Establishing direct connections in container shipping

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This Thesis is presented for the Degree of

Doctor of Philosophy

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March 2024

Abstract

The establishment of direct connections between trading countries in container shipping may be the joint result of various contributing factors, ranging from trade dynamics to carrier strategies. However, there has been only limited research on the systematic identification and quantification of the respective factors. This research investigated under which circumstances two trading countries may manage to attract the interest of a shipping line in order to support their existing bilateral trade flow with a direct connection.

This research embraced a mixed methods approach which was organised in three Phases. In Phase 1, a Systematic Literature Review of 130 publications identified 23 factors (variables) across 5 Themes that the literature has discussed as potential drivers for the establishment of direct connections between trading countries. In Phase 2, based on the principles of Causal Inference this research selected 9 variables of primary interest and employed an econometric model which quantified the relative importance of the identified variables. Those 9 variables were measured by employing 5 metrics from existing databases as well as 4 prototype metrics. The model utilised the UK as a case study and considered its connections with 114 trading partners across 2012-2020. Finally, in Phase 3 the research cross-checked the statistical results with the views of selected practitioners in order to validate the analysis.

This research concluded that certain variables (i.e. Colonial Ties, Connectivity, ECA Routing, Logistics Performance, MSR Routing, Trade Facilitation and Trade Imbalance) may be conditionally important for the establishment of direct connections between trading countries. Nevertheless, Trade Flow is the decisive driver, while for niche markets Reefer Cargo is also likely to be pivotal. Trade Flow and Reefer Cargo are important for connections that are active for both short and long periods of time, although the long-established connections are seemingly less sensitive to marginal Trade Flow fluctuations.

Acknowledgements

I would like to express my sincere gratitude to the following organisations and individuals for their invaluable contribution to the completion of this thesis:

The John Prime Foundation for generously making this doctoral research possible and allowing me to focus on my academic endeavors.

The broader supervisory team, Professor Roberto Palacin and Dr Agustina Calatayud for their valuable insights and support throughout this work.

Bluewater Reporting for granting unlimited access to the database without which this research would not have been feasible.

The interviewees who kindly dedicated their time and openhandedly shared their views and expertise, enriching considerably the validity of this thesis.

The School of Engineering and the broader Newcastle University personnel for their assistance in addressing my needs along the way.

The anonymous peer reviewers and editors of the published work related to this research.

And undoubtedly my family for their steadfast belief in me.

I would also like to express my heartfelt gratitude to my supervisor Professor John Mangan for his constructive feedback and tireless commitment to improve and enhance this work. Not only he inspired the commencement of this effort but also acted as a true mentor and a remarkable role model throughout this journey. It has been a great honor and pleasure to work under his guidance and I genuinely hope for his future friendship.

Finally, I want to offer a very special thanks to my wife, Valia, for her unwavering support throughout this journey. Her unconditional love and patience have been instrumental in the completion of this work. She consistently asked thoughtful questions, and – most importantly – was a committed source of encouragement during the darkest hours.

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Research Dissemination

The process of disseminating the insights / findings of this research included the following to date:

- The publication of a journal article which corresponds to the Literature Review of this research (Chapter 3):

  Tsantis, A., Mangan, J., Calatayud, A. and Palacin, R. (2023) 'Container shipping: a systematic literature review of themes and factors that influence the establishment of direct connections between countries', Maritime Economics & Logistics, 25(4), pp. 667-697, https://doi.org/10.1057/s41278-022-00249-3.

- A manuscript under second round of peer review by Maritime Policy and Management at the time of submission of this dissertation: '*What's inside the box? Evaluating the approximation of containerised trade flows based on trade commodity values*'. The manuscript provides tested insights on the nature of containerised freight and relates in particular to Section 4.4.8 of this research.

- The participation of the researcher in the Postgraduate Research Conference of Newcastle University (January 2023) where the preliminary findings of this research were presented.

''*Set your eyes on where you want to be,*

or you will end up where your eyes may see''.

Anonymous

Chapter 1. Introduction

1.1 Introduction

Maritime transport is at the heart of international trade, accounting for approximately 80% of global trade exchanges by volume. Container shipping and the globalised container shipping network allows importers and exporters of intermediate and manufactured goods to trade with remote partners from foreign countries. Bilateral trade between foreign countries in container shipping may be supported by either a direct connection or a connection via a third country and thus the quality of connectivity to international markets is of critical importance for the containerised trade of a country (Fugazza, 2015; de Benedictis and Tajoli, 2011).

A direct connection between countries is defined as the shipping link which does not require a transhipment via a third country. In container shipping, vessels may stop at other ports en route. However, if a container box remains on a single vessel during its transportation between two countries, then this still classifies as a direct connection (Fugazza, Hoffmann and Razafinombana, 2014). Direct connections can also serve more direct trade flows between bilateral trade partners because they offer targeted proximity to specific hinterlands (Tran and Haasis, 2018).

As an example, EURAF service was a container shipping string which was offered by the liner shipping company CMA-CGM:

(1) In 2018, EURAF service (Figure 1.1, Figure 1.2) provided a direct connection between Belgium, France, Portugal, Spain, Angola, Congo, Cameroon, and Ivory Coast.

(2) Thus, a direct connection existed between for example Congo and Cameroon but a container box originating in Belgium had to be transhipped via any of those countries in order to reach a third country, such as Gabon. This option would imply the involvement of an extra service that called at Gabon, such as WAF1 service which was offered by the liner shipping company Maersk (Figure 1.3). However, CMA-CGM in 2019 revised the EURAF service rotation to include a call at Gabon (Libreville port) as well, thus providing a direct connection for example between Belgium and Gabon (Figure 1.4):

Figure 1.1 – CMA-CGM EURAF 2018 (zoom out)

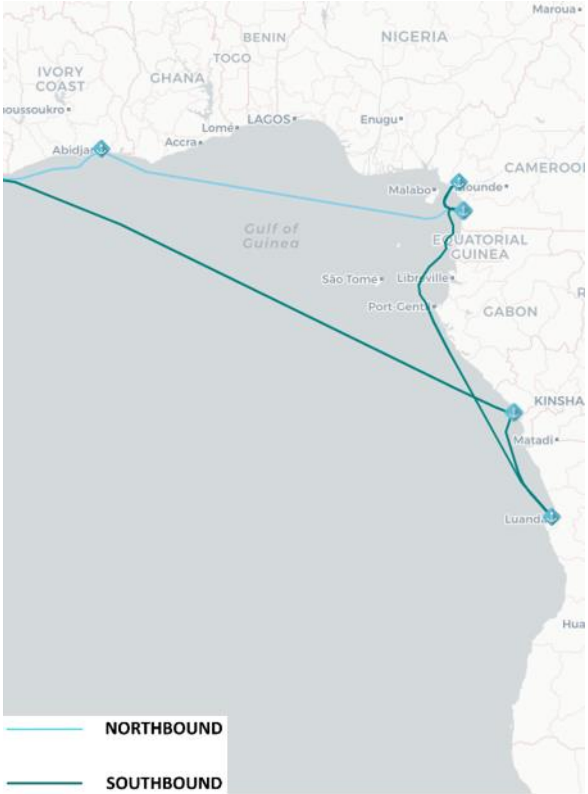

Figure 1.2 – CMA-CGM EURAF 2018 (zoom in)

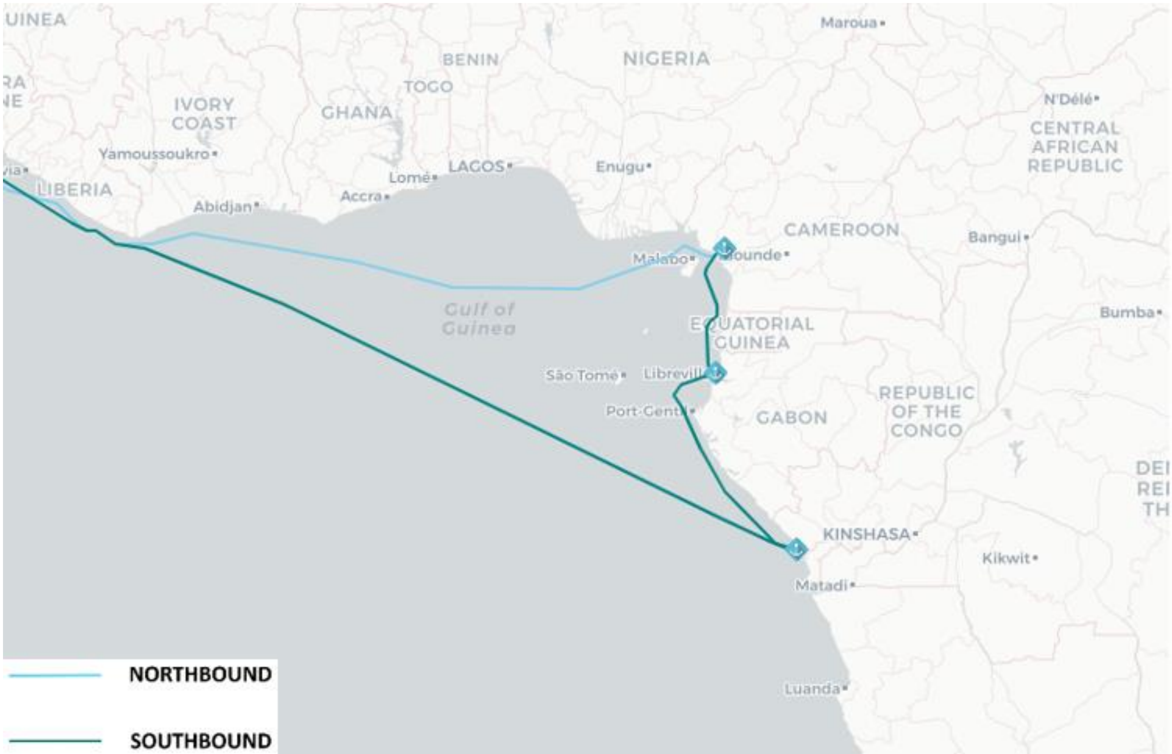

Figure 1.3 – Maersk WAF1 2018

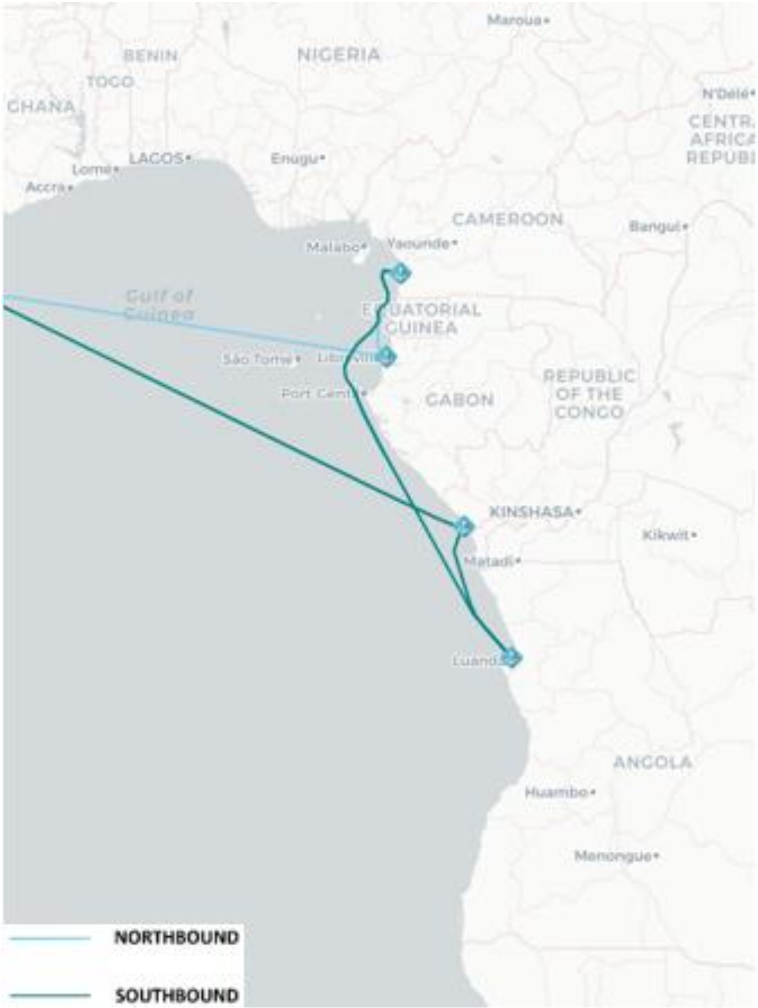

Figure 1.4 – CMA-CGM EURAF 2019 (zoom in)

This research aims to shed light on the underlying factors that encourage the establishment of direct shipping connections between trading countries, a topic which has not been systematically examined by the existing literature.

In this Chapter, Section 1.2 outlines the background to the research, Section 1.3 highlights the importance of direct connections, Section 1.4 presents the purpose and overview of the research, and Section 1.5 discusses the gap that this research attempts to fill. Finally, Section 1.6 comprises the concluding remarks of this Chapter.

1.2 Background to the research

According to Deardorff (1998), as transport cost declines trade between distant countries is expected to grow. Practical knowledge suggests that at some point in time, existing trading partners are finally offered a direct connection which – in the absence of a transhipment move – reduces transit time and service cost and thus supports the continuation, stabilisation, and promotion of the bilateral trade. However, Wang and Wang (2011), based on the monthly schedule of 24 liner companies, demonstrated that there is a substantial diversity on the connectivity of different regions with particular regions lagging behind on bilateral connections. The setup of the network as a mix of direct and transhipment connections ultimately remains a decision of the carriers (Rodrigue and Ashar, 2016).

Hence, it would be beneficial for academia and practitioners to further understand the factors that ought to be in place in order to allow or encourage liner shipping companies to offer a direct connection between trading countries and promote the further development of their bilateral trade relationship. A comprehensive analysis of those prerequisites and their relative importance may assist the shipping stakeholders to assess how the container shipping network develops in practice as well as to explore possible actions that may allow the establishment of direct connections between targeted country pairs.

1.3 The importance of direct container shipping connections between countries

Theoretically, a set of possible contributors towards the establishment of a direct connection between countries is expected to include – amongst others – factors such as historically high trade volumes, adequate infrastructure, and the geographical location of the countries with regard to the regional maritime hubs and core maritime routes (Fugazza, 2015). Lam (2011) also noted that direct calls represent less risk and cost for the supply chain compared to the transhipment option. However, as shown by Calatayud et al. (2017), various countries are rarely connected with a direct maritime link to their bilateral trade partners and their international markets. For example, in the Americas the maritime network accommodates only 33% of the bilateral connections that could possibly be established between countries (*ibid*). Wu *et al.* (2019) analysed the container shipping network of the top 100 carriers in 2015 and found that on average a container box needs to be transhipped 2-3 times to reach its final destination. Thus, there may be a set of certain contributors and additional prerequisites that need to be satisfied before shipping lines examine, consider, and finally develop a direct connection between trading countries.

Interestingly, in 2012 only 13.3% of country pairs were connected by direct container shipping services while large economies required less transhipments to connect with their trading partners. Fugazza, Hoffmann and Razafinombana (2014) calculated that in the absence of a direct connection, exports value may be decreased by 42-55% while the cost of any additional transhipment penalises the export value with a corresponding drop of 20-25%. Hence, the establishment of direct shipping connections is in the interest of the countries which are willing to support their international trade presence and access to the global market.

1.4 Research Purpose and Overview

The aim of this research is to **investigate how direct connections are established in container shipping**. Essentially, the research aims to explore whether there are any causal relationships between specific factors and their impact to the establishment of direct connections between trading countries. Rather than measuring the impact on the trade flows following the establishment of a direct connection between trading countries, the research examines which factors may encourage or discourage the establishment of a direct connection. In other words, the study attempts to explain under which circumstances two trading countries may manage to entice a shipping line to establish a direct connection in order to support their bilateral trade relationship.

This research focuses on coastal country pairs that have recorded any level of bilateral trade flow during the examined period. This includes countries for which a direct shipping connection has been recently granted or has been active across all years or has been periodically inactive despite the continuation of bilateral trade. This also includes countries that have recorded any bilateral trade flow but have not been granted with a direct connection. Consequently, a set of Research Objectives (RO) has been formed and these objectives are satisfied by answering the corresponding Research Questions (RQ).

The research has the following Research Objectives (RO):

- RO1: Identify the factors that contribute to the establishment of direct connections in container shipping.
- RO2: Measure the relative contribution of the identified factors.

Respectively, three Research Questions (RQ) are defined, as follows:

- RQ1: What are the factors that liner shipping companies consider in order to establish a direct shipping connection between two trading countries?
- RQ2: What is the relative importance and hierarchy of each of the factors?
- RQ3: What are the factors that characterise the long-established connections?

With regard to RO1, this research employs a Systematic Literature Review (SLR) in order to firstly identify the factors that carriers – according to theory – may consider as enablers or barriers for the initiation of a direct connection between two trading countries (RQ1). The SLR has been designed to include publications that cover all aspects of container shipping networks, direct shipping connections as well as potential parallels with airfreight and rail freight networks.

With regard to RO2, the research proceeds to quantitatively measure which of the factors found in the literature contribute to the initiation of direct connections in container shipping by employing an econometric model (RQ2). The analysis expands on testing whether the underlying dynamics which characterise the direct connections that last for longer periods of time are considerably different from those dynamics that characterise the direct connections that may last for shorter periods of time (RQ3). The overall Research Overview is illustrated in Figure 1.5:

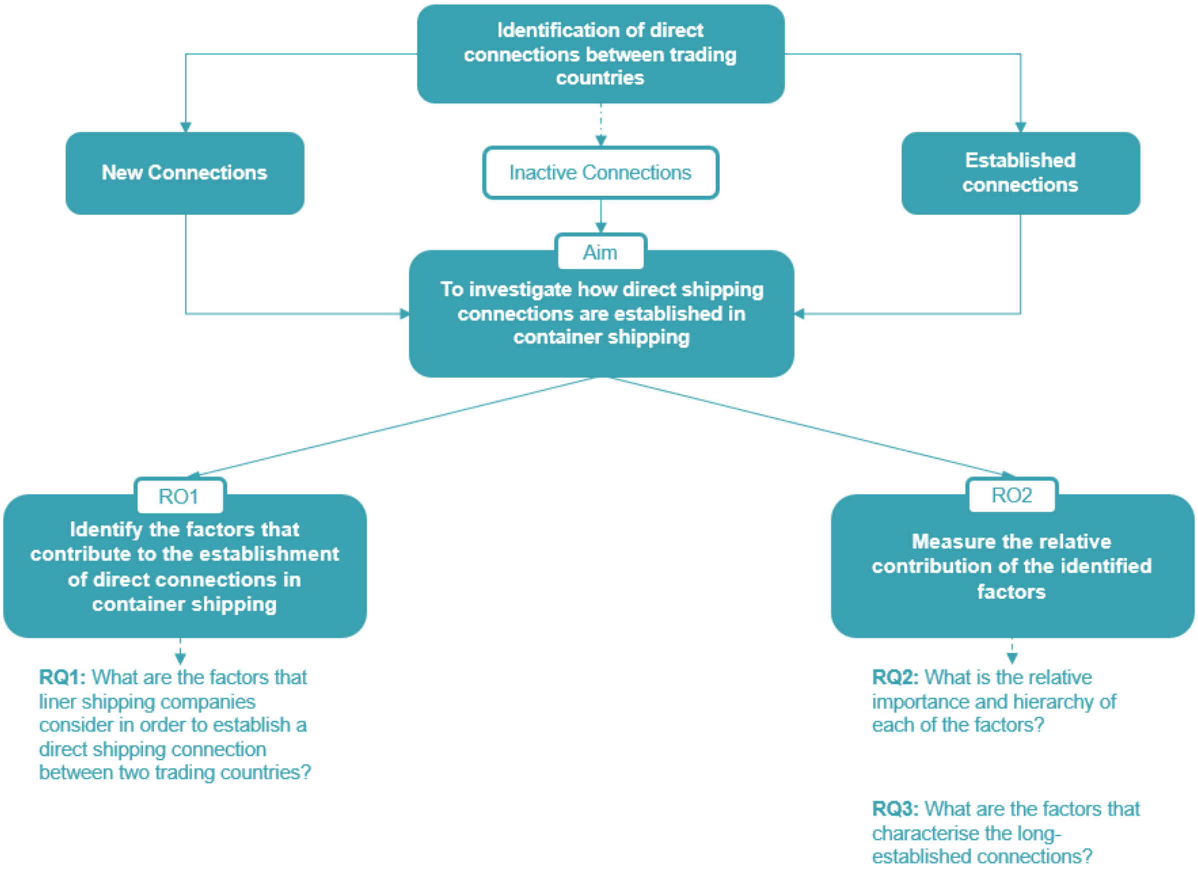

Figure 1.5 – Research Overview

The research is designed to address the research objectives and the corresponding research questions in three distinct phases in order to identify, quantify and verify the factors that may have an impact towards the establishment of direct connections between trading countries:

- Phase 1: Identification of factors – Systematic Literature Review (SLR)
- Phase 2: Quantification of factors – Econometric Model
- Phase 3: Validation of factors – Semi-structured interviews

The purpose of Phase 1 is to synthesise the different perspectives that have been discussed in the relevant literature, with the intention to identify the factors that may encourage – or discourage – the establishment of a direct shipping connection between two trading countries. Once a broad list of factors (variables) has been identified, Phase 2 proceeds to quantify and measure the relative importance of the variables towards to the establishment of a direct connection between trading countries. However, unraveling the factors deemed important by carriers in their decision-making process may necessitate a qualitative assessment of the results to ensure that "*the data are telling you what you think they are telling you*" (Saunders, Lewis and Thornhill, 2007a p139). Hence, the researcher does not aim to limit the analysis solely to quantified observations but acknowledges that incorporating a qualitative assessment may enhance the research results. The latter is accomplished through Phase 3 of the research which corresponds to a series of semi-structured interviews with container shipping practitioners.

It could be argued that the interviews should be conducted before employing the econometric model to allow practitioners to propose variables deemed relevant for establishing direct connections between countries. Nevertheless, this research opts to proceed with a systematic approach and allow theory (i.e. SLR) and data (i.e. econometric model) to suggest an *objective* manifestation of the analysed problem (i.e. the establishment of direct connections between countries). Then, the *subjective* views of the practitioners may offer an invaluable critique of the identified factors (variables) to validate and possibly enhance the research. Therefore, performing the qualitative analysis after the modelling effort aims to enhance the research while retaining *objectivity* and *rigor*.

The phasal design of the research is discussed in further detail in Section 3.12.

1.5 Research Gap and Contribution

The existing literature has referred to some of the factors that in theory may affect the establishment of direct connections and has mainly focused on the positive impact that a direct connection between two countries may have on bilateral trade development. However, there has been only limited research on the systematic identification and quantification of the factors that should be in place in order to promote and allow the initiation of a direct connection (Figure 1.6):

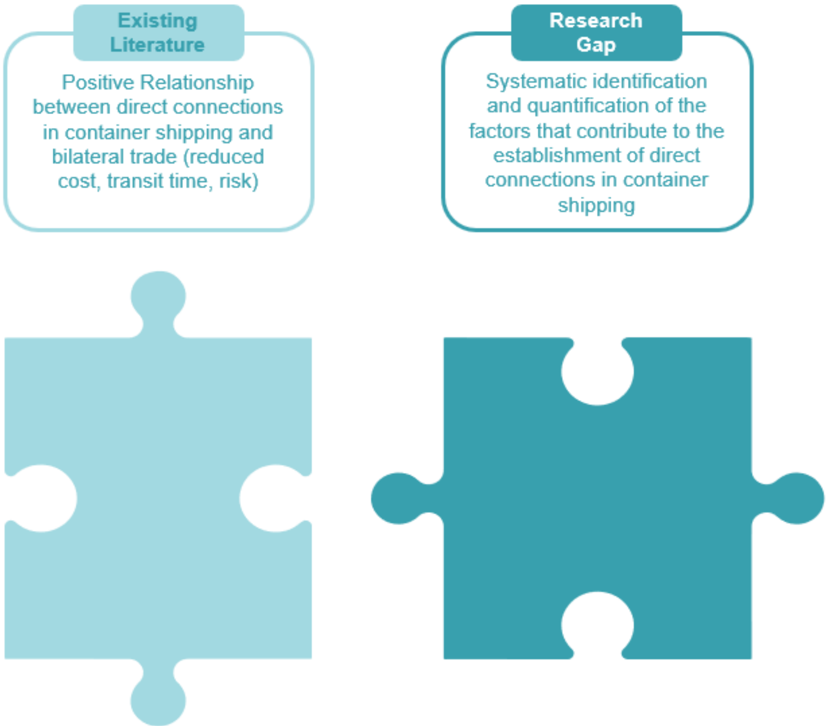

Figure 1.6 – Research Gap

Filling this gap would allow stakeholders to better understand the core factors that shape the international shipping network and quantify their relative importance. The understanding of those factors will assist on demystifying the decision-making process of liner shipping companies. Most importantly, the understanding of those factors could indicate to policy-makers of developing countries, the direction of the needed efforts which would allow the establishment of a direct shipping connection with their trade partners. The latter is expected to support and enhance the access of developing countries to their international markets.

Subsequently, the contribution of this research may be synopsised as follows:

- identifying the set of factors that may determine the establishment of direct container shipping connections between trading countries;
- quantifying the impact of specific factors through a robust econometric analysis;
- proposing a systematic approach regarding the selection of the appropriate set of variables for a model which allows the measurement of the true effect of the underlying dynamics;

- proposing a methodology to highlight the potential difference between *containerisable* and *containerised* cargo which may in turn allow a better understanding of a country's position on the container shipping network.

1.6 Concluding Remarks

This Chapter provided a definition of a direct connection between countries in container shipping. Then, this Chapter discussed why it may be beneficial for practitioners and academia to further understand the underlying drivers of direct connections as well as why direct connections are important for trading countries. Subsequently, the purpose of this research along with its overview were outlined. Finally, the research gap that this study attempts to fill as well as its contribution to the literature were highlighted. The next Chapter will detail the research purpose, design and approach.

Chapter 2. Research Purpose and Design

2.1 Introduction

The literature to date has mainly concentrated on the positive impact that a direct connection between two countries may have on bilateral trade development and has only partially discussed some of the factors that in theory may affect the establishment of direct connections. Scholars have extensively examined and quantified what the possible impact of direct connections may be for trading countries, however, there has been only limited research on the prerequisites that may encourage – or discourage – container shipping companies to establish a direct connection between trading countries. The latter is apparently a multifaceted issue: direct connections between trading countries are largely fueled by the underlying trade dynamics, but may also be rooted in a wide spectrum of factors spanning from infrastructure to carriers' strategies. Although there is theoretical evidence that the shipping community understands through empirical observation some of the driving factors (see Section 1.3), there has not been any systematic effort to both identify those factors and also quantify their relative importance. This research aims to shed light on this topic by presenting and measuring the corresponding factors. The quantification of the factors will be of use to interested stakeholders across the research and policy domains in order to demystify how container shipping companies develop their networks and hierarchise the factors that drive their decisions regarding direct connections. Finally, the quantification of the factors may also provide a platform for the prediction of the future evolution of container shipping networks.

This Chapter reviews the theoretical principles and milestones that characterise the development of a research study. Specifically, Section 2.2 outlines the key elements that a sound Methodological Approach of a research study should consider and Section 2.3 corresponds to the Preliminary Research Design of the Thesis. Finally, Section 2.4 comprises the concluding remarks of this Chapter.

2.2 Methodological Approach

The methodological approach of the research is developed with the assistance of the pivotal work by Saunders *et al.* (2019) who proposed the *''Research Onion''* as a framework that includes the aspects and stages that a researcher may progressively consider in order to proceed with the research design. The *''Research Onion''* comprises the layers of Philosophy (2.2.1), Approach to Theory Development (2.2.2) Methodological Choice (2.2.3), Strategy (2.2.4), Time Horizon (2.2.5) and finally the applicable Techniques and Procedures (2.2.6) of the research (Figure 2.1):

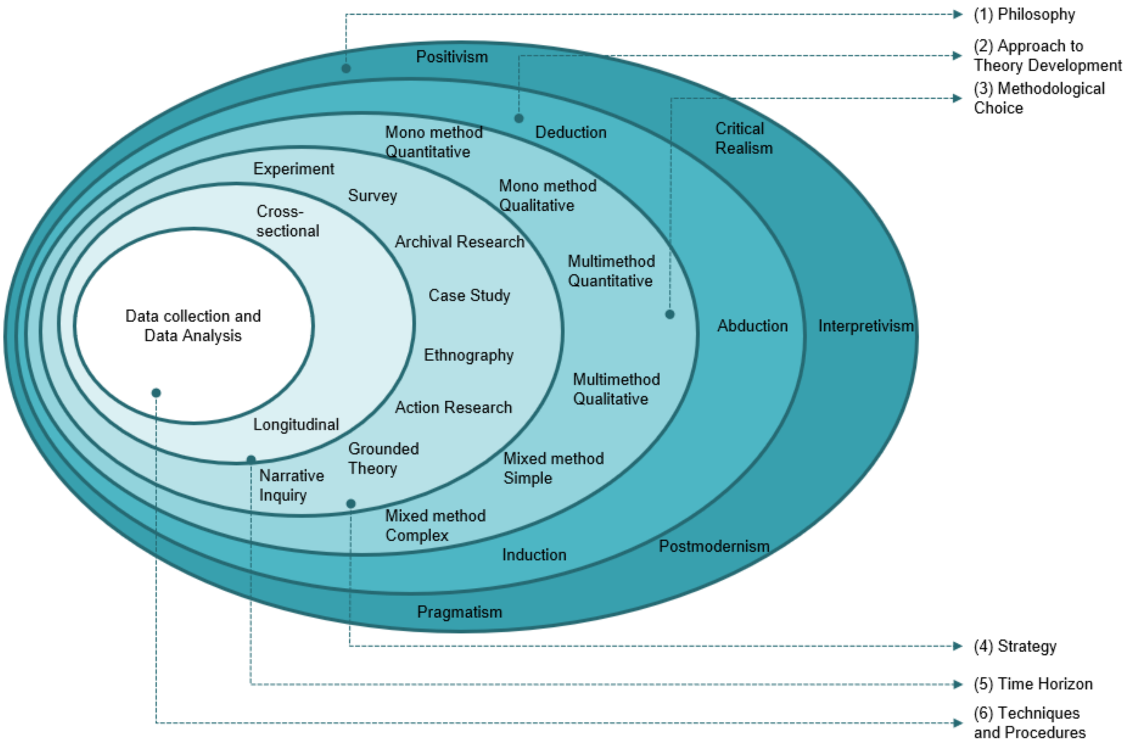

Figure 2.1 – The Research Onion, Saunders et al. (2019)

2.2.1 Research Philosophy

In every step of the research, different types of assumptions are inevitably formed (Burrell and Morgan, 2016). According to Saunders *et al.* (2019), researchers may often use the terms *''philosophy''* or *''paradigm''* interchangeably to refer to the different assumptions made during research. Thomas (1962) defined paradigms as well-esteemed and broadly accepted scientific accomplishments that can act as a framework for providing solutions to practitioners. According to Collis and Hussey (2014) paradigms outline and determine how research should be developed and is defined by the researcher's understanding of the world. Saunders *et al.* (2019) also agreed that research philosophy eventually incorporates the views and the assumptions of the researcher about the world and proposed that research philosophy is a term that denotes the *''systems of beliefs and assumptions about the development of knowledge''* (Saunders *et al.*, 2019 p159).

Research philosophies may be distinguished by the different types of assumptions made by the researcher regarding the understanding of the reality (ontological assumptions), the quality of the existing sources of knowledge (epistemological assumptions) and finally the impact of the researcher's own values on the research process (axiological assumptions) (Saunders *et al.*, 2019):

- Ontology corresponds to the researcher's understanding of the reality and largely determines the selection of the research topic (Saunders *et al.*, 2019). According to Denzin and Lincoln (1994 p615) ontology is a division of metaphysics which effectively deals with *''what exists (what ''is''), with being and reality and how entities are organized''.*
- Epistemology corresponds to the researcher's beliefs about which part of the human knowledge can be regarded as reliable (the *''dichotomy''* between true / false) as well as to the process of passing the knowledge to others (Burrell and Morgan, 2016).
- Axiology corresponds to the part that ethics play in research and largely determines which topic is considered important and which process is followed regarding the data collection (Saunders *et al.*, 2019). According to Denzin and Lincoln (1994) axiology sets the moral boundaries of the research.

The effective understanding of the research philosophy followed by a researcher dictates that the researcher should improve and develop the skill of reflexivity by scrutinising their own ideas, practices, methodological approach and prejudice and eventually the ways that the research and its results may be impacted by the researcher (Haynes, 2012). Each type of research philosophy may equally add value to the development of the research (Saunders *et al.*, 2019) by offering a *''fluid perspective''* into the various organisational challenges (Morgan, 2006). Overall, five types of research philosophies may be distinguished (Saunders *et al.*, 2019):

- Positivism: this philosophy corresponds to the posture of a natural scientist where the researcher focuses only on what can be scientifically observed as the only process that can yield trustworthy results (Crotty, 1998). A positivist would aim to understand the causal relationships between variables and produce *''law-like generalisations''* (Saunders *et al.*, 2019 p145). Positivists will likely opt for a detailed and strictly structured methodology that allows reproducibility and is largely orientated towards quantified methods and statistical analysis (Saunders *et al.*, 2019).

