developed countries and poor developing countries (Chase-Dunn and Grimes, 1995; Chirot and Hall, 1982; Coccia, 2019; Van Rossem, 1996).

World systems research has long been concerned with the division of international trading patterns into a tightly connected core and a disconnected periphery (Lloyd et al., 2009). The world systems perspective notes that global trade is segmented in countries belonging to the core (usually rich developed nations), that are more likely to trade heavily with each other. Along with the less connected periphery, often consisting of developing nations that are more likely to trade with the core than other members of the periphery (Magerman et al., 2020). The world systems perspective argues that relations between the core and the periphery are often characterised by unequal exchange (Clark and Cason, 2015; Clark and Mahutga, 2013), allowing members of the core to gain from trading with disconnected countries in the periphery, contributing to global inequalities (Mahutga et al., 2011). The process of unequal exchange results in the accumulation of capital in the core, with the appropriation of resources from the periphery (Hartmann et al., 2020).

Extant work has identified characteristics of the core and periphery (Roberts, 2013). Countries in the periphery tend to have larger informal economies (these are unrecorded and unregulated economic activities) and they tend to specialise in labour intensive and competitive industries (Goldfrank, 2000). Whereas countries in the core tend to specialise in capital and skill intensive production in monopolised industries.

Mahutga (2006) has noted the interplay with the technological (or industrial) sophistication of the products traded, and patterns of unequal exchange. In the complex network analysis presented by Gala et al. (2018), their findings suggest that countries at the core of the world system (high income) tend to specialise in the production and export of complex goods, whilst countries at the periphery (low income) are more likely to specialise in the low technology and low complexity products. Low levels of participation in the trade of complex products limits the opportunity for a country to reap the knowledge and efficiency gains associated with being part of a wider knowledge society (Stiglitz and Greenwald, 2014). This can subsequently impact export and economic developments, potentially resulting in countries finding themselves in development traps (Hartmann et al., 2020). However, Chase-Dunn and Rubinson (1977) argue that it is not the production of the commodity itself that results in differences between the core and periphery, rather how labour, technology, raw materials and fixed capital are brought together in production processes. Mahutga and Nash-Parkera (2015) note that products with low levels of technological sophistication tend to flow from the periphery to the core (up the hierarchy), whereas products with a high level of sophistication tend to flow from the core to the periphery (down the hierarchy).

There are several other topics that are examined through the world systems framework. Zhou (2020) provides a further contribution to the world systems literature, by noting that the benefits a country reaps from being embedded in a Regional Trade Agreement (RTA) depends on its world system status. The impact of the RTA on two trading core countries is greater than the said impact on two trading peripheral countries. Others have noted the interplay between world system strata and environmental impact (Prell et al., 2014; Rice, 2007; Roberts and Grimes, 2002).

Empirical work drawing on the world systems theory often draws on Social Network Analysis (SNA) (Gorgoni et al., 2018a; Kick and Davis, 2016). This has resulted in a stream of literature devoted to the development of algorithms to better categorise countries in the core and the periphery (Boyd et al., 2010; Csermely et al., 2013; Elliott et al., 2020; Holme, 2005; Kostoska et al., 2020; Tang et al., 2019). Additionally, there is a stream of literature that builds on the seminal work of Borgatti and Everett (2000) that developed a model of the core/periphery (for example the work of Nordlund 2018 and Clark and Beckfield, 2009).

The majority of extant literature considering core-periphery patterns in the global economy considers either how being a member of the core shapes economic development, or how to detect whether a country is part of the core or periphery. There is relatively little on the differences in behaviours between members of the core versus the periphery. This paper intends to fill this gap, by examining how export patterns of the core differ from the periphery based on a number of country level attributes.

Whilst world systems theory (through the use of SNA) addresses questions on the unequal division of labour and economic development, it is the gravity model that is most frequently used to explain patterns of international trade in the modern global economy (Baier et al., 2014; Escaith and Miroudot, 2015; Kabir et al., 2017). The gravity model is considered the standard bearer in the analysis of international trade (Ward et al., 2013), as it is a very successful empirical model in predicting bilateral trade flows. Given the success of the empirical model, it is often used as a practical tool by policy makers to examine the efficacy of trade promoting policy (Head and Mayer, 2014; Yotov et al., 2016). The gravity model is an econometric model reminiscent of Newton's law of universal gravitation; where the volume of trade between two nations is positively related to their economic size (as measured by GDP), and negatively to their distance (Anderson, 2011). A key virtue gravity model approach is parsimoniousness. The model specification often consists of a small selection of terms, such as GDP origin, GDP destination, distance, common language, shared border and colonial relationship (Greaney and Kiyota, 2020).

Whilst the gravity model has large empirical success, there are ongoing discussions and debates over particular issues with the specification and its ability to explain certain features of international trade. One of the most prominent debates is over the impact of distance trade, the so-called distance puzzle. One explanation for rapid globalisation of trade and production in past decades is cheaper, faster, and easier transport with lower costs (Lin, 2013), which resulted in many suggesting that there had been the "death of distance" within global trade (Cairncross, 2002; Couclelis, 1996). Although globalisation suggests that the importance of distance should be reduced, empirical work making use of gravity models continued to find a negative and significant impact of distance on international trade (Buch et al., 2004). Lin and Sim (2012) suggest that there is evidence (in gravity model estimations) that the impact of geographic distance on trade is increasing, rather than declining.

Arribas et al. (2011) note that the importance of distance on trade differs across countries. They note that distance matters more to industrialised and European countries, such as Austria, Belgium, Denmark, Italy, Spain, and the USA. Whereas distance matters less to developing (chiefly South American) nations such as Brazil, Chile, Peru, China, India, and South Africa. The role of distance is not frequently considered within world systems approaches, however, when peripheral nations are considering trade promoting policy, such as joining a Regional Trade Agreements (RTAs), there is a need to better understand how the role of distance impacts peripheral trade patterns (compared to the core).

The link between economic development and exports has also been examined separately from world systems theory, and gravity modelling approaches. A number of studies consider a country's specialisation patterns and the economic development levels (Bastos and Silva, 2010; Córcoles et al., 2014; Felipe et al., 2012; Ferrarini and Scaramozzino, 2016; Kali et al., 2013; Rodrik, 2006). In their seminal work, Hausmann et al. (2007) note that "what you export matters", where countries with a more diverse and complex export basket (in terms product specialisation and products traded) are more likely to experience higher levels of growth and development. Therefore, many developing and emerging economies make attempts to upgrade product capabilities to gain a comparative advantage in high-tech, more knowledge intensive goods (Barrientos et al., 2011). Extant work examining the differences in the topological properties of international trade network of products with varying technological content, note that low and high tech goods tend to have distinctive network features (Cingolani et al., 2018, 2015; Jiang and Qu, 2020). Others have noted that trade in low-tech and high-tech products have experienced the impacts of globalisation in contrasting ways. Palan et al. (2021) note that trade and production is far more global when considering low-tech goods compared to high-tech goods. Given the differences in trading patterns between different sectors, this paper considers two product groupings (low-tech and high-tech), to examine whether the core-periphery structure differs based on the technological content of products traded.

What is somewhat absent from the world systems literature is an explanation of the formation of economic ties. This paper seeks to examine whether gravity (or gravity model effects) impact the core and periphery in the same way. Are both countries in the core and periphery likely to gravitate towards larger economies? Does distance dampen the likelihood of trade for both the core and periphery? This paper seeks to understand how the export behaviour of the core differs from the periphery. Therefore, this paper aims to address the following research questions:

1. Do countries from the core export to smaller or larger markets (as measured by GDP) compared to the countries from the periphery?
2. Do countries from the core export to more or less affluent nations (as measured by GDP per capita) compared to the countries from the periphery?
3. How does distance impact export flow of countries from the core compared to countries form the periphery?
4. Are export patterns consistent across product groups?
5. Do core and periphery export patterns differ across product groups?

As noted in the first three research questions, this paper examines how the export behaviour of the core and periphery differ, focusing on whether they adhere to aspects of the gravity model. This paper aims to go beyond the gravity model approach in the model specification, in terms of market size and affluence. Rather than only looking at origin and destination attribute, we make use of a wider range of effects to also examine the attribute difference between trading partners, along with quadratic sender and receiver effects. More specifically we make use of the five effects approach developed by Snijders and Lomi (2019) for continuous variables (this will be discussed in further detail in method section of the paper) in our network modelling approach. This provides an opportunity to further unpack the gravity model, and for policy makers has the potential to inform further on how attribute values of both the sender and receiver impact trade when they are formulating trade promoting policy. Furthermore, we contribute to the ongoing distance puzzle, providing an exploration of the impact of distance on core and peripheral nations in low- and high-tech sectors.

Understanding the differences in trading behaviour of the core and periphery has the potential to inform on policy, more specifically the industrial strategy that peripheral, emerging economies can pursue to improve development levels. Especially as countries in the periphery are often viewed as so called "catching-up" economies (Landesmann and Stöllinger, 2019). Understanding export patterns is especially salient when considering policy related to peripheral or emerging economies, as there is often a focus on manufacturing and export-oriented development (Kim et al., 2018; Lee, 2017, 2016), along with the shift to the export of more knowledge intensive goods (Pangestu et al., 2015; Sato, 2016).

Cheong and Tang (2015) note that developing nations can benefit from further integration with industrial countries, highlighting the importance of a more nuanced understanding of export flows from core and peripheral nations. Many scholars note that the globalisation of industries in past decades, with the new international division of labour resulting from the rise of Global Value Chains (GVCs) and Global Production Networks (GPNs) represents an important development opportunity for emerging, often peripherical, economies (Raei et al., 2019). An understanding of export patterns can help inform on the global supply of labour to other countries and can therefore aid in the development of relevant trade promoting policy (Zhao, 2021). This is especially relevant for so called “core-contender” countries, which often consist of the BRICS nations (Mahutga and Smith, 2011).

This paper is structured as follows: the next section provides details on the data used in this paper, more specifically the international trade data used to construct the various networks. This is followed by the method section which will provide details on the five effects model specification and the modelling approach used to address the research questions posed by this paper. The fourth section of this paper presents the results, and this is followed by a discussion section that notes the concluding comments and avenues for future research.

2. Data

This paper draws on international trade data in high- and low-tech goods in order to construct two International Trade Networks (ITNs) with differing levels of technological content. This data is extracted from UN Comtrade, and the classification of high- and low-tech components is drawn from Lall et al. (2006). Data is extracted for 2017 and a network is constructed for each product group. This results in a network of countries linked by international trade; the sender is the exporter, and the receiver is the importer. The ties are weighted by the value of trade. In this study, a threshold is applied, given many ties are low value, and contribute little to international trade, yet significantly impact the structural features of the network. Therefore, we only retain ties that are 0.01% of total trade of the product groups; this approach has been frequently utilised in the literature (Smith et al., 2019; Smith and Sarabi, 2021). Several other country level attributes are included, such as GDP and GDP per capita (taken from the World Bank). A set of dyadic attribute data is also utilised, more specifically the distance matrix, whether countries have a border and common language information.

Figure (1) presents the visualisations of the high-tech and low-tech trade networks, where the node colour indicates the geographic partition. In both of these networks, European nations and South Asian & Pacific nations are at the centre of these trading systems. In the low-tech networks, there are nations from South Asia that are playing more prominent roles within the network.

Insert Figure 1 about here.

----

3. Method

Network analysis is an established technique to analyse ITNs (Gorgoni et al., 2018a) and has often been utilised to tackle hypotheses in world systems research (Babones, 2005; Gorgoni et al., 2018b; Nemeth and Smith, 1985; Smith and White, 1992; Snyder and Kick, 1979). SNA has been applied to the ITN to investigate a wide range of topics within economics and international business such as examining how a country's position in the trade network impacts performance (Smith et al., 2016) or development (Kastelle and Liesch, 2013), and examining to what extent the gravity model can explain the topological features of the ITN (Almog et al., 2019, 2015; Duenas and Fagiolo, 2013; Fagiolo, 2010).

To address the research questions posed by this paper, we make use of advanced network model, more specifically, an Exponential Random Graph Model (ERGM). The ERGM is a statistical model for cross sectional network data (Robins et al., 2007). ERGMs are parameterised in terms of patterns of local network substructures, termed network configurations. The parameter values indicate the weight and direction of the network configurations in explaining the global network structure. The configurations are often used as indicators of network processes, and therefore the parameter values can offer information about the processes that potentially underpin the network (Lusher et al., 2013; Robins, 2013). In the ERGM, we specify a set of structural effects, geometrically weighted in and out degree and geometrically weighted edgewise shared partner (GWESP). The degree effects capture the spread of imports and exports respectively in the network. A negative and significant effect would indicate that they are concentrated in a small handful of countries. The GWESP effect captures clustering in the network, the tendency for connected countries to have multiple shared trading partners.

Node based effects test how actor attribute influence and shape how actors connect in a network. We include nodal effects for GDP and GDP per capita, these allows us to examine how country characteristics shape international trade (and whether they adhere to the gravity model of international trade). In ERGMs, node-based effects tend to chiefly consist of homophily effects. Where these homophily effects capture whether actors with similar attribute values are more likely to establish a tie (McPherson et al., 2001). However, there are other mechanisms that determine how attribute values influence how actors connect. In the case of GDP, an homophily effect would indicate that nations that have similar market sizes are more likely to trade.

In the ERGM, we make use of the five-effects framework developed by Snijders and Lomi (2019) for GDP and GDP per capita, to further unpack how market size and affluence impact trade. Snijders and Lomi (2019) propose an extended parameter approach to capture how continuous attributes influence how actors connect. These parameters are a quadratic function of the values of the sender and receiver, and consist of homophily, aspiration, conformity, and sociability effects (see table (1)). These parameters are formulated as a positive choice, where the order of the covariate is framed as originating from actor i to actor j. This approach allows us to unpack the prediction of the gravity model (De Benedictis and Taglioni, 2011; Kabir et al., 2017), going beyond an examination of countries gravitating towards larger, more affluent nations.

Insert Table 1 about here.

The homophily effect captures the tendency for actors with similar attribute levels to trade; it is formulated in terms of the ego value minus the alter value squared, where a smaller value indicates homophily. The conformity effect is based on the notion that actors may base decisions to connect based on comparing the recipients attribute value to a reference group, where they may be more likely to preferentially connect with someone with an attribute value that is similar to the normative value. Snijders and Lomi (2019) describe this as a tendency toward conformity, that individuals are more likely to connect with actors when their characteristics are closer to the social norm (in the context of the empirical setting). In this setting, a GDP conformity effect would indicate whether countries are more likely to export to countries with a normative market size. The aspiration dimension captures whether actors are attracted to and are more likely to connect with actors with high attribute values. In this empirical context, it allows us to empirically test the gravity model; for instance, in the case of GDP, whether nations are more likely to gravitate (and trade with) larger nations. The sociability captures the tendency for actors with a high attribute value to send ties; for the case of GDP, this would indicate that larger nations are more likely to export. The sociability squared captures whether the sociability effect drops off at a certain level, pointing towards an invested U-shaped relationship between the attribute value and the tendency to send ties.

Dyadic covariate effects model how another network (or relationship) influences the formation of ties. In this empirical setting, dyadic covariates include the distance, common language, and shared border.

To explore the basis where the export ties differ between the core and periphery members, a set of interaction effects are specified (An and Mcconnell, 2015), which is not often utilised in empirical work applying ERGMs (as noted by Silk et al., 2017). In this case, we make use of interaction effects to distinguish between the process of exports from the core and exports from the periphery, utilising a dummy variable to identify whether a country is a member of the core. The approach outlined by Ma and Mondragón (2015) is applied to categorise a country as a member of the core or periphery in these international trade networks. The approach developed by Ma and Mondragón (2015) makes use of edge weights, therefore allows us to take into account the level of trade ties between countries. In their approach, nodes are ranked based on decreasing order of node strength (the weighted degree centrality), σ_i. Therefore, a node with rank r and node strength σ is referred to as σ_r. The quantity of the node strength arising from linking to higher ranked nodes is calculated and referred to as σ_r^+. There will be a node r^* where σ_r^+ has reached its maximum, and from that node onwards, σ_r^+ will always be less than $\sigma_{r^*}^+$ ($\sigma_{r^*}^+ > \sigma_r^+$). This is therefore used to identify the boundary been the core and the periphery, where all nodes with a rank less than or equal to r^* are included in the core, with all other nodes included in the periphery.

The core sender term is interacted with the five GDP and GDP per capita parameters to identify whether exports from the core as a function of key country attributes is significantly different from exports from the periphery. This is also interacted with the geographic distance dyadic covariate, to examine how distance impacts exports of the core compared to the periphery.

This approach chiefly allows for an investigation into how export patterns for the core differ from the periphery based on these five effects for market size and affluence. The core and periphery structure of the international trade network reflects the inequality in the global system (Garcia-Algarra et al., 2020). Low and middle income economies, often occupying peripheral positions tend to consider policy tools to promote participation in global trade and value chain activities (Flentø and Ponte, 2017; Kowalski et al., 2015; Tajoli and Felice, 2018), that could potentially generate a more fair and balanced trade network. Successful practices and policy for export promotion for low- and middle-income economies include establishing trade deals (often the more straightforward policy) along with increasing productivity and institutional development (which are far more complex) (Belloc and Di Maio, 2011). The five effects approach has the potential to inform on trade promotion policy discussions of low- and middle-income economies likely to be on the periphery of the international trade network. For instance, if a periphery country's policy is to promote export and GVC participation, it may wish to imitate core member trading patterns, and shape policy and trade agreements in line with this. Therefore, if the core effects indicate aspiration, then this would indicate that the periphery should focus on policy to drive trade with larger and more affluent markets. The sociability effects indicate which are the most active exporters in the network, which can inform on the key players that facilitate GVC participation.

In this paper, the ERGM is estimated using the ergm R package (Hunter et al., 2008b), which is part of the Statnet suite of packages for social network analysis (Handcock et al., 2008).

4. Results

Before presenting the modelling results, a descriptive analysis of the networks and country attributes is provided. Table (2) provides the descriptive statistics for GDP and GDP per capita, for the countries participating in the low- and high-tech networks, also distinguishing between the core and periphery. The GDP results indicate that on average nations participating in the high-tech trade network are larger than the low-tech trade network. When comparing the core and periphery in these two product groups, the market size (as captured by GDP) of nations in the core is greater than the periphery, and that market size is more dispersed amongst the periphery than the core. For market affluence (as captured by GDP per capita), the results indicate on average, for both groups, the core is much more affluent (in line with world systems theory). There is also more dispersion in market affluence amongst the periphery, especially in the low-tech group.

Insert Table 2 about here.

Table (3) provides the network statistics for the low- and high-tech product groups, many of these results are consistent across the two product groups. Network size indicates the number of countries participating in the trade networks; there are a greater number of countries involved in low-tech trade than high-tech trade (which is potentially associated with the production of more complex goods). Density is the ratio of observed to all possible ties in the network. Network connectivity is relatively low in both the high-tech and low-tech product groups. Reciprocity captures the level of two-way ties in the network, where two countries both import and export from one another. The proportion of reciprocal trade ties is slightly higher in the trade of high-tech goods, when compared to low-tech.

Insert Table 3 about here.

In degree and out degree centrality refers to the number of trade ties a country receives (imports) and sends (exports) respectively in these networks. Centralisation captures the distribution of these degree centrality scores. In this empirical setting, a high out degree centralisation score indicates that exports are concentrated in a small set of countries. In degree centralisation indicates that import ties are concentrated. Low centralisation scores would suggest that trade ties are spread evenly throughout the network (Borgatti et al., 2018). The centralisation scores are similar for the low- and high-tech groups, with a higher out degree centralisation and lower in degree centralisation scores. This suggests that exports are concentrated in small handful of countries, whilst imports are more evenly distributed throughout the trade networks. This indicates that exports exhibit a hierarchical structure, potentially pointing towards a hierarchical division of labour.

Degree assortativity captures the correlation of degree centrality between connected countries in the network (Newman, 2002). A positive assortativity score would indicate that there is a tendency for low degree countries to connect to high degree countries. Whereas a negative score would indicate that countries are more likely to trade with those with a similar degree centrality score. The results indicate that there is a tendency for degree assortativity in both trade networks, that there is tendency for nations with few trade ties to trade and connect with large hubs.

The regional homophily score is assortativity for the regional partition of nations, where it captures the correlation of regional partition membership between connected countries in the network. A positive score would point towards intra-regional trade, whilst a negative inter-regional. The results suggest that in both the high- and low-tech product groups there is a tendency for regional trade.

Figure (2) maps the countries present in the high-tech and low-tech networks, with the countries that are part of the core indicated by a lighter colour. In the case of high-tech, countries in the core include North American nations, European countries (excluding Spain and Portugal), and parts of South Asia and Pacific. Yet in the case of the low-tech product group, when examining North America, we observe a contrast to high-tech, that Canada is not part of the core. In Europe, there are also some differences between core membership for low- and high-tech; Ireland is not part of the core, whilst Spain is in the low-tech core.

This map indicates that out of the five BRICS nations, major emerging national economies, only India and China are part of the core (and India only in the case of the low-tech product group). Many have noted the ascent of China to the core, and the progress it has made through the various world system stratifications (Grell-Brisk, 2017; Li, 2020). Jacobs and Rossem (2016) note that whilst there has been a significant newcomer into the core, China, that this does not represent a substantial change in the power relations, or stratification of the world system.

From figure (2) we observe that there are more nations from South America and Sub-Sahara Africa involved in trade of low-tech goods (although in the periphery). This is perhaps not surprising, given that countries from these regions (especially larger countries such as Brazil) are more dependent on trade in low-tech and primary goods (Landesmann and Stöllinger, 2019).

Insert Figure 2 about here.

The results of the ERGMs are presented using a set of forest plots, providing a graphical presentation of the coefficients and confidence intervals for each term in the ERGM. The ERGM results are presented in figures (3) to (6). Each figure provides the forest plot for the high-tech and low-tech ERGM, one for the models without any interaction effects, then a separate figure for each model set for the GDP, GDP per capita and distance interaction effects.

This allows for a clear comparison between the high-tech and low-tech cases. The line is red when the confidence interval does not contain zero and blue otherwise. Tables (A1) and (A2) in the appendix provide the parameter estimates, standard errors and significance level details for each model estimated for the high-tech and low-tech cases.

Insert Figure 3 about here.

Figure (3) presents the models for the high-tech and low-tech case with no interaction effects. From figure (3), we observe that many processes underpinning the formation of trade ties are the same for both the high-tech and low-tech case. The negative and significant outdegree results indicate that export ties are concentrated in a handful of countries for both product groups. There is a positive and significant clustering effect. As expected, there is a positive and significant core exporter effect, indicating members of the core are more likely to export both high- and low-tech products. Distance is negative and significant; therefore, provides support against the so-called death of distance argument. In line with our expectations from the gravity model, countries with shared borders and a common language are more likely to trade, as indicated by the positive and significant effects.

Comparing the model for the low-tech components to the high-tech, there are several notable differences. In particular, the indegree effect, which indicates that the distribution of imports differs significantly between high- and low-tech goods. In the case of high-tech the indegree effect is negative and significant, suggesting that imports (along with exports) are concentrated in a small handful of countries. Whereas for low-tech, this term is non-significant, suggesting that we do not observe the same level of concentration of import ties.

The GDP results for high-tech indicate there is a tendency for homophily, as the negative result indicates a larger difference in market size is associated with a reduced tendency for a trade tie to form. The conformity result indicates that there is not a tendency for trade with a country with a normative market size, rather the positive aspiration effect indicates there is a tendency to trade with larger markets. The positive sociability suggests larger nations are more active in trade of high-tech goods (in line with the gravity model specification). When considering these results together, it suggests that trade in high-tech goods tends to occur between nations with a larger market size; it is important to note that this tendency would not be captured by the typical gravity model estimation. For low-tech trade, there is a negative conformity and positive aspiration effect, this indicates that there is a tendency for countries to export low-tech goods to larger markets. This highlights some key differences between the high-tech and low-tech case, where there is some evidence of homophily based on market size in the high-tech grouping, this is not observed for trade in low-tech products. Additionally, there is a tendency for larger nations to export high-tech goods (as indicated by the GDP sociability effect), this is not observed for low-tech goods.

For the GDP per capita five effects, in the case of the high-tech product group there is a negative aspiration, indicating nations are likely to trade with less affluent nations. This, taken with GDP effects, indicates that there is a tendency for countries to export to large emerging economies, and these are more active in the trade network. The GPN for electrical goods is centred on Southeast Asia and Pacific, including many larger emerging economies (Sturgeon and Kawakami, 2011; Sturgeon and Van Biesebroeck, 2011); this may explain the pattern observed here. When considering the GDP per capita for the low-tech group, there are a number of contrasting features when comparing with the high-tech group. For low-tech, there is a negative conformity effect indicating a tendency against export to nations with normative affluence levels. There is a negative sociability effect and a positive sociability squared effect.

This suggests that there is only a tendency for the most affluent nations to be more active in low-tech goods, which is a somewhat surprising observation.