- Critical Realism: in contrast to Positivists, Critical Realists focus on the further understanding of the underlying structures that dictate the observable world and aim to explain the broader picture rather than constraining the research only to the perceptible information (Saunders *et al.*, 2019).
- Interpretivism: the aim of the Interpretivists is to access the world of the research participants and conceptualise the world from their point of view (Saunders *et al.*, 2019). Interpretivists also suggest that humans differ from the physical phenomena because they create meanings and thus social sciences should adopt a different stance as well compared to the natural sciences while they are also critical of Positivism's effort to determine universal truths (*ibid*).
- Postmodernism: the researchers following this philosophy may question the established norms of thinking (Kilduff and Mehra, 1997) and rather strive to highlight and give voice to marginalised approaches and ideologies which have previously been disregarded (Chia, 2003).
- Pragmatism: the research design of the Pragmatists is primarily dictated by the research question and the willingness to offer a practical solution to a research problem (Saunders *et al.*, 2019). Pragmatists accept that there may be various interpretations of the reality and thus various applicable research methods that may be combined within a single study in order to offer a more complete understanding of the world (*ibid*). However, Pragmatists will specifically select those methods that can support the collection of the most credible data which is guided by strong ethics and will enable the further progression of the future knowledge (Kelemen and Rumens, 2008).

2.2.2 Research Approach to Theory Development

The design of a research project is also determined by its aim regarding theory development: a research orientated towards theory testing (falsification or verification) may follow a deductive reasoning while a research orientated towards theory generation and building may follow an inductive reasoning (Saunders *et al.*, 2019). However, it is possible that a research may combine both approaches and thus follow an abductive reasoning:

- Deduction: a deductive research begins with a theory (which often derives from a literature review), develops a series of propositions and collects data in order to test their validity. Deduction effectively includes the rigorous testing of a theory in order to be accepted (or rejected). It is usually well-structured, quantified and generalisable and thus mainly corresponds to the research philosophy of Positivism (Saunders *et al.*, 2019).
- Induction: an inductive research collects data in order to analyse a phenomenon, suggest themes and often a theory (untested) via a conceptual framework. It advocates the importance of alternative and subjective interpretations and thus mainly corresponds to the research philosophy of Interpretivism (Saunders *et al.*, 2019).
- Abduction: an abductive approach instead of moving from theory to data (i.e. deduction) or from data to theory (i.e. induction) interplays between both approaches (Suddaby, 2006). It collects data in order to analyse a phenomenon, suggest themes and often a theory (untested) via a conceptual framework, then tests this theory with additional data collection and so forth (Saunders *et al.*, 2019). It may be developed in topics where existing literature has only partially discussed such topics allowing for the modification of an existing theory and mainly corresponds to the research philosophy of Pragmatism as well as Critical Realism and Postmodernism (*ibid*).

2.2.3 Research Methodological Choice

Research studies are usually classified based on their purpose as exploratory, descriptive or explanatory although the research may also have multiple purposes (Saunders, Lewis and Thornhill, 2007a) especially when the study is based on plenty of resources (Robson and McCartan, 2016). The main characteristics of each class are as follows:

- Descriptive: aims to depict a situation when adequate insights are already available to the researcher (Robson and McCartan, 2016) but it is regarded as a tool towards the completion of the research rather the completion itself (Saunders, Lewis and Thornhill, 2007a).

- Exploratory: aims to answer *''what''* is happening (Robson and McCartan, 2016) and to offer insights on the nature of a problem (Saunders, Lewis and Thornhill, 2007a).
- Explanatory: aims to identify the underlying relationships between variables via statistical correlation or the causal patterns of the gathered data (Saunders, Lewis and Thornhill, 2007a; Robson and McCartan, 2016).

The Methodological choice is largely defined by the data collection and data analysis techniques that the research employs (Saunders, Lewis and Thornhill, 2007a). As such, the respective methods may be characterised as quantitative or qualitative. A quantitative method utilises or produces numerical data while a qualitative method is orientated towards non-numerical data (Saunders, Lewis and Thornhill, 2007a). When a research uses a single data collection method / approach and a corresponding analysis technique it is classified as a *''mono-method''* research which differ from a *''multimethod''* research that uses several data collection and analysis techniques (either quantitative or qualitative) (Saunders and Tosey, 2013). When a research uses both quantitative and qualitative techniques then it is classified under the umbrella term of *''mixed methods''* research design (*ibid*). A mixed methods research may for instance begin with qualitative data collection and analysis (e.g. focus groups to highlight factors) and continue with quantitative data collection and analysis (e.g. a questionnaire that will indicate the frequency of those factors) and in this case it falls under the category of *''Mixed Method Simple''* research design (*ibid*). On the contrary, a research may for instance proceed to analyse qualitative data quantitatively (e.g. statistical comparison of a concept's occurrence frequency in the transcript of interviews) or vice versa and in this case it falls under the category of *''Mixed Method Complex''* research design (*ibid*).

Easterby-Smith *et al.* (2008 p65) advocated that mixed methods may be beneficial for the enhancement of a research providing that the selected methods are *''reasonably compatible''*. The selection of a mixed methods approach offers the opportunity to employ different methods in order to serve different purposes within a study and is also the framework that allows the use of *triangulation* methods (Saunders, Lewis and Thornhill, 2007a) (e.g. conducting semi-structured interviews in order to test the validity of observed data). Triangulation as a term derives from a practice developed for navigation in shipping: identify three landmarks, take their respective compass bearings, project the corresponding points in a chart and then draw lines from them in order to finally generate a triangle which would indicate the position of the vessel (Easterby-Smith *et al.*, 2008). Triangulation allows for the combination of sources and methods which can also reduce any bias that a mono-method approach may introduce to the research (Collis and Hussey, 2014). Mangan, Lalwani and Gardner (2004) further discussed how the triangulation of qualitative and quantitative methodologies (i.e. methodological triangulation) may complement each other and enrich a research with multifaceted insights.

2.2.4 Research Strategy

In practice, the research strategy is largely determined by the nature of the research question (Saunders, Lewis and Thornhill, 2007a). The various strategies are not *''mutually exclusive''* and can be used in various combinations albeit in certain occasions a distinct research study is likely to have a relative advantage in addressing the topic under investigation (Yin, 2003 p8). According to Saunders, Lewis and Thornhill (2007a), the following research strategies may be identified:

- Experiment: this strategy corresponds to the classic method of the natural sciences and it is usually executed in a laboratory (Saunders, Lewis and Thornhill, 2007a). The purpose of the researcher is to measure whether a change in an independent variable causes a change in a dependent variable (Hakim, 2000).
- Survey: this strategy mainly utilises a questionnaire with the aim to conduct either exploratory or descriptive research (i.e. answering the '*who', 'what', 'where', 'how much'* and *'how many'* questions) although it can be undertaken in a form of a structured interview (i.e. uniform questions to all interviewees) as well (Saunders, Lewis and Thornhill, 2007a).
- Action Research: this strategy corresponds to the combined effort of collecting data and enabling change within an organisation. It may take the form of one of the following: (a) the settlement of issues within an organisation, (b) the collaboration of practitioners and researchers, (c) the iteration of the process

of *''diagnosing, planning, taking action and evaluating''*, (d) the enrichment of established theoretical frameworks (Saunders, Lewis and Thornhill, 2007a).

- Grounded Theory: the strategy focuses on the research of behaviour and emphasises on the generation of new theory (Saunders, Lewis and Thornhill, 2007a). The strategy includes an iteration between inductive / deductive approaches with a persistent reference to the data in order to *''ground''* the theory (Mangan, Lalwani and Gardner, 2004).

- Ethnography: the strategy aims to outline the world of the research subjects from their own perspective and requires close cooperation with a specifically selected group of participants (Saunders, Lewis and Thornhill, 2007a).

- Archival Research: the strategy utilises prototype records as the primary source of data and the accomplishment of the research is subject to the quality and the availability of the targeted records (Saunders, Lewis and Thornhill, 2007a).

- Narrative Inquiry: the strategy utilises the personal stories of the research participants and allows for an in-depth description of their personal experiences through story-telling and thus effectively sheds light into marginalised voices and detailed views of multiple individuals (Wang and Geale, 2015).

- Case Study: the strategy is particularly useful in order to answer not only the *''why''* but also the *''what''* and *''how''* questions which makes it appropriate for both exploratory and explanatory research (Saunders, Lewis and Thornhill, 2007a). A case study is defined by (Robson and McCartan, 2016 p150) as *''a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence''*. A case study is also preferrable when the researcher aims to conduct an explanatory research while having minimal control over the studied events (Yin, 2003 p1). According to Morris and Wood (1991) this strategy is suitable for any research that aims to obtain rich insights of the studied topic and the processes being established. A case study may employ various techniques – often in combination – and it is possible to be coupled with triangulation techniques (i.e. the utilisation of different data collection techniques within a single study with the aim to cross-check and validate conclusions and findings such as the check of quantitative data via semi-structured interviews) (Saunders, Lewis and Thornhill, 2007a). Finally, a case study may be considered as a proper scientific method in order to test or challenge the existing theory (*ibid*).

2.2.5 Research Time Horizon

The time horizon of a research are dictated by whether the research aims to analyse a static situation on a single and defined point of time or to analyse a sequence of events within a period of time. Based on this differentiation, a research may be classified as cross-sectional or longitudinal:

- Cross-sectional studies analyse a phenomenon at a specific time period (Saunders, Lewis and Thornhill, 2007a) thus within a limited time horizon. A cross-sectional study may undoubtedly assist to highlight the attributes of a phenomenon but a longitudinal study may also go further and attempt to explore the causal underlying patterns that arise from the observed data (Easterby-Smith *et al.*, 2008). In the context of this research a cross-sectional study would be the analysis of the pair-wise direct shipping connections between countries in a single year.

- Longitudinal Studies on the contrary observe the cross-sectional development of a phenomenon over multiple time periods (Baltagi, 2005). A longitudinal study, given the time-constraints of an academic project, is more demanding than a cross-sectional study (Saunders, Lewis and Thornhill, 2007a) but allows the understanding of more complex behavioural models (Hoffmann, Saeed and Sødal, 2020). Furthermore, the applicable models of longitudinal studies can take into consideration the heterogeneity between the individuals of the study, be more informative and – if the time-horizon is long enough – offer great insights regarding the adjustment of the individuals to change (e.g. between different economic states or before / after a policy adaptation etc.) (Baltagi, 2005). A core question that a longitudinal study aims to answer is whether there has been a change during a set period of time (Bouma and Atkison (1995), as cited in Saunders, Lewis and Thornhill, 2007a). In the context of this research a longitudinal study would be the analysis of the pair-wise direct shipping connections development between countries over a number of years.

2.2.6 Research Techniques and Procedures

The final layer of the *''Research Onion"* by Saunders *et al.* (2019) corresponds to the applicable Research Techniques and Procedures which are largely defined by the data collection and analysis needs of the research. The approach that this research adopts for this layer of the *'onion'* will be discussed in detail in Chapter 5.

2.3 Preliminary Research Design

At this stage, the research is largely agnostic towards the specific research design that should be followed. However, the review of the principles and milestones that characterise the development of research in this Chapter has provided a preliminary direction for this research. Specifically, the researcher is of the view that the topic under examination is a multifaceted issue since it examines the decision-making process of multiple carriers which operate across various geographies and under different market conditions. Thus, it is likely that a triangulation of qualitative and quantitative methodologies (e.g. an econometric analysis further explored via semi-structured interviews) may complement each other and enrich the results of the research (Figure 2.2):

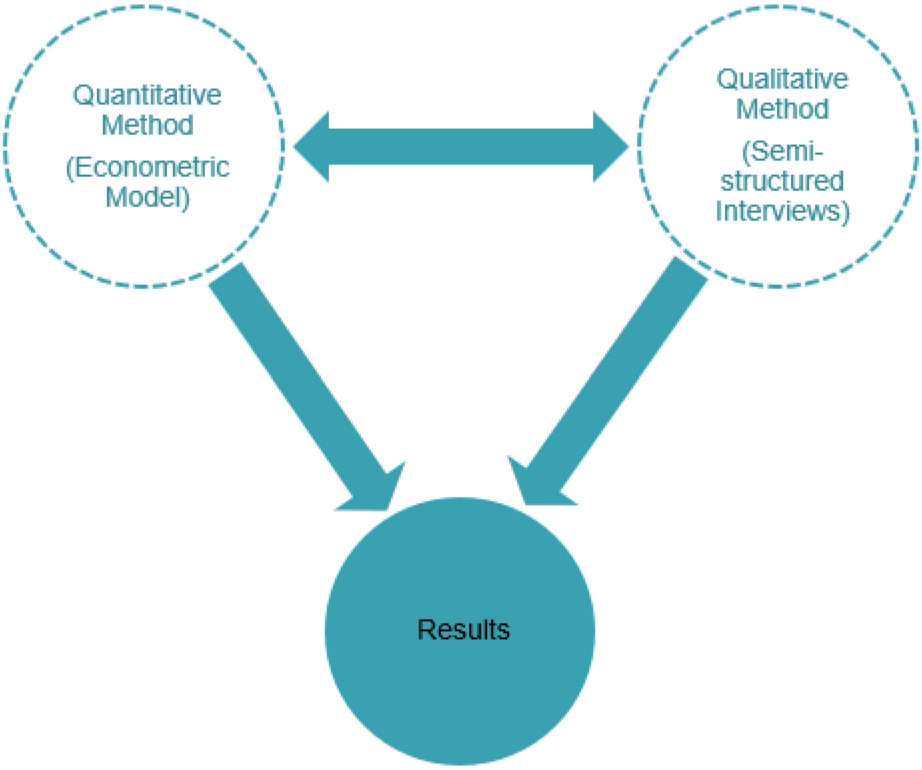

Figure 2.2 – Preliminary Research Design: Triangulation of Methods

Nevertheless, the Preliminary Research Design outlined in this Section will be revisited once the literature review around the examined topic is finalised and a clearer understanding of the dynamics that characterise the establishment of direct connections between countries in container shipping is achieved (see Section 3.12).

2.4 Concluding Remarks

This Chapter discussed the theory that underpins the methodological approach of a research. Then, the preliminary design of the Thesis was detailed. The next Chapter will proceed with a literature review which will present the different perspectives that previous research has offered regarding the establishment of direct connections in container shipping.

Chapter 3. Systematic Literature Review

3.1 Introduction

Ducruet and Notteboom (2012b) noted that although the shape of the shipping network follows the trade patterns, it is also characterised by other practical intricacies comprising technological factors (e.g. infrastructure) as well as territorial factors (e.g. socio-economic developments). Fugazza and Hoffmann (2017), showed that the absence of a direct connection between two countries is related to lower exports value and also any additional transhipment is likely to be linked to 40% less bilateral exports value. Calatayud, Mangan and Palacin (2017), underlined that the shipping network does not perfectly overlap with the corresponding trade network. This is a reflection of the hub-and-spoke shipping network organisation by the carriers which however ensures the continuous trade flow between countries. Ultimately, the connectivity of the nodes that form the shipping network is largely dictated by the carriers' strategies. Wilmsmeier and Notteboom (2011) identified 4 phases on the development of the liner shipping networks: (1) direct services to serve the local or regional needs; (2) intermediate hubs to serve the needs for further connections overseas; (3) further access to the broader hub-and-spoke network by various ports; and (4) the volumes of several ports are large enough to attract the interest of the shipping lines for direct connections to overseas regions. Consequently, the connection of two countries is a decision associated with the strategy of the shipping company (i.e. network design) and affects operations. Simultaneously, it is largely driven by short-term choices on a tactical level and reflects the market responsiveness of the company (Meng *et al.*, 2014). Thus, it becomes evident that the establishment of direct shipping connections in container shipping is largely fueled by the underlying trade dynamics, but it is also the joint result of various other contributing factors, spanning from infrastructure to carriers' strategies.

The existing literature has interchangeably used terms such as ''*countries*'', ''*economies*'' and ''*partners*'' to describe the corresponding international trade relationships. In the context of this research, the term ''*country*'' refers to territories with political independence (The World Bank, 2022b) controlled by their own government (Britannica, 2022a). The purpose of this literature review is to examine the different perspectives that have been brought in the relevant literature, with the intention to identify the factors that may encourage – or discourage – the establishment of a direct shipping connection between two trade partners. In order to meet the aforementioned purpose, the present research adopts the approach of a Systematic Literature Review (SLR). This approach assists on integrating divergent findings into rigorous reviews based on scientific evidence (Tranfield, Denyer and Smart, 2003) and aims to synthesize the existing perspectives into a wider understanding of the explored topic (Wang and Notteboom, 2014). Hence, SLR is regarded as a suitable approach for conducting the literature review of the present study. In particular, this SLR aims to systemically identify the factors that should be in place in order to motivate carriers towards a direct connection between two trading countries.

In this Chapter, Section 3.2 introduces the theory behind SLR and the adopted stages that apply in the present research, Section 3.3 describes the planning element, Section 3.4 corresponds to the execution structure of the review and Section 3.5 presents an overview of the results. Sections 3.6 - 3.10 discuss thoroughly the findings on the basis of a thematic analysis. Section 3.11 provides a summary of the findings while also outlining the use of the results. Then, Section 3.12 finalises the Research Design. Lastly, Section 3.13 comprises the concluding remarks of this Chapter.

3.2 Systematic Literature Review (SLR): Theory

While traditional literature review is often characterised by the inclusion of biased choices made by the researcher (Fink, 1998; Hart, 1998), a systematic literature review allows for the minimisation of bias through a thorough selection of both published and unpublished studies and techniques that guarantee the production of superior evidence (Tranfield, Denyer and Smart, 2003). A systematic literature review follows an audit structure which is clearly documented and includes all relevant decisions regarding the process and the outcome of the decisions made by the researcher (Cook, Mulrow and Haynes, 1997). All decisions are captured in a formal document (protocol) which includes all relevant information on the questions asked, the structure of the search and the criteria for the final inclusion or exclusion of particular studies (Davies and Crombie, 1998). The selection of a study is respectively based on preset criteria (Oxman, 1994) and generally the importance of a study for the conducted review is based on its quality in terms of methodology and its research questions (Tranfield, Denyer and Smart, 2003). The studies that are finally included should meet all the criteria manifested in the protocol. The strict criteria aim to secure a top-quality review. All studies that meet the criteria are then closely examined and a part of them is further selected to be systemically reviewed according to their relevance. When a study is excluded, the corresponding reasons are also recorded accordingly (Tranfield, Denyer and Smart, 2003). A systematic literature review avoids the possible bias imposed by the implicit likings of the researcher, achieving thoroughness (Wang and Notteboom, 2014) and thus making a decisive step towards scientific conclusions (Rousseau, Manning and Denyer, 2008). In systematic literature review the gathered evidence is summarised by a well-defined and explicit methodology and this ultimately differentiates the systematic approach from traditional approaches (Khan *et al.*, 2003; Lavissière, Sohier and Lavissière, 2020).

Fruth and Teuteberg (2017) also recognised the important advantages of a systematic approach over traditional methods but they also identified possible limitations that may characterise a systematic literature review, such as an unintended exclusion of particular studies in the selection phase. This may be the result of keywords incompleteness or a degree of subjectivity during the evaluation phase. However, the vast majority of the scholars that have employed a systematic approach to the literature review, advocate the superiority of the systematic over the traditional literature review approach. The latter lacks a defined methodology and thus the results may be both irrelevant and biased (Becheikh, Landry and Amara, 2006; Vieira, Kliemann Neto and Amaral, 2014).

Following the paradigm of Tranfield, Denyer and Smart (2003), the majority of the publications that apply a systematic approach for literature review are organised on discreet stages. The present research combines the 3-stage approach of Parola *et al.* (2017) with the respective 5-step structure applied by Wang and Notteboom (2014). The first stage relates to the Planning of the review and corresponds to the formulation of the Review Question. The second stage proceeds with the Execution of the review and includes the search and collection of the studies as well as their evaluation and selection according to preset criteria. Finally, the third stage comprises the Reporting of the results through the Analysis and Synthesis of the findings as well the synopsis of the results use. The approach of the Systematic Literature Review is illustrated in Figure 3.1:

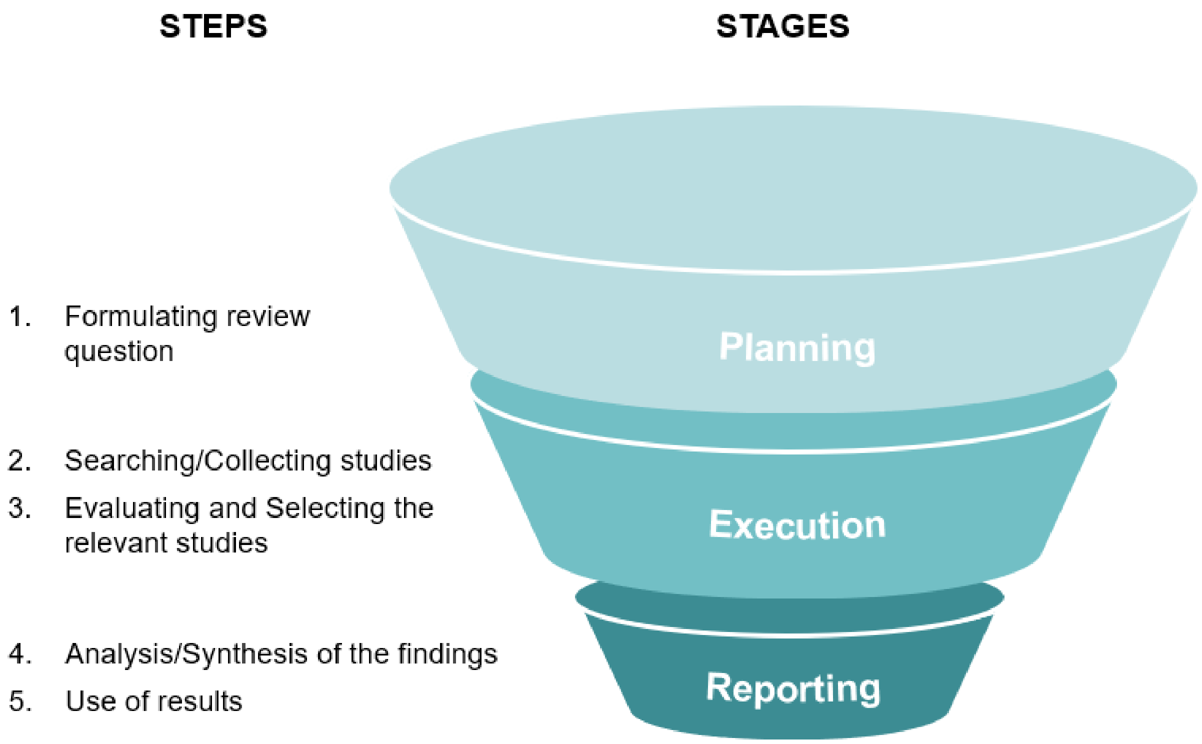

Figure 3.1 – Systematic Literature Review Approach

3.3 Planning

Step 1 – Formulating review question

Routes in container shipping are organised as sequences of port calls which collectively shape the container shipping network. The consideration towards establishing a pairwise connection between two countries may be triggered by specific dynamics (e.g. the momentum of the bilateral trade) but may ultimately be depended on whether specific countries constitute good candidates in order to become part of a carrier's route sequence. Hence, this literature review is designed to include previous studies that have discussed routes within the container shipping network context, with a particular focus on direct connections.

Consequently, the SLR has been conducted as a structured deep-dive into the existing literature with the intention to provide an insight to the first Research Question (RQ1): *what are the factors that liner shipping companies consider in order to establish a direct shipping connection between two trading countries?* The latter corresponds to the first step of the SLR which suggest the need of formulating a review question.

Thus, during the review of each publication, the researcher aimed to systemically identify references to factors that could promote or respectively prevent a direct shipping connection between two trading countries.

The body of the SLR was conducted by interrogating Scopus database, because of its high reputation and exceptional coverage of the existing literature (Parola *et al.*, 2017; Lavissière, Sohier and Lavissière, 2020). However, the main research queries were also applied to Google Scholar database with the aim to broaden the research (Fruth and Teuteberg, 2017) and to possibly include other sources and publications, generated and published outside of the classic academic channels, such as working papers or reports by national or international institutions (Calatayud *et al.*, 2016).

3.4 Execution

Step 2 – Searching / Collecting studies

A core step of a systematic literature review is the identification of the search keywords in accordance with the scope of the study. The *''search strategy''* should be reported in detail, allowing for replication (Tranfield, Denyer and Smart, 2003). The refining of the respective keywords is an iterative process which can also be schematically represented (Raza, Svanberg and Wiegmans, 2020). This process is more thorough than the adoption of a single Boolean algorithm that could potentially overlook a series of relevant results (Sanchez-Gonzalez *et al.*, 2019) and may include multiple interchanging keywords and combinations relevant to the studied topic (Parola *et al.*, 2017; Vieira, Kliemann Neto and Amaral, 2014). Subsequently and with regard to the Searching / Collecting step of the SLR, the study applied a series of queries which utilised relevant keywords in accordance with the study scope. As outlined in *Step 1,* the review has targeted previous academic work with regard to routes that shape the network of container shipping. The latter is also interchangeably described by the umbrella term of *''liner shipping''*, due to the nature of the itineraries which offer fixed-time scheduled ocean transportation services (Premti, 2016).

Thus, Query 1 was applied to Scopus database and included the keywords of *''route'', ''network'', ''container shipping''* and *''liner shipping''*. The search was enriched with a set of Boolean (i.e. AND, OR) operators (Raza, Svanberg and Wiegmans, 2020) and also allowed for possible variances (Fruth and Teuteberg, 2017) of the utilised keywords (i.e. rout*, network*). The search was executed based on title, abstract and keywords:

Query 1: TITLE-ABS-KEY (''rout*'' OR ''network*'' AND ''container shipping'' OR ''liner shipping'')

Since the focus of the research is towards direct routes, the results of Query 1 were thoroughly scanned with the aim to identify synonyms of ''*route''* which have been used in the literature in conjunction with ''*direct"*. This effort revealed a set of additional keywords, comprising ''*call'', ''shipment'', ''operation'', ''delivery'', ''service'', ''connection'', ''transport'', ''link'',* and *''port''* as well as their variances. The new set of keywords formed Query 2 which was also applied to Scopus database, as follows:

Query 2: TITLE-ABS-KEY (''direct'') AND (''rout*'' OR ''call*''OR ''ship*'' OR ''operation*'' OR ''deliver*'' OR ''service*'' OR ''connect*'' OR ''transport*'' OR ''link*'' OR ''port*'') AND (''container shipping'' OR ''liner shipping'').

As discussed during the Planning stage, the research was extended to Google Scholar in older to widen the findings list of Scopus database. Thus, Query 3 was executed as a repeat of Query 1 and 2 on Google Scholar search (full article):

Query 3: Query 1-2 on Google Scholar

In order to explore any parallels and good practices with regard to routes for other transport modes, Query 1 was also applied to Scopus by substituting the shipping element with *''rail freight''* or *''railfreight''* or *''air freight''* or *''airfreight''*.

Query 4: TITLE-ABS-KEY (''rout*'' OR ''network*'' AND (''rail freight'' OR ''railfreight'') OR (''air freight'' OR ''airfreight''))

Finally, with the aim of accounting for any omitted relevant publications, the research applied the Snowballing practice (Raza, Svanberg and Wiegmans, 2020; Fruth and

Teuteberg, 2017). Snowballing practice may take two forms: backward and forward. Backward Snowballing suggests using the reference list of a paper in order to identify relevant citations that can be included in the body of the literature review. Forward Snowballing suggests identifying additional papers that have cited the examined paper (Jalali and Wohlin, 2012).

Step 3 – Evaluating and Selecting the relevant studies

Following the execution of each query, a structured and standardised appraisal was conducted, satisfying the third step of the SLR for *Evaluating and Selecting* the relevant studies. This includes a crucial classification of the collected studies based on their relevance to the review question as well as their reliability (Wang and Notteboom (2014). Thus, the appraisal of the collected studies was conducted in two phases. On the first phase, the results of the queries were evaluated with regard to their relevance to the research scope and on the second with regard to their quality (Calatayud *et al.*, 2016), following a thorough review. The relevance evaluation was executed based on title, abstract and keywords. For the quality evaluation, assessment forms such as the one suggested by the Critical Appraisal Skills Program (CASP) are commonly used (Campbell *et al.*, 2003), although CASP has primarily been focused on the training of healthcare professionals. For the inclusion or exclusion of studies on the final list, the researcher applied a modified version of the CASP checklist, as suggested by Wang and Notteboom (2014). A relevant sample is available on Appendix A.