Figure (4) presents the ERGM results for low-tech and high-tech, when the GDP five effects were interacted with core exporter. The interaction effects in this model contribute to addressing the first research question posed by this paper. For both the high-tech and low-tech product groups, there is little change in the magnitude and significance of the main effects included in the first model sets (with no interaction effects included).

Insert Figure 4 about here.

We observe notable differences between the high-tech and low-tech cases when considering the GDP interaction effects. For the high-tech, the interaction effects are non-significant, suggesting that the high-tech export patterns of countries from the core do not differ from the periphery based on market size (as captured by GDP). However, when considering low-tech, there are some significant interaction effects, more specifically the GDP sociability interaction, (which is negative and significant), and the GDP sociability squared interaction (which is positive and weakly significant). Taking these results with the negative and weakly significant GDP sociability effects and non-significant GDP sociability squared, this suggests that whilst larger nations in the periphery are more likely to export, this is not the case for the core. Rather in the core, it is smaller nations that are more likely to export low-tech goods (up to a point, as indicated by the sociability squared interaction).

Figure (5) presents the ERGM results for the two product groups when the GDP per capita five effects were interacted with core exporter. There are a number of similarities between the low-tech and high-tech groups in terms of how export patterns differ for the core and periphery. For both models, the main (baseline) GDP per capita effects are non-significant, this suggests in the main models (as presented in figure (3)), the GDP per capita effects are driven by the activities of the core. In both the high-tech and low-tech there is a negative and significant GDP per capita sociality interaction effect, where this is even more pronounced for the low-tech case. This suggests that less affluent nations in the core are more likely to export these products. It is not surprising that this is more pronounced for low-tech, as less affluent nations often hold a comparative advantage in low tech goods. There is a positive sociability squared interaction for the low-tech case, which suggests this effect is dampened for the most affluent nations in the core.

Insert Figure 5 about here.

Figure (6) presents the final set of ERGM results, when the distance term was interacted with core-exporter. We observe that the distance interaction effect is non-significant for both low- and high-tech cases, suggesting that distance has a negative impact on exports from both the core and the periphery. However, after including the distance interaction effect in the model for the high-tech, the core exporter effect becomes non-significant, whilst in the low-tech case, the core exporter becomes more prominent. This potentially highlights there is a need to further unpack the impact of distance.

Insert Figure 6 about here.

Figures (7) and (8) provide the goodness of fit results for the high-tech and low-tech models without any interaction effects. The goodness of fit plots compares the salient structural features of the observed networks with a set of networks simulated from the estimated ERGM (Hunter et al., 2008a). We can see that the ERGMs are able to explain the export and imports for both groups, as indicated by the indegree and outdegree plots. The export patterns (outdegree) are explained a little better than imports (indegree). The models are also able to sufficiently explains minimum geodesic distance yet does not explain the edgewise shared partner patterns to same level. The goodness of fit results for the models with interaction effects are not presented here, however, they follow a similar pattern to figures (7) and (8).

Insert Figure 7 about here.

Insert Figure 8 about here.

In order to further examine the differences between export patterns of members of the core versus members of the periphery, we utilise selection function plots. The selection function plots capture the effect of GDP and GDP per capita on exports for members of the core and periphery. The continuous curves are the separate selection functions for three values of the exporting country's (the ego's) GDP/GDP per capita as a function of the importer's (the alter's) GDP/GDP per capita (as captured on the horizontal axis). The three values capture small, medium, and large (based on quartiles) values for market size and market affluence.

Figures (9) and (10) present the selection functions for high-tech for GDP and GDP per capita respectively. Figure (9) indicates that for nations in the periphery of the high-tech network, there is a tendency for countries of any size to gravitate to larger markets, and that this is even more prominent for larger nations (as it is only for larger nations that the selection function is greater than zero). For the members of the core, similar patterns are observed, where again there is a tendency to gravitate towards larger nations, with the selection value even greater than in the case of the periphery. There is a strong indication that markets of any size in the core are unlikely to export to smaller markets.

Insert Figure 9 about here.

Figure (10) presents the selection function for high-tech regarding GDP per capita, market affluence. In the case of the core, very rich nations (as indicated by the blue line), are likely to export to poorer nations, perhaps capturing the process of unequal exchange amongst the most affluent member of the core. For the periphery similar patterns are observed, yet not to the same extent as the core.

Insert Figure 10 about here.

Figures (11) and (12) are the selection plots for the low-tech group for GDP and GDP per capita respectively. Figure (11) indicates comparable patterns to the high-tech case; for the core there is a tendency to export to larger markets, and this is more pronounced for smaller nations. For the periphery, there is a tendency for nations to export to larger markets, yet this result is not as prominent as for core nations (and the selection function value is only positive for large countries).

Insert Figure 11 about here.

Figure (12) presents the GDP per capita patterns for the low-tech group, where we observe clear differences when compared to the high-tech GDP per capita results. For the core members of low-tech trade there is a tendency to export to rich nations, which is especially key for less affluent nations in the core.

Insert Figure 12 about here.

For countries in the periphery, there is a tendency to export to mid-range affluent nations, with this trend amplified for less affluent peripheral nations.

5. Discussion

This paper posed five research questions; the first asked do countries from the core export to smaller or larger markets (as measured by GDP) compared to the countries from the periphery?. The analysis indicates that differences emerge between the core and the periphery on the basis of sociability, including for market size. Our analysis indicated that differences between the core and periphery exporting behaviour on the basis of market size only varies for the low-tech case (as indicated by figure (4)). For low-tech goods, larger nations in the periphery are more likely to export, whilst it is smaller nations in the core (up to a point) that export these low-tech goods. This potentially reflects that larger emerging economies are likely to specialise in the production of low-tech goods.

The second research question asked do countries from the core export to more or less affluent nations (as measured by GDP per capita) compared to the countries from the periphery? The results from the ERGM with GDP per capita interaction effects, as presented in figure (5) indicate (to some extent) consistent results between the high-tech and low-tech product groups. It appears that less affluent nations in the core are more likely to export, and that this result is more pronounced for the low-tech group. This perhaps reflects the active role of certain emerging economies with core membership to be active exporters in these networks (especially the low-tech case).

Whether distance impacted export activity of the core and periphery was the third research question posed by this paper. Our results indicated that distance impacted the core and periphery in the same way, that it had a negative and significant impact on trade. This suggests for both the core and periphery, they are likely to trade with geographically closer countries in both product groups. These results contrast with the work of Arribas et al. (2011), that suggests distance matters more for certain countries.

The fourth research question asked whether patterns were consistent between the two groups with two different levels of technological content. We observe similarities in terms of how the core differs from the periphery. However, the main difference is in the distribution of import ties. There are other differences in terms of how GDP and GDP per capita impact trade ties, as observed in figures (3) to (6). The final question posed by this paper considered whether differences between the core and periphery varied by product groups. We note that the differences between the core and periphery for market size were only observed for low-tech and that for market affluence, the difference were more pronounced for low-tech.

A key point to note, especially when considering the policy implications, is that the differences between the core and periphery are chiefly in terms of the sender attributes, and not the destination of the exports. This potentially suggests that in terms of the market characteristics that the core and periphery serve (in terms of size and affluence), there is little difference. A potential policy implication for peripheral countries, to increase participation in GVCs or promote exports, in order to reduce inequality in the trade network, would be to promote trade with smaller core nations (Garcia-Algarra et al., 2020). The analysis indicated that the main difference between the core and periphery were concentrated in the low-tech grouping. This reflects that market size, affluence, and distance are potentially a larger driver in inequality in the trade network (and potentially the wealth gap) in the low tech. Policy makers often aim to increase the sophistication of exports, therefore, in this case, there could be a call for countries to shift from low tech to high tech trade. The interaction effect were not significant in the case of the high tech group, indicating that there is not a substantial difference in exporting behaviour in the core and periphery on the basis of these attributes This suggests that there is a need for more nuanced analysis of trade in high tech goods to better understand how differences between the core and periphery emerge, and what policy tools could be used by members of the periphery to reduce inequality in the global trade network.

This research has a number of limitations, which present avenues for future research. Firstly, this approach is limited to a cross sectional case, there is scope to extend this to a longitudinal setting to unpack further whether the differences in export between the core and periphery has changed over time. Furthermore, we only examine international trade ties, yet the world system is characterised by a wider range of political, military, and economic types of relations (such as FDI) (Chase-Dunn, 1998), where many argue that these additional types of interactions play as much as an important role in the emergence of the core-periphery structure in the world system as global trade (Kentor, 2014; Snyder and Kick, 1979). Therefore, future work could examine a wider set of connections through a multiplex or multilayer approach, to further examine where differences in the behaviour of the core and periphery emerge.

6. References

Almog, A., Bird, R., Garlaschelli, D., 2019. Enhanced Gravity Model of Trade: Reconciling Macroeconomic and Network Models. Front. Phys. 7. https://doi.org/10.3389/fphy.2019.00055

Almog, A., Squartini, T., Garlaschelli, D., 2015. A GDP-driven model for the binary and weighted structure of the International Trade Network. New J. Phys. 17, 013009. https://doi.org/10.1088/1367-2630/17/1/013009

An, W., Mcconnell, W.R., 2015. The origins of asymmetric ties in friendship networks: From status differential to self-perceived centrality. Network Science 3, 269–292. https://doi.org/10.1017/nws.2015.12

Anderson, J.E., 2011. The gravity model. Annu. Rev. Econ. 3, 133–160. https://doi.org/10.1146/annurev-economics-111809-125114

Arribas, I., Pérez, F., Tortosa-Ausina, E., 2011. A New Interpretation of the Distance Puzzle Based on Geographic Neutrality. Economic Geography 87, 335–362. https://doi.org/10.1111/j.1944-8287.2011.01120.x

Babones, S., 2005. The Country-Level Income Structure of the World-Economy. JWSR 29–55. https://doi.org/10.5195/jwsr.2005.392

Baier, S.L., Bergstrand, J.H., Feng, M., 2014. Economic integration agreements and the margins of international trade. Journal of International Economics 93, 339–350.

Barrientos, S., Gereffi, G., Rossi, A., 2011. Economic and social upgrading in global production networks: A new paradigm for a changing world. International Labour Review 150, 319–340. https://doi.org/10.1111/j.1564-913X.2011.00119.x

Bastos, P., Silva, J., 2010. The quality of a firm’s exports: Where you export to matters. Journal of International Economics 82, 99–111. https://doi.org/10.1016/j.jinteco.2010.07.001

Belloc, M., Di Maio, M., 2011. Survey of the literature on successful strategies and practices for export promotion by developing countries.

Borgatti, S.P., Everett, M.G., 2000. Models of core/periphery structures. Social Networks 21, 375–395. https://doi.org/10.1016/S0378-8733(99)00019-2

Borgatti, S.P., Everett, M.G., Johnson, J.C., 2018. Analyzing Social Networks, Second edition. ed. SAGE Publications Ltd, Los Angeles.

Boyd, J.P., Fitzgerald, W.J., Mahutga, M.C., Smith, D.A., 2010. Computing continuous core/periphery structures for social relations data with MINRES/SVD. Social Networks 32, 125–137. https://doi.org/10.1016/j.socnet.2009.09.003

Buch, C.M., Kleinert, J., Toubal, F., 2004. The distance puzzle: on the interpretation of the distance coefficient in gravity equations. Economics Letters 83, 293–298. https://doi.org/10.1016/j.econlet.2003.10.022

Cairncross, F., 2002. The death of distance. RSA Journal 149, 40–42.

Chase-Dunn, C., Grimes, P., 1995. World-Systems Analysis. Annual Review of Sociology 21, 387–417.

Chase-Dunn, C., Rubinson, R., 1977. Toward a structural perspective on the world-system. Politics & Society 7, 453–476.

Chase-Dunn, C.K., 1998. Global formation: Structures of the world-economy. Rowman & Littlefield.

Cheong, J., Tang, K.K., 2015. Heterogeneous effects of preferential trade agreements: How does partner similarity matter? World Development 66, 222–236.

Chirot, D., Hall, T.D., 1982. World-system theory. Annual Review of sociology 8, 81–106.

Cingolani, I., Iapadre, L., Tajoli, L., 2018. International production networks and the world trade structure. International Economics, SI: Global Value Chains 153, 11–33. https://doi.org/10.1016/j.inteco.2017.10.002

Cingolani, I., Piccardi, C., Tajoli, L., 2015. Discovering Preferential Patterns in Sectoral Trade Networks. PLOS ONE 10, e0140951. https://doi.org/10.1371/journal.pone.0140951

Clark, R., Beckfield, J., 2009. A New Trichotomous Measure of World-system Position Using the International Trade Network. International Journal of Comparative Sociology 50, 5–38. https://doi.org/10.1177/0020715208098615

Clark, R., Cason, T., 2015. Getting on good terms: Examining cross-national variation in the terms of trade, 1990–2012. Sociology of Development 1, 374–399.

Clark, R., Mahutga, M.C., 2013. Explaining the trade-growth link: Assessing diffusion-based and structure-based models of exchange. Social Science Research 42, 401–417.

Coccia, M., 2019. Comparative World-Systems Theories. Global Encyclopedia of Public Administration, Public Policy, and Governance, Springer Nature Switzerland. https://doi. org/10.1007/978-3-319-31816-5_3705-1.

Córcoles, D., Díaz-Mora, C., Gandoy, R., 2014. Product sophistication: A tie that binds partners in international trade. Economic Modelling, XVI edition of the Applied Economics Meeting 44, S33–S41. https://doi.org/10.1016/j.econmod.2013.12.009

Couclelis, H., 1996. The death of distance.

Csermely, P., London, A., Wu, L.-Y., Uzzi, B., 2013. Structure and dynamics of core/periphery networks. Journal of Complex Networks 1, 93–123. https://doi.org/10.1093/comnet/cnt016

De Benedictis, L., Taglioni, D., 2011. The Gravity Model in International Trade, in: De Benedictis, L., Salvatici, L. (Eds.), The Trade Impact of European Union Preferential Policies: An Analysis Through Gravity Models. Springer, Berlin, Heidelberg, pp. 55–89. https://doi.org/10.1007/978-3-642-16564-1_4

Duenas, M., Fagiolo, G., 2013. Modeling the international-trade network: a gravity approach. Journal of Economic Interaction and Coordination 8, 155–178. https://doi.org/10.1007/s11403-013-0108-y

Elliott, A., Chiu, A., Bazzi, M., Reinert, G., Cucuringu, M., 2020. Core–periphery structure in directed networks. Proceedings of the Royal Society A 476, 20190783.

Escaith, H., Miroudot, S., 2015. World trade and income remain exposed to gravity. Originally published as 127–160.

Fagiolo, G., 2010. The international-trade network: gravity equations and topological properties. J Econ Interact Coord 5, 1–25. https://doi.org/10.1007/s11403-010-0061-y

Felipe, J., Kumar, U., Abdon, A., Bacate, M., 2012. Product complexity and economic development. Structural Change and Economic Dynamics 23, 36–68. https://doi.org/10.1016/j.strueco.2011.08.003

Ferrarini, B., Scaramozzino, P., 2016. Production complexity, adaptability and economic growth. Structural Change and Economic Dynamics 37, 52–61. https://doi.org/10.1016/j.strueco.2015.12.001

Flentø, D., Ponte, S., 2017. Least-developed countries in a world of global value chains: are WTO trade negotiations helping? World Development 94, 366–374.

Gala, P., Camargo, J., Freitas, E., 2018. The Economic Commission for Latin America and the Caribbean (ECLAC) was right: scale-free complex networks and core-periphery patterns in world trade. Cambridge Journal of Economics 42, 633–651.

Garcia-Algarra, J., Bengoechea, G.G., Mouronte-López, M.L., 2020. Reducing Trade Inequality: A Network-Based Assessment. Complexity 2020, e1593215. https://doi.org/10.1155/2020/1593215

Goldfrank, W.L., 2000. Paradigm regained? The rules of Wallerstein s world-system method. Journal of world-systems research 150–195.

Gorgoni, S., Amighini, A., Smith, M., 2018a. Networks of International Trade and Investment: Understanding globalisation through the lens of network analysis. Vernon Press.

Gorgoni, S., Amighini, A., Smith, M., 2018b. Automotive international trade networks: A comparative analysis over the last two decades. Network Science 6, 571–606.

Greaney, T.M., Kiyota, K., 2020. The gravity model and trade in intermediate inputs. The World Economy 43, 2034–2049. https://doi.org/10.1111/twec.12947

Grell-Brisk, M., 2017. China and global economic stratification in an interdependent world. Palgrave Communications 3, 1–12.

Handcock, M.S., Hunter, D.R., Butts, C.T., Goodreau, S.M., Morris, M., 2008. statnet: Software Tools for the Representation, Visualization, Analysis and Simulation of Network Data. J Stat Softw 24, 1548–7660.

Hartmann, D., Bezerra, M., Lodolo, B., Pinheiro, F.L., 2020. International trade, development traps, and the core-periphery structure of income inequality. EconomiA 21, 255–278. https://doi.org/10.1016/j.econ.2019.09.001

Hausmann, R., Hwang, J., Rodrik, D., 2007. What You Export Matters. Journal of Economic Growth 12, 1–25.

Head, K., Mayer, T., 2014. Chapter 3 - Gravity Equations: Workhorse,Toolkit, and Cookbook, in: Gopinath, G., Helpman, E., Rogoff, K. (Eds.), Handbook of International Economics, Handbook of International Economics. Elsevier, pp. 131–195. https://doi.org/10.1016/B978-0-444-54314-1.00003-3

Holme, P., 2005. Core-periphery organization of complex networks. Phys. Rev. E 72, 046111. https://doi.org/10.1103/PhysRevE.72.046111

Hunter, D.R., Goodreau, S.M., Handcock, M.S., 2008a. Goodness of Fit of Social Network Models. Journal of the American Statistical Association 103, 248–258. https://doi.org/10.1198/016214507000000446

Hunter, D.R., Handcock, M.S., Butts, C.T., Goodreau, S.M., Morris, M., 2008b. ergm: A Package to Fit, Simulate and Diagnose Exponential-Family Models for Networks. J Stat Softw 24, nihpa54860.

Jacobs, L.M., Rossem, R.V., 2016. The Rising Powers and Globalization: Structural Change to the Global System Between 1965 and 2005. JWSR 22, 373–403. https://doi.org/10.5195/jwsr.2016.624

Jiang, J., Qu, L., 2020. Changes in Global Trade Patterns in Manufacturing, 2001-2018. American Journal of Industrial and Business Management 10, 876–899. https://doi.org/10.4236/ajibm.2020.105059

Kabir, M., Salim, R., Al-Mawali, N., 2017. The gravity model and trade flows: Recent developments in econometric modeling and empirical evidence. Economic Analysis and Policy 56, 60–71. https://doi.org/10.1016/j.eap.2017.08.005

Kali, R., Reyes, J., McGee, J., Shirrell, S., 2013. Growth networks. Journal of Development Economics 101, 216–227. https://doi.org/10.1016/j.jdeveco.2012.11.004

Kastelle, T., Liesch, P.W., 2013. The Importance of Trade in Economic Development. International Studies of Management & Organization 43, 6–29. https://doi.org/10.2753/IMO0020-8825430201

Kentor, J.D., 2014. Capital and coercion: The economic and military processes that have shaped the world economy, 1800-1990. Routledge.

Kick, E.L., Davis, B.L., 2016. World-System Structure and Change: An Analysis of Global Networks and Economic Growth across Two Time Periods. American Behavioral Scientist. https://doi.org/10.1177/00027640121958050

Kim, S., Lee, J.-W., McKibbin, W.J., 2018. Asia’s rebalancing and growth. The World Economy 41, 2709–2731. https://doi.org/10.1111/twec.12608

Kostoska, O., Mitikj, S., Jovanovski, P., Kocarev, L., 2020. Core-periphery structure in sectoral international trade networks: A new approach to an old theory. PLOS ONE 15, e0229547. https://doi.org/10.1371/journal.pone.0229547

Kowalski, P., Gonzalez, J.L., Ragoussis, A., Ugarte, C., 2015. Participation of Developing Countries in Global Value Chains: Implications for Trade and Trade-Related Policies. OECD, Paris. https://doi.org/10.1787/5js33lfw0xxn-en

Lall, S., Weiss, J., Zhang, J., 2006. The “sophistication” of exports: A new trade measure. World Development, Part Special Issue (pp. 324–404). Corruption and Development: Analysis and Measurement 34, 222–237. https://doi.org/10.1016/j.worlddev.2005.09.002

Landesmann, M.A., Stöllinger, R., 2019. Structural change, trade and global production networks: An ‘appropriate industrial policy’ for peripheral and catching-up economies. Structural Change and Economic Dynamics, Frontiers of Industrial Policy: Structures, Institutions and Policies 48, 7–23. https://doi.org/10.1016/j.strueco.2018.04.001

Lee, J.-W., 2017. China’s economic growth and convergence. The World Economy 40, 2455–2474. https://doi.org/10.1111/twec.12554

Lee, J.-W., 2016. Korea’s Economic Growth and Catch-up: Implications for China. China & World Economy 24, 71–97. https://doi.org/10.1111/cwe.12175

Li, X., 2020. The rise of China and its impact on world economic stratification and re-stratification. Cambridge Review of International Affairs 1–21. https://doi.org/10.1080/09557571.2020.1800589

Lin, F., 2013. Are distance effects really a puzzle? Economic Modelling 31, 684–689.

Lin, F., Sim, N.C.S., 2012. Death of distance and the distance puzzle. Economics Letters 116, 225–228. https://doi.org/10.1016/j.econlet.2012.03.004

Lloyd, P., Mahutga, M.C., Leeuw, J.D., 2009. Looking Back and Forging Ahead: Thirty Years of Social Network Research on the World-System. JWSR 48–85. https://doi.org/10.5195/jwsr.2009.335

Lusher, D., Koskinen, J., Robins, G., 2013. Exponential Random Graph Models for Social Networks: Theory, Methods, and Applications. Cambridge University Press.

Ma, A., Mondragón, R.J., 2015. Rich-Cores in Networks. PLOS ONE 10, e0119678. https://doi.org/10.1371/journal.pone.0119678

Magerman, G., Bruyne, K.D., Hove, J.V., 2020. Pecking order and core-periphery in international trade. Review of International Economics 28, 1113–1141. https://doi.org/10.1111/roie.12483

Mahutga, M.C., 2006. The Persistence of Structural Inequality? A Network Analysis of International Trade, 1965–2000. Social Forces 84, 1863–1889. https://doi.org/10.1353/sof.2006.0098

Mahutga, M.C., Kwon, R., Grainger, G., 2011. Within-Country Inequality and the Modern World-System: A Theoretical Reprise and Empirical First Step. JWSR 279–307. https://doi.org/10.5195/jwsr.2011.417

Mahutga, M.C., Nash-Parkera, R., 2015. Visualizing Globalization, in: Emerging Trends in the Social and Behavioral Sciences. American Cancer Society, pp. 1–11. https://doi.org/10.1002/9781118900772.etrds0379

Mahutga, M.C., Smith, D.A., 2011. Globalization, the structure of the world economy and economic development. Social Science Research 40, 257–272. https://doi.org/10.1016/j.ssresearch.2010.08.012

McPherson, M., Smith-Lovin, L., Cook, J.M., 2001. Birds of a Feather: Homophily in Social Networks. Annual Review of Sociology 27, 415–444. https://doi.org/10.1146/annurev.soc.27.1.415

Nemeth, R.J., Smith, D.A., 1985. International Trade and World-System Structure: A Multiple Network Analysis. Review (Fernand Braudel Center) 8, 517–560.

Newman, M.E., 2002. Assortative mixing in networks. Physical review letters 89, 208701.

Nordlund, C., 2018. Power-relational core–periphery structures: Peripheral dependency and core dominance in binary and valued networks. Network Science 6, 348–369. https://doi.org/10.1017/nws.2018.15

Palan, N., Simoes, N., Crespo, N., 2021. Measuring fifty years of trade globalisation. The World Economy 44, 1859–1884. https://doi.org/10.1111/twec.13016

Pangestu, M., Rahardja, S., Ing, L.Y., 2015. Fifty Years of Trade Policy in Indonesia: New World Trade, Old Treatments. Bulletin of Indonesian Economic Studies 51, 239–261. https://doi.org/10.1080/00074918.2015.1061915

Prell, C., Feng, K., Sun, L., Geores, M., Hubacek, K., 2014. The economic gains and environmental losses of US consumption: a world-systems and input-output approach. Social Forces 93, 405–428.

Raei, M.F., Ignatenko, A., Mircheva, M., 2019. Global Value Chains: What are the Benefits and Why Do Countries Participate? International Monetary Fund.

Rice, J., 2007. Ecological Unequal Exchange: International Trade and Uneven Utilization of Environmental Space in the World System. Social Forces 85, 1369–1392. https://doi.org/10.1353/sof.2007.0054

Roberts, A., 2013. Peripheral accumulation in the world economy: A cross-national analysis of the informal economy. International Journal of Comparative Sociology 54, 420–444. https://doi.org/10.1177/0020715213519458

Roberts, J.T., Grimes, P.E., 2002. World-system theory and the environment: Toward a new synthesis. Sociological theory and the environment: Classical foundations, contemporary insights 167–196.