Query 1 returned 697 papers and Query 2 returned 57 papers of which 107 matched the relevance criterion. Hence, 107 papers were selected to be further scrutinised under CASP criteria. Finally, 81 papers matched the quality criterion. Query 3, Query 4 and Snowballing provided 51 additional publications that were considered relevant to the scope of the research, and which were selected to be further filtered through CASP checklist. The quality check via CASP criterion resulted in 49 publications to be included on the final list of the studies that formed the body of the literature review. The execution of the queries and the evaluation of the collected studies, resulted in 130 studies which finally formed the body of the SLR, as illustrated in Figure 3.2:

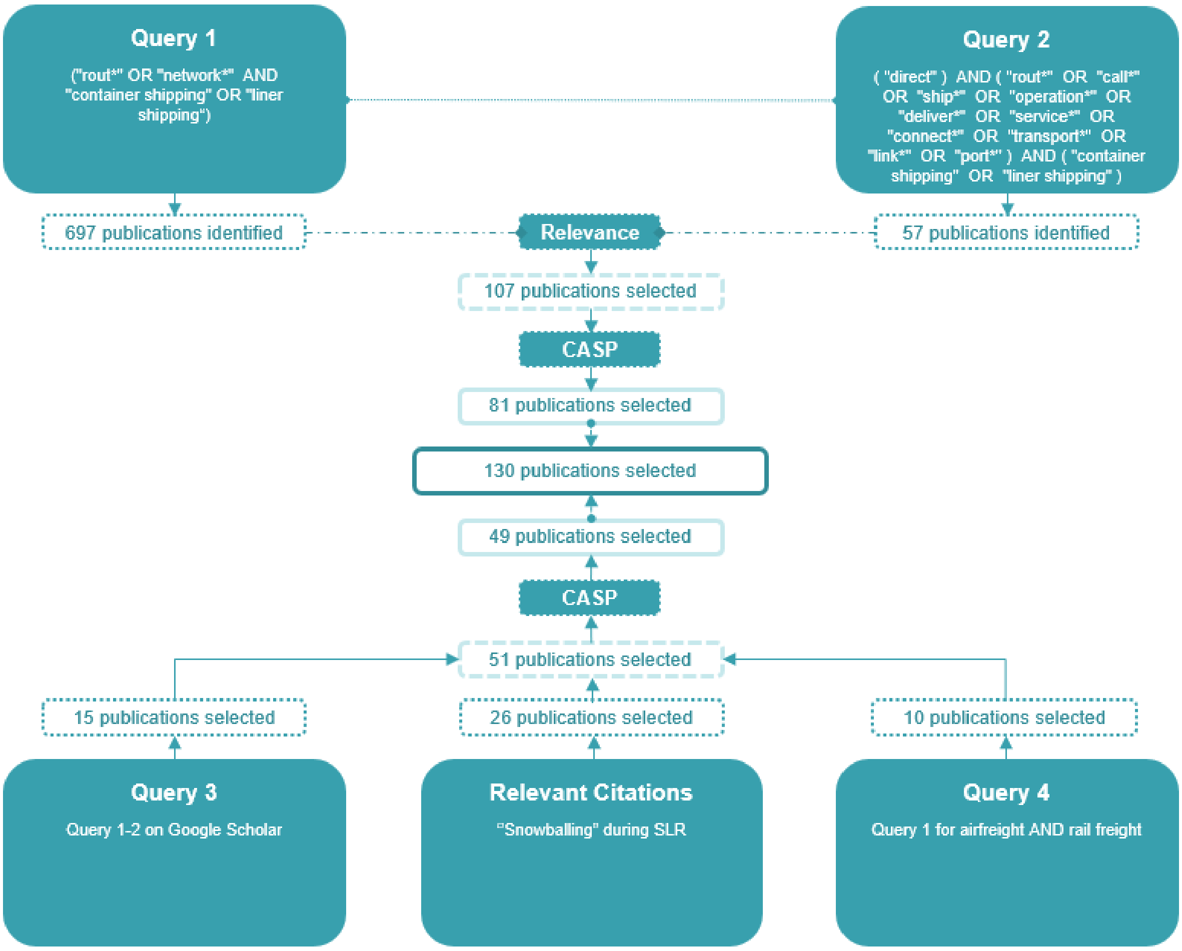

Figure 3.2 – Systematic Literature Review Process

Snowballing allows for broader coverage of the literature review and can strengthen the systematic approach by accounting for any overlooked studies, a possible downsize of SLR, as previously noted. However, Snowballing unavoidably implies a degree of subjectivity thus explicit presentation of the methodological approach is advisable (Jalali and Wohlin, 2012). SLR is ultimately an unbiased scientific approach that should guarantee replicability as well as transparency while securing an audited trail of the overall process (Sanchez-Gonzalez *et al.*, 2019). Figure 3.3, contributes to that direction by displaying the full selection path of publications through Snowballing. The papers closer to the center of the network were derived directly from the SLR list (illustrated in dark color), while the ones on the periphery correspond to the 26 additional papers that were gathered via Snowballing on SLR papers (illustrated in light color):

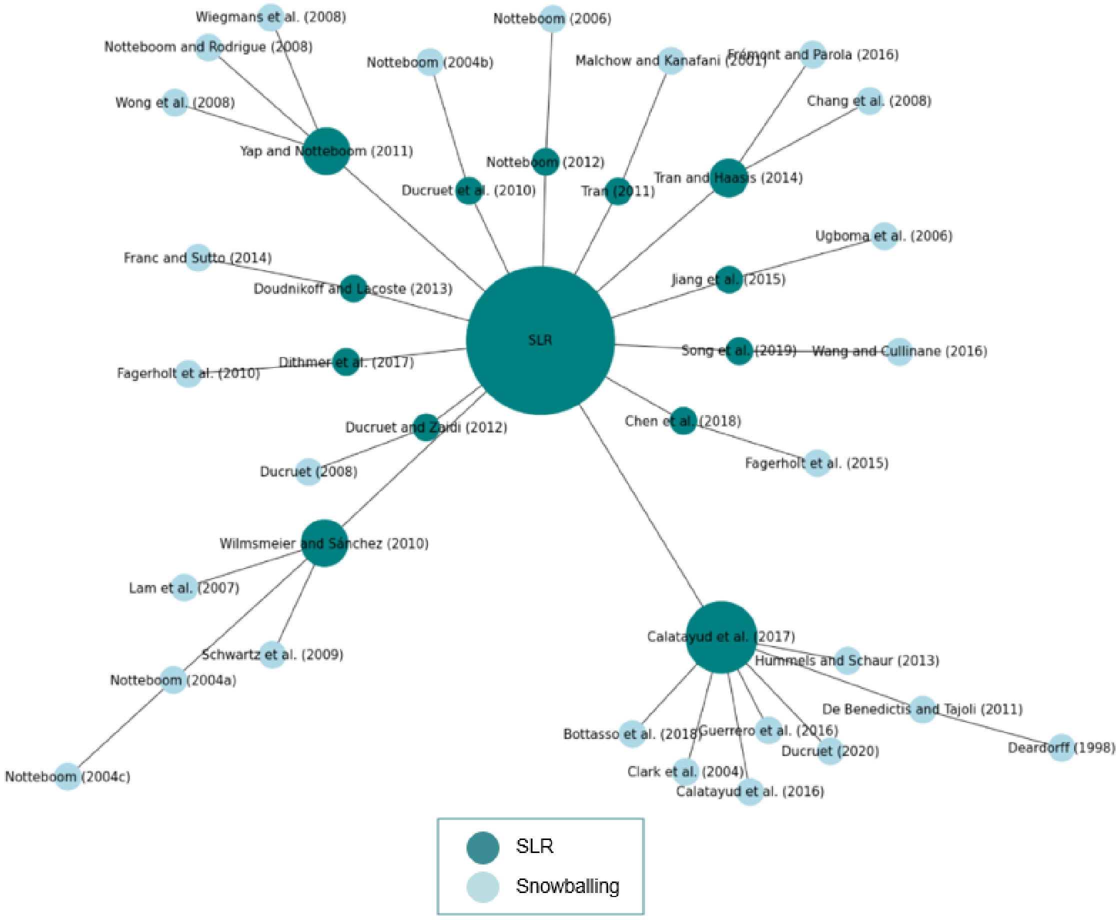

Figure 3.3 – SLR Snowballing

The final list includes publications spanning from 1998 to 2021 and corresponding to various disciplines. The majority of the publications relate to the research field of Transportation (TRA), but the SLR also includes inputs from other research fields such as Economics and Econometrics (ECO), Geography, Planning and Development (GEO), Business and International Management (BUS), General Computer Science (GCS), General Engineering (GEN), Management Science and Operations Research (MOR), Environmental Studies (EST), and Mathematics (MAT). The classification in research fields has followed the typical subject area used by Elsevier B.V. (2022) and it is illustrated in Figure 3.4:

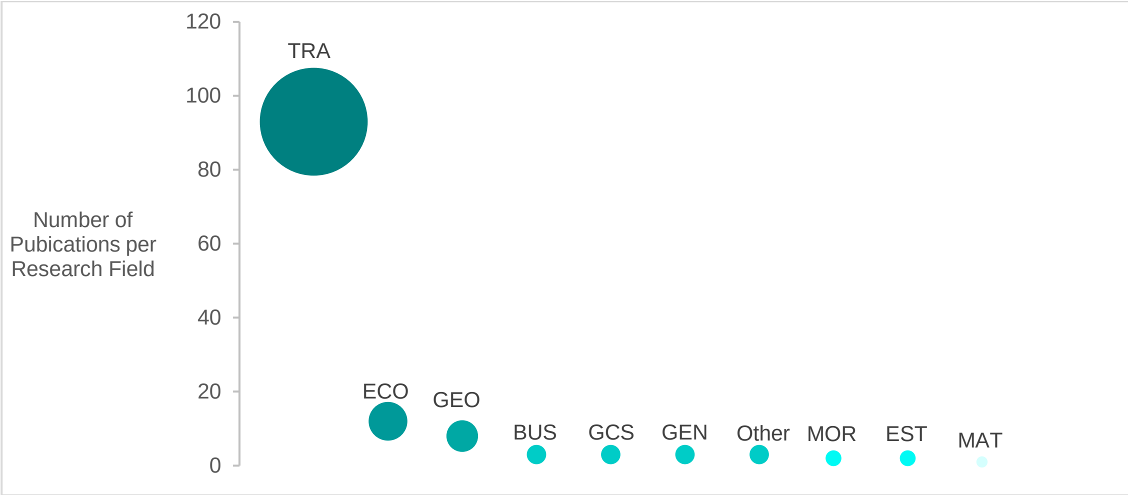

Figure 3.4 – Number of publications per research field

The body of the SLR consists of 114 journal articles and 16 publications from other type of sources (i.e. book sections, working papers and conference proceedings). Figure 3.5 illustrates the frequency of the journals, based on the number of the corresponding articles that each journal contributed to the body of the SLR:

Figure 3.5 – Word cloud of journal titles based on frequency of use during SLR

3.5 Reporting

3.5.1 Results

Step 4 – Analysis / Synthesis of the findings

The evaluation of the publications should be followed by the extraction of the relevant information from each publication through analysis, and the integration of the findings through synthesis (Wang and Notteboom, 2014; Mulrow, 1994). In accordance with Wang and Notteboom (2014) and since the reviewed studies included both quantitative and qualitative results, the researcher adopted an integrative approach that allowed the aggregation of the results in a manner of '*'general sense from each study*''. Wang and Notteboom (2014) noted that such an approach imitates a respective approach that was previously adopted by Yin (1989). With regard to the identified factors, the present SLR follows the example of Raza, Svanberg and Wiegmans (2020) and reports both enablers as well as possible barriers towards the establishment of a direct shipping connection between countries. Table 3-1 presents a brief explanation of the identified factors, as those have been broadly discussed and defined by the reviewed publications:

#	Factor	Description
(1)	Affiliated Terminal	A container handling facility which is affiliated with a container shipping company
(2)	Colonial Ties	The relationship between two countries when one has been a colony of the other or the pair has shared a common colonizer
(3)	Common Border	A land border shared by two neighbouring countries
(4)	Common Language	An official language shared by two countries
(5)	Connectivity	The degree of a country's integration in the container shipping network
(6)	ECA Routing	A shipping itinerary that crosses an established Emission Control Area (ECA) while connecting two countries
(7)	GDP per Capita	The Gross Domestic Product (GDP) of a country per individual, as a prosperity indicator at country level
(8)	Logistics Performance	The overall efficiency of the logistics network of a country
(9)	Market Concentration	The relative power of shipping companies in a route, based on the deployed shipping capacity shares
(10)	MSR Routing	A shipping itinerary that crosses the Maritime Silk Road (MSR) while connecting two countries
(11)	Nautical Distance	The actual maritime distance in nautical miles that a vessel covers in order to connect two countries
(12)	Political Stability	The level of social unrest in a country that may lead to the destabilisation of the government
(13)	Port Infrastructure	The quality and efficiency of the port facilities in a country
(14)	Reefer Cargo	The importance of the refrigerated cargo for the overall containerised market of a country
(15)	Route Deviation	The additional nautical distance that a vessel needs to cover when an intermediate call is added between two – already connected – nodes
(16)	Seasonality	The fluctuation of the cargo volume during specific periods within a year
(17)	Security Issues	Security threats and concerns regarding organised crime actions in a country
(18)	Trade Agreement	The participation of an analysed pair of countries in a multilateral or bilateral trade agreement
(19)	Trade Facilitation	The streamlining and improvement of trade processes in a country
(20)	Trade Flow	The overall trade exchanges between two countries
(21)	Trade Imbalance	The difference between the value (or volume) of exports and imports of a country
(22)	Transit Time	The overall travel time of a shipment between the origin and the destination country
(23)	Voyage Cost	The sum of the major cost categories for running a container shipping service (i.e. capital cost, fuel cost and daily operating cost)

Table 3-1 – Description of the Identified Factors

SLR theory also suggests that a researcher should report the outcomes of a *''thematic analysis''*, potentially including comments on whether there has been a consensus across themes or not (Tranfield, Denyer and Smart, 2003). The analysis aims to classify the reviewed publications into themes, on the basis of the discussed topics and problems (Raza, Svanberg and Wiegmans, 2020) or the shared characteristics and perspectives (Calatayud *et al.*, 2016). The present SLR uncovers various factors that liner shipping companies may examine when considering the establishment of a direct connection. Each publication discusses possible factors from a particular perspective which indicates towards the classification of the publications under 5 broad themes (Figure 3.6):

(1) Shipping Network

The theme includes publications discussing how carriers' decision to connect directly two countries may be affected by (a) the characteristics of the current shipping network; (b) opportunities for its enhancement; and (c) route design considerations and practices.

(2) Connectivity

The theme includes publications discussing how carriers' decision to connect directly two countries may be influenced by the country-level connectivity characteristics. The connectivity of a country may (a) define its seamless and successful integration in a container shipping route and (b) enable further connections which can enhance carriers' portfolio. A number of publications discuss connectivity explicitly as a standalone factor whereas other publications refer to factors that impact connectivity.

(3) Port Selection Criteria

The theme includes publications discussing how carriers' decision to connect directly two countries may be affected by specific port selection criteria. Those criteria define the accessibility and the attractiveness of a port, both from a carrier and a cargo owner point of view. Ports are the ultimate facilitators of bilateral trade at country level thus certain characteristics of theirs may play a central role to the establishment of a shipping connection between trading partners.

(4) Trade

The theme includes publications discussing how carriers' decision to connect directly two countries may be affected by trade dynamics and needs (i.e. reduction of transportation costs for the enhancement of bilateral trade flow etc.).

(5) Alternative Transport Modes

The theme includes publications discussing factors that the stakeholders of air freight and rail freight networks tend to consider as contributors towards the establishment of connections for the respective transport modes. The organisation of the network around hub-and-spoke or direct connections is a topic of discussion for road transportation as well (e.g. Lumsden, Dallari and Ruggeri, 1999; Zhang, Wu and Liu, 2007). However, road transportation fundamentally serves domestic and last mile deliveries while the SLR investigates international and overseas connections. Thus, the SLR has attempted to find parallels with air freight and rail freight networks but has not considered road networks.

Notably, several factors are common across different themes although each theme examines the reviewed topic from a distinct perspective. This is evidently a logical outcome: the research analyses the factors that may define the establishment of a direct connection in container shipping. However, a shipping route is an integral element of the Shipping Network (Theme 1), can be influenced by the Connectivity (Theme 2) characteristics of a country, materialises if certain Port Selection Criteria (Theme 3) are fulfilled, derives from the dynamics of Trade (Theme 4) between countries and may generally share a number of similar features across Alternative Transport Modes (Theme 5).

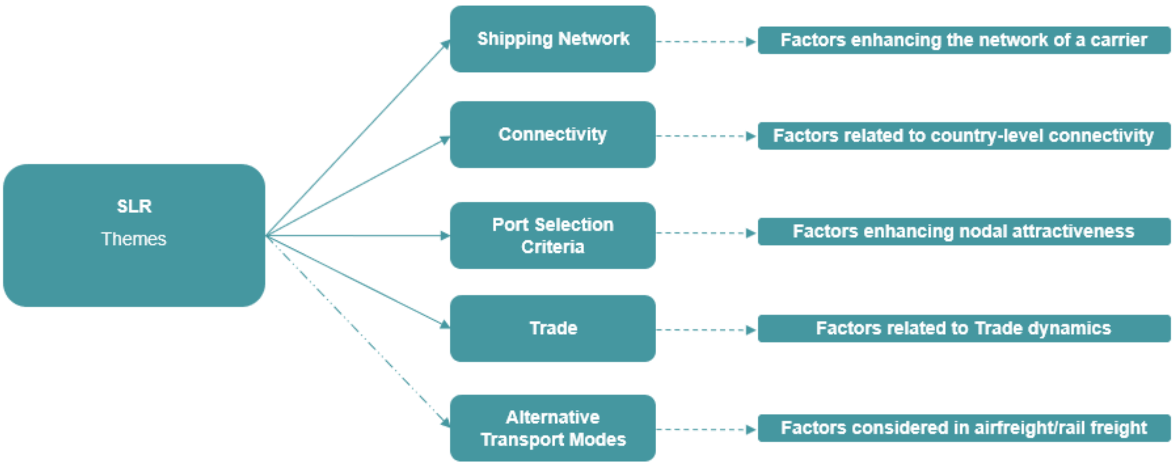

Figure 3.6 – SLR Themes

Thus, the defining factors of a direct shipping connection have been discussed by the existing literature from various angles. The thematic discussion of the SLR has been organised by grouping the corresponding papers under each identified factor. The aggregation of the results aims to reveal the expected impact of each factor towards a direct shipping connection between two countries, based on the *''general sense from each study''* (Wang and Notteboom, 2014), as previously noted.

3.6 Theme 1: Shipping Network

(1) Affiliated Terminal (also arises in Theme 3)

Liner shipping companies may frequently operate their own container terminals. Hence, one may anticipate that the service pattern of certain liners tends to complement the geographical distribution of their container terminals (Parola and Veenstra, 2008). According to Parola and Veenstra (2008) however global players in liner shipping do not necessarily support their shipping operations with a respective terminal network. Those authors underlined that for the examined years (2002 and 2005) only one player (Maersk) was an active global player in both sectors, with overlapping liner and terminal networks.

Theme 3 also discusses whether a shipping alliance may opt for a call at a specific terminal in case one of its members is affiliated with the respective facility.

(2) Colonial Ties (also arises in Theme 4 and Theme 5)

Although geography is expected to have a strong influence towards the establishment of a connection between nodes of the shipping network, cultural and historical aspects may also play a significant role. Ducruet and Zaidi (2012) concluded that sub-groups of ports generally arise based on geographical proximity. However, the authors found concrete evidence that there might also be long-distance connections that can attributed to former colonial relationships. Ducruet, Rozenblat and Zaidi (2010) provided a geographical focus on the shipping network of the Atlantic Ocean and among other findings highlighted the links between countries with former colonial ties.

Theme 4 and Theme 5 also discuss colonial ties, examining whether they can boost bilateral trade flows in container shipping or in air freight, respectively.

(3) Common Border (arises in Theme 5)

This factor was not explicitly discussed by the publications included in Theme 1.

(4) Common Language (arises in Theme 4 and Theme 5)

This factor was not explicitly discussed by the publications included in Theme 1.

(5) Connectivity (also arises in Theme 2, Theme 3, and Theme 4)

One of the pillars that support the connectivity of a country to its trade and shipping network is the transport services which depend on the particular strategies of the carriers (Calatayud, Mangan and Palacin, 2017). The reach of a liner shipping company to international markets allows the expansion of its customer portfolio. An enhanced network would allow both local and international customers to serve their overseas partners without being encumbered by unnecessary transhipments (Gadhia, Kotzab and Prockl, 2011). Overall, calling at a node that generates strong gateway cargo while simultaneously its connectivity can also offer further opportunities for reaching other nodes is considered an attractive factor for a carrier in order to establish a direct call (Notteboom, 2004c). The United Nations Conference on Trade and Development (UNCTAD) in 2006 proposed the development of an index that can capture the connectivity of the countries in the container shipping network: the Liner Shipping Connectivity Index (LSCI) (Hoffmann, Van Hoogenhuizen and Wilmsmeier, 2014). The index allows for benchmarking between countries and across multiple years. The initial version of the index was compiled based on 5 components. However, the index was updated in August 2019 to also include for each country, the number of other countries which can be reached with a direct connection (Niérat and Guerrero, 2019). According to UNCTAD (2019), the current version of the index includes the following factors:

- *i.* *The number of scheduled ship calls per week in the country;*
- *ii.* *Deployed annual capacity in Twenty-Foot-equivalent Units (TEU): total deployed capacity offered at the country;*
- *iii.* *The number of regular liner shipping services from and to the country;*
- *iv.* *The number of liner shipping companies that provide services from and to the country;*
- *v.* *The average size in TEU (Twenty-Foot-equivalent Units) of the ships deployed by the scheduled service with the largest average vessel size; and*
- *vi.* *The number of other countries that are connected to the country through direct liner shipping services*

The higher the connectivity of a country, as reflected by its LSCI score, the more likely it is to attract additional services which eventually will promote its better access to the international trade network (Wilmsmeier and Sánchez, 2010).

Theme 2 also discusses the connectivity of a node as a reflection of its potential to reach other nodes, Theme 3 argues that the connectivity of a node may define its attractiveness as a port of call and Theme 4 outlines connectivity as a trade-related measure that may define the relative importance of a node for the shipping ecosystem.

(6) ECA Routing

An Emission Control Area (ECA) is a designated sea area in which strict limitations for sulphur emissions have been imposed, as per Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL) (IMO, 2019a).

Fagerholt *et al.* (2015) computed that the establishment of an Emission Control Area (ECA) may push operators to sail longer distances in order to completely avoid or reduce steaming through it while burning more expensive fuel. Such a practice can also be negative from an environmental perspective due to the increase in sailing distance. Thus, operators may factor in the crossing of an ECA during route design and follow alternatives that may include delivery at an alternative port and then a shift to other modes should this be operationally attainable. This argument was also confirmed by Chen, Yip and Mou (2018) who developed a route choice model to test mathematically whether the introduction of an ECA in the Mediterranean Sea would have any implications on the routing preferences and found that a considerable number of vessels would be inclined to consider an alteration of their route. The introduction of various environmental instruments such as a cap-and-trade scheme may also have implications on route selection. Under such as scheme, regulators set specific emissions limits and operators may sell and buy excessive or additional allowances respectively, at a price which is set by the supply / demand dynamics of the trading scheme. Although carriers may pass a part of the compliance costs to the customers via a Bunker Adjustment Factor (BAF), operational adaptations would be pursued aiming towards cost minimisation. Consequently, a spatial reshuffle of the services may take place as one of the possible measurements by carriers which in turn may lead to selecting or deselecting particular network nodes (Franc and Sutto, 2014). Dai *et al.* (2018) advocated that the introduction of a CO_2 emission charge in

Europe could incentivise the reconfiguration of the calling pattern by the carriers for Asia-Europe tradelane and – under certain circumstances – it could potentially be more beneficial for carriers to reorganise the location of their consolidation centres. The latter would negatively influence the connectivity of certain nodes along the Asia-Europe route in general.

However, Doudnikoff and Lacoste (2013) tested the economic benefit for a mainline service on Asia-Europe tradelane should the operators decide to avoid both the North Europe ECA as well as any potential CO_2 quotas imposed in European territory. The authors compared the option of a standard mainline service calling directly at Hamburg against the alternative of transhipping at the port of Tangier. The authors concluded that such an approach, apart from being impractical, is also not beneficial from an economic perspective. Their calculation showed that the benefits from the economies of scale that a mother vessel achieves are greater than the savings that the avoidance of the ECA would secure, once the feeder cost is added. Schinas and von Westarp (2017) also calculated that the introduction of a 100-mile Emission Control Area (ECA) in the Strait of Malacca would not have an impact on the routing decision for Asia to Europe voyage. The authors noted that the savings from burning standard Heavy Fuel Oil (HFO) on the longer route through the Strait of Sunda instead of ECA-compliant fuel through the Strait of Malacca does not secure a more economical solution for carriers. Furthermore, considering the cost of emissions as a component of the total operating cost when transiting via an ECA, a service may even lead to savings for a shipping company under the condition that the service speed is optimised while sailing both inside and outside an ECA (Dithmer, Reinhardt and Kontovas, 2017a).

(7) GDP per Capita (arises in Theme 2)

This factor was not explicitly discussed by the publications included in Theme 1.

(8) Logistics Performance (also arises in Theme 2, Theme 3, Theme 4, and Theme 5)

The existence of an efficient logistics network which can support maritime operations is considered a substantial advantage for a shipping node. Wang, Wang and Ducruet (2012) studied the *''Phase of the Peripheral Challenge''* (Hayuth (1981; 1988), as cited in Wang, Wang and Ducruet, 2012) where nodes on the periphery of the shipping network challenge established hubs and claim a share of direct connections.

According to Wang, Wang and Ducruet (2012), the challenge by peripheral nodes to the established hubs is supported by certain improvements, such as the advancement of their logistics networks (hinterland connections). Notteboom (2004a) underlined the importance that the harmonised performance of the entire logistics system has for the shippers: carriers should aim for the *''synchronization''* of their services across the full spectrum of the logistics system, both in the foreland as well as the hinterland system. Any delays in the sea leg of a journey need to be avoided in order to diminish the impact on the other transportation legs across the supply chain and to prevent the generation of indirect logistics costs for their customers (e.g. production disruption due to delays).

Theme 2 also discusses logistics performance as a factor that can enhance the overall connectivity of a node and Theme 3 highlights the inclination of carriers to select nodes which are supported by an advanced logistics network. Theme 4 argues that logistics performance can impact the maritime trade exchanges of a country and Theme 5 confirms the respective importance of logistics performance for both air freight and rail freight.

(9) Market Concentration

The relative strength of a carrier in a market is considered as one of the reasons that may influence its decision about offering a direct call at targeted nodes (Notteboom, 2004c). Jensen and Bergqvist (2011) noted that there can be tangible cost savings for an operator when a direct link is preferred compared to a transhipment connection. The cost savings though are greater when the associated service is offered in a monopolistic environment. For a market under competition, the savings are lower since the volume is split between different players, the pressure on the vessel utilisation is higher and thus the economies of scale are not maximised. Lim and Das (2009) concluded that initially the number of players (carriers) to enter a trade route is expected to increase but as competition intensifies this trend is expected to decrease. According to Lam, Yap and Cullinane (2007), the commercial and operating positioning and behaviour of carriers within a market is largely associated with the market structure. The latter is outlined by the ''*committed*'' slot capacity (deployed tonnage controlled by a carrier) which ultimately defines the concentration of the market, without necessarily affecting market contestability *(ibid).*

(10) MSR Routing (also arises in Theme 2)

The Maritime Silk Road (MSR) is a strategic framework which aims to connect China with Europe, utilising ports along the route that includes Southeast Asia, India, Africa, and Eastern Mediterranean (WTO, 2019).

Wang *et al.* (2020) studied the development of the shipping network of COSCO after its merging with China Shipping Container Lines (CSCL) in 2016. The updated network had significantly more direct connections between nodes that were not directly linked previously, including nodes from different shipping regions. Secondary markets such as West Africa and South America were the most benefitted by the integration of the networks. However, that authors underlined that COSCO has shown a strong inclination on its involvement in shipping routes along the MSR in particular.

Theme 2 also discusses China's efforts to promote MSR by encouraging the establishment of direct shipping connections between certain countries.

(11) Nautical Distance (also arises in Theme 2, Theme 3, Theme 4, and Theme 5)

The nautical distance between two nodes is regarded as an important driver that shapes the shipping network since proximity is largely expected to promote the establishment of a connection. Ducruet and Notteboom (2012b) examined the development of the container shipping network between 1996 and 2006 from a spatial perspective. The authors concluded that geography and thus distance between nodes continued to have a substantial impact on the shipping network distribution. Notteboom (2012b) commented that nautical distance is associated with fuel consumption and may represent a concern for liners although the severity of the concern fluctuates depending on the fuel price. However, Ducruet and Notteboom (2012a) discussed the increase in length of the shipping network between 1996 and 2006 and indicated that although the bulk of the shipping network exchanges utilised short distances, the popularity of connections between remote trades had also been increasing.

Theme 2 also discusses that longer nautical distance may imply a higher number of transhipments and thus higher cost while Theme 3 highlights long distance as a disadvantage from a shipment perspective. Theme 4 argues that distance can explain maritime trade flows but only if an appropriate metric is employed and finally

Theme 5 confirms that air freight flows may be equally impacted by the flying distance.

(12) Political Stability (also arises in Theme 2 and Theme 3)

Political stability is regarded an essential factor for the attraction of direct shipping services calling at a region (Fraser, Notteboom and Ducruet, 2016). Fang *et al.* (2018) concluded that the political status update following the presidential elections in Sri Lanka contributed to a boost of container vessel movements by 74% between Sri Lanka and India, Singapore, and Malaysia. In contrast, the military conflict between India and Pakistan in August 2015 contributed to a decrease of 69% in container shipping journeys. Hence, political instability (i.e. war risk, political tensions) may harm the potential of a country to attract long-haul direct calls and large vessels (Ducruet, 2008). The avoidance of politically unstable areas (e.g. unrest around Suez Canal) is also taken into consideration by carriers in order to form a reliable schedule for their network (Pham, Kim and Yeo, 2018).

Theme 2 also discusses the fact that the political stability status of a country may attract or repel maritime business and thus impact its connectivity while Theme 3 recognises political instability as a potential obstacle for a carrier when deciding whether to call at a country or not.

(13) Port Infrastructure (also arises in Theme 2, Theme 3, Theme 4, and Theme 5)

The shipping network does not perfectly overlap with the corresponding trade network and although transport services generally enhance the connectivity of a country, other factors such as port infrastructure should also be taken into consideration if one aims to fully assess a country’s ability to connect with its international trade partners (Calatayud, Mangan and Palacin, 2017). Wilmsmeier and Notteboom (2011) claimed that port infrastructure is regarded as a core determinant for the development of the shipping network and that ports which lag behind in terms of development are pushed to the periphery of the network (i.e. missing opportunities for direct connections). In effect, Wilmsmeier and Notteboom (2011) argued that a trade route grows in parallel with the developments of the respective infrastructure. Efficient service in terms of port infrastructure is anticipated to attract more direct calls at a node of the shipping network and to improve its position in the shipping network hierarchy (Fraser, Notteboom and Ducruet, 2016). The distribution of a carrier's deployed capacity on the shipping network is actually an indication of its perception for the quality of the services offered by a port. For example, an increase of deployed tonnage in a port may indicate its enhanced capability of accommodating larger vessels (Lam and Yap, 2011). High port infrastructure standards are a precondition for a node in order to be included on the main deep-sea services or fast ("*express*") direct itineraries since carriers opt for facilities that can secure a quick turnaround time of the vessels (Ferrari, Parola and Tei, 2015). Overall, the generation of an end-to-end link (direct connection) and a sizeable container traffic can only be enabled if the bilateral trade potential is supported by a respective upgrade in infrastructure that in turn secures efficiency. The latter can then allow the integration of a node into deep-sea (i.e. connections between important and remote nodes) networks (Robinson, 1998). The productivity of the port infrastructure can also significantly reduce the time spent at port and thus allow vessels to avoid any unnecessary speed increases while at sea in order to meet their pro-forma schedule. Therefore, carriers may selectively design their network to include nodes where fast vessel turnaround is attainable (Pierre, Francesco and Theo, 2019). Ducruet, Lee and Ng (2008) noted that the carriers tend to sustain the level of market coverage but are open to diversifying by offering options for niche markets and promising connections. During this process, liners are inclined to select direct calls at ports where local policies promote technological and port infrastructure advancement which ultimately boosts a port's position in the shipping network. Ducruet, Lee and Ng (2010) emphasised that the advantage of the dominant nodes that can concentrate a substantial share of traffic and eventually become ''*polars*'' of the shipping network is usually rooted on their technological edge with regard to infrastructure. The latter triggers the memory effect of carriers to select nodes that provide high service standards. Improvements on infrastructure (e.g. deep waters, space for expansion) is a common characteristic of the peripheral nodes that aim to challenge established nodes and claim a share of direct connections (Wang, Wang and Ducruet, 2012).

Additionally, carriers also examine constraints that could be set by specific nodes of the network because of their infrastructure and facilities limitations. These constraints can harm the reliability of a service and negatively characterise a shipping route (Pham, Kim and Yeo, 2018). Operational concerns associated with the port infrastructure (e.g. insufficient depth, low productivity, and delays), may lead to the exclusion of a node from a direct service and the replacement of the latter with a transhipment connection (Notteboom, 2004c; Rodrigue and Ashar, 2016). Ducruet (2008) included obsolete port infrastructure to the local limitations that may lead a shipping network node (e.g. North Korea) to be serviced by feeders rather than direct services. Furthermore, Ducruet (2020) referred to the example of North Korea as a spoke to the South Korean hub of Incheon. The infrastructure of North Korea became obsolete and unable to accommodate direct calls by modern vessels, following the collapse of the Union of Soviet Socialist Republics (USSR) and eventually increased its dependence to the closest hub of South Korea (port of Incheon). Notably, in this case the geographical closeness and the need for reliable infrastructure that can secure the continuation of trade, overcame the political barriers between the two countries.

Theme 2 also discusses that decent port infrastructure can promote direct connectivity between countries and Theme 3 classifies port infrastructure as a definitive factor of consideration by the carriers when selecting ports of call. Theme 4 recognises the fact that improvements in port infrastructure can facilitate higher trade exchanges between countries while Theme 5 also confirms that infrastructure (e.g. equipment, cargo handling facilities) are similarly important for both rail freight and air freight flows.

(14) Reefer Cargo (arises in Theme 2)

This factor was not explicitly discussed by the publications included in Theme 1.

(15) Route Deviation (also arises in Theme 2 and Theme 3)

Although a node may generate an attractive traffic with respect to volume, its *''inconvenient''* position in the shipping network may equally prevent carriers from selecting it for a direct call. The *''inconvenient''* position of a node in the network is expressed as the deviation of the vessel from the arterial maritime route in order to reach that node. For instance, for an artery that connects Singapore to Suez, the corresponding deviation to reach Dubai is the difference in distance of the itinerary Singapore-Dubai-Suez minus the distance of the itinerary Singapore-Suez (Tran and Haasis, 2014). Pierre, Francesco and Theo (2019) analysed the factors affecting CO_2 emissions by container ships and commented on the potential implications that those may have on the shipping network configuration. Apart from an effort towards the optimisation of the vessel speed, an initiative towards shorter distances may be also adopted by carriers aiming to reduce fuel consumption and consequently emissions. Hence, it is likely that carriers may design their itineraries with the minimum possible deviation from the main sailing arteries. The latter was also argued by Rodrigue and Ashar (2016). According to Notteboom (2004c), the distance of the required deviation is one of the factors which may influence the decision of a carrier towards a direct call to a load centre versus offering an indirect service via feeder.

Theme 2 also discusses that deviation may harm a country's potential to achieve high direct connectivity and Theme 3 equally classifies deviation as a possible consideration of a carrier for including or excluding a country from a shipping itinerary.

(16) Seasonality

The demand for transportation between nodes may vary throughout the year due to seasonality. The seasonal variance may be of global scale (e.g. inventory replenishment for Christmas sales) but also of regional scale if related to a crop, such as specific fruits like citrus. Consequently, the shipping network design may fluctuate but also reveal seasonal patterns and trends (Brouer *et al.*, 2014). Panayides and Wiedmer (2011) noted that services might be continuously adjusted for strategic or operational reasons but also due to seasonality. Cheng and Wang (2021) suggested that a seasonal planning of a service may result in low or excessive demand during off-season periods thus services should be designed to cover a fluctuating market although the carriers may be ultimately called to adjust their services according to the cost or time preferences of their customers. Seasonality may also push liner shipping companies to review and potentially revise their network every 3-6 months, based on the fluctuating transportation demand (Huang, Hu and Yang, 2015).

(17) Security Issues (also arises in Theme 3 and Theme 5)

Criminal actions may constitute a reason for rerouting a container shipping service. Fu, Ng and Lau (2010) noted that during the peak of piracy incidents in the Gulf of Aden liners started to consider the alternative route around the Cape of Good Hope. The authors simulated that without proper measurements to ensure the safe navigation in the area approximately 18% of the Asia-Europe traffic could deviate to the longer route. However, the authors mentioned that although security concerns about piracy may trigger additional operating costs, the burden could be well passed to the customers.

Theme 3 also discusses that security issues may harm the efficiency of port infrastructure and Theme 5 indicates that security issues can also harm the reputation of a route.

(18) Trade Agreement (also arises in Theme 2, Theme 4, and Theme 5)

A trade agreement represents an immediate removal of an important bilateral trade barrier and practically diminishes the long-distance factor between bilateral trade partners Lee and Lee (2012). According to those authors, the signing of such an agreement promotes the increase of trade between remote trade partners over the regional trade exchanges between nearby countries. Consequently, the demand for additional deep-sea direct connections is expected to increase. Lee and Lee (2012) also advocated that a free-trade agreement (FTA) would have a tangible effect on South-South trade flow and particularly on the TEU exchanges between Brazil and India. Fraser, Notteboom and Ducruet (2016) applied graph theory to study the peripherality of the Southern Africa main ports on the global container shipping network and concluded that trade agreements could be a contributing factor for additional direct connections. Trade agreements, such as the inter-Korean maritime agreement of 2004, have also proven to be beneficial for the opening of new sea routes between nodes that face trading constraints due to political reasons (Ducruet, 2008).

Theme 2 also discusses that a trade agreement can assist connectivity by reducing trade costs, Theme 4 underlines that a trade agreement may boost the direct links between trade partners and Theme 5 claims that trade agreements have also been proven to be beneficial for air freight exchanges.

(19) Trade Facilitation (also arises in Theme 2, Theme 3, Theme 4, and Theme 5)

Eventually, the shape of the shipping network organisation may be largely dictated by the carriers' strategies but trade facilitation is another essential factor that should be factored in for the assessment of a country's potential to connect with its international markets (Calatayud, Mangan and Palacin, 2017). Walenciak, Constantinou and Roe (2001) noted that the liner shipping sector expansion in Poland and specifically the connection between Poland and the UK might have faced difficulties partially due to the inheritance of inflexible governmental policies and thus inefficient business environment for trade. Interestingly, Fang *et al.* (2018) concluded that the lifting of the economic sanctions that were previously imposed on Iran in 2015 did not materialise into any substantial increase on container journeys to and from the country. Ducruet (2008) underlined that an appealing trade potential and modernised port infrastructure may not be adequate conditions for the attraction of direct services by a country if the latter is characterised by broader limitations in trade facilitation (e.g. trade embargo).

Theme 2 also discusses that shipping connections need a business-friendly environment in order to flourish while Theme 3 highlights that a carrier may seek the right mix of flexibility and regulation. Theme 4 underlines that an improvement in trade facilitation may have a tangible impact on trade flows and finally Theme 5 also suggests that any form of trade facilitation enhancement (e.g. trade liberalisation) can be beneficial for the air freight business.

(20) Trade Flow (also arises in Theme 2, Theme 3, Theme 4, and Theme 5)

The strategic and operational reasons which drive shipping companies to design their network and select the appropriate nodes, are highly associated with the performance of the nodes in terms of throughput (Notteboom, 2004c; Kang and Woo, 2017). Wilmsmeier and Sánchez (2010) noted that carriers design their networks in order to serve the need for transportation of the trade volume of a region or country. Guy (2003) investigated whether the coverage of secondary markets (North-South) by liners is driven by the need to accumulate additional cargo in order to support the main network (East-West) or by an independent effort to expand their presence into emerging markets. The author, based on the case of South America, concluded that the expansion into secondary markets materialises in order to primarily accommodate the bilateral trade exchanges between partners rather than to boost East-West services. González Laxe, Jesus Freire Seoane and Pais Montes (2012) commented that emerging nodes of the shipping network can more often be related to regions characterised by substantial economic expansion which is reflected to higher flows of containers. According to Ducruet, Berli and Bunel (2020), trade dynamics may push towards multiport (direct) connections without the need of a hub mediation, particularly for intra-regional flows. Fremont (2007), based on the case of

Maersk, showed that a hub-spoke network organisation actually complements direct connections and noted that – following a certain increase in exchanged traffic – carriers may substitute an indirect connection with a direct link between two markets.

Direct services may suffer from low load factors and thus underutilisation for certain links between nodes. Therefore, adequate trade volume is needed to support the connection accordingly (Tran and Haasis, 2018). With references to the case of China, Robinson (1998) underlined that the inclusion of a node into a deep-sea network is initially triggered by an – unspecified – volume threshold which secures the respective economies of scale and thus justifies a direct call by carriers. While carriers may be driven by various strategic reasons during their decision-making process (e.g. portfolio expansion), in the long-term the fundamental target is profit maximisation. Consequently, the behaviour of the carriers with regard to the network design is largely driven by the preferences of the shippers since that finally defines the volume throughput (Chen, Xu and Haralambides, 2020). Notteboom (2012a) remarked that indeed shippers apply a considerable amount of pressure on the shipping lines in order to achieve a direct connection between the origin-destination pairs they desire. However, the shipping lines aim for the right balance between accommodating their customers' requests and optimising their network planning – including vessel utilisation – in order to reap the benefits of the economies of scale. Hence, a direct connection between two nodes of the shipping network can only be realistically anticipated when there are sufficient cargo exchanges. The more containers on board, the better the spread of fixed costs and thus economies of scale are also more likely to be achieved. Hence, adequate cargo exchanges are a prerequisite in order to keep the vessel load factor as high as possible (Lin and Huang, 2017). Ferrari, Parola and Tei (2015), claimed that a node should provide a minimum of volume per vessel call in order to be considered either for the main deep-sea services or fast *("express")* direct itineraries. Fremont and Parola (2016) noted that approximately 10% of the vessel capacity needs to be loaded / discharged during a port visit to justify a direct call.

In contrast, insufficient volume is the one of the most significant reasons for the substitution of a direct call by a feeder service (Rodrigue and Ashar, 2016). Wang and Wang (2011), based on the monthly schedule of 24 liner companies, demonstrated that there is a substantial diversity on the connectivity of different regions and that particular regions are lagging behind in terms of their integration into the shipping network. For example, the authors observed the limited connectivity between East / West Coast of South America and East / West Africa. This characteristic was attributed to the underdeveloped nature of the involved economies which reduces their maritime trade activity. As a result, those regions are pushed to the periphery of the container shipping network with the need of feeder connection between them and the main network. Li, Xu and Shi (2015) suggested that in periods of economic growth the direct container shipping connections between areas tend to grow while during recessions, the number of partners with direct connections declines due to insufficient volume of containerised cargo flows.

Theme 2 also discusses that a strong trade flow record is a core driver towards the establishment of a direct connection between partners and Theme 3 indicates that trade flow outlines the business opportunity that a node can offer to a carrier. Theme 4 claims that an upcoming trade flow between trade partners may attract the interest of carriers in order to support with a direct connection. Theme 5 highlights that a robust trade flow and a supportive underlying economy are needed in order to secure the viability of a route in rail freight and air freight business.

(21) Trade Imbalance (also arises in Theme 4)

Trade imbalance (i.e. the difference between the value of exports and imports of a country) may affect the container management cost (empty repositioning cost, capital cost of own fleet, leasing cost and storage cost) of a shipping company and, depending on the respective overheads, it may have an impact on the decision by the company between a hub-and-spoke and a direct call (multi-port) setup (Imai, Shintani and Papadimitriou, 2009). Notteboom and Rodrigue (2008) underlined that apart from the production level and the volume of trade, trade imbalance may also impact the geography of the shipping network and the strategies of the carriers.

Theme 4 also discusses that trade imbalance may result in unfavourable pricing policies by carriers thus decreasing the attractiveness of the corresponding direct shipping connection.

(22) Transit Time (also arises in Theme 4 and Theme 5)

Carriers design services with the shortest possible transit time as a differentiation factor (Notteboom, 2006; Wang, Meng and Lee, 2016) and they have a strong focus on schedule reliability which effectively means no delays on the scheduled port calls (Notteboom, 2006). Notteboom (2004b) commented that the shape of the network cannot be purely defined by the operational needs of the carriers – such as cost minimisation – but is also inevitably affected by customer's needs and preferences, such as better transit time between specific nodes by establishing a direct connection. An important factor for consideration for liners is the overall transit time (from origin to destination) because shippers aim for the shortest possible transit duration in order to reduce the required inventory (Meng *et al.*, 2014). If the overall transit time is lengthened to extreme levels, carriers will need to reduce the number of calling nodes and select the ones with the higher cargo exchanges (Wu, Luo and Zhang, 2017). Jiang *et al.* (2020) concluded that the time preferences of big customers is of great importance for carriers when designing the service schedule, indicating that extreme variations from the advertised schedule have important implications on the associated costs. Transit time is even more essential for the design of a liner shipping service when the targeted cargo is of perishable or short-life cycle nature (Wang, Meng and Lee, 2016) since the time-to-market becomes a critical factor (Brouer *et al.*, 2014). Wang *et al.* (2018b) also examined the importance of time in the transportation of perishable cargo. The authors underlined that the total transportation time is a constraint to be taken into consideration and indirect connections might be acceptable, only under the condition that a certain limit in the total transportation time is not exceeded. In any other case, their model suggests that a direct connection is always preferable. Cheaitou and Cariou (2012) calculated that the elasticity of demand with regard to transit time is of paramount importance, particularly when time-sensitive cargo is on board. The authors specifically estimated that a direct connection between Europe and South America with a high-speed service may increase the fuel cost, but the high quality of the service returns higher profits by meeting the demand for shorter transit time.

Benedyk and Peeta (2018) surveyed the opinion of the carriers' customers (shippers and forwarders) towards the possible use of the Northern Sea Route (NSR) by the carriers and found that at least during the initial stages the market may be reluctant to divert substantial volumes via the new alternative route. Although a reduction in the advertised transit time and possible price initiatives could persuade customers to risk more cargo via NSR, clarity and accuracy on the actual transit time (reliability) of the schedules (e.g. delays due to adverse weather) would be a challenge. Tran and Haasis (2018) underlined that transit time reflects the total time required for cargo to travel between origin and destination and is a measure of quality for a service. According to Pham, Kim and Yeo (2018), transit time between nodes is an essential factor that carriers take into consideration when designing their shipping network, aiming for the shortest possible lead time.

Theme 4 also discusses that a very long transit time may utterly diminish the likelihood of a direct shipping connection between trade partners and Theme 5 highlights that transit time is regarded as a measure of quality for a connection in both air freight and rail freight.

(23) Voyage Cost (also arises in Theme 4 and Theme 5)

The voyage (or shipping) cost comprises mainly fuel cost, capital cost and the daily operating cost of a container service (Tran and Haasis, 2015) and according to Pham, Kim and Yeo (2018) may determine the selection between alternative routes since it largely defines the overall cost structure and the profitability of a shipping company. Pham, Kim and Yeo (2018) underlined that shipping companies are the ultimate decision-makers with regard to the design of the shipping network and that the voyage cost of a service is a major determinant of their decisions.

Theme 4 also discusses the fact that any comparative savings in voyage cost may promote the development of a bilateral trade relationship and Theme 5 classifies voyage (transport) cost as a criterion in selecting between routes in rail freight.

All of the above identified factors within the Shipping Network theme are synopsised on Table 3-2:

Theme	Factor	References	Expected impact towards a Direct Connection
Shipping Network	Affiliated Terminal	Parola and Veenstra (2008)	+
	Colonial Ties	Ducruet, Rozenblat and Zaidi (2010); Ducruet and Zaidi (2012)	+
	Connectivity	Calatayud, Mangan and Palacin (2017); Gadhia, Kotzab and Prockl (2011); Notteboom (2004c); Wilmsmeier and Sánchez (2010)	+
	ECA Routing	Chen, Yip and Mou (2018); Dai *et al.* (2018); Dithmer, Reinhardt and Kontovas (2017b); Doudnikoff and Lacoste (2013); Fagerholt et al. (2015)	-
		Franc and Sutto (2014); Schinas and von Westarp (2017)	
	Logistics Performance	Notteboom (2004a); Wang, Wang and Ducruet (2012)	+
	Market Concentration	Jensen and Bergqvist (2011); Lam et al. (2007); Lim and Das (2009); Notteboom (2004c)	-
	MSR Routing	Wang *et al.* (2020)	+
	Nautical Distance	Ducruet and Notteboom (2012b); Ducruet and Notteboom (2012a); Notteboom (2012b)	-
	Political Stability	Ducruet (2008); Fang *et al.* (2018); Fraser, Notteboom and Ducruet (2016); Pham, Kim and Yeo (2018)	+
	Port Infrastructure	Calatayud, Mangan and Palacin (2017); Ducruet (2008); Ducruet (2020); Ducruet, Lee and Ng (2008); Ducruet, Lee and Ng (2010); Ferrari, Parola and Tei (2015)	+
		Fraser, Notteboom and Ducruet (2016); Lam and Yap (2011); Notteboom (2004c); Pham, Kim and Yeo (2018); Pierre, Francesco and Theo (2019)	
		Robinson (1998); Rodrigue and Ashar (2016); Wang, Wang and Ducruet (2012); Wilmsmeier and Notteboom (2011)	
	Route Deviation	Notteboom (2004c); Pierre, Francesco and Theo (2019); Rodrigue and Ashar (2016); Tran and Haasis (2014)	-
	Seasonality	Brouer *et al.* (2014); Cheng and Wang (2021); Huang, Hu and Yang (2015); Panayides and Wiedmer (2011)	+ / -
	Security Issues	Fu, Ng and Lau (2010)	-
	Trade Agreement	Ducruet (2008); Fraser, Notteboom and Ducruet (2016); Lee and Lee (2012)	+
	Trade Facilitation	Calatayud, Mangan and Palacin (2017); Ducruet (2008); Fang *et al.* (2018); Walenciak, Constantinou and Roe (2001)	+
	Trade Flow	Chen, Xu and Haralambides (2020); Ducruet, Berli and Bunel (2020); Ferrari, Parola and Tei (2015); Fremont (2007); Fremont and Parola (2016)	+
		González Laxe, Jesus Freire Seoane and Pais Montes (2012); Guy (2003); Kang and Woo (2017); Li, Xu and Shi (2015); Lin and Huang (2017); Notteboom (2012a)	

		Notteboom (2004c); Robinson (1998); Rodrigue and Ashar (2016); Tran and Haasis (2018)	
		Wang and Wang (2011); Wilmsmeier and Sánchez (2010)	
	Trade Imbalance	Imai, Shintani and Papadimitriou (2009); Notteboom and Rodrigue (2008)	-
	Transit Time	Benedyk and Peeta (2018); Brouer *et al.* (2014); Cheaitou and Cariou (2012); Jiang *et al.* (2020); Meng *et al.* (2014)	-
		Notteboom (2004b); Notteboom (2006); Pham, Kim and Yeo (2018); Tran and Haasis (2018); Wang, Meng and Lee (2016)	
		Wang *et al.* (2018b); Wu, Luo and Zhang (2017)	
	Voyage Cost	Pham, Kim and Yeo (2018)	-

Table 3-2 – Identified Factors, Shipping Network Theme

3.7 Theme 2: Connectivity

(1) Affiliated Terminal (arises in Theme 1 and Theme 3)

This factor was not explicitly discussed by the publications included in Theme 2.

(2) Colonial Ties (arises in Theme 1, Theme 4, and Theme 5)

This factor was not explicitly discussed by the publications included in Theme 2.

(3) Common Border (arises in Theme 5)

This factor was not explicitly discussed by the publications included in Theme 2.

(4) Common Language (arises in Theme 4 and Theme 5)

This factor was not explicitly discussed by the publications included in Theme 2.

(5) Connectivity (also arises in Theme 1, Theme 3, and Theme 4)

The connectivity level of a node reflects the enrichment it can offer to a carrier's network. If a node is characterised by high connectivity this translates to wide options for a carrier to reach further destinations. On the contrary, a node with limited connectivity indicates less options and provides quite limited enhancement to the network (Jiang *et al.*, 2015). Overall, connectivity can also be defined as the level of a node’s integration within a network and its ability to reach other nodes (Calatayud *et al.*, 2016). Yap and Notteboom (2011) observed that carriers in the East Asia market tend to call at nodes that offer gateway cargo opportunities but simultaneously offer a promising prospect for further transhipment volumes. Wang and Cullinane (2014) observed that shipping companies may choose to include multiple nodes on their networks (e.g. simultaneous use of Singapore and Port Kelang hubs in East Asia) in order to enhance their network connectivity to other trades and routes (Yap and Notteboom (2009), as cited in Wang and Cullinane, 2014).

Various indices and metrics have been proposed by the literature that aim to quantify the connectivity of a node. For example, Bartholdi, Jarumaneeroj and Ramudhin (2016) proposed a shipping connectivity measurement to account for both the economic and network characteristics of the ports. Each port was awarded with a high score based on its trade connections but also partially assumed the importance of its neighbours and their neighbours and so forth. The score is determined by the respective role of the other ports that connect with the targeted port. If one port receives a great deal of services from a port with a high outbound score, then it receives a high inbound score and vice versa. Hence, a node with high score on connectivity as measured by Bartholdi, Jarumaneeroj and Ramudhin (2016), effectively connects with other well-connected nodes and this characteristic may act as a multiplier for further network opportunities. This was also confirmed by Song, Park and Yeo (2019) who suggested – using the port of Gwangyang as a case study – that a node of the maritime network will establish its importance if it manages to increase its connections with other essential nodes of great influence for the network. Xu *et al.* (2020) validated the theoretical perception in maritime economics that the stronger the integration of a country into the container shipping network the better its access to the international markets. The authors proposed two connectivity indices which incorporated attributes of network theory and practically measured the significance of a country for the container shipping network. Cullinane and Wang (2009) recognised the importance of a connectivity measurement (in the form of nodal accessibility) as a determinant of the attractiveness of a node for the shippers and the carriers of a shipping network. At country level this may be synopsised by an index such as LSCI although the authors proceeded to propose a relevant method at port level. Wilmsmeier, Martinez-Zarzoso and Fiess (2011) claimed that although the geographical location of a country is indeed of paramount importance, its relative position in the liner shipping network is the defining factor of its competitiveness and is likely to impact the maritime costs of a nation. According to Wilmsmeier, Martinez-Zarzoso and Fiess (2011), the LSCI by UNCTAD is a relevant proxy of the accessibility of a country to the global trade network. Wilmsmeier, Martinez-Zarzoso and Fiess (2011) also noted that a high LSCI score reveals an easier access to liner shipping services of high capacity and frequency which boosts a country's participation in the international maritime and thus trade network.

(6) ECA Routing (arises in Theme 1)

This factor was not explicitly discussed by the publications included in Theme 2.

(7) GDP per Capita

GDP per Capita may be utilised as an indicator of prosperity and economic growth of a country (Vidya and Taghizadeh-Hesary, 2021). In a report commissioned for the Asian Development Bank Institute (ADBI), Vidya and Taghizadeh-Hesary (2021) combined network analysis with econometrics in order to test how a series of variables may impact bilateral connectivity at country level. They showed that an increase on GDP per Capita can boost bilateral connectivity between trade partners.

(8) Logistics Performance (also arises in Theme 1, Theme 3, Theme 4, and Theme 5)

A node of the container shipping network which is supported by an enhanced logistics system, becomes more attractive for shipping lines and manages to sustain and broaden its hinterland (Yap, Lam and Notteboom, 2006). Shibasaki *et al.* (2019) claimed that Pakistani ports could handle a viable quantity of container cargo, provided they were supported by advancements and further integration of the logistics network in their hinterland (e.g. efficient rail connections). Schwartz, Guasch and Wilmsmeier (2009) also noted that the performance of the logistics system in factors such as customs clearance and border crossings are of pivotal importance towards the efficient and timely transportation of food cargo. Any delays are particularly detrimental for the stakeholders of distinct supply chains transporting sensitive cargo such as perishable products. The World Bank has developed a relevant index in order to capture the overall logistics sector performance of a country. According to the The World Bank (2022b), the Logistics Performance Index (LPI) is compiled based on six distinct factors:

i. *The efficiency of customs and border clearance*

ii. *The quality of trade and transport infrastructure*

iii. *The ease of arranging competitively priced shipments*

iv. *The competence and quality of logistics services*

v. *The ability to track and trace consignments*

vi. *The frequency with which shipments reach consignees within scheduled or expected delivery times*

Ojala and Çelebi (2015) noted that the LPI is a useful tool for companies and investors when evaluating the overall logistics capabilities (i.e. efficiency of supply chain and transport infrastructure) of a country in order to decide where to locate operations. Saeed and Cullinane (2021) concluded that if a country manages to improve its LPI score performance, it is more likely to achieve better connectivity with targeted trade partners. The authors selected the LPI because a good logistics performance (including port sector) boosts the competitiveness of a country regarding access to its international markets.

(9) Market Concentration (arises in Theme 1)

This factor was not explicitly discussed by the publications included in Theme 2.

(10) MSR Routing (also arises in Theme 1)

Countries located along the MSR may be encouraged to enhance their direct shipping connections and be benefitted by the initiative. For instance, Pan *et al.* (2020) stated that since the introduction of the Maritime Silk Route (MSR) initiative, China has been promoting more direct connections between nodes across the MSR. This initiative has been implemented in the form of partial subsidies to shipping companies through local governments in order to support direct links.

(11) Nautical Distance (also arises in Theme 1, Theme 3, Theme 4, and Theme 5)

In general, the longer the nautical distance between trade partners the higher the anticipated cost of trade. According to Fugazza, Hoffmann and Razafinombana (2014), the sea distance itself however may not be able to fully describe the increased cost of bilateral container flows unless the cost of transhipment is also taken into consideration. The authors claimed that the longer the distance between two countries the more transhipments are likely needed. Most importantly, each transhipment requires a divergence from the shortest direct route. Thus, Fugazza, Hoffmann and Razafinombana (2014) concluded that the establishment of direct shipping connections could decrease cost and distance and assist remote trade partners to boost their exporting activity. However, if no specific maritime connectivity variables are also taken into consideration, the standalone impact of maritime distance on trade costs between partners is likely to be overestimated (Fugazza and Hoffmann, 2017) since distance becomes practically insignificant for a trade model when a direct connection exists (Asturias and Petty (2012), as cited in Fugazza and Hoffmann, 2017). Hence, the combination of metrics that take into consideration the *''effective distance''* between countries is preferable for the analysis of bilateral trade dynamics (Hoffmann, Van Hoogenhuizen and Wilmsmeier, 2014). Nevertheless, neighbouring nodes which belong to the same shipping network cluster tend to be better connected with each other than with remote nodes (Pan *et al.*, 2019).

(12) Political Stability (also arises in Theme 1 and Theme 3)

The stability of the political climate in a country can enable the attraction of investment and business activity. Yap, Lam and Notteboom (2006) recognised political stability as an encouraging factor for specialised container terminal operators to increase presence in East Asia. This development consequently granted an important boost of efficiency to emerging nodes and positioned them as strong competitors to claim a larger share of the deployed shipping capacity. On the contrary, Xu *et al.* (2015) noted that the political instability of a region decreases its potential to entice shipping services.

(13) Port Infrastructure (also arises in Theme 1, Theme 3, Theme 4, and Theme 5)

Sufficiently good port infrastructure is an apparent contributing factor towards the establishment of a direct connection between countries (Fugazza, 2015). Wilmsmeier and Hoffmann (2008) concluded that competitive port infrastructure (i.e. berth length, storage capacities and draft) can secure lower transport costs and attract shipping services to call at a country. Vidya and Taghizadeh-Hesary (2021) tested the importance of infrastructure on connectivity between countries and found a positive relationship. On the contrary, inadequate port infrastructure may discourage carriers to deploy their services at a region (Xu *et al.*, 2015). Schwartz, Guasch and Wilmsmeier (2009) studied the nuances of the food trade in Latin America and the Caribbean and concluded that the efficiency of the port infrastructure and the connectivity of a country is a strong determinant of the associated costs. The authors also noted that the countries that can provide a set of efficient policies towards this direction may benefit by faster services, achieve economies of scale, and ultimately decrease the shipping costs across the food supply chain. Yap (2019) warned that in the case of Vietnam, the country should proceed to upgrade the port infrastructure (with an emphasis to the water depth) otherwise it may be bypassed by larger vessels and could miss the opportunity to accommodate direct calls.

(14) Reefer Cargo

There can be particular countries (e.g. the islands of the Eastern Caribbean Sea) where more than half of the imports by value correspond to perishable products of the food supply chain, such as vegetables, fruits, dairy, fish and meat (Schwartz, Guasch and Wilmsmeier, 2009). The food supply chain expansion may also be a driver for distinct increases in trade flows such as in the case of vegetables and fruits exports from Patagonia in Argentina. Overall, recent changes in trade mix have highlighted the significance of refrigerated products such as fruits and fish and have encouraged the growth of the respective transportation capacity, aiming to serve the corresponding trade flows (Wilmsmeier et al., 2011).

(15) Route Deviation (also arises in Theme 1 and Theme 3)

The establishment and endurance of a direct shipping connection between countries is heavily related to the geographical location of each partner with regard to the main shipping arteries. Hence, it is not unlikely that countries which are not included on the major maritime routes may suffer from a degree of latency with regard to direct shipping connections (Fugazza, 2015).

(16) Seasonality (arises in Theme 1)

This factor was not explicitly discussed by the publications included in Theme 2.

(17) Security Issues (arises in Theme 1, Theme 3 and Theme 5)

This factor was not explicitly discussed by the publications included in Theme 2.

(18) Trade Agreement (also arises in Theme 1, Theme 4, and Theme 5)

Free Trade Agreements (FTAs) can signal the removal of unnecessary trade barriers and costs between trade partners and thus highlight and accelerate a direct shipping connection. According to Vidya and Taghizadeh-Hesary (2021), FTAs can promote foreign investments and enhance connectivity between countries. For instance, a decisive step towards the establishment of a direct shipping connection between China and Taiwan was the signing of The Cross-Strait Sea Transport (CST) Agreement in November 2008. A direct connection was granted the following month with the benefit of lower cost and shorter transit time (Yang, Chung and Lee, 2014).

(19) Trade Facilitation (also arises in Theme 1, Theme 3, Theme 4, and Theme 5)

From the early days of containerisation it became evident that an inflexible and unfavourable entrepreneurship environment may decelerate the introduction of shipping connections, as happened for the Australia-Japan line in the 1960s. The protectionism practices followed by the Australian government complicated the decision of liners to establish a direct connection while particular players were more reluctant to join the route, potentially due to concerns of high costs and disadvantages against subsidized or generally government-supported rivals (Lin, 2015). Vidya and Taghizadeh-Hesary (2021) claimed that any tariff or non-tariff barriers to trade facilitation can have a negative impact on the connectivity between countries. The latter is in accordance with the theoretical background which suggests that a reduction of the trade costs can promote trade integration and facilitation (Krugman (1991), as cited in Vidya and Taghizadeh-Hesary, 2021).

(20) Trade Flow (also arises in Theme 1, Theme 3, Theme 4, and Theme 5)

Historically high volumes of trade is among the most essential drivers for the establishment of a direct shipping connection between trading countries (Fugazza, 2015). According to Wang and Cullinane (2008), the volume performance of a node acts as a reinforcing factor for further development: a broad portfolio is an attraction for feeder services that will in turn attract more mainline vessels (Cullinane and

Khanna (2000), as cited in Wang and Cullinane, 2008). Yap, Lam and Notteboom (2006) noted that that a sufficient level of gateway volume is a major driver for the attraction and establishment of a direct call and that those nodes which cannot generate adequate trade flows may lose the comfort of being directly called by a service. According to Yap (2019), an expanding local container traffic is anticipated to encourage more regional and mainline direct calls at a country, such as Vietnam. An improvement in trade performance (as measured by the natural log of imports / exports value) may improve a country's connectivity with a targeted trading partner since trade promotes economies of scale and reduces transport costs (Saeed and Cullinane, 2021). Indeed, despite the historical political tensions, the remarkable intensity of bilateral trade between China and Taiwan pushed towards the re-establishment of a direct connection that allowed for the further expansion of the trade exchanges (Yang, Chung and Lee, 2014). On the contrary, Xu *et al.* (2015) added that insufficient seaborne trade volume may explain the reluctance of carriers to call at a region.

(21) Trade Imbalance (arises in Theme 1 and Theme 4)

This factor was not explicitly discussed by the publications included in Theme 2.

(22) Transit Time (arises in Theme 1, Theme 4 and Theme 5)

This factor was not explicitly discussed by the publications included in Theme 2.

(23) Voyage Cost (arises in Theme 1, Theme 4 and Theme 5)

This factor was not explicitly discussed by the publications included in Theme 2.

All of the above identified factors within the Connectivity theme are synopsised on Table 3-3:

Theme	Factor	References	Expected impact towards a Direct Connection
Connectivity	Connectivity	Bartholdi, Jarumaneeroj and Ramudhin (2016); Calatayud *et al.* (2016); Cullinane and Wang (2009); Jiang *et al.* (2015); Song, Park and Yeo (2019)	+
		Yap and Notteboom (2011); Wang and Cullinane (2014); Wilmsmeier, Martinez-Zarzoso and Fiess (2011); Xu *et al.* (2020)	
	GDP per Capita	Vidya and Taghizadeh-Hesary (2021)	+
	Logistics Performance	Ojala and Çelebi (2015); Saeed and Cullinane (2021) Shibasaki *et al.* (2019)	+
		Schwartz, Guasch and Wilmsmeier (2009); Yap, Lam and Notteboom (2006)	
	MSR Routing	Pan *et al.* (2020)	+
	Nautical Distance	Fugazza, Hoffmann and Razafinombana (2014); Fugazza and Hoffmann (2017); Hoffmann, Van Hoogenhuizen and Wilmsmeier (2014); Pan *et al.* (2019)	-
	Political Stability	Xu *et al.* (2015); Yap, Lam and Notteboom (2006)	+
	Port Infrastructure	Fugazza (2015); Schwartz, Guasch and Wilmsmeier (2009); Wilmsmeier and Hoffmann (2008)	+
		Vidya and Taghizadeh-Hesary (2021); Xu *et al.* (2015); Yap, Lam and Notteboom (2006)	
	Reefer Cargo	Schwartz, Guasch and Wilmsmeier (2009); Wilmsmeier, Martinez-Zarzoso and Fiess (2011)	+
	Route Deviation	Fugazza (2015)	-
	Trade Agreement	Vidya and Taghizadeh-Hesary (2021); Yang, Chung and Lee (2014)	+
	Trade Facilitation	Lin (2015); Vidya and Taghizadeh-Hesary (2021)	+
	Trade Flow	Fugazza (2015); Saeed and Cullinane (2021); Wang and Cullinane (2008); Yang, Chung and Lee (2014); Yap (2019)	+
		Yap, Lam and Notteboom (2006); Xu *et al.* (2015)	

Table 3-3 – Identified Factors, Connectivity Theme

3.8 Theme 3: Port Selection Criteria

(1) Affiliated Terminal (also arises in Theme 1)

The affiliation of a liner with a terminal may influence the decision of the corresponding shipping alliance to call at this terminal with at least one service. This argument was tested empirically by Notteboom *et al.* (2017). The study targeted the ports in the Le Havre-Hamburg range, UK and the Baltics, utilised binary and non-binary data and analysed only alliance services (no standalone) on Far East-North Europe trade for the periods of Q2 2006, Q2 2015 and Q2 2017. The analysis of the non-binary data provided no clear indication on the practices of the alliances while the analysis of the binary data revealed that the possibility of a direct call by an alliance service at a specific port is much higher when a member of the alliance holds a stake in a particular terminal of the port. The authors underlined that their analysis may carry a regional component and potentially the results in other regions could be different. Wiegmans, Hoest and Notteboom (2008) also underlined that carriers tend to prefer the use of their own terminals, or the ones owned by other alliance associates.

(2) Colonial Ties (arises in Theme 1, Theme 4, and Theme 5)

This factor was not explicitly discussed by the publications included in Theme 3.

(3) Common Border (arises in Theme 5)

This factor was not explicitly discussed by the publications included in Theme 3.

(4) Common Language (arises in Theme 4 and Theme 5)

This factor was not explicitly discussed by the publications included in Theme 3.

(5) Connectivity (also arises in Theme 1, Theme 2 and Theme 4)

The opportunities to enhance their network are important for carriers since according to Chang, Lee and Tongzon (2008), carriers tend to choose nodes with further transhipment options and feeder connections. Apart from feeder connections, carriers may also consider the connectivity of the port in terms of mainline options as well, during port selection process (Wiegmans, Hoest and Notteboom, 2008). Thus, the connectivity of a node is seemingly essential for carriers in order to include it on their network.

(6) ECA Routing (arises in Theme 1)

This factor was not explicitly discussed by the publications included in Theme 3.

(7) GDP per Capita (arises in Theme 2)

This factor was not explicitly discussed by the publications included in Theme 3.