Robins, G., 2013. A tutorial on methods for the modeling and analysis of social network data. Journal of Mathematical Psychology, Social Networks 57, 261–274. https://doi.org/10.1016/j.jmp.2013.02.001

Robins, G., Pattison, P., Kalish, Y., Lusher, D., 2007. An introduction to exponential random graph (p*) models for social networks. Social Networks, Special Section: Advances in Exponential Random Graph (p*) Models 29, 173–191. https://doi.org/10.1016/j.socnet.2006.08.002

Rodrik, D., 2006. What's So Special about China's Exports? China & World Economy 14, 1–19. https://doi.org/10.1111/j.1749-124X.2006.00038.x

Sato, Yuri, 2016. Curse or Opportunity? A Model of Industrial Development for Natural Resource–Rich Countries on the Basis of Southeast Asian Experiences, in: Sato, Yukihito, Sato, H. (Eds.), Varieties and Alternatives of Catching-up: Asian Development in the Context of the 21st Century, IDE-JETRO Series. Palgrave Macmillan UK, London, pp. 211–246. https://doi.org/10.1057/978-1-137-59780-9_8

Silk, M.J., Croft, D.P., Delahay, R.J., Hodgson, D.J., Boots, M., Weber, N., McDonald, R.A., 2017. Using Social Network Measures in Wildlife Disease Ecology, Epidemiology, and Management. BioScience 67, 245–257. https://doi.org/10.1093/biosci/biw175

Smith, D.A., White, D.R., 1992. Structure and Dynamics of the Global Economy: Network Analysis of International Trade 1965–1980. Soc Forces 70, 857–893. https://doi.org/10.1093/sf/70.4.857

Smith, M., Gorgoni, S., Cronin, B., 2019. International production and trade in a high-tech industry: A multilevel network analysis. Social Networks 59, 50–60. https://doi.org/10.1016/j.socnet.2019.05.003

Smith, M., Gorgoni, S., Cronin, B., 2016. The fragmentation of production and the competitiveness of nations in the automotive sector–A network approach, in: 5th Annual CIRANO-Sam M. Walton College of Business Workshop on Networks in Trade and Finance. Fayetteville AR.

Smith, M., Sarabi, Y., 2021. UK trading patterns within and between regions in the automotive sector—A network analysis. The World Economy 44, 510–529. https://doi.org/10.1111/twec.13006

Snijders, T.A.B., Lomi, A., 2019. Beyond homophily: Incorporating actor variables in statistical network models. Network Science 7, 1–19. https://doi.org/10.1017/nws.2018.30

Snyder, D., Kick, E.L., 1979. Structural Position in the World System and Economic Growth, 1955-1970: A Multiple-Network Analysis of Transnational Interactions. American Journal of Sociology 84, 1096–1126. https://doi.org/10.1086/226902

Stiglitz, J.E., Greenwald, B.C., 2014. Creating a learning society: A new approach to growth, development, and social progress. Columbia University Press.

Sturgeon, T.J., Kawakami, M., 2011. Global value chains in the electronics industry: characteristics, crisis, and upgrading opportunities for firms from developing countries. International Journal of Technological Learning, Innovation and Development 4, 120–147. https://doi.org/10.1504/IJTLID.2011.041902

Sturgeon, T.J., Van Biesebroeck, J., 2011. Global value chains in the automotive industry: an enhanced role for developing countries? International Journal of Technological

Learning, Innovation and Development 4, 181–205. https://doi.org/10.1504/IJTLID.2011.041904

Tajoli, L., Felice, G., 2018. Global Value Chains Participation and Knowledge Spillovers in Developed and Developing Countries: An Empirical Investigation. Eur J Dev Res 30, 505–532. https://doi.org/10.1057/s41287-017-0127-y

Tang, W., Zhao, L., Liu, W., Liu, Y., Yan, B., 2019. Recent advance on detecting core-periphery structure: a survey. CCF Transactions on Pervasive Computing and Interaction 1–15.

Van Rossem, R., 1996. The world system paradigm as general theory of development: A cross-national test. American sociological review 508–527.

Wallerstein, I., 1974. The Rise and Future Demise of the World Capitalist System: Concepts for Comparative Analysis. Comparative Studies in Society and History 16, 387–415.

Ward, M.D., Ahlquist, J.S., Rozenas, A., 2013. Gravity's Rainbow: A dynamic latent space model for the world trade network. Network Science 1, 95–118. https://doi.org/10.1017/nws.2013.1

Yotov, Y.V., Piermartini, R., Monteiro, J.-A., Larch, M., 2016. An advanced guide to trade policy analysis: The structural gravity model. World Trade Organization Geneva.

Zhao, J., 2021. Investigating the Asymmetric Core/Periphery Structure of International Labor Time Flows. Journal of World-Systems Research 27, 231–264.

Zhou, M., 2020. Differential Effectiveness of Regional Trade Agreements, 1958-2012: The Conditioning Effects from Homophily and World-System Status. The Sociological Quarterly 0, 1–22. https://doi.org/10.1080/00380253.2020.1834463

7. Tables

Table 1 Five effects

Parameter	Definition
Homophily	Export to countries who have similar values for a given attribute
Conformity	Export to ties to countries with a normative value for a given attribute
Aspiration	Export to ties to individuals with a higher value for a given attribute
Sociability	Countries with higher values for a given attribute are more likely to export
Sociability Squared	The effect of sociability drops off at certain point

Table 2 Descriptive Statistics

	GDP Mean	GDP Standard Deviation	GDP per capita Mean	GDP per capita Standard Deviation
High Tech All	23339.00	23436.24	31378.44	22826.27
High Tech Core	34292.67	22389.46	42340.75	21941.93
High tech Periphery	19140.09	22621.92	27176.22	21904.96
Low Tech All	18072.62	21864.33	25799.04	24102.40
Low Tech Core	30155.33	18812.43	36164.56	16887.94
Low tech Periphery	16213.74	21785.35	24204.35	24705.75

Table 3 Descriptive Network Statistics

	High Tech	Low Tech
Size	83	121
Density	0.1099	0.0749
Reciprocity	0.607	0.5851
Out Degree Centralisation	0.8047	0.7751
In Degree Centralisation	0.3535	0.4251
Region Homophily	0.1559	0.2427
Degree Assortativity	-0.4501	-0.3904