(8) Logistics Performance (also arises in Theme 1, Theme 2, Theme 4, and Theme 5)

Carriers may take a holistic approach when assessing the cost of offering a service as well as when deciding their call patterns. Tran (2011) examined the port selection process in liner shipping from the perspective of an end-to-end supply chain and indicated that shipping cost – albeit considerable – is only a part of the overall logistics cost for a shipment. Tran (2011) indicated that other elements such as inventory (which is affected by sailing time, port time, inland time) and inland distribution costs are factors that eventually need to be taken into consideration for the better understanding of the benefits realised by direct call patterns. Thus, the decision for a direct call at a port by a carrier may also be driven by the assessment of its overall logistics network. This was confirmed by Wiegmans, Hoest and Notteboom (2008) who noted that with regard to port selection, the existence of a reliable and efficient logistics network in the hinterland is an important factor for carriers. Wong, Yan and Bamford (2008) concluded that shippers also aim to utilise an effective inland network in order to reduce transit time.

(9) Market Concentration (arises in Theme 1)

This factor was not explicitly discussed by the publications included in Theme 3.

(10) MSR Routing (arises in Theme 1 and Theme 2)

This factor was not explicitly discussed by the publications included in Theme 3.

(11) Nautical Distance (also arises in Theme 1, Theme 2, Theme 4, and Theme 5)

An increase of the nautical distance between a node and the origin or destination (including inland distance) of a shipment can considerably decrease the attractiveness of the node when port selection is examined from a shipment perspective (Malchow and Kanafani, 2001). However, they note that further details would be revealed if a study could be conducted for a longer time-series as their study covered a limited period of 3 months only.

(12) Political stability (also arises in Theme 1 and Theme 2)

The decision to establish a shipping connection at an area which is politically unstable may lead to increased costs of various forms. Jia, Lee Lam and Tran (2020) indicated that sailing via areas characterised by political instability and high risk can contribute to uncertainty which increases the cost of time in liner business. According to Gohomene *et al.* (2016), the overall political instability of West African countries may lead to increased transport costs and insurance premiums thus becoming a barrier for shipping operations in the area.

(13) Port Infrastructure (also arises in Theme 1, Theme 2, Theme 4, and Theme 5)

The quality of the port infrastructure is a factor of consideration for carriers when selecting a port of call – particularly in certain areas – since carriers may be exposed to hidden risks and costs. Tang, Low and Lam (2011) concluded that efficient port infrastructure is one of the most influential parameters when liner shipping companies select port calls in Asia. Similarly, Gohomene *et al.* (2016) suggested that carriers value the quality of port infrastructure (including port draft) as a vital characteristic for the selection of their main calls in West Africa. Jia, Lee Lam and Tran (2020) argued that carriers aim to minimise as much as possible the uncertainty of their business and that poor port infrastructure increases the cost of time in liner shipping (i.e. failure to meet pro-forma schedules and to serve just-in-time supply chains). Clark, Dollar and Micco (2004) found that port efficiency is also an important determinant of transport costs. When port efficiency improves from the 25th to the 75th percentile, shipping costs drop by 12% which corresponds to an equivalent distance reduction by 5,000 miles. On the contrary, port inefficiencies increase handling costs. Subsequently, when port inefficiency decreases from the 25th to the 75th percentile, bilateral trade increases by 25% (*ibid*). Ugboma, Ugboma and

Ogwude (2006) concluded that efficiency of the port infrastructure is the most salient characteristic that attracts shippers' attention during port selection and urged policy-makers to focus their efforts on this issue. The efficiency of port infrastructure is of great importance even if sometimes it may point shippers to select a more costly loading port (Wong, Yan and Bamford, 2008).

(14) Reefer Cargo (arises in Theme 2)

This factor was not explicitly discussed by the publications included in Theme 3.

(15) Route Deviation (also arises in Theme 1 and Theme 2)

Although the port selection process can largely focus on a straight comparison between individual port facilities of the same country, the overall geographical position of a country with regard to the main sailing routes may also influence the call pattern of the carriers. Yeo, Roe and Dinwoodie (2008) examined the main components that the shipping and logistics stakeholders regard as significant for the competitiveness of a port and listed various criteria suitable for a comparative analysis between competing ports. However, they also referred to broader attributes of a port that may also be applicable at country level and noted for instance that shipping lines may opt for the minimum possible deviation from the main shipping arteries while organising their network.

(16) Seasonality (arises in Theme 1)

This factor was not explicitly discussed by the publications included in Theme 3.

(17) Security Issues (also arises in Theme 1 and Theme 5)

The quality and the efficiency of the port infrastructure is not purely related to the condition of the assets or their technological advancement. Clark, Dollar and Micco (2004) for instance, claimed that port inefficiency is not only associated with the infrastructure but extends to the levels of crime related to the port. When organised crime increases from the 25th to the 75th percentile, port efficiency decreases from the 50th to the 25th percentile which may harm bilateral trade.

(18) Trade Agreement (arises in Theme 1, Theme 2, Theme 4, and Theme 5)

This factor was not explicitly discussed by the publications included in Theme 3.

(19) Trade Facilitation (also arises in Theme 1, Theme 2, Theme 4, and Theme 5)

Carriers are seemingly attracted by a reasonable level of regulation that defines a well-organised but nonetheless business-friendly framework for their operations. Clark, Dollar and Micco (2004) suggested that a certain degree of regulation positively affects port efficiency. For example, the authors referred to the cases of Argentina and Brazil, indicating that the former capitalised on a moderate level of regulation regarding its ports while the latter suffered a decrease on its port efficiency due to overwhelming regulation. Overall, excessive regulation leads to port inefficiency and can be eroding for bilateral trade since it increases the respective transport costs (*ibid*).

(20) Trade Flow (also arises in Theme 1, Theme 2, Theme 4, and Theme 5)

The trade flow that can be captured by a targeted port may suggest an approximate revenue that a carrier can anticipate if a direct call at the respective port facility is established. Halim, Kwakkel and Tavasszy (2015) conducted a port-to-port analysis with the aim to identify the impact of new direct connections on the Bremen-Le Havre range and concluded that a certain trade volume threshold is required in order to promote the establishment of a new direct shipping route, assuming shipping supply as a given. To this extent, Halim, Kwakkel and Tavasszy (2015) also noted that the emergence of bilateral trade flows between certain countries can lead to new direct shipping connections that will accommodate the increasing need for transportation among trade partners (e.g. developing countries and the rest of the world). Tang, Low and Lam (2011) underlined the fact that economies of scale are of paramount importance for liner shipping since fixed costs can be efficiently and widely spread, increasing the profitability of the shipping companies. Hence, they concluded that trade volume is a core parameter for liner shipping companies' selecting port calls in the Asian market. According to Gohomene *et al.* (2016), seaborne trade volume is a core parameter for liners in order to select a port call in the West African market. Hsu *et al.* (2020) studied the ''*policy gap''* between the carriers and port managers regarding the factors that they respectively consider as important during port selection. The authors concluded that carriers consider cargo volume more important than the respective port charges in order to call at a port. According to Chang, Lee and Tongzon (2008), local cargo is the most decisive factor for a carrier in order to select a port of call. A prosperous hinterland that can generate strong trade volumes is considered an advantage (Wiegmans, Hoest and Notteboom, 2008).

(21) Trade Imbalance (arises in Theme 1 and Theme 4)

This factor was not explicitly discussed by the publications included in Theme 3.

(22) Transit Time (arises in Theme 1, Theme 4, and Theme 5)

This factor was not explicitly discussed by the publications included in Theme 3.

(23) Voyage Cost (arises in Theme 1, Theme 4, and Theme 5)

This factor was not explicitly discussed by the publications included in Theme 3.

All of the above identified factors within the Port Selection Criteria theme are synopsised on Table 3-4:

Theme	Factor	References	Expected impact towards a Direct Connection
Port Selection Criteria	Affiliated Terminal	Notteboom *et al.* (2017); Wiegmans, Hoest and Notteboom (2008)	+
	Connectivity	Chang, Lee and Tongzon (2008); Wiegmans, Hoest and Notteboom (2008)	+
	Logistics Performance	Wiegmans, Hoest and Notteboom (2008); Tran (2011); Wong, Yan and Bamford (2008)	+
	Nautical Distance	Malchow and Kanafani (2001)	-
	Political stability	Gohomene *et al.* (2016); Jia, Lee Lam and Tran (2020)	+
	Port Infrastructure	Clark, Dollar and Micco (2004); Gohomene *et al.* (2016); Jia, Lee Lam and Tran (2020); Tang, Low and Lam (2011); Ugboma, Ugboma and Ogwude (2006); Wong, Yan and Bamford (2008)	+
	Route Deviation	Yeo, Roe and Dinwoodie (2008)	-
	Security Issues	Clark, Dollar and Micco (2004)	-
	Trade Facilitation	Clark, Dollar and Micco (2004)	+
	Trade Flow	Chang, Lee and Tongzon (2008);Halim, Kwakkel and Tavasszy (2015);Hsu *et al.* (2020);Gohomene *et al.* (2016);Tang, Low and Lam (2011);Wiegmans, Hoest and Notteboom (2008)	+

Table 3-4 – Identified Factors, Port Selection Criteria Theme

3.9 Theme 4: Trade

(1) Affiliated Terminal (arises in Theme 1 and Theme 3)

This factor was not explicitly discussed by the publications included in Theme 4.

(2) Colonial Ties (also arises in Theme 1 and Theme 5)

Common colonial ties between countries has been identified as an important variable for the explanation of bilateral trade flows in container transport (Biermann, 2012). Saeed, Cullinane and Sødal (2020) however tested the importance of various gravity variables including colonial ties (in the form of ''*common coloniser''*) for trade (imports / exports value) between trade partners. The results did not confirm any positive relationship between gravity variables such as common coloniser and bilateral trade but rather indicated that the relationship receives a negative sign for the analysed sample. Specifically, the results suggested that the nations which were previously united under the same country, speak the same official language and have shared a common coloniser after 1945, record lower bilateral trade flows.

(3) Common Border (arises in Theme 5)

This factor was not explicitly discussed by the publications included in Theme 4.

(4) Common Language (also arises in Theme 5)

It can be expected that – apart from sharing colonial ties – two countries may trade more should they share certain cultural aspects such as a common language which may ease trade barriers between nations. Saeed, Cullinane and Sødal (2020) however did not find any significant relationship between common language and bilateral trade.

Theme 5 also discusses the fact that common language may be one of the drivers of the trade exchanges in air freight.

(5) Connectivity (also arises in Theme 1, Theme 2, and Theme 3)

The geographical distance as a sole determinant of international trade is likely overrated, simplistic and does not reflect the actual level of access to the markets for the countries (Wilmsmeier and Martínez-Zarzoso, 2010). On the contrary, according to Wilmsmeier and Martínez-Zarzoso (2010), a trade-driven measure can better capture the relative position of a country within the container shipping network. Therefore, Wilmsmeier and Martínez-Zarzoso (2010) proposed the use of the "*Liner Service Network Structure (LSNS)*" – which is a similar metric to the Liner Shipping Connectivity Index (LSCI) by UNCTAD – and comprises shipboard capacity, number of services, number of deployed vessels, shipping opportunities and average ship size on the individual routes. Furthermore, Wilmsmeier and Martínez-Zarzoso (2010) underlined that deploying additional capacity in a trade route results in lower transportation costs. Hoffmann, Saeed and Sødal (2020) discussed the academic consensus regarding the importance of a country's enhanced shipping connectivity which reduces transport costs and thus promotes trade and access to international markets. A carriers' decision to directly connect two trading countries supports the enhancement of bilateral trade. Additionally, the study recognised the bidirectional relationship between connectivity and trade since one is an explanatory variable of the other and aimed to analyse the impact of bilateral connectivity on trade flows. Saeed, Cullinane and Sødal (2020) analysed both direct and indirect connections and underlined the importance of reducing the number of transhipments between trade partners for the development of the bilateral trade value. Chang *et al.* (2020) indicated that the connection of a country to the global shipping network is reflected on its LSCI score and that the higher the score the more likely it is to attract higher shipping capacity and frequency.

(6) ECA Routing (arises in Theme 1)

This factor was not explicitly discussed by the publications included in Theme 4.

(7) GDP per Capita (arises in Theme 2)

This factor was not explicitly discussed by the publications included in Theme 4.

(8) Logistics Performance (also arises in Theme 1, Theme 2, Theme 3, and Theme 5)

A developed logistics network with a strong performance record can promote the trading potential for a country. For example, Chang *et al.* (2020) noted that an advanced maritime-related logistics and infrastructure system as reflected on the LPI score of a country, implies higher reliability and efficiency thus leading to higher trade movements due to lower trade costs.

(9) Market Concentration (arises in Theme 1)

This factor was not explicitly discussed by the publications included in Theme 4.

(10) MSR Routing (arises in Theme 1 and Theme 2)

This factor was not explicitly discussed by the publications included in Theme 4.

(11) Nautical Distance (also arises in Theme 1, Theme 2, Theme 3, and Theme 5)

The physical distance between countries can indeed be an important determinant of bilateral trade flows, provided that the correct measure is employed. Guerrero, Claude and Ducruet (2015) showed that shipping is still a ‘’*distance-constrained*’’ industry and that the corresponding importance of distance for bilateral trade flows is expected to be high and negative. Saeed, Cullinane and Sødal (2020) also suggested that the nautical distance between two trade partners may negatively affect the bilateral trade value. Biermann (2012) also focused on the importance of distance for bilateral trade flows but showed that the selection of the correct distance measure as well as the model specification does affect the calculations. According to the author, when measuring the distance in seaborne trade, using a generic computation based on great circles is not accurate. In reality, vessels follow distinct shipping routes at sea —including navigation via key locations such as the Suez or Panama Canals — and the final distance covered may differ considerably. As such, the distance of the actual shipping routes is a more appropriate measure compared to great circle distance while the corresponding importance of distance is commonly expected to be high and negative (*ibid*).

(12) Political Stability (arises in Theme 1, Theme 2 and Theme 3)

This factor was not explicitly discussed by the publications included in Theme 4.

(13) Port Infrastructure (also arises in Theme 1, Theme 2, Theme 3, and Theme 5)

Advancements in port infrastructure represent a decisive step towards better trade facilitation and thus enhancement of trade exchanges between partners. Biermann (2012) indicated that port infrastructure may play a significant role towards the development of bilateral trade flows while Hummels and Schaur (2013) also suggested that any effort to upgrade the respective infrastructure may translate to benefits quantified as a reduction of trading time in days. Bottasso *et al.* (2018) showed that there is a positive impact of port infrastructure endowment on international trade flows which is greater for exports than imports.

(14) Reefer Cargo (arises in Theme 2)

This factor was not explicitly discussed by the publications included in Theme 4.

(15) Route Deviation (arises in Theme 1, Theme 2 and Theme 3)

This factor was not explicitly discussed by the publications included in Theme 4.

(16) Seasonality (arises in Theme 1)

This factor was not explicitly discussed by the publications included in Theme 4.

(17) Security Issues (arises in Theme 1, Theme 3, and Theme 5)

This factor was not explicitly discussed by the publications included in Theme 4.

(18) Trade Agreement (also arises in Theme 1, Theme 2, and Theme 5)

Trade agreements such as World Trade Organisation (WTO) membership can decrease the centralisation of a network (i.e. the need of bilateral trade flows to be served via a central network node) by increasing the linkages between countries (de Benedictis and Tajoli, 2011). Biermann (2012) also found WTO membership to be a variable with significant effect on bilateral trade flows. Prokopowicz and Berg-Andreassen (2016) discussed the great expectations that the anticipated (but later cancelled) Transatlantic Trade and Investment Partnership (TTIP) (between the United States of America and the European Union) agreement generated. The agreement was projected to provide a great boost to the containerised bilateral trade between European countries and the US. In general, maritime transportation plays an important role for trade which is also positively affected by regional trade agreements. However, an efficient maritime transportation network should be in place in order to enable the realisation of the benefits that trade agreements may offer (Chang *et al.*, 2020).

(19) Trade Facilitation (also arises in Theme 1, Theme 2, Theme 3, and Theme 5)

Any enhancement of trade facilitation may result in quantifiable benefits for bilateral trade flows (Hummels and Schaur, 2013) and vice versa. This was confirmed by Bertho, Borchert and Mattoo (2016) who examined the impact of policy restrictions on liner shipping costs and trade flows. Their study showed that specific routes may witness trade flow reductions of up to 46% under stringent policies. Costs may be respectively increased between 24% and 50%. The observation of bilateral flows can be between 17% and 25% lower for routes that are characterised by policy barriers, reflecting the damaging impact of stringent policies with regard to trade facilitation. Biermann (2012) also included trade facilitation (trade freedom) as an explanatory variable of bilateral trade.

(20) Trade Flow (also arises in Theme 1, Theme 2, Theme 3, and Theme 5)

Shipping companies may be willing to support with more frequent service connections an emerging trade flow between partners in order to encourage its further growth. This is evident in Guerrero, Claude and Ducruet (2015) where the authors showed that additional service frequency between two countries can be an important determinant for the development of the bilateral trade flows. Maritime transport is considered to increasingly pursue cost savings through economies of scale while the cost of shipping containerised goods largely defines a country's competitiveness to connect with its international markets (Bertho, Borchert and Mattoo, 2016). Consequently, the overall trade flow across a shipping route may affect its attractiveness.

(21) Trade Imbalance (also arises in Theme 1)

Trade imbalance may indeed play a role on the transport costs and thus the peripherality of a country: if the country's trade is greatly imbalanced, freight rates are quite poor for the backhaul trade. Low and unattractive freight rates are fueled by limited cargo opportunities, targeted by severe competition (Wilmsmeier and Martínez-Zarzoso, 2010). In order to account for the importance of trade flows on the economic viability of a shipping route, Bertho, Borchert and Mattoo (2016) also considered the aggregate bilateral trade of the containerisable cargo as well as route-specific cargo imbalances between the trade partners. They however did not manage to show any statistical significance of trade imbalance in their model specifications.

(22) Transit Time (also arises in Theme 1 and Theme 5)

Should transit time be excessively prolonged this may affect the overall probability that bilateral trade may happen, although estimates may fluctuate for different types of goods. This was discussed by Hummels and Schaur (2013) who indicated that an extra day in transit counts as an equivalent of 0.6%-2.3% ad-valorem tariff increase.

(23) Voyage Cost (also arises in Theme 1 and Theme 5)

The voyage cost to connect two remote trade partners may represent a definitive factor for the establishment of bilateral trade and any proportional savings may respectively boost the likelihood of the bilateral trade growth. Deardorff (1998) indicated that as long as the transport cost declines, bilateral trade between distant countries is expected to expand. A comment by Bergstrand on the epilogue of the same study reinforced the argument: a classic gravity model specification that considers only distance between trade partners would potentially overlook an important variable with explanatory power which is the comparative transport cost between countries.

All of the above identified factors within the Trade theme are synopsised on Table 3-5:

Theme	Factor	References	Expected impact towards a Direct Connection
Trade	Colonial Ties	Biermann (2012); Saeed, Cullinane and Sødal (2020)	+ / -
	Common Language	Saeed, Cullinane and Sødal (2020)	-
	Connectivity	Chang *et al.* (2020); Hoffmann, Saeed and Sødal (2020); Saeed, Cullinane and Sødal (2020); Wilmsmeier and Martínez-Zarzoso (2010)	+
	Logistics Performance	Chang *et al.* (2020)	+
	Nautical Distance	Biermann (2012); Guerrero, Claude and Ducruet (2015); Saeed, Cullinane and Sødal (2020)	-
	Port Infrastructure	Biermann (2012); Bottasso *et al.* (2018); Hummels and Schaur (2013)	+
	Trade Agreement	Biermann (2012); Chang *et al.* (2020); de Benedictis and Tajoli (2011); Prokopowicz and Berg-Andreassen (2016)	+
	Trade Facilitation	Bertho, Borchert and Mattoo (2016); Biermann (2012); Hummels and Schaur (2013)	+
	Trade Flow	Bertho, Borchert and Mattoo (2016); Guerrero, Claude and Ducruet (2015)	+
	Trade Imbalance	Bertho, Borchert and Mattoo (2016); Wilmsmeier and Martínez-Zarzoso (2010)	-
	Transit Time	Hummels and Schaur (2013)	-
	Voyage Cost	Deardorff (1998)	-

Table 3-5 – Identified Factors, Trade Theme

3.10 Theme 5: Alternative Transport Modes

(1) Affiliated Terminal (arises in Theme 1 and Theme 3)

This factor was not explicitly discussed by the publications included in Theme 5.

(2) Colonial Ties (also arises in Theme 1 and Theme 4)

Long-standing colonial ties have also been identified as an important determinant of air freight bilateral trade flows. For example, Hwang and Shiao (2011) claimed that the bilateral trade between Taiwan and Japan can be rooted to the fact that Japan colonised Taiwan in the past for half a century.

(3) Common Border

The existence of a common border between regions is anticipated to have a negative impact for an air freight connection since shippers may also utilise other prominent land modes of transport. This for instance was discussed in Gong *et al.* (2018) who studied the key drivers of the international air freight trade network of China and found that a land border can decrease the bilateral airborne trade flows between countries.

(4) Common Language (also arises in Theme 4)

Cultural ties between trading regions can enhance the development of trade flows by air. For example, Gong *et al.* (2018) claimed that China tends to trade more with regions that share common cultural aspects such as language (e.g. Hong Kong, Macao, Taiwan).

(5) Connectivity (arises in Theme 1, Theme 2, Theme 3, and Theme 4)

This factor was not explicitly discussed by the publications included in Theme 5.

(6) ECA Routing (arises in Theme 1)

This factor was not explicitly discussed by the publications included in Theme 5.

(7) GDP per Capita (arises in Theme 2)

This factor was not explicitly discussed by the publications included in Theme 5.

(8) Logistics Performance (also arises in Theme 1*,* Theme 2*,* Theme 3*, and* Theme 4*)*

A competitive logistics network at both ends of a bilateral trade flow can encourage the development of the trade relationship between trading countries. This is evident in Walcott and Fan (2017) who indicated that air freight volume between the US and China is complemented by a competitive logistics network on either side which supports the efficient distribution of the cargo in the respective hinterlands and thus attracts numerous forwarders and manufacturers to establish their operating centres accordingly. The logistics services quality and particularly the traceability of the cargo is a criterion that rail freight users also take into consideration (Li *et al.*, 2020).

(9) Market Concentration (arises in Theme 1)

This factor was not explicitly discussed by the publications included in Theme 5.

(10) MSR Routing (arises in Theme 1 and Theme 2)

This factor was not explicitly discussed by the publications included in Theme 5.

(11) Distance[1] (also arises in Theme 1, Theme 2, Theme 3, and Theme 4)

The international trade flow of air freight is largely affected by similar parameters with those of the shipping network. This was supported by Gong *et al.* (2018) who suggested for example that bilateral airborne trade may be negatively affected by the flying distance between trade partners (i.e. in a similar way that the nautical distance can affect maritime trade).

(12) Political Stability (arises in Theme 1, Theme 2, and Theme 3)

This factor was not explicitly discussed by the publications included in Theme 5.

[1] Within the context of Theme 5, *Distance* refers to the *Great Circle Distance* while the corresponding factor within the maritime context (Themes 1,2,3 and 4) is the *Nautical Distance*.

(13) Infrastructure[2] (also arises in Theme 1, Theme 2, Theme 3, and Theme 4)

Sufficient infrastructure is necessary for the establishment of a route in rail freight. For instance, Islam *et al.* (2013) noted that sufficient infrastructure is an essential attribute that routes should have in order to become established rail corridors between Europe and Asia. For example, inadequate terminal capacity can lead to bottlenecks and thus delays and was considered by the stakeholders as a barrier towards the establishment of an efficient logistic solution. The same axiom is seemingly applicable for air freight as well since Chu (2014) for example recognised that forwarders prefer facilities (airports) that are efficient in cargo handling.

(14) Reefer Cargo (arises in Theme 2)

This factor was not explicitly discussed by the publications included in Theme 5.

(15) Route Deviation (arises in Theme 1, Theme 2 and Theme 3)

This factor was not explicitly discussed by the publications included in Theme 5.

(16) Seasonality (arises in Theme 1)

This factor was not explicitly discussed by the publications included in Theme 5.

(17) Security Issues (also arises in Theme 1 and Theme 3)

The reputation of a rail connection can deteriorate if there are any concerns regarding security along the route. According to Islam *et al.* (2013) for example, an improvement in security (e.g. reduction of theft incidents) is a factor for consideration for rail connections in the Europe-Asia corridor otherwise the competence of a route along this corridor can be negatively affected.

(18) Trade Agreement (also arises in Theme 1, Theme 2, and Theme 4)

The existence of a favourable trade agreement has been identified by Hwang and Shiao (2011) as a factor that promotes bilateral air freight exchanges. This was endorsed by Walcott and Fan (2017) who claimed that the signing of a trade

[2] Within the context of Theme 5, *Infrastructure* refers to the quality and condition of the track (rail freight) or the existence of state-of-the-art cargo handling equipment (air freight) while the corresponding factor within the maritime context (Themes 1,2,3 and 4) is the *Port Infrastructure.*

agreement between the US and China in 2004 encouraged the establishment of delicately specified bilateral air freight connections.

(19) Trade Facilitation (also arises in Theme 1, Theme 2, Theme 3, and Theme 4)

An improvement in trade facilitation – such as initiatives towards trade liberalisation – promotes the investment by international air freight operators in regional hubs which affects positively the development of bilateral trade (Gong *et al.*, 2018). Walcott and Fan (2017) also underlined the importance of China's trade liberalisation for the development of the air freight volume post 1978. Competency in other trade facilitation aspects – such as customs performance – is likewise important for air freight stakeholders when selecting routes (Chu, 2014). Other forms of improvement in trade facilitation – such as the elimination of any governmental interference in operations – can also assist the development of bilateral trade flows for the air freight industry (Hwang and Shiao, 2011).

(20) Trade Flow (also arises in Theme 1, Theme 2, Theme 3, and Theme 4)

Trade volume is a critical factor for the generation of regular direct services in rail freight since adequate cargo is a prerequisite for attractive and sustainable direct connections (Kreutzberger and Konings, 2016). Respectively, trade volume is a strong determinant for bilateral air freight flows as well. For example, Hwang and Shiao (2011) concluded that a core determinant of the air freight exchanges between areas is the overall economic prospects of the connecting partners. However, the composition of the economy is the actual driver since the latter dictates the type of cargo which can be actually targeted by the air freight industry (Gong *et al.*, 2018) thus defining the bilateral trade volume potential.

(21) Trade Imbalance (arises in Theme 1 and Theme 4)

This factor was not explicitly discussed by the publications included in Theme 5.

(22) Transit Time (also arises in Theme 1 and Theme 4)

Transit time is acknowledged as a parameter that defines the connection quality of a node in the air freight industry and that a direct connection diminishes possible delays as well as the risk of damage during transhipment (Boonekamp and

Burghouwt, 2017). According to Li *et al.* (2020), time is an important factor for rail freight users as well. Andersen and Christiansen (2009) argued that the variables that impact the design of a rail freight service are a trade-off between price and service quality and that the latter is largely defined by a competitive and stable transit time. Islam *et al.* (2013) also identified transit time as an important factor for rail freight connections between Europe and Asia. Jeong, Lee and Bookbinder (2007) examined the potential organisation of the European rail network under hub-and-spoke configuration. The authors noted that hubs could possibly secure operational savings in monetary costs but would most likely suffer from increases in time cost thus reducing the quality of the service.

(23) Voyage Cost (also arises in Theme 1 and Theme 4)

The voyage (transport) cost can be regarded as one of the core ‘*’pressing issues’’* when the rail freight stakeholders consider their supply chain options. This was for example underlined by Islam *et al.* (2013) who identified transport cost as an important factor that operators may consider when selecting a route for rail freight between Europe and Asia.

All of the above identified factors within the Alternative Transport Modes theme are synopsised on Table 3-6:

Theme	Factor	References	Expected impact towards a Direct Connection
Alternative Transport Modes	Colonial Ties	Hwang and Shiao (2011)	+
	Common Border	Gong *et al.* (2018)	-
	Common Language	Gong *et al.* (2018)	+
	Logistics Performance	Li *et al.* (2020); Walcott and Fan (2017)	+
	Distance[3]	Gong *et al.* (2018)	-
	Infrastructure[4]	Chu (2014); Islam *et al.* (2013)	+
	Security Issues	Islam *et al.* (2013)	-
	Trade Agreement	Hwang and Shiao (2011); Walcott and Fan (2017)	+
	Trade Facilitation	Chu (2014); Gong *et al.* (2018); Hwang and Shiao (2011); Walcott and Fan (2017)	+
	Trade Flow	Gong *et al.* (2018); Hwang and Shiao (2011); Kreutzberger and Konings (2016)	+
	Transit Time	Andersen and Christiansen (2009); Boonekamp and Burghouwt (2017); Islam *et al.* (2013)	-
		Jeong, Lee and Bookbinder (2007); Li *et al.* (2020)	
	Voyage Cost	Islam *et al.* (2013)	-

Table 3-6 – Identified Factors, Alternative Transport Modes Theme

3.11 Summary

Step 5 – Use of Results

On the final step of the SLR, the researcher should synopsise the outcome of the synthesis, discuss the scientific consensus about the researched topic and identify any possible limitations (Wang and Notteboom, 2014).

[3] Within the context of Theme 5, *Distance* refers to the *Great Circle Distance* while the corresponding factor within the maritime context (Themes 1,2,3 and 4) is the *Nautical Distance*.
[4] Within the context of Theme 5, *Infrastructure* refers to the quality and condition of the track (rail freight) or the existence of state-of-the-art cargo handling equipment (air freight) while the corresponding factor within the maritime context (Themes 1,2,3 and 4) is the *Port Infrastructure.*

Synopsis

As illustrated in the left axis of Figure 3.7, the majority of the publications were classified under Shipping Network (67), followed by Connectivity (27), Port Selection Criteria (14), Trade (12) and Alternative Transport Modes (10). As illustrated in the right axis of Figure 3.7 the Shipping Network theme considered 19 factors, Connectivity 12 factors, Port Selection Criteria 10 factors and finally Trade as well as Alternative Transport Modes considered 12 factors each:

Figure 3.7 – Number of Publications and Factors per Theme

Overall, 23 factors have been identified throughout the SLR as potential drivers towards the initiation, establishment, or termination of a direct connection between trade partners in container shipping (see left axis of Figure 3.8):

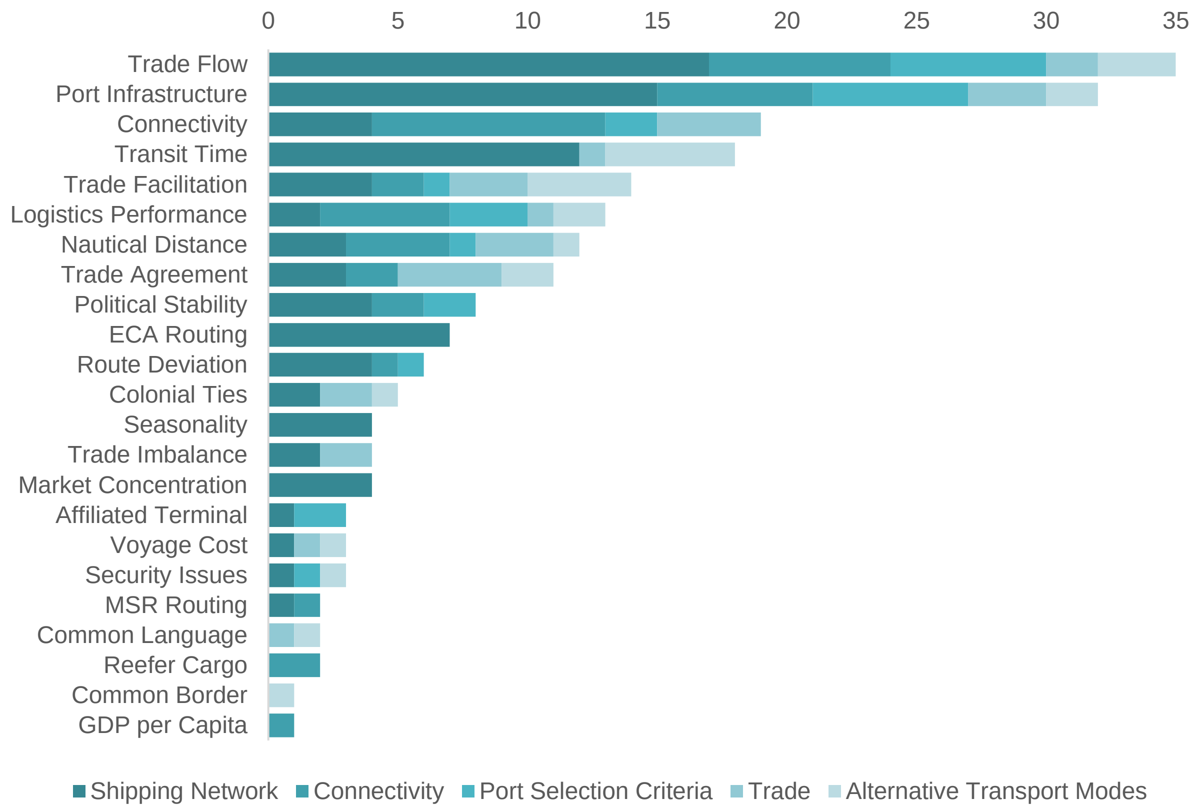

Figure 3.8 – Number of Publications per Theme per Factor

The number of occurrences corresponds to the number of publications that discussed each factor in the SLR and does not imply the magnitude of the factor. For the purpose of the aggregation of the results and consistency, the research has grouped *Distance* and *Infrastructure* – as those have been defined within the context of Theme 5: Alternative Transport Modes – under the corresponding factors within the maritime context: *Nautical Distance* and *Port Infrastructure,* respectively. Additionally and as previously mentioned, several factors are shared across the themes although each theme has explored the reviewed topic from a distinct perspective. Nevertheless, certain factors were specifically considered by a single theme:

- Shipping Network: ECA Routing, Seasonality, Market Concentration
- Connectivity: Reefer Cargo, GDP per Capita
- Alternative Transport Modes: Common Border

The identified factors may have a positive, ambiguous, or negative impact towards the initiation, establishment, or termination of a direct connection between trading partners in container shipping (Figure 3.9).

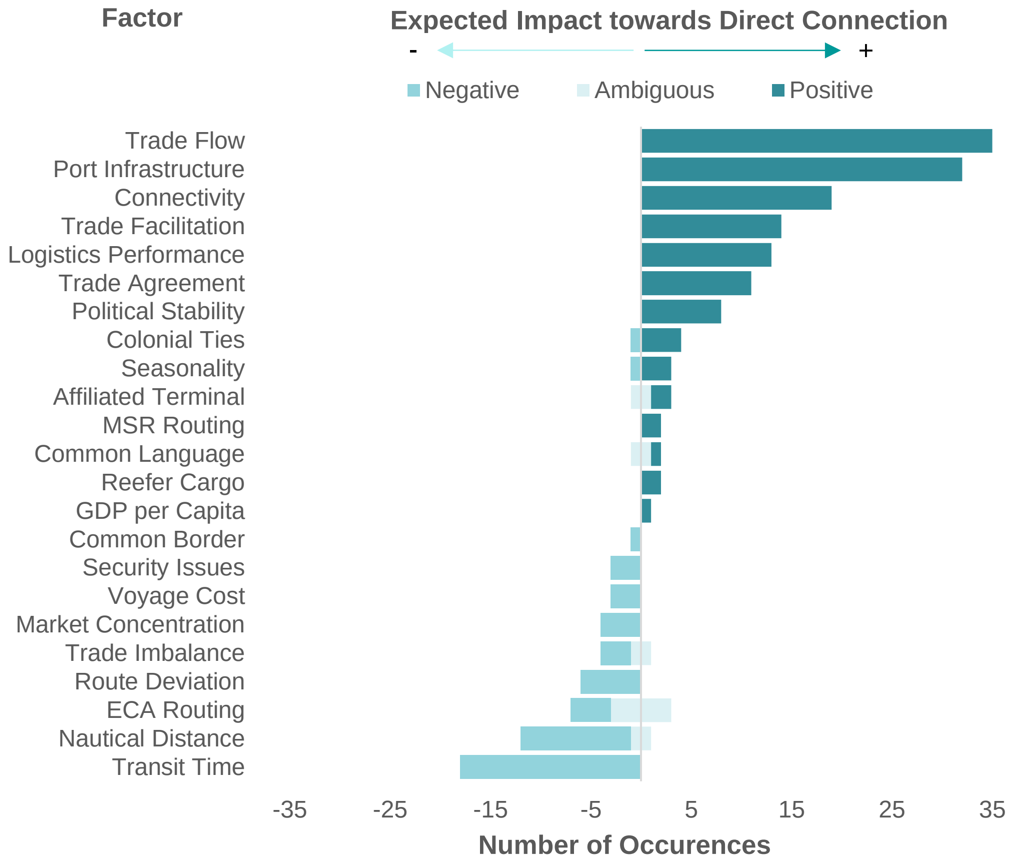

Figure 3.9 – Occurrences of identified factors throughout SLR

The positive / negative sign corresponds to the overall discussed impact that each factor may have towards the establishment of a direct connection, according to the reviewed publications.

A framework is subsequently developed which synopsises the number of occurrences, the expected sign of the impact as well as the categorisation of the factors under the identified Themes:

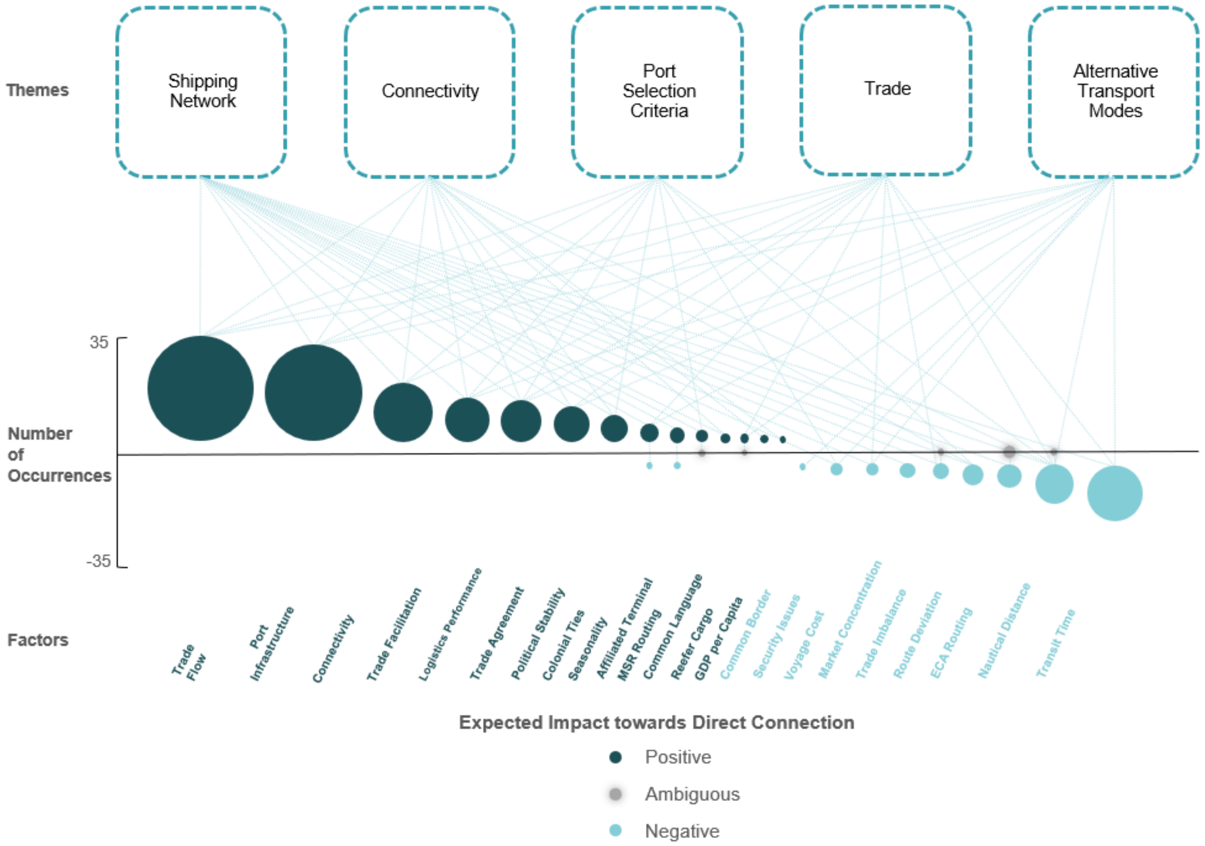

Figure 3.10 – SLR framework

Consensus

For the majority of the identified factors, there is a strong convergence regarding their potential impact towards the establishment of a direct connection between two trading countries. For instance, the reviewed literature unanimously suggested that a well-developed logistics network of a country is expected to have a positive impact while for example security issues in one or both trading countries are expected to have a negative impact on the establishment of a direct connection between them.

Additionally, a few publications – without necessarily suggesting that a widely accepted view regarding the impact of a factor should be reversed – underlined that they did not find strong evidence in order to adopt the established view and indicated a rather ambiguous impact towards the establishment of a direct connection between two trading countries (Figure 3.9):

- Theme 1: Shipping Network – Affiliated Terminal: Despite the expected synergies between a carrier and an affiliated terminal, Parola and Veenstra (2008) did not find concrete evidence that carriers tend to support their deployment strategy with a respective terminal network that is geographically distributed in accordance with the operating areas of their fleet.
- Theme 1: Shipping Network – ECA Routing: Although the establishment of an ECA is likely to fuel a tendency towards rerouting by the carriers, this is not regarded as a necessity for all routes (e.g. Doudnikoff and Lacoste, 2013; Schinas and von Westarp, 2017; Dithmer, Reinhardt and Kontovas, 2017b)
- Theme 1: Shipping Network – Nautical Distance: Ducruet and Notteboom (2012a) underlined that although short-distance shipping connections are common, in the period 1996-2006 long-distance connections became more frequent.
- Theme 4: Trade – Common Language: Intuitively, cultural aspects such as common language should act as enablers of bilateral trade as this was for instance proposed by Gong *et al.* (2018). However, the analysis of Saeed, Cullinane and Sødal (2020) did not reveal any statistical significance between common language and bilateral trade flows.
- Theme 4: Trade – Trade Imbalance: Despite the broadly accepted principle that trade imbalance may harm the attractiveness of a route, this was not statistically confirmed by the analysis of Bertho, Borchert and Mattoo (2016) at a significant level.

However, the SLR also revealed factors for which a general consensus has evidently not been reached and their positive or negative impact towards the establishment of a direct connection between two trading countries appears to be directly or indirectly questioned by some researchers. A noteworthy divergence has been identified with regard to the following factors (Figure 3.9):

- Theme 1: Shipping Network – Seasonality: the fluctuating demand for transportation may be a reason for the initiation of a service but the reviewed papers also implied that the same reason may equally lead to the periodical termination of a connection (Huang, Hu and Yang, 2015).

- Theme 4: Trade – Colonial Ties: Although the relationship between two countries when one is a former colony of the other is largely regarded as a factor that promotes bilateral connectivity and trade, this can also be contradicting with the statistical analysis of certain samples pointing to the opposite direction (Saeed, Cullinane and Sødal, 2020).

Limitations

The SLR also revealed that there are factors which have not been included in the final list because of their unclear importance or untested impact within the context of the reviewed topic:

- Port Cost: The reviewed papers showed that carriers may identify port cost as a factor for consideration during the port selection process (Wiegmans, Hoest and Notteboom, 2008). Based on the example of Shenzhen-Hong Kong, Wang et al. (2012) noted that the former has managed to attract direct calls by carriers at the expense of the latter due to more competitive handling tariffs. However, according to Fraser et al. (2016), although reasonable port tariffs could theoretically assist the individual ports of a region such as South Africa to improve its position in the hierarchy of the shipping network, the effect of regional initiatives remains uncertain.

  Thus, port cost is seemingly a factor for consideration but regarding the selection between ports rather than countries. While there are port characteristics that may have an impact at country level (e.g. nations with obsolete port infrastructure that cannot accommodate large vessels), port cost has not prevailed as a decisive factor for the exclusion of a country from an itinerary and its impact on the establishment of a direct connection between countries is likely to be discounted by carriers[5].

- Corruption: Chen, Xu and Haralambides (2020) studied the design of the container shipping network within the Asia - West Africa tradelane and commented that although they did not take into account public corruption as

[5] This point has been verified by one of the top liners during an interview: if a country can offer an attractive volume, port cost at national level will not be a reason to reject the option for a direct call. Indeed, a liner will be selective between ports within a country (should there be competitive alternatives) or aim to make specific procurement arrangements with terminals within ports but will not abstain from directly calling at a country as a whole because its ports are considered expensive. Ultimately, any potential savings from not calling directly at a country with a mother vessel will be diminished if a carrier will finally send cargo to that country via transhipment.

part of their modelling effort, the latter may be an area of concern for carriers when designing their network.

Thus, corruption has not been included on the final list of the identified factors since it was not clearly defined as a factor that may have an impact on the design of the shipping network. However, this comment by Chen, Xu and Haralambides (2020) potentially reveals an additional dimension that is worth to be further explored.

- Number of Common Direct Connections: Hoffmann, Van Hoogenhuizen and Wilmsmeier (2014) proposed the development of a Liner Shipping Bilateral Connectivity Index (LSBCI), which is effectively an extension of UNCTAD's LSCI (see Connectivity, Theme 1) and accounts for both direct and indirect connections between countries. The authors aimed to compile an index based on hard shipping data only and proposed that the index should include the following components: *(1) the number of transhipments required to get from A to B; (2) the number of common direct connections; (3) the number of common connections with one transhipment; (4) the level of competition on services that connect country pairs and (5) the size of the largest ships on the weakest route* (as an indicator of the infrastructure level and any opportunity for economies of scale). The second component of the LSBCI – the number of common direct connections between a country pair – is the total number of third countries that connect directly to both countries of an analysed pair. The authors utilised the example of LinkedIn and quoted that this would be the equivalent of the ''*shared*'' or ''*1st*'' common contacts between two people participating in this social network. The equivalent in the container shipping network would be the number of alternatives that a shipper would theoretically have in order to send a cargo between two countries with only one transhipment. The more the common connections, the higher the connectivity and trade potential (*ibid*). This could potentially imply that a comparatively high number of options to move cargo between two countries with a single transhipment may underline an upcoming trade opportunity earlier than any other random flow between partners which connect with two or more transhipments. Specifically, according to Fugazza and Hoffmann (2017), the addition of one extra common direct connection is linked to approximately 5% of additional bilateral exports value.

Thus, this may respectively trigger carriers to remove the transhipment leg between two particular trade partners, support them with a direct shipping connection and allow a promising bilateral flow to further flourish. Overall, this constitutes another dimension that is worth to be further explored.

3.12 Final Research Design

The literature review on the factors that drive the establishment of direct connections in container shipping revealed that the research to date on the topic has been largely fragmented. The existing literature has referred to some of the factors that in theory may affect the establishment of direct connections and has mainly focused on the positive impact that a direct connection between two countries may have on bilateral trade development. However, there has been only limited research on the systematic identification and quantification of the factors that should be in place in order to promote and allow the initiation of a direct connection. Thus, following on from the SLR and the deeper understanding of the research gap, the *Research Onion* (see Figure 2.1) is revisited and the adopted approach for each layer is specified. The adopted approach per layer of the *''Research Onion''* for this research is highlighted in Figure 3.11 and further justified as follows:

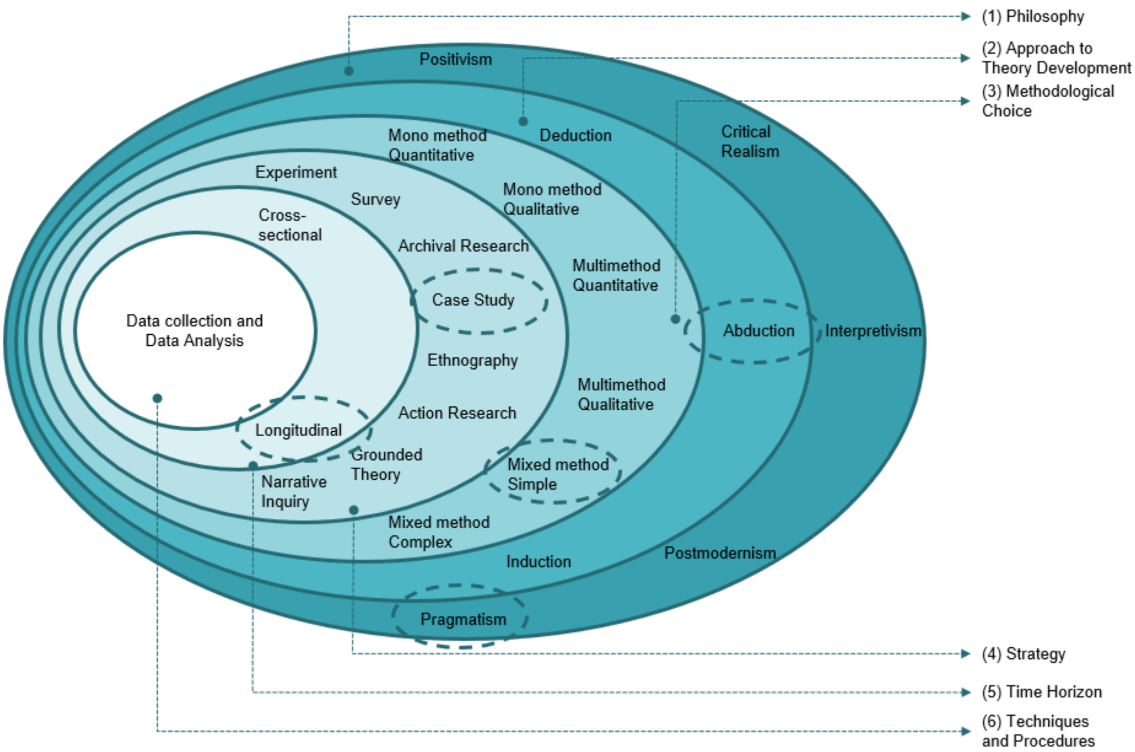

Figure 3.11 – The Research Onion, adapted from Saunders et al. (2019)

(1) Research Philosophy

This research contains an element of causal reasoning since it aims to explore the impact of specific factors to the establishment of direct connections between trading countries. Additionally, this research contains a strong element of a structured approach (i.e. the SLR detailed in this Chapter). Those two elements may indicate towards the philosophy of Positivism. Adopting the philosophy of Positivism in the context of this research would suggest that the findings should take the form of a law-like conclusion as the outcome of a solely quantified approach. However, demystifying the factors that are considered as important by the carriers during their decision-making process may require a qualitative assessment of the results to verify that *"the data are telling you what you think they are telling you"* (Saunders, Lewis and Thornhill, 2007a p139). Thus, the researcher does not strive to restrict the analysis only to quantified scientific observations, but rather accepts that the inclusion of a qualitative assessment is an element that may enrich the results of the research.

This research also has some elements that may indicate towards the philosophy of Critical Realism since it pursues a further understanding of the causal relationships that may explain the empirically collected data. Critical Realism proposes that what a researcher understands empirically is only an indication of the real world rather than its accurate representation (Saunders *et al.*, 2019) and that the social structures may significantly contribute to the explanation of a social phenomenon (Elder-Vass, 2022). In other words, adopting the philosophy of Critical Realism in the context of this research would suggest that the empirical data may be regarded as deceiving or at least not representative of the real world until backward reasoning could reveal the real underlying structures that shape the container shipping network. On the contrary, the researcher accepts that the empirical data can be a pragmatic manifestation of the real world and can provide a representative demonstration of the mechanisms that shape the shipping network. A thorough analysis of those factors may shed light on their relative importance but it is not expected that direct connections in container shipping are decisively driven by any underlying and largely unobservable mechanisms.

Furthermore, this research shares some common ground with the philosophy of Interpretivism since it largely accepted the fact that the shape of the shipping network is sometimes defined by heterogeneous market conditions across different tradelanes or carriers. Adopting the Philosophy of Interpretivism in the context of this research would suggest to (a) question the usefulness of a universal answer to the research questions and (b) access the world of the real actors in order to explain things from their perspective. The researcher accepts that liner shipping companies may develop their individual strategies but largely share a common approach when deciding about direct connections. Thus, although the discovery of a universal truth regarding direct connections may be unattainable or meaningless, a certain degree of generalisation within certain geographies may still be valid and meaningful. Additionally, the researcher accepts that accessing the world of the real actors (i.e. stakeholders from the shipping industry) should not automatically imply the adoption of their subjective views but should rather provide a basis of comparison between those views and the findings of the empirical analysis.

Finally, adopting the philosophy of Postmodernism in the context of this research would suggest to highlight those marginalised direct shipping connections that have departed from the norm and have been established although their characteristics substantially vary from what is commonly regarded as a good business case by the majority of the carriers. On the contrary, the researcher has been inclined to analyse the factors that generally contribute to the development of the shipping network and to reveal what may normally encourage or discourage the majority of the shipping companies in order to support the trade relationship between two countries with a direct shipping connection.

The establishment of direct shipping connections between countries is ultimately the product of a complex decision-making process, conducted by multiple carriers across various geographies and under different market conditions. This is seemingly a multifaceted issue and its analysis requires the undogmatic use of multiple perspectives and methods. Hence, this research adopts the philosophy of Pragmatism since it accepts that there may be various interpretations of the reality and thus various applicable research methods. Pragmatism acts as a bridge between contradictory philosophies and promotes *''practical theory''* and *''practical empiricism''* with the aim to provide a *''workable solution''* (Johnson and Onwuegbuzie, 2004). This is at the heart of this research which opts to make the best of two worlds: to develop a structured and quantified approach which can be qualitatively assessed. Adopting the philosophy of Pragmatism dictates the subsequent chosen approaches regarding the rest of the *''Research Onion''* layers.

(2) Research Approach to Theory Development

With the aim to build a bridge between ''practical theory'' and ''practical empiricism'', an abductive approach is deemed most appropriate for this research. The research started inductively with an SLR which suggested 5 Themes and developed a framework of 23 factors that in theory drive the establishment of direct shipping connections. Thus, it is likely that a quantitative model should be generated in order to deductively check the outcome of the SLR (i.e. to test the relative importance of the identified factors). Moreover, as stated in Section 2.3, the examined topic is ultimately the product of a complex decision-making process that carriers conduct. Thus, the results of the deductive model could be further validated by container shipping stakeholders in an inductive manner. Effectively, this rationale outlines a research study which moves iteratively from induction to deduction and again to induction and thus adopts an abductive approach to theory development.

(3) Research Methodological Choice

A Mixed Methods approach is deemed most appropriate for this research. Mixed Methods may assist a researcher to use the advantages of one method in order to compensate for the disadvantages of the other and can enrich the research conclusions through synthesis and validation (Johnson and Onwuegbuzie, 2004). According to Eisenhardt (1989), the combination of qualitative and quantitative data may reveal great synergies: quantitative evidence may be used as a control against any false impressions that qualitative data may suggest, while qualitative data may explain the patterns revealed by quantitative evidence or even propose theory which can be further reinforced by quantitative evidence. The latter is at the heart of the methodology of this research. It is also likely that the research may employ qualitative methods for the analysis of qualitative data and respectively quantitative methods for the analysis of quantitative data. Hence, within the context of the Mixed Methods this research specifically adopts the *''Mixed Method Simple''* approach.

(4) Research Strategy

This research adopts a case study approach, focusing on the development of the direct connections of the UK (the specific country choice is elucidated in Section 4.2) with its trading partners (countries), for the following reasons. While the aim is to obtain rich insights of the studied topic (Morris and Wood, 1991), the researcher also took into consideration a view that was repeatedly discussed by a number of the reviewed papers in the early stages of the SLR. According to this view, container shipping is largely heterogeneous across different tradelanes and the carriers may also be driven by a diversified set of factors under various circumstances. Specifically, Notteboom and Rodrigue (2008) highlighted the fact that the geography of the shipping network is based on the decisions made by the carriers according to their strategic, operational, and commercial needs and varies among different carriers. Correspondingly, Tran and Haasis (2014) commented that as the shipping network develops over time, different regions and carriers show different trends and strategies, respectively. Thus, not every carrier engages into new markets with the same pace (Gadhia, Kotzab and Prockl, 2011). Ducruet, Rozenblat and Zaidi (2010) also noted that in the real world there is a distinction between the parameters that shape the intra-regional and the inter-regional connections while Yap and Notteboom (2011) commented that between different regions, carriers and routes there might be distinct variables that shape the competitive environment in container shipping. Finally, Wiegmans, Hoest and Notteboom (2008) highlighted that the decision-making process regarding the calling pattern varies among carriers and tradelanes, and thus the examination of those factors that dictate the carriers' preferences should be disaggregated to targeted samples.

Thus, although the compilation of a global model that captures all direct connections between trading countries would be an interesting study, the corresponding values of the factors that dictate the connections at a global level may not be truly meaningful. On the contrary, a case study focused on a particular country and its trading partners may represent a more targeted effort towards the deeper understanding of the examined phenomenon. Additionally a case study – as previously mentioned – may be greatly complemented by a triangulated approach where semi-structured interviews are used to validate the findings of a quantitative model (Saunders et al., 2007). Finally, as will be further discussed in

Sections 4.2 and 4.4, the utilisation of a global dataset with actual containerised flows (originally recorded in TEU) between pairs of trading countries is not readily available from public sources. Hence, a case study based on national statistics of a targeted country – such as the UK – which does report its bilateral containerised exchanges with other countries can significantly add to the accuracy of the final outcome of the research. Thus, the adoption of a case-study as a research strategy is most appropriate for this research in order to yield both meaningful and accurate results.

(5) Research Time Horizon

This research adopts a longitudinal approach. The impact that certain factors may have towards the establishment of a direct connection between trading countries can be better understood and quantified only through the observation of the corresponding values of the factors over time and thus is largely based on the understanding of how those values change (or not) over time. This research intends to test whether those values are correlated to the connectivity pattern between the trading countries. Consequently, the understanding of this pattern cannot be observed or understood if the time horizon is static and concentrated in a single year as would be the case if a cross-sectional study was utilised. Thus, conducting a longitudinal study is most appropriate for this research in order to capture the adjustment of the container shipping connections to changing factors.

(6) Research Techniques and Procedures

The approach that this research adopts for this layer of the 'onion' will be discussed in detail in Chapter 5.

Therefore, following on from the SLR as well as the finalisation of the methodological approach, the research is organised into three distinct phases. Each phase is designed to employ a distinct technique, approach to theory development and method. Mangan, Lalwani and Gardner (2004) also applied a three-phase iterative research which involved alterations between inductive, deductive, and finally inductive process showing the complementary nature that fundamentally different thought processes may have in logistics research. In the context of this research, this iterative process is designed to include the identification of the factors that may impact the establishment of direct shipping connections between countries, the quantification of those factors, and finally their validation (Figure 3.12):

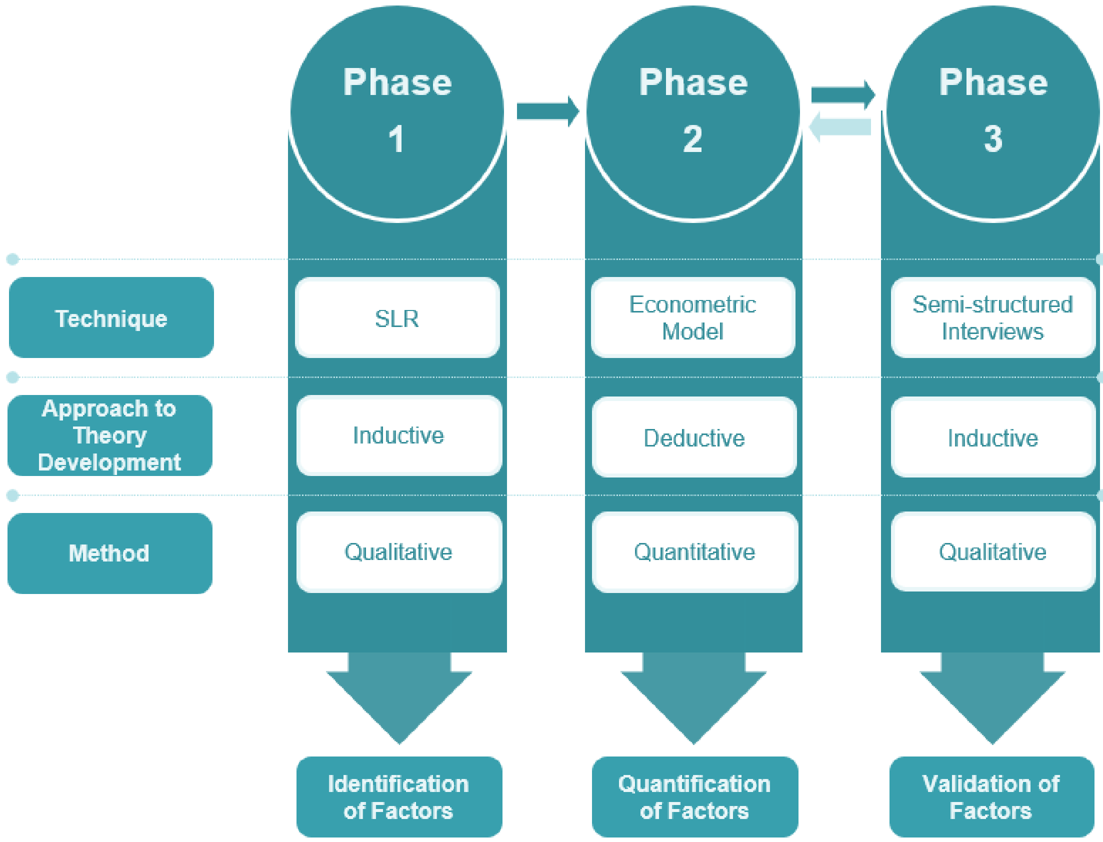

Figure 3.12 – Triangulated Research Design

Following Phase 1 and the corresponding SLR, Phase 2 effectively aims to move from theory to data employing an econometric model using a deductive approach. In turn, Phase 3 aims to investigate if "*the data are telling you what you think they are telling you"* (Saunders, Lewis and Thornhill, 2007a p139) using an inductive approach which would in turn help to validate and refine the model developed in Phase 2.

3.13 Concluding Remarks

This Chapter employed a Systematic Literature Review (SLR) to identify the factors that carriers may consider in their decision-making process towards the establishment of a direct connection between trading countries. The reviewed literature revealed 23 factors across 5 Themes: (1) Shipping Network, (2) Connectivity, (3) Port Selection Criteria, (4) Trade and (5) Alternative Transport Modes with some factors appearing across multiple Themes. For the majority of the identified factors, there is a strong convergence regarding their potential impact. However, the analysis also revealed that for a few factors a general consensus has not been reached in the literature.

The SLR identified and reconfirmed the importance of factors that have traditionally been regarded as important for the establishment of direct connections between countries (e.g., Trade Flow, Port Infrastructure, Connectivity, etc.). It is likely however that the shape of the future shipping network may be increasingly co-defined by environmental, geopolitical, cultural, and security-related characteristics of the shipping routes. The SLR has also highlighted those relevant factors (e.g., ECA Routing, MSR Routing, Common Language, Political Stability etc.).

The identification and understanding of the various factors can help policy-makers in their efforts to promote the establishment of a direct shipping connection between trading countries. The SLR, through its identification of the 23 factors and 5 Themes, also provides a platform for further analysis into the relative roles of these factors in the establishment of direct shipping connections between trading countries.

Following on from the completion of the SLR, this Chapter also outlined the methodological approach and research design that is finally applied on this dissertation. The next Chapter will proceed with the presentation of the case study which is utilised in this research.

Chapter 4. United Kingdom as a Case Study

4.1 Introduction

The intention of the analysis in this research is to quantify the factors that may encourage – or discourage – the establishment of a direct shipping connection between two trading countries. The research adopts the United Kingdom (UK) as a case study. Then, a rigorous process is followed in order to justify which of the 23 factors identified during the SLR (Chapter 3) are likely to be of primary interest for the analysis. The selected variables span from trade flow to cultural aspects such as colonial ties. In this Chapter the identified factors are introduced as variables and certain metrics for their measurement are proposed. Those metrics are essentially a mix of established indices / databases published by esteemed institutions as well as a series of prototype measurements. The latter are employed where established indices / databases are not available or suitable for the measurement of the selected variables.

In this Chapter, Section 4.2 discusses the selection of the UK as a case study, Section 4.3 describes the rationale that underpins the final set of the variables of primary interest, Section 4.4 introduces the applicable data sources and metrics, Section 4.5 outlines the preprocessing of the utilised data, Section 4.6 assesses the data completeness, Section 4.7 outlines the applicable modelling approaches and finally Section 4.8 comprises the concluding remarks of this Chapter.

4.2 Case Study Selection: United Kingdom

In Section 3.12, the adoption of a case-study as a research strategy was proposed and justified. Regarding the selection of a particular country as a reference case, the researcher aimed to focus on a country whose characteristics could yield fruitful results. Specifically, the researcher assessed candidate countries based on the following criteria:

- Container Shipping Trade: a good candidate country should be an active trader of containerised cargo. The research effectively accepts Trade Flow as a known prerequisite for the establishment of direct connections between countries and strives to identify other contributing factors. Thus, a good candidate should be a nation which is active in container shipping and records exchanges with multiple partners. The UK as an island nation[6] bases its trade on maritime transport and has container trade activity with over 150 partners (DfT, 2021b).