8. Figures

Figure 1 High tech and low tech ITN

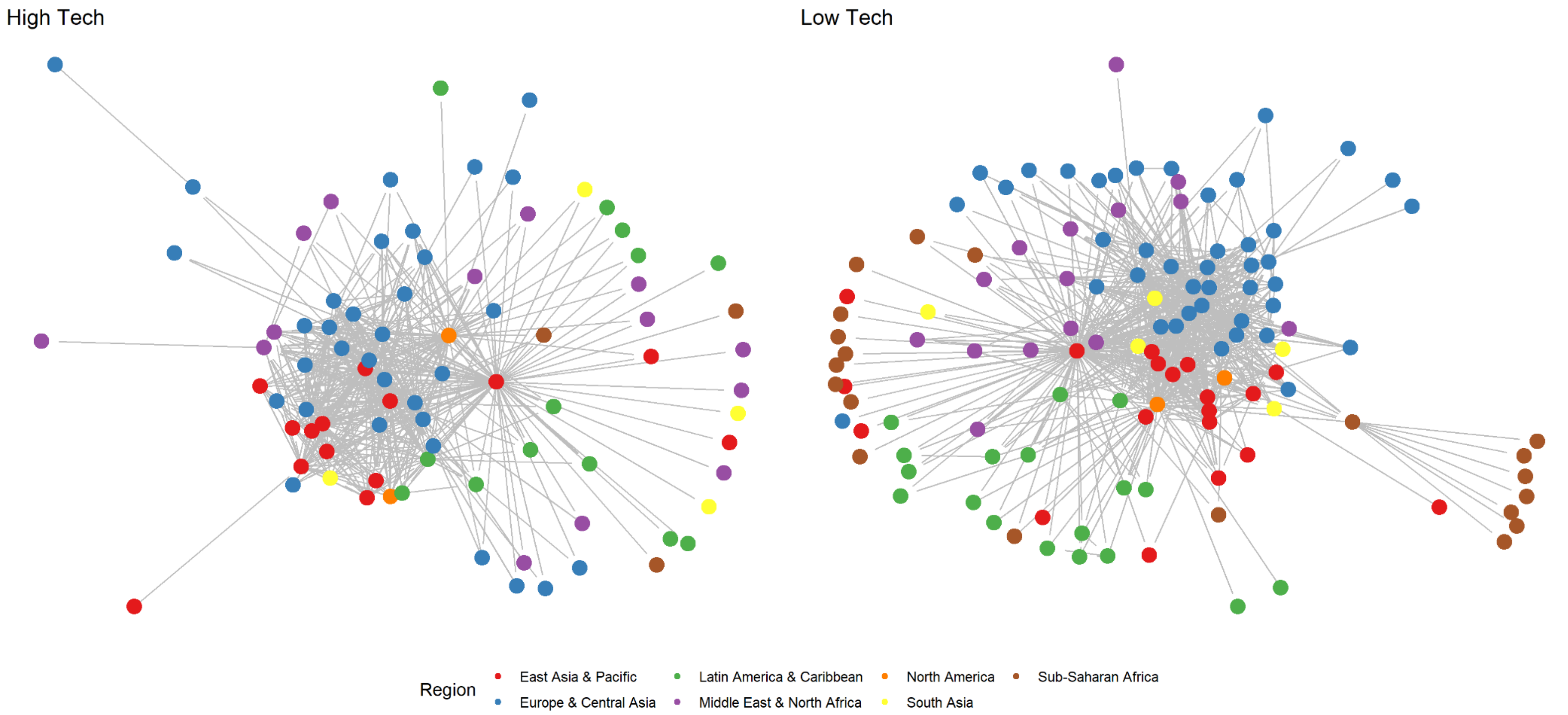


Figure 2 Countries in the high- and low-tech networks

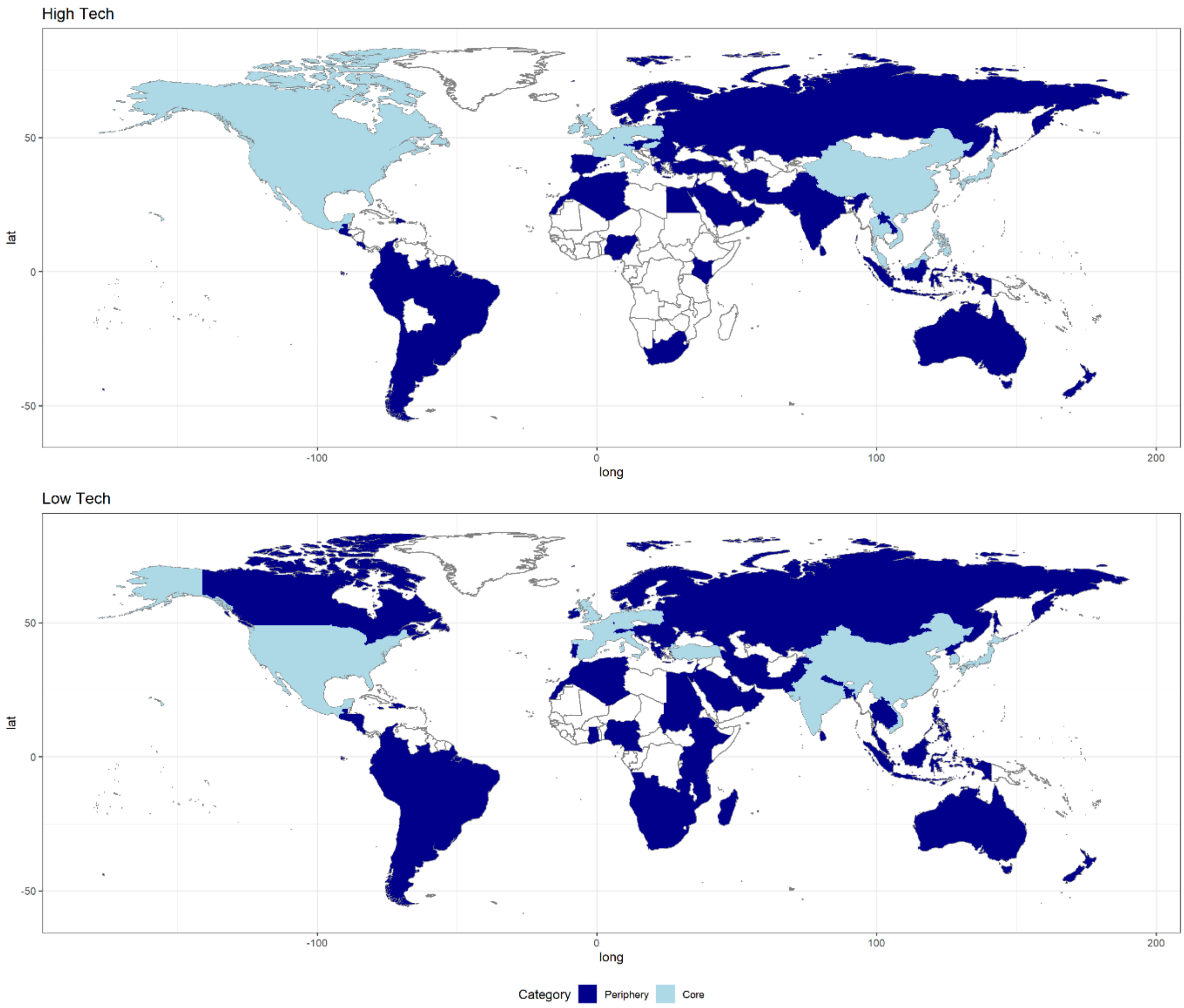


Figure 3 ERGM Results - No Interactions

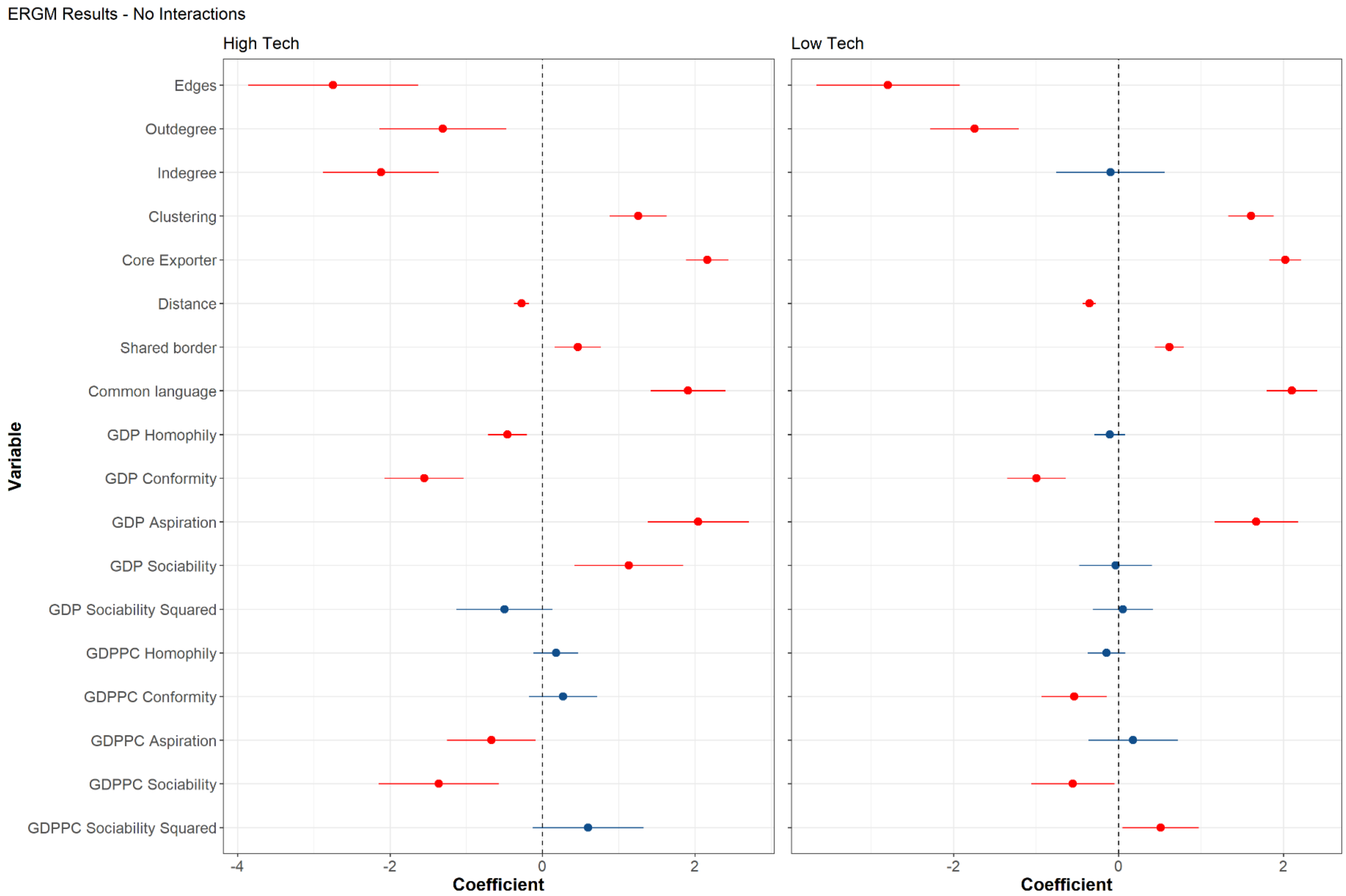


Figure 4 ERGM Results - GDP Interactions

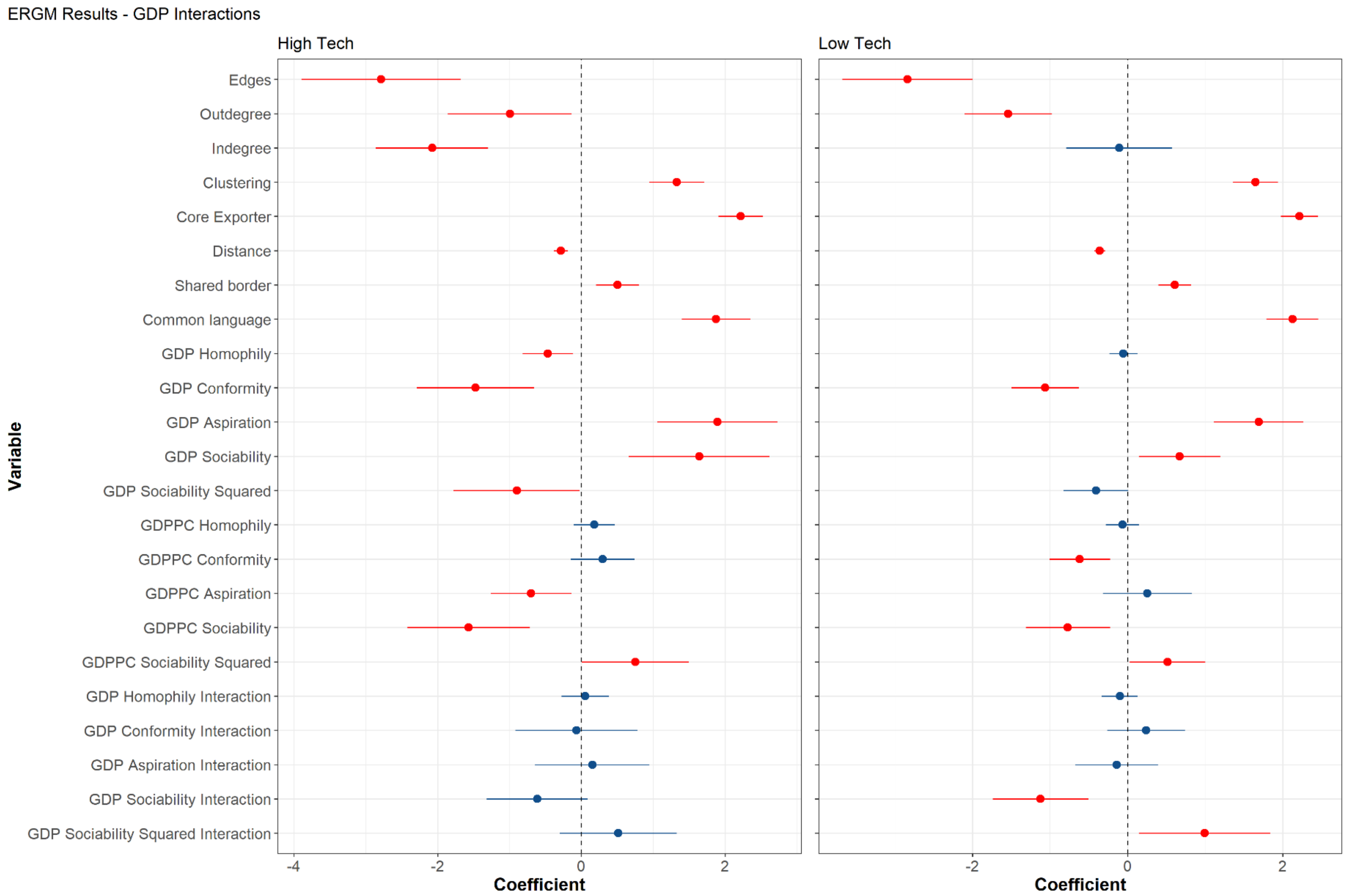


Figure 5 ERGM Results - GDP per capita Interactions

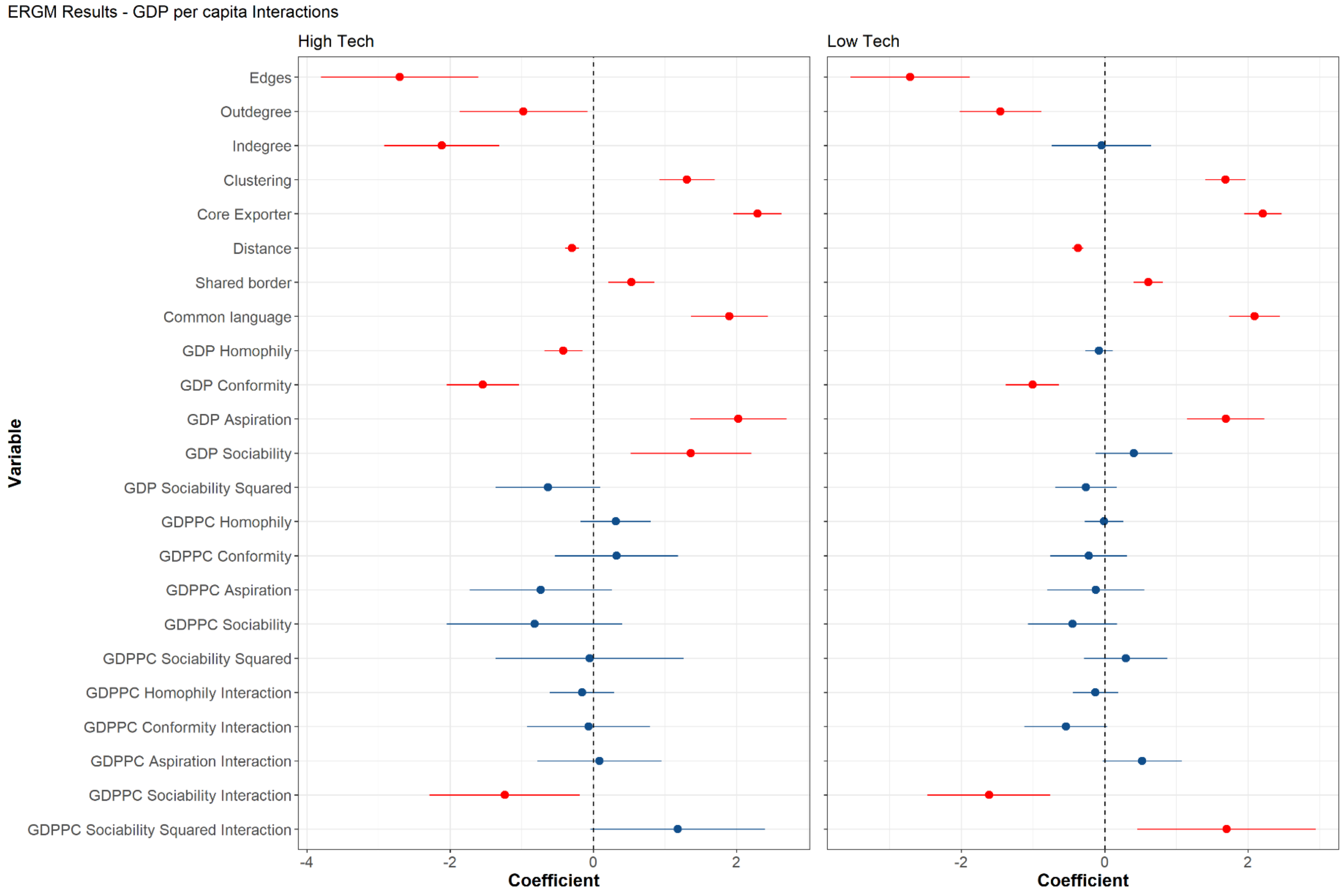


Figure 6 ERGM Results - Distance Interaction

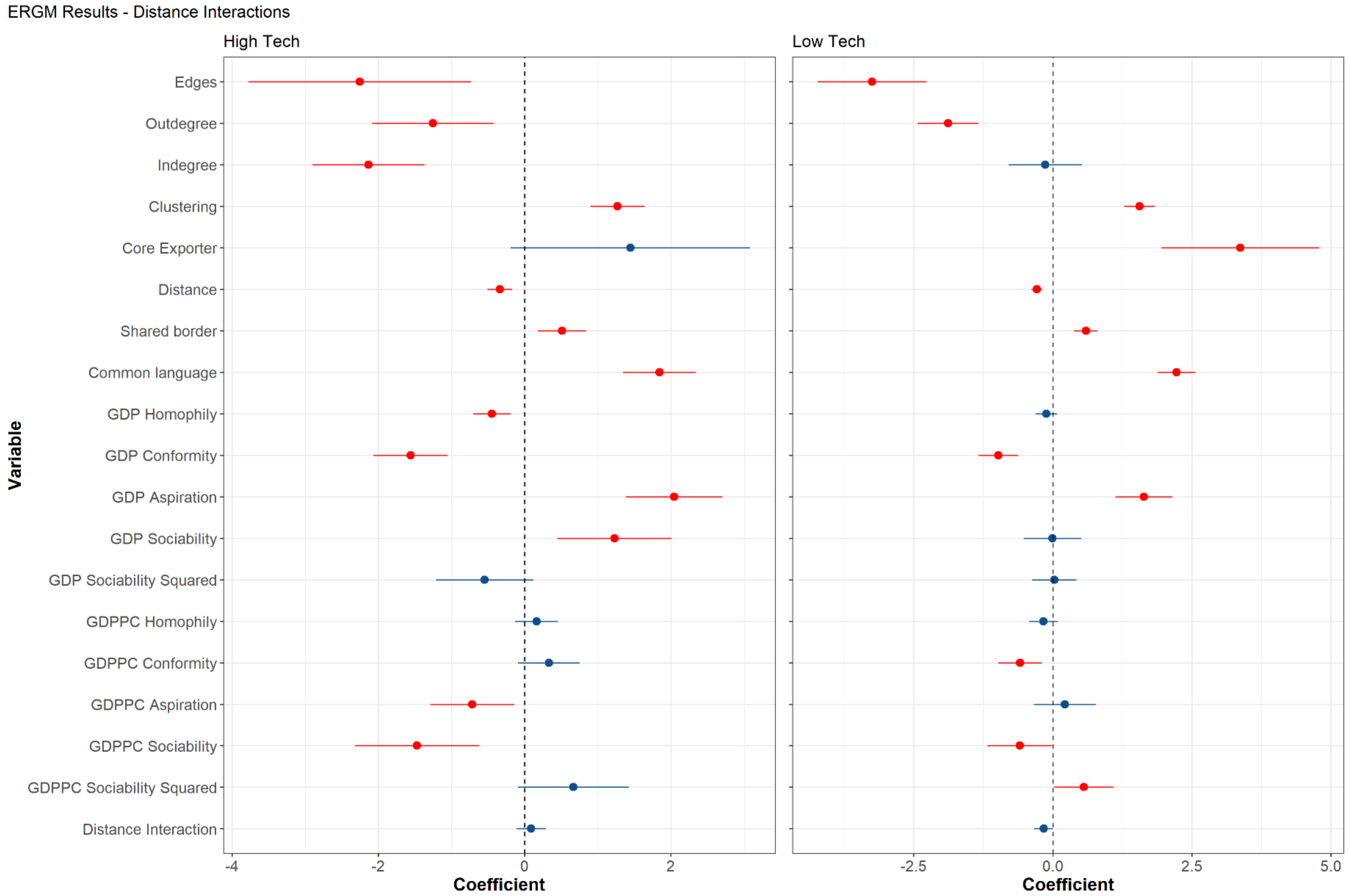


Figure 7 High Tech ERGM No Interactions - Goodness of Fit

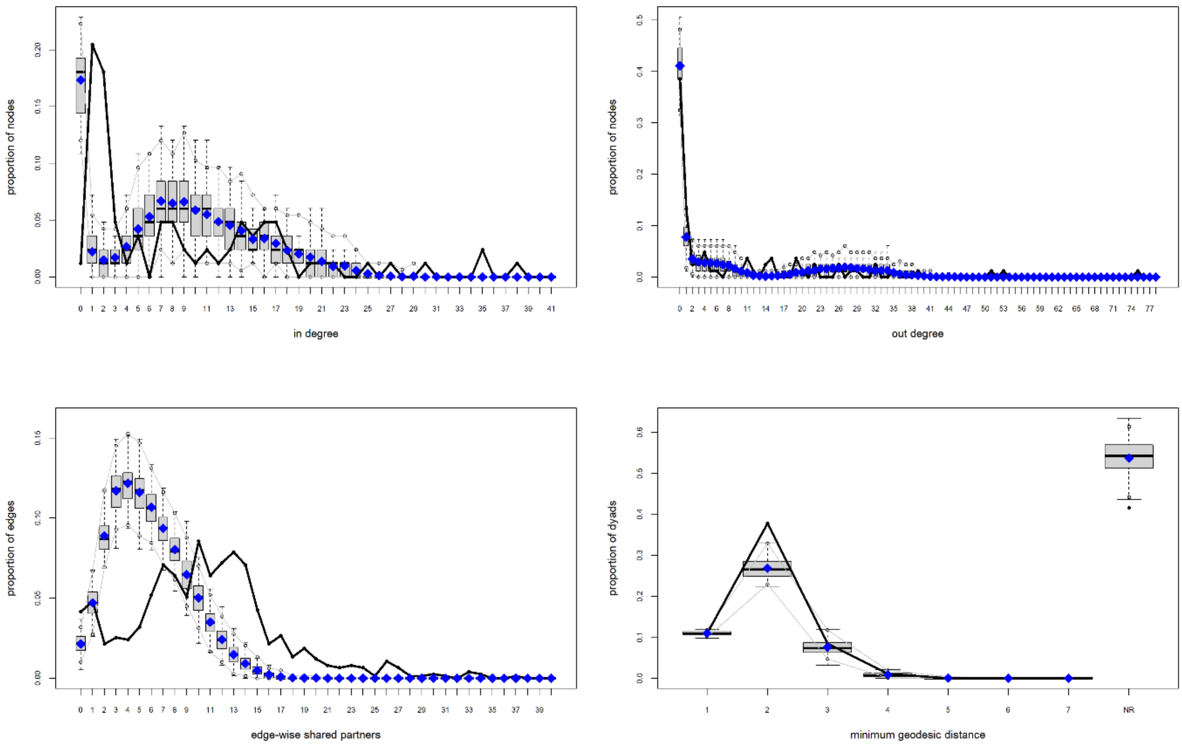


Figure 8 Low Tech ERGM No Interactions - Goodness of Fit

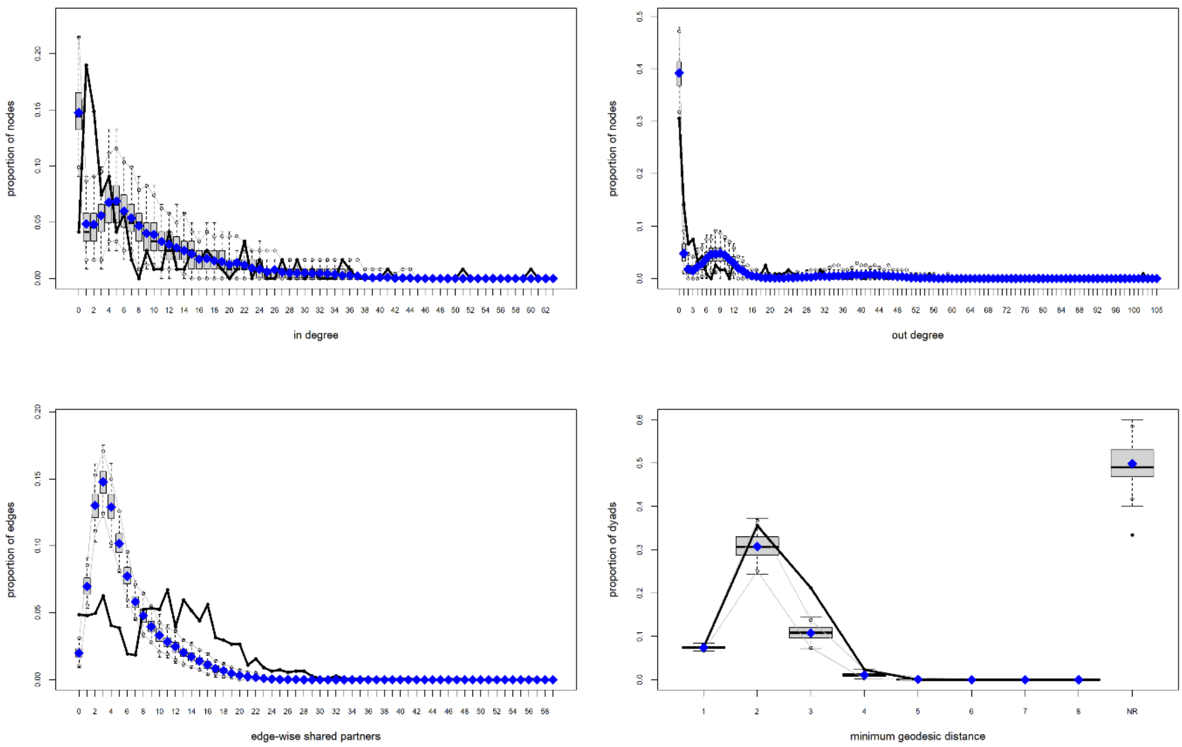


Figure 9 Selection function - High Tech & GDP

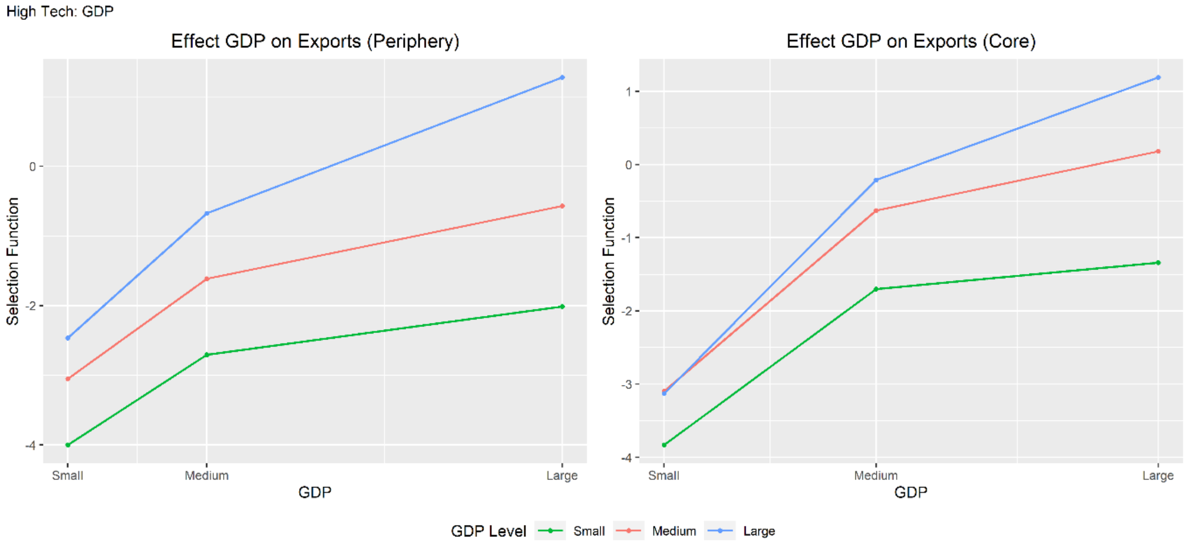


Figure 10 Selection function - High Tech & GDP per capita

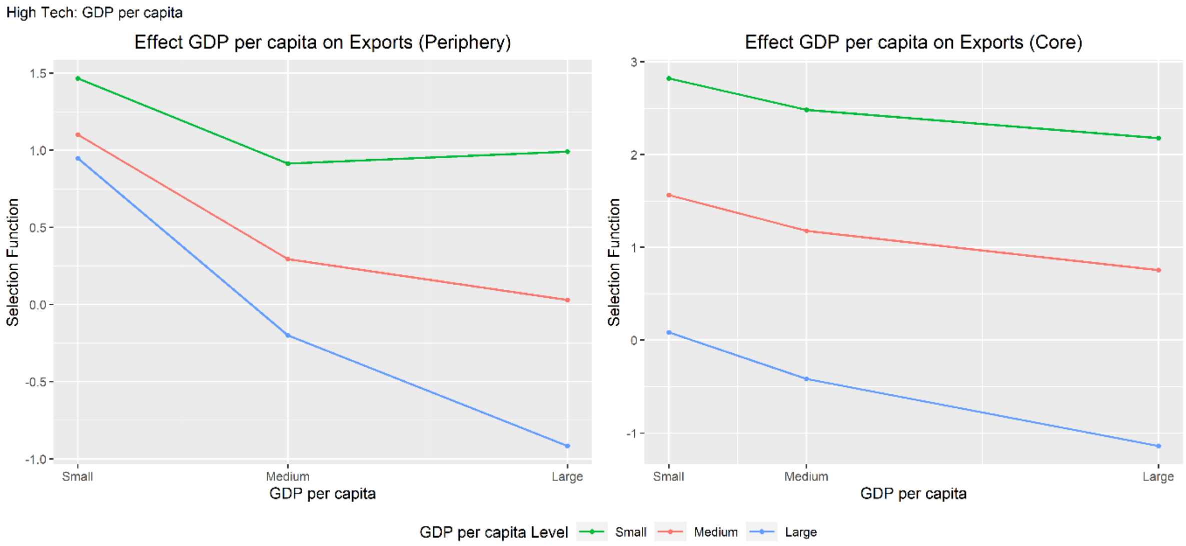


Figure 11 Selection function - Low Tech & GDP

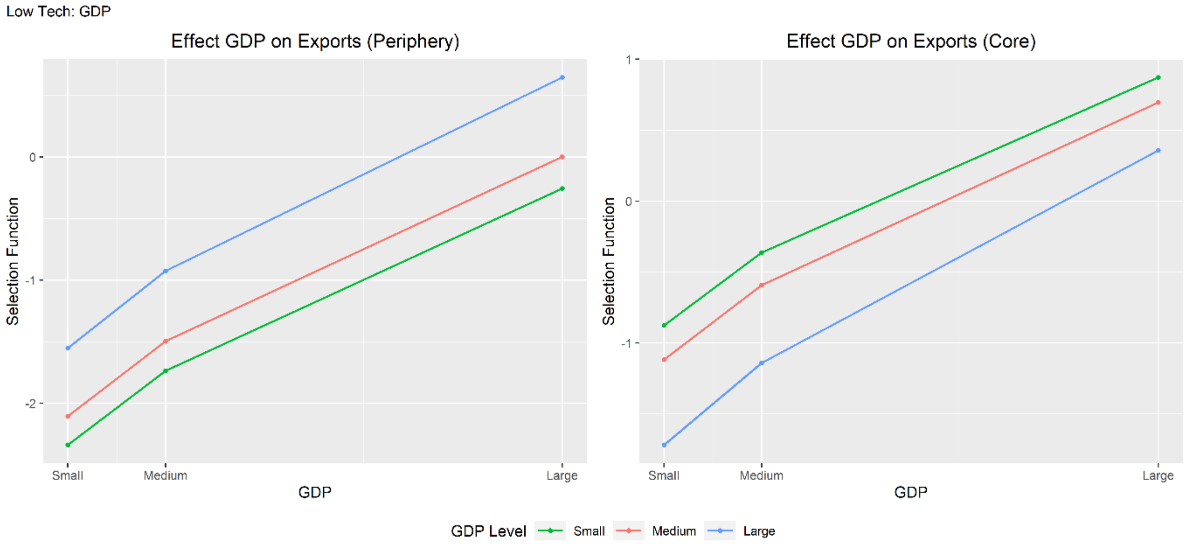
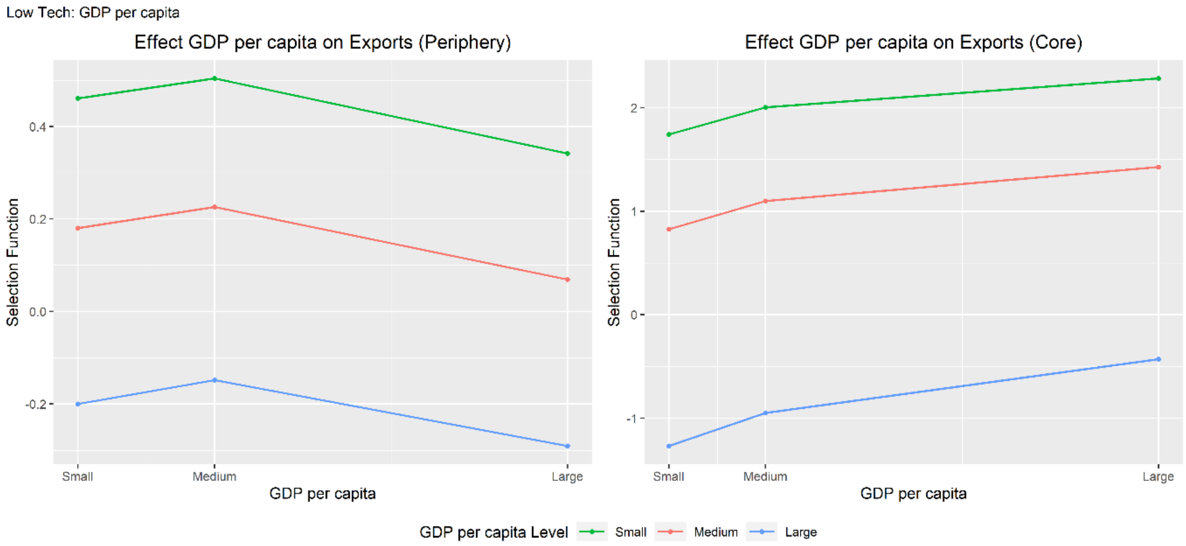


Figure 12 Selection function - Low Tech & GDP per capita



9. Appendix

Tables (A1) and (A2) provide the ERGM parameter estimates and standard errors for the various models for the high tech and low-tech component groups. These correspond to figures (3) to (6).

Table A1 High Tech ERGM Results

	No Interaction	**GDP Interaction**	**GDP per capita Interaction**	**Distance Interaction**
Edges	-2.745***	-2.787***	-2.701***	-2.256**
	(0.569)	(0.565)	(0.560)	(0.776)
Outdegree	-1.305**	-0.993*	-0.975*	-1.256**
	(0.425)	(0.440)	(0.456)	(0.425)
Indegree	-2.118***	-2.074***	-2.115***	-2.136***
	(0.388)	(0.398)	(0.411)	(0.392)
Clustering	1.254***	1.327***	1.308***	1.267***
	(0.190)	(0.196)	(0.198)	(0.189)
Core Exporter	2.161***	2.217***	2.292***	1.445
	(0.141)	(0.157)	(0.171)	(0.834)
Distance	-0.274***	-0.285***	-0.298***	-0.340***
	(0.050)	(0.049)	(0.050)	(0.087)
Shared border	0.464**	0.504**	0.531**	0.511**