- Container Shipping Connectivity: a good candidate country should be an active member of the global container shipping network with as many connections as possible in order to allow a deep-dive into the characteristics and the historical development of those connections. The UK ranked in the top 10 economies regarding their LSCI score for 2020 (UNCTAD, 2020) and is regarded as one of the most well-connected countries in the world.
- Availability of container statistics: a good candidate country should report its bilateral container trade in the official measurement unit of the containerised trade (i.e. a Twenty-foot equivalent unit – TEU). As will be thoroughly discussed in Section 4.4.8 – Trade Flow, the use of publicly available datasets which provide bilateral trade exchanges expressed in value rather than in actual volume (TEU) may be problematic. Therefore, the researcher decided to proceed with a more concrete approach and pursued the use of a dataset which reports the corresponding data in TEU. The option of using a commercial source of global container trade flows coverage (e.g. Container Trade Statistics – CTS) was also pursued but abandoned due to high cost. On the contrary, the Department for Transport (DfT) in the UK shares a publicly available annual report as well as the corresponding data[7] regarding all of its maritime trade activity. The data includes containerised trade exchanges with all of the UK's trade partners reported in TEU and is available on an annual basis with no gaps between years.
- Cultural aspects: since the variable set includes Common Language and Colonial Ties, the corresponding reference country should provide a certain degree of variance regarding those variables among its trade partners. For instance, a case study based on Greece would practically restrict any inference regarding those variables since Greece hardly shares a common

[6] The UK comprises mainland Great Britain (England, Wales, and Scotland) which is an island and Northern Ireland which adjoins the Republic of Ireland.
[7] Data up to 2020 is available at https://www.gov.uk/government/statistics/port-freight-annual-statistics-2020

> language or former colonial relationships with third countries. On the contrary, the UK is in fact an ideal candidate to investigate those variables due to the wide number of countries for which English is an official language and also because of the UK's colonialism background.

Thus, the UK is selected as a case study which in fact can allow the examination of the full spectrum of the pre-identified variables, based on credible and readily available data and regarding a major trading and well-connected country in the container shipping network.

4.3 Variable Selection

4.3.1 Approach

In Chapter 3, the research identified 23 factors (variables) that the literature has discussed as potential drivers for the establishment of direct connections between trading countries. The identification of a considerable number of factors indicates the multidimensional nature of the corresponding dataset that should be modelled. A common practice for the analysis of a multivariate dataset is the application of techniques that can assist with the reduction of its dimensionality while preserving the underlying information with the ultimate goal to provide a more interpretable outcome (Jolliffe and Cadima, 2016). Common practices include Principal Component Analysis (PCA) and Factor Analysis (FA) techniques (Liu *et al.*, 2022) (see Appendix B).

In the context of this research, the researcher questioned whether the consideration of all identified variables was indeed an advisable and feasible approach for modelling. As argued by Cinelli, Forney and Pearl (2022), a common econometric problem is the decision of whether the addition of a variable in a regression eventually assists towards a better estimation of the parameters of interest. In fact, the impression that adding as many variables as possible strengthens a regression model is likely false and the addition of unnecessary variables may actually introduce bias to the model (*ibid*). This problem has been widely addressed by the theory of *Causal Inference* which (through graphical models) has discussed a range of criteria to assist with the selection of the correct set of variables for a model. Those criteria ensure that a model can return unbiased causal effects (e.g. Pearl, 1995; Shpitser, VanderWeele and Robins, 2010) as well as accurate estimates (Rotnitzky and Smucler, 2020) and may be considered for the selection of the correct set of variables for this research.

Causal Inference is a seminal topic which has been widely explored and discussed in the literature in recent decades (e.g. Holland, 1986; Pearl, 1995; Pearl, 2009; Rubin, 2005). Causal Inference is broadly referring to *''the examination of causal associations to estimate the causal effect of an exposure on an outcome''* (Lederer *et al.*, 2019). It should be highlighted though that a true causal effect can hardly be established by a single study based on observational data (*ibid*). A researcher should rather declare the purpose of the modelling effort and then proceed to identify *''causal associations''* instead of *''causal effects''* for the results of an observational study (*ibid*). Nevertheless, outlining the causal assumptions that underpin a research increases the transparency of a study (Lederer *et al.*, 2019) and allows the use of the criteria that Causal Inference provides regarding variable selection. In Causal Inference theory the following nomenclature is adopted (Figure 4.1): a *parent* variable X causes a *child* variable Y (Elwert, 2013):

$$X \rightarrow Y$$

Figure 4.1 – Parent - Child variable notation in Causal Inference

According to Cinelli, Forney and Pearl (2022) *''As a general rule of thumb, parents of X which are not necessary for identification are harmful for the asymptotic variance of the estimator; on the other hand, parents of Y which do not spoil identification are beneficial''.* This rule indicates that certain variables may increase or respectively decrease the precision of the model. This concept is illustrated in the following figures:

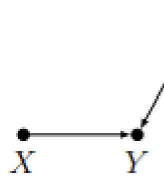

Figure 4.2 – Inclusion of variable Z in the model: possibly good for precision, Source: Cinelli, Forney and Pearl (2022)

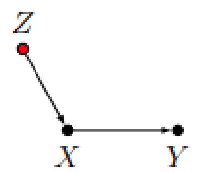

Figure 4.3 – Inclusion of variable Z in the model: possibly bad for precision, Source: Cinelli, Forney and Pearl (2022)

This research aims to explore whether there are any causal associations between specific variables and their impact to the establishment of direct connections between trading countries. Thus, in the context of this research, it may be beneficial to include in the model those variables (e.g. X, Z in Figure 4.2) which are considered to have a seemingly direct (causal) association with the establishment of a Direct Connection (variable Y). Conversely, it may not be advisable to include those variables (e.g. Z in Figure 4.3) that have an association with the establishment of Direct Connections (variable Y) only indirectly through other variables (X).

A deeper appraisal of the SLR discussion (Chapter 3) reveals that the 23 identified factors are effectively a group of parent and children variables. For instance, the literature discusses the positive impact that a Trade Agreement may have towards the establishment of a direct connection between two countries. Effectively, as it will be highlighted in Section 4.3.2 what the literature suggests is that a Trade Agreement is expected to increase the Trade Flow between trading countries thus carriers may then be enticed to award this country-pair with a direct connection. In other words, the signing of a Trade Agreement is not a direct cause which may trigger a direct connection between countries. If the content of an agreement cannot encourage the expansion of the bilateral trade exchanges then it is possible that the signing of that agreement may have no impact regarding the establishment of a direct connection. Trade Agreement is effectively a parent of Trade Flow which in turn is a parent of Direct Connection:

Trade Agreement → Trade Flow → Direct Connection

Hence, the addition of Trade Agreement variable may not be advisable and is expected to harm the accuracy of the model (Figure 4.3). Conversely, Trade Flow should be included in the model as a potential direct cause of Direct Connections (Y) along with other X variables which are respectively direct causes of a Direct Connection (Y) but without their parents (Figure 4.2).

Would that however imply that there are a few unimportant variables suggested by the SLR (such as Trade Agreement) or that those variables cannot be modelled under any possible model specification? What if it is necessary to measure the association of Trade Agreement with Direct Connection? The answer to those questions may provide an additional justification of why the researcher may select for instance to model Trade Flow over Trade Agreement.

Undoubtedly, any of the 23 variables suggested by the SLR could be selected for modelling should this be explicitly dictated by the research needs. For instance, continuing with the previously used example of Trade Agreement, Trade Flow and Direct Connection, a different approach could specifically target to identify the total effect (association) of Trade Agreement to Direct Connection. In that case, it would rather be advisable to remove Trade Flow from the model in order to allow the causal effect (association) to *''flow untouched''* (Cinelli, Forney and Pearl, 2022). In Figure 4.4, Trade Flow (Z) would act as a *''mediator''* of the causal effect (association) of Trade Agreement (X) on Direct Connection (Y) and that would lead to biased results due to *''overcontrol bias''* (*ibid*). The removal of Trade Flow (Z) from the model would allow the unbiased estimate of the association between Trade Agreement (X) and Direct Connection (Y):

Figure 4.4 – Overcontrol Bias, Source: Cinelli, Forney and Pearl (2022)

In an analysis which considers multiple controls (i.e. multiple variables, such as is the case in this Research), a single control may be classified as *''good''* or *''bad''* based on the context of the other covariates (*ibid*). Nevertheless, the discussed principles of Causal Inference remain valid in order to classify *''a set of controls''* as *''good'' (ibid).* At this stage the research is largely agnostic towards the importance of each variable and the Research Questions do not specify any variables which are of increased interest. Thus, if it is advisable to select either X or Z (Figure 4.4) then how should the researcher select between the two? As clarified by Cinelli, Forney and Pearl (2022), the selection of those variables that are *''closer''* to the outcome (Direct Connection) adds to the *efficiency* of the model and should be preferred. Hence, the researcher reaches the same conclusion as before and opts to add Trade Flow (Z) rather than (its parent) Trade Agreement (X) on the model.

The following Section will follow on from the SLR and attempt to outline all of the corresponding parent-child relationships as those have been discussed by the reviewed literature.

4.3.2 Discussion

Table 4-1 synopsises the parent-child relationships between the variables that were identified in the SLR (Chapter 3). The synopsis includes both direct parent-child relationships between specific variables and the establishment of a Direct Connection (highlighted in bold) but also any other parent-child relationship between any two variables in the system. This process suggests that Trade Flow, Colonial Ties, Connectivity, ECA Routing, Logistics Performance, Trade Imbalance, Trade Facilitation and Reefer Cargo are the variables most likely to have a direct association with Direct Connection.

Once all relationships are listed and justified (Table 4-1) they are then depicted in Figure 4.5. The latter effectively aggregates the relationships from Table 4-1 and illustrates (a) whether a variable has a direct or an indirect association with the establishment of a Direct Connection; (b) the corresponding paths (both direct and indirect) between all variables and Direct Connection; and (c) any further interrelations between any two variables according to the SLR.

#	Variable	Parent – Child Relationships	SLR Justification
(1)	Affiliated Terminal	Affiliated Terminal -> Connectivity	The affiliation of a liner with a terminal may influence the decision of the corresponding shipping alliance to call at this terminal with at least one service Notteboom *et al.* (2017) thus boosting the connectivity of the port (e.g. larger vessels, extra services etc.) and consequently the connectivity of the country.
(2)	**Colonial Ties**	Colonial Ties -> **Direct Connection**	Ducruet and Zaidi (2012) found concrete evidence that there might be long-distance connections that can be attributed to former colonial relationships. Ducruet, Rozenblat and Zaidi (2010) also highlighted the links between countries with former colonial ties.
		Colonial Ties -> Trade Flow	Common colonial ties between countries have been identified as an important variable for the explanation of bilateral trade flows in container transport (Biermann, 2012).
(3)	Common Border	Common Border -> Trade Flow	Gong *et al.* (2018) studied the key drivers of the international (air) freight trade network of China and found that a land border can decrease the bilateral trade flows between countries.
(4)	Common Language	Common Language -> Trade Flow	Gong *et al.* (2018) claimed that China tends to trade more with regions that share common cultural aspects such as language (e.g. Hong Kong, Macao, Taiwan).
(5)	**Connectivity**	Connectivity -> **Direct Connection**	Overall, calling at a node which has high connectivity can offer further opportunities for reaching other nodes. This is considered an attractive factor for a carrier in order to establish a direct call (Notteboom, 2004c).
		Connectivity -> Trade Flow	Hoffmann, Saeed and Sødal (2020) discussed the academic consensus regarding the importance of a country's enhanced shipping connectivity which reduces transport costs and thus promotes trade and access to international markets.
(6)	**ECA Routing**	ECA Routing -> **Direct Connection**	The establishment of an ECA may push operators to sail longer distances in order to completely avoid or reduce steaming through the ECA or deliver at an alternative port and then a shift to other modes should this be operationally attainable (Fagerholt *et al.*, 2015). The latter could mean the exclusion of a node as a direct call.
(7)	GDP per Capita	GDP per Capita -> Trade Flow	Vidya and Taghizadeh-Hesary (2021) combined network analysis with econometrics in order to test how a series of variables may impact bilateral trade connectivity at country level. They showed that an increase in GDP per Capita can boost bilateral trade connectivity between partners.

(8)	**Logistics Performance**	Logistics Performance -> **Direct Connection**	Saeed and Cullinane (2021) concluded that if a country manages to improve its LPI score performance, it is more likely to connect with targeted trade partners.
		Logistics Performance -> Trade Flow	Chang *et al.* (2020) noted that an advanced maritime-related logistics and infrastructure system as reflected on the LPI score of a country, implies higher reliability and efficiency thus leading to higher trade movements due to lower trade costs.
		Logistics Performance -> Reefer Cargo	Schwartz, Guasch and Wilmsmeier (2009) noted that the performance of the logistics system in factors such as customs clearance and border crossings are of pivotal importance towards the efficient and timely transportation of food cargo. Any delays are particularly detrimental for the stakeholders of distinct supply chains transporting sensitive cargo such as perishable products.
(9)	Market Concentration	Market Concentration -> Connectivity	Lim and Das (2009) concluded that initially the number of the liner shipping companies (carriers) to enter a trade route is expected to increase but as competition intensifies this trend is expected to decrease. *"The number of liner shipping companies that provide services from and to the country*" is actually one of the definitive factors of Connectivity (as the latter is measured by UNCTAD and LSCI (Hoffmann, Van Hoogenhuizen and Wilmsmeier, 2014)).
(10)	**MSR Routing**	MSR Routing -> **Direct Connection**	Pan *et al.* (2020) stated that since the introduction of the Maritime Silk Route (MSR) initiative, China has been promoting more direct connections between nodes across the MSR. This initiative has been implemented in the form of partial subsidies to shipping companies through local governments in order to support direct links.
(11)	Nautical Distance	Nautical Distance -> Voyage Cost	Notteboom (2012b) commented that nautical distance is associated with fuel consumption and may represent a concern for liners although the severity of the concern fluctuates depending on the fuel price.
		Nautical Distance -> Trade Flow	Guerrero, Claude and Ducruet (2015) showed that shipping is still a ‘’distance-constrained’’ industry and that the corresponding importance of distance for bilateral trade flows is expected to be high and negative.
(12)	Political Stability	Political Stability -> Connectivity	The avoidance of politically unstable areas (e.g. unrest around Suez Canal) is taken into consideration by carriers in order to form a reliable schedule for their network (Pham, Kim and Yeo, 2018) thus Connectivity may be impacted.

		Political Stability -> Logistics Performance	Jia, Lee Lam and Tran (2020) indicated that sailing via areas characterised by political instability and high risk can contribute to uncertainty which increases the cost of time in liner business (i.e. time uncertainty). The latter is a component of the Logistics Performance of a country (measured by LPI) regarding the "*The frequency with which shipments reach consignees within scheduled or expected delivery times"* (The World Bank, 2022b).
		Political Stability -> Port Infrastructure	Yap, Lam and Notteboom (2006) recognised political stability as an encouraging factor for specialised container terminal operators to increase presence in East Asia. This development consequently granted an important boost of efficiency to emerging nodes.
(13)	Port Infrastructure	Port Infrastructure -> Connectivity	Overall, the generation of an end-to-end link (direct connection) and a sizeable container traffic can only be enabled if the bilateral trade potential is supported by a respective upgrade in infrastructure that in turn secures efficiency. The latter can then allow the integration of a node into deep-sea (i.e. connections between important and remote nodes) networks (Robinson, 1998).
		Port Infrastructure -> Logistics Performance	Jia, Lee Lam and Tran (2020) argued that carriers aim to minimise as much as possible the uncertainty of their business and that poor port infrastructure increases the cost of time in liner shipping (i.e. failure to meet pro-forma schedules and to serve just-in-time supply chains). Saeed and Cullinane (2021) noted that the logistics performance of a country as measured by the LPI incorporates the port sector since port are an integral part of the overall supply chain of the country.
		Port Infrastructure -> Trade Flow	Biermann (2012) indicated that port infrastructure may play a significant role towards the development of bilateral trade flows.
		Port Infrastructure -> Trade Facilitation	Clark, Dollar and Micco (2004) found that port efficiency is also an important determinant of transport costs and thus contributes to an improvement in Trade Facilitation.
(14)	**Reefer Cargo**	Reefer Cargo -> **Direct Connection**	Recent changes in trade mix have highlighted the significance of refrigerated products such as fruits and fish and have encouraged the growth of the respective transportation capacity, aiming to serve the corresponding trade flows (Wilmsmeier, Martinez-Zarzoso and Fiess, 2011).

		Reefer Cargo -> Trade Flow	There can be particular countries (e.g. the islands of the Eastern Caribbean Sea) where more than half of the imports by value correspond to perishable products of the food supply chain, such as vegetables, fruits, dairy, fish, and meat (Schwartz, Guasch and Wilmsmeier, 2009). The food supply chain expansion may also be a driver for distinct increases in trade flows such as in the case of vegetables and fruits exports from Patagonia in Argentina (Wilmsmeier, Martinez-Zarzoso and Fiess, 2011).
(15)	Route Deviation	Route Deviation -> Nautical Distance	The establishment and endurance of a direct shipping connection between countries is heavily related to the geographical location (thus nautical distance) of each partner with regard to the main shipping arteries (i.e. the additional Nautical Distance that vessels need to cover in order to reach those countries). Hence, it is not unlikely that countries which are not included on the major maritime routes may suffer from a degree of latency with regard to direct shipping connections (Fugazza, 2015).
(16)	Seasonality	Seasonality -> Trade Flow	Seasonality may cause a fluctuating trade demand (transportation) and thus may push liner shipping companies to review and potentially revise their network every 3-6 months (Huang, Hu and Yang, 2015).
(17)	Security Issues	Security Issues -> Port Infrastructure	Clark, Dollar and Micco (2004) claimed that port inefficiency is not only associated with the infrastructure but extends to the levels of crime related to the port. When organised crime increases from the 25th to the 75th percentile, port efficiency decreases from the 50th to the 25th percentile.
(18)	Trade Agreement	Trade Agreement -> Trade Flow	According to Lee and Lee (2012), the signing of a trade agreement between trade partners located in separate regions (i.e. distant from each other) promotes the increase of trade exchanges between them over the regional trade exchanges between nearby countries. Consequently, the demand for additional deep-sea direct connections is expected to increase.
		Trade Agreement -> Trade Facilitation	Free Trade Agreements (FTAs) can signal the removal of unnecessary trade barriers between trade partners and thus accelerate a direct shipping connection. For instance, a decisive step towards the establishment of a direct shipping connection between China and Taiwan was the signing of The Cross-Strait Sea Transport (CST) Agreement in November 2008. A direct connection was granted the following month with the benefit of lower cost and shorter transit time (Yang, Chung and Lee, 2014).

(19)	**Trade Facilitation**	Trade Facilitation -> **Direct Connection**	Ducruet (2008) underlined that an appealing trade potential and modernised port infrastructure may not be adequate conditions for the attraction of direct services by a country if the latter is characterised by broader limitations in trade facilitation (e.g. trade embargo).
		Trade Facilitation -> Connectivity	Vidya and Taghizadeh-Hesary (2021) claimed that any tariff or non-tariff barriers to trade facilitation can have a negative impact on countries' connectivity.
		Trade Facilitation -> Logistics Performance	According to Clark, Dollar and Micco (2004) excessive regulation leads to logistics incompetence (including increases in ports inefficiency and transport costs).
		Trade Facilitation -> Trade Flow	Bertho, Borchert and Mattoo (2016) showed that bilateral flows can be between 17% and 25% lower for routes that are characterised by policy barriers, reflecting the damaging impact of stringent policies with regard to trade facilitation.
(20)	**Trade Flow**	Trade Flow -> **Direct Connection**	Halim, Kwakkel and Tavasszy (2015) noted that the emergence of bilateral trade flows between certain countries can lead to new direct shipping connections that will accommodate the increasing need for transportation among trade partners (e.g. developing countries and the rest of the world). Historically high volumes of trade are among the most essential drivers for the establishment of a direct shipping connection between trading countries (Fugazza, 2015).
		Trade Flow -> Connectivity	Wang and Wang (2011) suggested that the reduced maritime trade activity of certain regions has a knock-on effect on their connectivity. Those regions are pushed to the periphery of the container shipping network with the need for feeder connection between them and the main network.
(21)	**Trade Imbalance**	Trade Imbalance -> **Direct Connection**	Trade imbalance (i.e. the difference between the value of exports and imports of a country) may affect the container management cost (empty repositioning cost, capital cost of own fleet, leasing cost and storage cost) of a shipping company and, depending on the respective overheads, it may have an impact on the decision by the company between a hub-and-spoke and a direct call (multi-port) setup (Imai, Shintani and Papadimitriou, 2009).

(22)	Transit Time	Transit Time -> Trade Flow	Should transit time be excessively prolonged this may affect the overall probability that bilateral trade may happen, although estimates may fluctuate for different types of goods. This was discussed by Hummels and Schaur (2013) who indicated that an extra day in transit counts as an equivalent of 0.6%-2.3% ad-valorem tariff increase.
		Transit Time -> Reefer Cargo	Transit time is particularly essential for the design of a liner shipping service when the targeted cargo is of perishable or short-life cycle nature (Wang, Meng and Lee, 2016) since the time-to-market becomes a critical factor (Brouer *et al.*, 2014).
(23)	Voyage Cost	Voyage Cost -> Trade Flow	Deardorff (1998) indicated that as long as the transport cost declines, bilateral trade between distant countries is expected to expand.
		Voyage Cost -> Connectivity	According to Pham, Kim and Yeo (2018) voyage cost may determine the selection between alternative routes (and thus influence the connectivity of the involved nodes) since it largely defines the overall cost structure and the profitability of a shipping company.

Table 4-1 – Parent-child variable relationship based on the SLR

The causal assumptions of a study are commonly visualised in a Directed Acyclic Graph (DAG) (Lederer *et al.*, 2019). Recent developments in Causal Inference include specialised computer programs that highlight biased paths in a given DAG and can automatically suggest which variables in the graph are good or bad controls (Cinelli, Forney and Pearl, 2022). This research has utilised the web application of *Daggity* (Textor *et al.*, 2016) because of its transparent function and well-documented rationale. The compilation of the DAG that largely underpins this research in Daggity served not only for the illustration of the parent-child assumptions derived from the SLR but also utilised the functionality of the application to check whether those assumptions violate any causal effect criteria suggested by the Causal Inference theory. Should any of those criteria be violated, the corresponding paths between variables are automatically flagged with red colour by Daggity. The corresponding DAG is illustrated in Figure 4.5 and includes no biasing (red) paths:

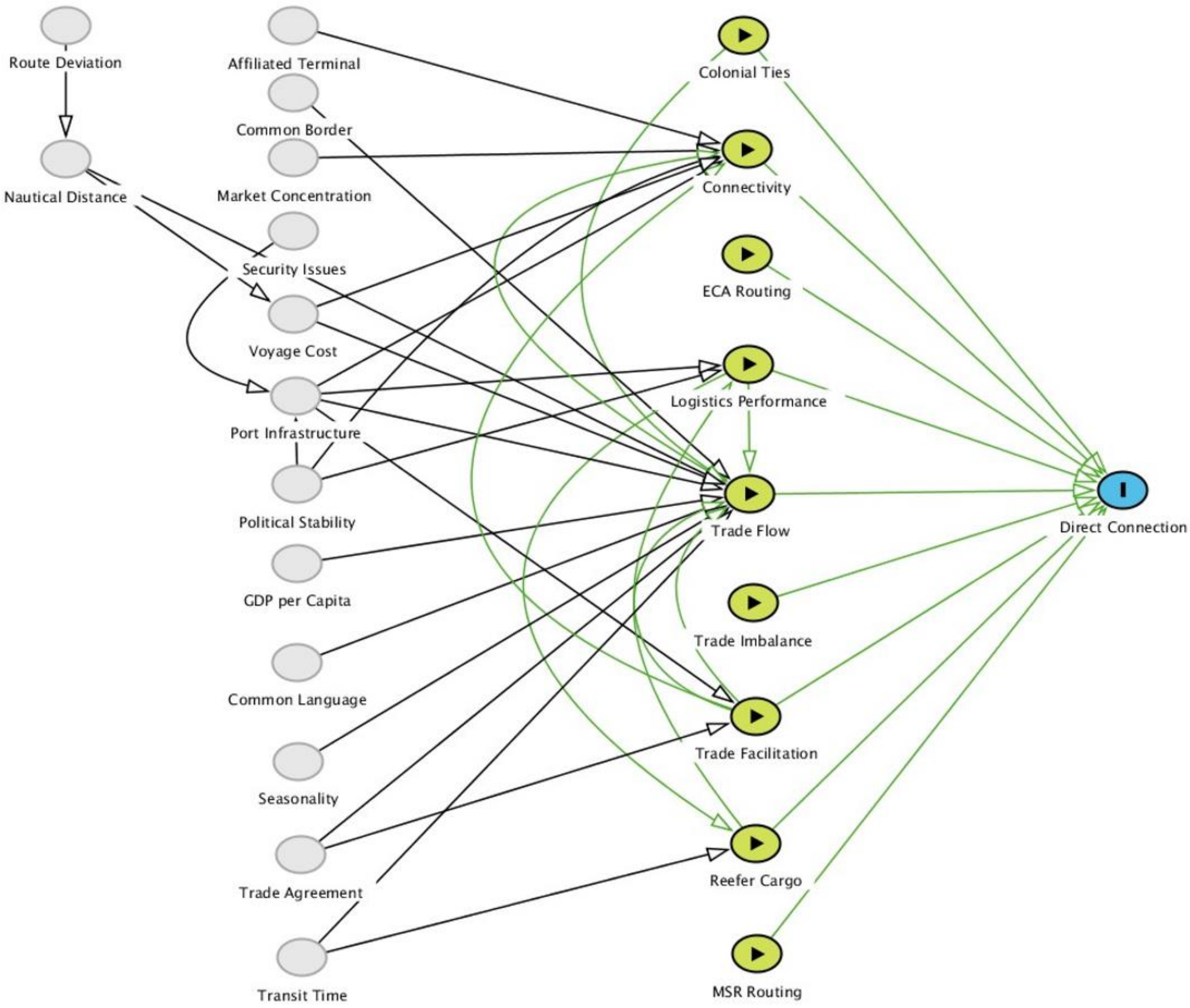

Figure 4.5 – Causal Assumptions of the Research

In Figure 4.6, the variables that have been identified as the ones which are likely to have a direct association with Direct Connection (i.e. Trade Flow, Colonial Ties, Connectivity, ECA Routing, Logistics Performance, Trade Imbalance, Trade Facilitation and Reefer Cargo) are shown in bold. This is effectively a cross-comparison of the Causal Graph assumptions and the importance that was assumed for the factors (variables) in the SLR (Chapter 3) based on the number of publications that discussed each variable. This cross-comparison indicates the following:

- The majority of the selected variables (7 out of 9) are expected to have a positive impact towards the establishment of a direct connection, according to the SLR.
- The most important variables of positive impact – according to the SLR – are also picked by the Causal Graph process (i.e. Trade Flow, Connectivity, Trade Facilitation and Logistics Performance). Port Infrastructure is seemingly an exception but in practice it is incorporated in Logistics Performance, as

discussed in Table 4-1. Colonial Ties, MSR Routing and Reefer Cargo are also picked by the Causal Graph process although they appeared in rather low positions in the ranking based on the SLR. Colonial Ties is also a variable with ambiguous impact according to the SLR.

- Regarding the variables which are expected to have a negative impact – according to the SLR – only 2 are picked (ECA Routing, Trade Imbalance) which have been moderately discussed in the literature. Interestingly, both of them were also suggested to have an ambiguous impact according to the SLR.

- The outcome of the Causal Inference approach effectively suggests a diverse mix of variables which (a) are expected to have a positive / negative impact; (b) their expected impact has been defined or is ambiguous; and (c) have been extensively / moderately discussed in the literature. The analysis of this dataset may yield fruitful results and shed light on whether the expected magnitude and sign (positive / negative) of those variables can be confirmed by the statistical analysis of this research.

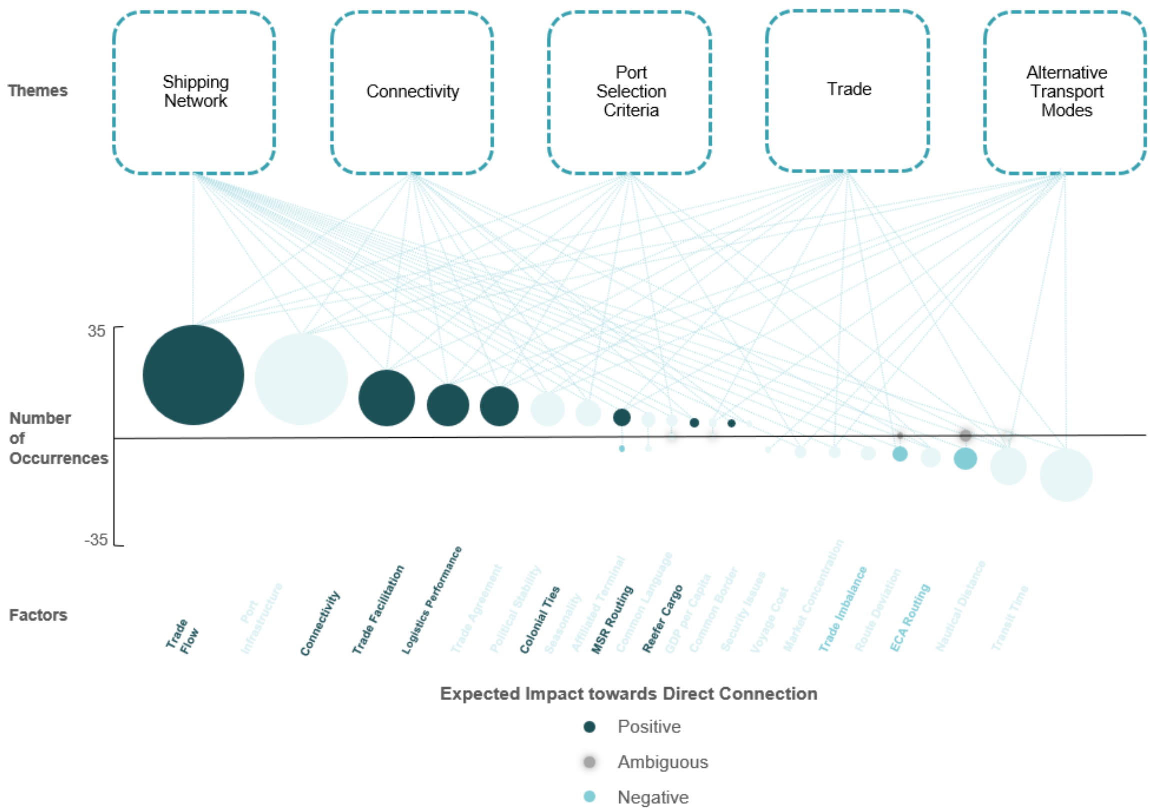

Figure 4.6 – SLR framework and Selected Variables by Causal Inference

4.3.3 Caveats

The use of the causal graph as guidance for the selection of variables takes into consideration the following caveats:

- Graph Completeness: A causal diagram effectively encodes the understanding of a researcher about the function of the world (regarding the corresponding research field) and it is built upon qualitative assumptions (Elwert, 2013). However, building a causal graph based on the understanding of a researcher about the world is likely to introduce a degree of subjectivity and thus bias to the research. As suggested by Westreich and Greenland (2013), a rational basis for building a causal graph is the understanding of the literature. In order to reduce as much as possible any subjectivity bias, the researcher decided to build the causal graph by closely following the findings of the SLR (Chapter 3). As discussed in Section 3.2, a systematic literature review avoids the possible bias imposed by the implicit likings of the researcher, achieving thoroughness (Wang and Notteboom, 2014) and thus making a decisive step towards scientific conclusions (Rousseau, Manning and Denyer, 2008). Thus, a causal graph built upon a process designed to minimise bias (SLR) should be able to provide a valuable guidance for the compilation of a model under the same principles. Undoubtedly, a subjective observer could propose additional paths in the displayed DAG. However, the researcher is of the view that all direct associations suggested by theory (i.e. SLR) are present in the DAG and thus the diagram provides a solid basis for further modelling.

- Causality: As discussed in Section 4.3.1, extracting causal claims from an observational study (such as this research) requires a careful approach. Thus, the causal graph of the previous Section is (at this stage of the research) only a reflection of the assumptions of the study. As underlined by Cooper and Glymour (1999), in observational studies, causal effects cannot either be truly accepted or rejected without verification by subject-matter experts such as practicing professionals. This is a task that Chapter 6 aims to accomplish.

- Time Horizon: the use of a causal graph assists solely for outlining the assumptions of the study based on the SLR and the selection of an unbiased and efficient set of variables. The graph however does not depict (at this stage of the research) the full set of the assumptions and dependencies that may underpin the final econometric model which may be applicable for this research. The main reason is that the graph is only a non-parametric representation of the assumed dependencies between the variables at a given point in time. Since this research opted for a longitudinal analysis (see Section 3.12), a graphical representation that attempts to visualise the underlying modelling effort of the research may expand to illustrate further characteristics of the analysis including time dimensionality and clustering by country.

4.4 Data Sources and Metrics

This research utilises a longitudinal dataset (2012-2020) which (1) details the containerised trade flows between the UK and its partners (i.e. trading countries) per year; (2) cross-checks whether there has been a direct container shipping route connecting the UK with those countries for the 2012-2022 period; and (3) employs various metrics to quantify the driving factors (variables) that may have contributed towards the establishment – or the disruption – of a direct container shipping connection between trading countries (Figure 4.7).