	(0.154)	(0.153)	(0.166)	(0.167)
Common language	1.909***	1.875***	1.900***	1.842***
	(0.250)	(0.245)	(0.275)	(0.254)
GDP Homophily	-0.457***	-0.466**	-0.418**	-0.450***
	(0.130)	(0.178)	(0.136)	(0.129)
GDP Conformity	-1.552***	-1.473***	-1.541***	-1.560***
	(0.263)	(0.415)	(0.258)	(0.259)
GDP Aspiration	2.043***	1.893***	2.025***	2.041***
	(0.339)	(0.426)	(0.344)	(0.337)
GDP Sociability	1.133**	1.639**	1.364**	1.228**
	(0.364)	(0.499)	(0.429)	(0.398)
GDP Sociability Squared	-0.496	-0.898*	-0.633	-0.547
	(0.321)	(0.447)	(0.372)	(0.340)
GDP per capita Homophily	0.177	0.181	0.312	0.162
	(0.149)	(0.144)	(0.249)	(0.151)
GDP per capita Conformity	0.269	0.296	0.326	0.329
	(0.228)	(0.226)	(0.439)	(0.215)
GDP per capita Aspiration	-0.668*	-0.699*	-0.734	-0.716*
	(0.296)	(0.285)	(0.506)	(0.294)
GDP per capita Sociability	-1.359***	-1.567***	-0.821	-1.472***

	(0.402)	(0.434)	(0.625)	(0.433)
GDP per capita Sociability Squared	0.600	0.752*	-0.051	0.666
	(0.371)	(0.379)	(0.670)	(0.388)
GDP Homophily Interaction		0.055		
		(0.168)		
GDP Conformity Interaction		-0.068		
		(0.433)		
GDP Aspiration Interaction		0.153		
		(0.405)		
GDP Sociability Interaction		-0.614		
		(0.359)		
GDP Sociability Squared Interaction		0.512		
		(0.415)		
GDP per capita Homophily Interaction			-0.157	
			(0.229)	
GDP per capita Conformity Interaction			-0.065	
			(0.439)	
GDP per capita Aspiration Interaction			0.087	
			(0.442)	
GDP per capita Sociability Interaction			-1.236*	
			(0.536)	
GDP per capita Sociability Squared Interaction			1.180	
			(0.621)	
Distance Interaction				0.089
				(0.102)
Shared Border Interaction				
Common Language Interaction				

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

Table A2 Low Tech ERGM Results

	No Interaction	GDP Interaction	GDP per capita Interaction	Distance Interaction
edges	-2.793***	-2.837***	-2.712***	-3.247***
	(0.443)	(0.428)	(0.426)	(0.501)
Outdegree	-1.743***	-1.537***	-1.453***	-1.884***
	(0.275)	(0.288)	(0.291)	(0.280)
Indegree	-0.097	-0.107	-0.045	-0.135
	(0.335)	(0.347)	(0.353)	(0.339)
Clustering	1.606***	1.648***	1.684***	1.561***
	(0.141)	(0.148)	(0.145)	(0.139)
Core Exporter	2.023***	2.216***	2.209***	3.373***
	(0.099)	(0.122)	(0.132)	(0.722)
Distance	-0.353***	-0.359***	-0.374***	-0.288***
	(0.041)	(0.037)	(0.039)	(0.050)
Common language	0.616***	0.609***	0.607***	0.596***
	(0.090)	(0.108)	(0.103)	(0.108)
Shared border	2.101***	2.126***	2.090***	2.227***
	(0.156)	(0.170)	(0.181)	(0.172)
GDP Homophily	-0.106	-0.053	-0.081	-0.112
	(0.094)	(0.092)	(0.098)	(0.097)
GDP Conformity	-0.992***	-1.061***	-1.006***	-0.979***
	(0.181)	(0.221)	(0.190)	(0.179)
GDP Aspiration	1.671***	1.690***	1.691***	1.641***
	(0.257)	(0.295)	(0.275)	(0.261)
GDP Sociability	-0.036	0.671*	0.408	-0.003
	(0.225)	(0.268)	(0.273)	(0.263)
GDP Sociability Squared	0.055	-0.405	-0.262	0.028
	(0.185)	(0.213)	(0.220)	(0.204)
GDP per capita Homophily	-0.145	-0.065	-0.008	-0.167
	(0.117)	(0.110)	(0.137)	(0.131)
GDP per capita Conformity	-0.537**	-0.615**	-0.222	-0.587**
	(0.202)	(0.199)	(0.273)	(0.199)
GDP per capita Aspiration	0.176	0.256	-0.124	0.220
	(0.276)	(0.293)	(0.346)	(0.284)
GDP per capita Sociability	-0.552*	-0.769**	-0.447	-0.590*
	(0.257)	(0.277)	(0.317)	(0.298)
GDP per capita Sociability Squared	0.511*	0.514*	0.297	0.560*
	(0.236)	(0.248)	(0.297)	(0.270)
GDP Homophily Interaction		-0.098		
		(0.118)		

GDP Conformity Interaction	0.241		
	(0.255)		
GDP Aspiration Interaction	-0.139		
	(0.271)		
GDP Sociability Interaction	-1.121***		
	(0.314)		
GDP Sociability Squared Interaction	0.993*		
	(0.432)		
GDP per capita Homophily Interaction		-0.128	
		(0.162)	
GDP per capita Conformity Interaction		-0.540	
		(0.296)	
GDP per capita Aspiration Interaction		0.525	
		(0.283)	
GDP per capita Sociability Interaction		-1.612***	
		(0.437)	
GDP per capita Sociability Squared Interaction		1.702**	
		(0.635)	
Distance Interaction			-0.163
			(0.085)
Shared Border Interaction			
Common Language Interaction			

***p < 0.001; **p < 0.01; *p < 0.05