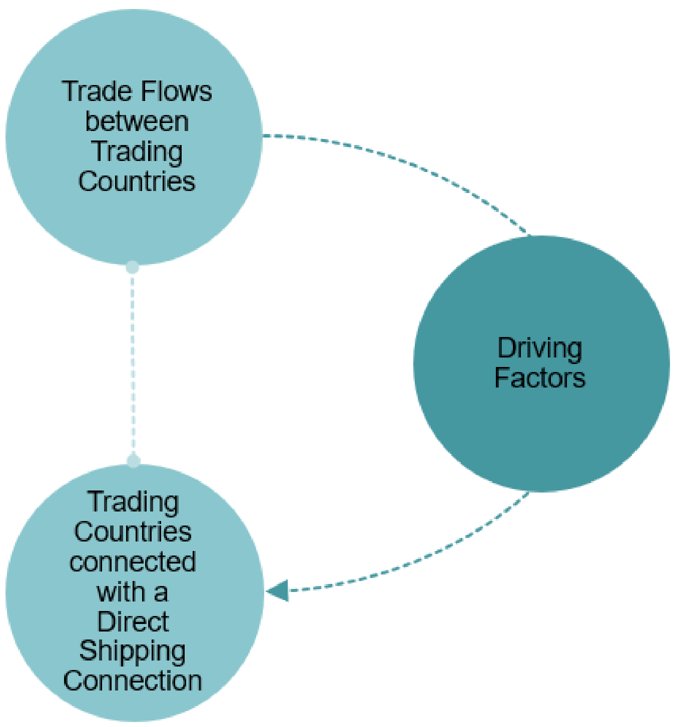

Figure 4.7 – Structuring the Analysis dataset

As discussed in Section 4.2 and as it is also thoroughly justified later on this Chapter (see Section 4.4.8), the data source with regard to the container flows between the UK and its partners is the publicly available statistics provided by the DfT[8].

The corresponding data source with regard to the respective shipping connections is the commercial database of COMPAIR Data (Bluewater Reporting, 2021) which has been used for relevant studies in the past (e.g. Wilmsmeier and Sánchez, 2010; Wilmsmeier and Notteboom, 2011; Bartholdi, Jarumaneeroj and Ramudhin, 2016). The database holds detailed historical data regarding the itineraries of the container services and the characteristics of the deployed fleet. Specifically, the database is one of the very few commercial products that contain a systematic historical record of the container shipping services with global coverage. The data covers approximately 250 trade routes (including niche markets), 300 carriers (including historical players which are not active anymore), 2,600 service itineraries (which are audited and updated monthly), 13,300 vessels (along with their container capacity and calling ports), and 11,500 ports worldwide (Bluewater Reporting, 2020). For the purpose of this research, unlimited access to the database has been granted with the generous support of the database owner (Bluewater Reporting). The digitised organisation of the historical data allows for broad and detailed downloads and the corresponding data has been proved of critical importance for the completion of this research. The starting point of the analysis (2012) is effectively the year with the oldest data available by the COMPAIR database regarding container service itineraries. The ending point of the analysis (2020) includes the impact of the COVID-19 crisis in the first half of the year as well as the gradual recovery of the containerised shipping in the second half of the year. Thus, the analysis period allows for testing the development of the direct shipping connections under various circumstances. Specifically, this period includes a few years that were characterised by overall normality, an endogenous crisis caused by the collapse of Hanjin in 2017 and finally an exogenous crisis caused by the COVID-19 pandemic (2020).

Each country with recorded containerised cargo exchanges with the UK is assessed based on selected metrics per variable (Table 4-2). The rationale for the selection of each metric by variable is discussed in Sections 4.4.1 to 4.4.9.

[8] Data up to 2020 is available at https://www.gov.uk/government/statistics/port-freight-annual-statistics-2020

#	Variable	Metric	Prototype / Database	Source / Data
(1)	Colonial Ties	Binary Indicator	Database	CEPII
(2)	Connectivity	Liner Shipping Connectivity Index (LSCI)	Database	UNCTAD
(3)	ECA Routing	Binary Indicator	Prototype	IMO
(4)	Logistics Performance	Adjusted Logistics Performance Index (ALPI)	Prototype	World Bank
(5)	MSR Routing	Binary Indicator	Prototype	UNESCO
(6)	Reefer Cargo	Reefer Cargo Index (RCI)	Prototype	Bluewater Reporting
(7)	Trade Facilitation	Trade Freedom	Database	The Heritage Foundation
(8)	Trade Flow	Containerised trade exchanges between UK and trading countries	Database	DfT
(9)	Trade Imbalance	Containerised trade imbalance between UK and trading countries	Database	DfT

Table 4-2 – Variables and Applicable Metrics

4.4.1 Colonial Ties

The literature commonly tracks the colonial ties between countries from the Center for Prospective Studies and International Information (CEPII) database. CEPII was founded in 1978 and is a public French organisation which consolidates data and studies on macroeconomics, trade finance and migration with the aim to enhance the dialogue between academia and practitioners from both the public and private domains. Specifically, the data regarding colonial ties between countries is provided by the CEPII's Gravity database (Conte, Cotterlaz and T. Mayer, 2022) which is regularly updated and it has been widely used by various scholars (e.g. Biermann, 2012; Fugazza, 2015; Saeed, Cullinane and Sødal, 2020).

The Gravity database is the main data source for the compilation of *''gravity-type''* models which are commonly employed in research regarding trade flows. Those models are in turn based on an analogy of the bilateral trade flows to the force between two bodies, as this derives from Newton's Law of Universal Gravity (Baier and Standaert, 2020). The latter proposes that *''the force of attraction between two bodies is proportional to the product of their masses and inversely proportional to their distance squared''(ibid).* Respectively, the econometric gravity model in its basic form proposes that the bilateral trade flows between countries i and j (X_{ij}) can be explained by a proportional relationship to their GDP product, an inversely proportional relationship to their distance and a gravitational constant (Biermann, 2012) which is also included in Newton's Law equation:

$$X_{ij} = \mathrm{G} \times \frac{GDP_i \times GDP_j}{Distance_{ij}} \qquad (4\text{-}1)$$

As noted by Bottasso *et al.* (2018), gravity equations have been a traditional estimation method of international trade flows since at least the seminal work of Tinbergen (1962). The classic gravity equation has been amended and augmented by various scholars (de Benedictis and Tajoli, 2011) while its theoretical basis and statistical robustness has also been scrutinised (Anderson and Wincoop, 2003). However, gravity-type models have been the *''workhorse''* for the analysis of international trade (Fugazza and Hoffmann, 2017) and have been also widely applied in panel data analysis or have contributed to panel data analysis with gravity-type variables (e.g. Colonial Ties, Common Language etc.).

This research does not focus on the calculation of bilateral trade flows between two countries but rather utilises trade flows as one of the possible drivers towards the establishment of a direct connection between two countries. Thus, this research does not consider a gravity-type model as an estimation method. However, this research utilises the Gravity database for the extraction of the respective data regarding Colonial Ties.

The corresponding data regarding Colonial Ties is derived by the respective *''col45''* column of the dataset which corresponds to *''1 if countries are or were in colonial relationship post 1945''* or 0 otherwise (Conte, Cotterlaz and T. Mayer, 2022). From a total of 136 trading countries that this research analyses, CEPII suggests that 44 of them (32%) have had a colonial relationship with the UK post 1945. This substantial share confirms that the UK is indeed a suitable case study for research that wishes to examine – among other variables – the importance of colonial ties for the establishment of a direct connection between trading countries in container shipping.

4.4.2 Connectivity

Connectivity in container shipping literature is a seminal topic and has been widely discussed over the years. This research has extensively addressed Connectivity in the SLR (Chapter 3) and indicated that certain publications have discussed Connectivity explicitly as a standalone factor whereas other publications refer to factors that impact Connectivity, such as macroeconomic as well as trade-related factors. As also addressed in Chapter 3, various metrics have been developed over the years that aim to quantify the Connectivity of a shipping network node either at port or country level (Table 4-3):

Section	Source	Rationale / Outcome	Analysis Level
3.7	Bartholdi et al. (2016)	Each node partially assumes the network importance of its neighbours	Port
3.7	Cullinane and Wang (2009)	Accessibility is a determinant of the attractiveness of a node for the shippers and the carriers of a shipping network	Port
3.7	Song et al. (2019)	A node of the maritime network will establish its importance if it manages to connect with other essential nodes	Port
3.7	Xu et al. (2020)	Proposal of an index that employs network analysis attributes and assists to the prediction of the trade flows for a country	Country
3.9	Wilmsmeier and Martínez-Zarzoso (2010)	Proposal of a trade-driven measure which can holistically capture the relative position of a country within the container shipping network	Country
3.11	Hoffmann, Van Hoogenhuizen and Wilmsmeier (2014)	A Connectivity index that accounts for both direct and indirect connections between countries	Country

Table 4-3 – Connectivity Metrics identified in the SLR (Chapter 3)

This research accepts that Connectivity can be overall defined as the level of a node's integration within a network and its ability to reach other nodes (Calatayud *et al.*, 2016). This definition matches the purpose of the most recognisable and widely used Connectivity metric in the context of containerisation at country level which is the LSCI (see Section 3.6). The latter was developed by UNCTAD in 2006 and was updated and enhanced in 2019 (UNCTAD, 2019). Specifically, UNCTAD suggests that the LSCI '*'indicates a country's integration level into global liner shipping networks"* (UNCTAD, 2019). Various publications – which were also discussed in Chapter 3 – outline why LSCI can quantify the integration of a country in the shipping network:

- According to Wilmsmeier, Martinez-Zarzoso and Fiess (2011), the LSCI by UNCTAD is a relevant proxy of the accessibility of a country to the global trade network. Wilmsmeier, Martinez-Zarzoso and Fiess (2011) also noted that a high LSCI score reveals an easier access to liner shipping services of high capacity and frequency which boosts a country's participation in the international maritime and thus trade network.
- The higher the connectivity of a country, as reflected by its LSCI score, the more likely it is to attract additional services which eventually will promote its

better access to the international trade network (Wilmsmeier and Sánchez, 2010).

- Chang *et al.* (2020) indicated that the connection of a country to the global shipping network is reflected on its LSCI score and that the higher the score the more likely it is to attract higher shipping capacity and frequency.

Moreover, LSCI is published by a very credible source (i.e. UNCTAD) and covers 179 economies[9] (as of end 2020). Thus, LSCI is a Connectivity metric which:

- derives from a dataset of high quality and broad geographic coverage
- is widely accepted by the literature
- synopsises Connectivity at country level in a fashion which is perfectly aligned with the definition of Connectivity that this research accepts

Hence, this research adopts the LSCI as the corresponding Connectivity metric. Since LSCI data is updated on a quarterly basis and this research is oriented towards a longitudinal analysis on an annual basis, the corresponding annual figure per country is the arithmetic mean of the quarterly LSCI scores of a given year. Figure 4.8 illustrates a comparison of the UK's LSCI score with the average, minimum and maximum global LSCI score for each year of the examined period:

Figure 4.8 – LSCI score development: UK vs Global Values, Source: Author based on UNCTAD data

[9] UNCTAD uses the term *''economy''* to refer to countries or other *''territorial units''* (e.g. China, Taiwan Province of).

4.4.3 ECA Routing

As previously discussed (Section 3.6), an Emission Control Area (ECA) is a designated sea area in which strict limitations for vessel emissions have been imposed, as per Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL) (IMO, 2019a). MARPOL dictates that the vessels which sail within ECAs should switch to a compliant fuel such as Low Sulphur Marine Gas Oil (LSMGO) or Ultra Low Sulphur Fuel Oil (ULSFO) (Ship and Bunker, 2022) in order to meet the corresponding limits of sulphur oxide (SOx), nitrogen oxide (NOx) and particulate matter (PM), depending on the requirements of each ECA (IMO, 2019b).

There are 4 designated ECAs defined by MARPOL Annex VI which regulate SOx and PM emissions: (a) the Baltic Sea; (b) the North Sea (and the English Channel); (c) the North America (USA and Canada Atlantic / Pacific Coasts); and (d) the USA Caribbean Sea (Fagerholt *et al.*, 2015; Chen, Yip and Mou, 2018). The latter two also regulate NOx emissions (Fagerholt *et al.*, 2015; Chen, Yip and Mou, 2018). The USA Caribbean Sea refers to Puerto Rico and the US Virgin Islands (IMO, 2022). Apart from the ECAs regulated by IMO, China has also proceeded to define a national ECA for sulfur emissions for all vessels sailing within 12 miles from the Chinese coasts (BIMCO, 2018) excluding however the waters under the jurisdiction of Hong Kong, Taiwan and Macau (NEPIA, 2020).

The enforcement dates of the ECAs are illustrated in Table 4-4:

ECA Area	Enforcement Date
Baltic Sea	19 May 2006
North Sea	22 November 2007
North America	1 August 2012
USA Caribbean Sea	1 January 2014
China Territorial Waters	1 January 2019

Table 4-4 – Enforcement date by ECA, Source: Author based on IMO (2019b) and BIMCO (2018)

The research aims to explore whether the establishment of an ECA may trigger carriers to rethink their scheduling decisions and possibly to prevent them from calling at specific countries within the boundaries of an ECA. The exploration of this point can be of particular usefulness not only regarding the analysis of the carriers' past decisions but in order to also understand their potential future actions since ECA areas (or other relevant schemes) may continue to be introduced. For instance, a new designated ECA (SOx) is going to be introduced in the Mediterranean Sea with an expected enforcement in 2025 (IMO, 2022).

As the UK is by definition within the boundaries of the North Sea ECA, the analysis measures how the possible inclusion of other trading countries within an ECA may impact the establishment of a direct connection with the UK. Hence, the researcher proceeds to flag accordingly each country based on whether it has been included within the geographical boundaries of an ECA or not (i.e. 0 for no inclusion, 1 for inclusion) thus indicating whether any direct connection with the UK should be classified as an ECA Routing or not. The classification takes into consideration the timings of each ECA's establishment as presented in Table 4-4 (e.g. a direct connection between the UK and China is considered as an ECA Routing only from 2019 onwards). This classification however hides a further challenge for those countries that due to geography have some of their ports within and some others outside an ECA. Those countries are Canada, France, Norway and Russia. A detailed check of the particular itineraries is subsequently performed to verify that when a connection is flagged as an ECA Routing then the corresponding itinerary has indeed utilised a port within ECA boundaries (e.g. a connection between Russia and the UK is considered as an ECA Routing if the Russian port call corresponds to Saint Petersburg but it is not considered as an ECA Routing if the Russian port call corresponds exclusively to Vladivostok).

4.4.4 Logistics Performance

As suggested by Notteboom (2004a), a harmonised functioning of the entire logistics system is critical for shippers who seek for *''synchronization''* of carriers' services across the full spectrum of the logistics system, both in the foreland as well as the hinterland system in order to avoid or minimise any disruption of their production. As also discussed in Section 3.8, carriers tend to holistically assess the overall logistics network of a node and seek for efficiency both at port and in the hinterland (Tran, 2011; Wiegmans, Hoest and Notteboom, 2008; Wong, Yan and Bamford, 2008). Thus, this research needs a relevant metric that can quantify the performance of a country across its logistics network.

Although Supply Chain and Logistics are fields with a large body of literature, there is limited availability on relevant metrics that quantify the performance of a logistics network at an international level. A promising approach is offered by the World Bank and the Private Participation in Infrastructure (PPI) database which effectively quantifies on an annual basis the degree of the private (only) investment on the logistics infrastructure of a country (The World Bank, 2022c). However, this metric has two major disadvantages: (a) it is characterised by limited data availability (i.e. only 10 countries included in the 2012 dataset and 25 countries respectively in the 2020 dataset and (b) it depicts the degree of the investment but not the actual performance of the assets and the logistics network (i.e. there is no guarantee that a very high investment secures an efficient logistics network).

Furthermore, there are a few additional indices which quantify the performance or the stresses across the logistics network but only at city level such as the City Logistics Indices (CLI) (De Marco, Mangano and Zenezini, 2018) or at national level such as the UK Logistics Confidence Index (Barclays and BDO, 2022) or even provide an aggregate figure at a global level such as the Global Supply Chain Pressure Index (GSCPI) (Federal Reserve Bank of New York, 2022).

Consequently, the literature has widely utilised the Logistics Performance Index (LPI) (see Section 3.7) (e.g. Zaman and Shamsuddin, 2017; Aldakhil *et al.*, 2018; Dang and Yeo, 2018; Sharipbekova and Raimbekov, 2018; Khan *et al.*, 2019; Anser *et al.*, 2020; Magazzino, Mele and Schneider, 2022). The LPI as a metric has been utilised by various publications discussed in the SLR (Chapter 3) (e.g. Ojala and Çelebi, 2015; Chang *et al.*, 2020; Saeed and Cullinane, 2021). Further to its wider acceptance and use, the LPI dataset also provides a respective score for over 150 countries and thus it is a popular source not only because of its quality but also because of the broad geographic coverage it provides. Hence, this research considers the LPI as the most relevant metric for the quantification of the Logistics Performance of a country.

The downsize of the LPI however is the scarcity of its data due to the fact that the corresponding report is biannual (post 2010 and until 2018) while no report was conducted in 2020 due to COVID-19 complexities and the latest report became available in 2023 (i.e. reports are available for 2007, 2010, 2012, 2014, 2016, 2018, and 2023). As commented by Magazzino, Mele and Schneider (2022) this is potentially a reason why the majority of the literature that has utilised LPI has also inevitably produced short-term analysis (e.g. cross-sectional for a single year). Thus, although the LPI is seemingly a relevant metric for the purpose of this research, its biannual availability is slightly problematic since this research aims to undertake an annual approach from 2012 to 2020.

Additionally, a thorough review of each LPI report provides important insights regarding the period that the scores effectively cover. For instance, the 2018 report suggests that "*For the 2018 edition, the survey was open between September 2017 and February 2018*" (The World Bank, 2018) thus the scores of the 2018 report correspond to the industry's perception for both 2017 and 2018. This is not however a standard practice and a cautious approach may be needed. For example, the 2012 report corresponds exclusively to 2011 data. This research accepts that since the essence of the LPI is a scoring exercise based on the perceptions of the industry's stakeholders then this score actually reflects the performance of a given country in a given year. In order to capture the data on an annual basis without violating the fundamentals of the index generation, the researcher contacted the World Blank and the LPI team via email. The LPI team responded that a workaround based on the timing of the interviews is suggested. The corresponding analysis of the interview timings and the respective data availability for each targeted year is reported in Table 4-5:

Year	LPI Report Interviews	Data Availability Status
2012	2012 data refers to interviews undertaken within 2011 and thus has been deleted	Missing
2013	2013 data derives from 2014 LPI Report (see 2014)	Available
2014	2014 data refers to interviews undertaken between October – December 2013 and thus has been transferred to 2013	Missing
2015	2015 data derives from 2016 LPI Report (see 2016)	Available
2016	2016 data refers to interviews undertaken between October – December 2015 and March - April 2016 and thus has been used for both 2015-2016	Available
2017	2017 data derives from 2018 LPI Report (see 2018)	Available
2018	2018 data refers to interviews undertaken between September 2017 – February 2018 and thus has been used for both 2017-2018	Available
2019	No survey was conducted between 2019 and 2021 – the latest report was issued in 2023 and the data refers to interviews undertaken between September- November 2022	Missing
2020	No survey was conducted between 2019 and 2021 – the latest report was issued in 2023 and the data refers to interviews undertaken between September- November 2022	Missing

Table 4-5 – LPI Data Availability Status

The LPI team though also claimed that the *''official''* scores correspond to the published years (i.e. it cannot be claimed a 2013 LPI score since no *''official''* report was released). Thus, the researcher proceeds to build upon the official LPI scores based on Table 4-5 and proposes the *Adjusted* LPI (ALPI) as the metric that this research may employ. The ALPI utilises the available data by the official LPI reports and proceeds to fill in the remaining void years (i.e. 2012, 2014, 2019, and 2020). In order to fill the data for the missing years, the statistical software STATA is utilised and specifically the *tsfill* (*epolate*) option. The latter is a built-in function which is utilised specifically for filling the gaps in time-series datasets. The function is effectively a linear interpolation and extrapolation. The former is used to estimate the missing data between two existing datapoints (i.e. estimating 2014 using 2013 and 2015 data). The latter is a linear projection of the existing data to estimate a missing value outside the existing datapoints (Meijering, 2002; StataCorp., 2022e; StataCorp., 2022i). In this exercise the missing data is interpolated and extrapolated as follows:

- The data for 2012 is interpolated using 2011 and 2013 data. In order to allow interpolation for 2012 missing data, the process includes 2011 data which is available from 2012 LPI Report.
- The data for 2014 is interpolated using 2013 and 2015 data.
- The data for 2019 and 2020 is interpolated using 2018 and 2022 data. In order to allow interpolation for 2019 and 2020 missing data, the process includes 2022 data which is available from the 2023 LPI Report (see Table 4-5).
- The data for any missing year is extrapolated from its latest available data point in case there is no other available data point until the end of the period 2012-2020 (e.g. if the latest available data point for a country is for 2018 and this country is not included in 2022 data then a 2018 value is extrapolated for 2019 and 2020).

A random example (Australia) of the process before (LPI) and after the filling (ALPI) is illustrated in Table 4-6:

Country	Year	LPI	ALPI
Australia	2011	3.73	3.73
	2012		**3.77**
	2013	3.81	3.81
	2014		**3.80**
	2015	3.79	3.79
	2016	3.79	3.79
	2017	3.75	3.75
	2018	3.75	3.75
	2019		**3.74**
	2020		**3.73**
	2021		3.71
	2022	3.70	3.70
	MIN (2012-2020)	3.75	3.73
	MAX (2012-2020)	3.81	3.81
	AVERAGE (2012-2020)	3.78	3.77

Table 4-6 – LPI and ALPI of Australia

Notably, LPI and ALPI have identical maximum values and almost identical minimum and average values for the period 2012-2020. The same applies for the overall analysed dataset as well. Effectively, the generation of ALPI takes into consideration the dynamic development of the official LPI and utilises it in order to simply compensate for the missing values. ALPI is subsequently generated for all countries in the dataset.

4.4.5 MSR Routing

As previously discussed (Section 3.6), the Maritime Silk Road (MSR) is a strategic framework which aims to connect China with Europe through India and Africa (WTO, 2019) and it was introduced by China in 2013 (Jiang, Li and Gong, 2018). Pan *et al.* (2020) also included a separate direction of the MSR towards Australia and New Zealand. However, the latter has not gained any momentum because of Australia's reluctance to embrace the initiative, both for trade and geostrategic reasons (CSIS, 2018; Australian Institute of International Affairs, 2021). According to UNESCO (2020), the MSR has enhanced the cultural and trade background of the involved communities and in its modern version includes 54 countries spanning geographically from China to the United Kingdom.

In the context of this research, the examination of MSR Routing as a variable aims to measure whether countries located along the MSR may be encouraged to enhance their direct shipping connections and be benefitted by the initiative. Thus, the research proceeds to flag accordingly each country based on whether it has been included as a participant of the modern MSR in the corresponding MSR countries list generated by UNESCO (2020) or not (i.e. 0 for no inclusion, 1 for inclusion) from 2013 onwards (i.e. the introduction of the initiative). This indicates whether any direct connection with the UK should be classified as an MSR Routing or not. The corresponding list of UNESCO (2020) is accordingly processed and the landlocked countries are excluded (Afghanistan, Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Mongolia, Nepal, Tajikistan, Turkmenistan, and Uzbekistan). Those countries are effectively part of the *''New Economic Silk Road''*, an inland corridor through the Western and Central Asia (Pan *et al.*, 2020) which is out of the scope of this research. The final list includes the countries that are illustrated in Figure 4.9:

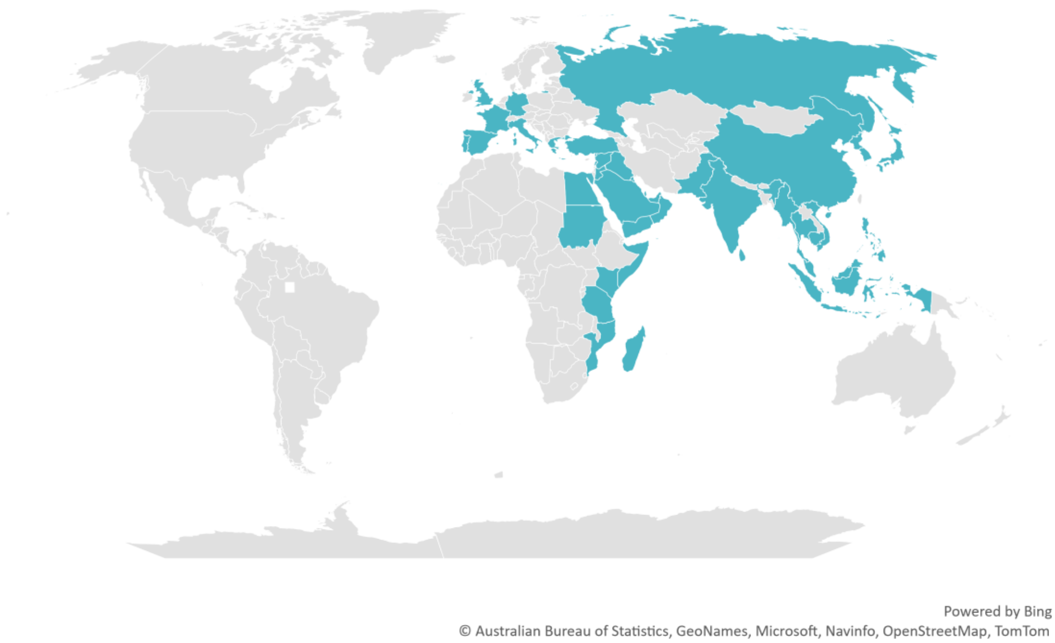

Figure 4.9 – MSR, Source: Author based on UNESCO (2020)

4.4.6 Reefer Cargo

Reefer containers usually accommodate perishable food and products such as meat, fish, dairy, vegetables, and fruits (Bernhofen, El-Sahli and Kneller, 2021). Additionally, reefer containers are widely used to carry pharmaceuticals by utilising the safety standards and the technological comforts (e.g. tracking, remote control etc.) that the specialised reefer container boxes can guarantee (Maersk, 2022). The special treatment of the refrigerated cargo results in considerably higher charges by the carriers which have been estimated to hover between 12% and 37% over standard charges for dry (i.e. non-refrigerated) cargo (Wilmsmeier and Martínez-Zarzoso, 2010). Hence, Reefer Cargo is of particular importance for carriers because it can offer substantially higher revenues.

The researcher reviewed the existing literature but did not manage to identify any metrics that can reflect the importance of a country for the container shipping network because of its Reefer Cargo. Due to its sensitive nature, refrigerated cargo requires competitive transit times and due to its special treatment it requires sophisticated planning by the carriers. Thus, the literature has mainly focused on discussing various scheduling and planning problems in the presence of refrigerated cargo (e.g. Lu, Chu and Che, 2010; Cheaitou and Cariou, 2012; Chao and Chen, 2015; Dulebenets and Ozguven, 2017). Other studies have considered Reefer Cargo as a variable in their statistical analysis but the corresponding metric presumably derived by filtering accordingly the utilised dataset (for instance, Schwartz, Guasch and Wilmsmeier (2009) who utilised COMTRADE data or Wilmsmeier and Martínez-Zarzoso (2010) who utilised the International Transport Database (BTI)). Unfortunately, the containerised trade data provided by DfT that this research employs does not separately report Reefer Cargo flows. Hence, this research proceeds to compile a prototype index. The compilation of the index is based on a series of arguments which are discussed by the literature and allow the researcher to form a series of hypotheses (Table 4-7):

Argument	Hypothesis
The deployed capacity (i.e. the available TEU capacity on board the deployed vessels) can be used as a proxy for the size of the container trade market in a given region (Wilmsmeier and Martínez-Zarzoso, 2010).	The deployment characteristics at a country level may reveal the perception of the carriers for a country's market.
It is widely accepted that carriers tend to deploy vessels with high reefer capacity at those regions that are of high importance for refrigerated cargo (Alphaliner, 2022).	The respective reefer capacity of the deployed vessels in a country as a share of the overall deployed TEUs in the same country may reveal the attractiveness of that country for its Reefer Cargo.
More than half of the Eastern Caribbean Sea imports by value are perishable products (Schwartz, Guasch and Wilmsmeier, 2009). Central and South America are considered specialists in banana exports (Arduino, Carrillo Murillo and Parola, 2015).	A relevant metric for Reefer Cargo should reflect a relatively high score for countries located in the mentioned regions.

Table 4-7 – Arguments and Hypotheses regarding Reefer Cargo Index (RCI)

COMPAIR Data (Bluewater Reporting, 2021) provides details about the services that were deployed during a given year at a country level as well as the corresponding vessels that were assigned on those services. For every vessel – among other details – COMPAIR Data (Bluewater Reporting, 2021) also provides both the nominal capacity of the vessel in TEU as well as its reefer capacity measured in reefer plugs. It is assumed that the vast majority of the reefer plugs will be utilised by 40ft reefer containers (i.e. 2 TEUs) since 20ft reefer containers are very rare (Alphaliner, 2022). Consequently, reefer plugs may be expressed in TEU by multiplying each plug by 1.98 (i.e. the vast majority of the reefer plugs will be utilised by 40ft reefer containers which equals 2 TEU but a small minority will also be utilised by 20ft reefer containers) (*ibid*). Hence, a Reefer Cargo Index (RCI) for country i and year t may be calculated as follows:

$$\mathrm{RCI_{it}} = \frac{\sum_{i=1}^{n} ReeferPlugs_{it} \times 1.98}{\sum_{i=1}^{n} TEU_{it}}$$

RCI is effectively a ratio which corresponds to the deployed capacity that can be used for reefer cargo over the total deployed capacity hence it is defined on the interval [0, 1]. In practice, no country can receive an RCI score equal to zero since this would suggest that none of the vessels deployed in that country in a given year was equipped with reefer plugs. Respectively, an RCI score equal to 1 would also be an extreme case and it would suggest that the total capacity deployed in that country in a given year corresponded to vessels for which every single slot was effectively equipped with a reefer plug. In order to add some perspective on the RCI calculation it is worth noting that at the end of 2020 the average ratio of Reefer slots (measured in TEU) to Nominal TEU capacity of all active vessels was equal to 0.2374. Correspondingly, in 2020 in the UK there were deployed vessels of total capacity 9,467,402 TEU and a corresponding reefer intake of 1,552,799 Reefer slots (measured in TEU). By dividing the latter by the former, the RCI_{UK2020} is equal to 0.1640.

The research proceeds to calculate the annual score for all countries included in COMPAIR Data (Bluewater Reporting, 2021). This is implemented by averaging the annual RCI scores for those countries with available data for the whole period 2012-2020. Then, in order to check the robustness of the RCI and whether the proposed index is a realistic measurement, the score of the countries with the highest ranking (Top10) is examined. The results are displayed in Table 4-8:

Country	Top10 Countries by RCI 2012-2020
Grenada	0.4670
Saint Lucia	0.4461
St Vincent / Grenadine	0.4398
Honduras	0.4257
Belize	0.4243
Guyana	0.4236
Barbados	0.4191
Ireland	0.4182
Costa Rica	0.4026
Haiti	0.4005

Table 4-8 – Top10 Countries by RCI score (2012-2020)

Remarkably, the Top10 comprises primarily countries located in the expected regions:

- 5 countries located in the Caribbean Sea: Grenada, Saint Lucia, St Vincent / Grenadine, Barbados, and Haiti
- 4 countries located in Central – South America: Honduras, Belize, Guyana, and Costa Rica
- 1 country located in Europe: Ireland

  The latter is apparently an unexpected result. However, a closer look on Ireland's export mix reveals that the lion's share (in value) corresponds to pharmaceuticals (ITC, 2022) which is a favorable commodity for reefer containers (Maersk, 2022).

Thus, RCI is seemingly a reasonable metric for quantifying how carriers perceive a country considering its attractiveness regarding Reefer Cargo.

4.4.7 Trade Facilitation

The level of the Trade Facilitation in a country is regarded as a prerequisite for the enticement of carriers who seek for a flexible business environment (Ducruet, 2008). Emerging trade flows and competing infrastructure may not be enough in the presence of broader limitations in trade facilitation (*ibid*).

The degree of Trade Facilitation has been widely assessed and modelled by various publications over the years. A few publications have utilised the Enabling Trade

Index (ETI) developed by the World Economic Forum (e.g. Lourey, 2010; Korinek and Sourdin, 2011; El-Khoury, 2017; Ivashchenko *et al.*, 2019). ETI (started in 2008 on annual basis and post 2010 continued on biannual basis) assesses the capacity of 136 economies in facilitating the trade flow between countries, based on 4 subindexes: (1) Market Access; (2) Border Administration; (3) Infrastructure; and (4) Operating Environment (WEF and the Global Alliance for Trade Facilitation, 2016). However, the index has not been issued since 2016.

A wider body of literature has however utilised the Doing Business (DB) index by the World Bank (e.g. Dong and Manning, 2017; Korauš, Mazák and Dobrovič, 2018; Chambers, McLaughlin and Stanley, 2019; Kisel'áková *et al.*, 2019; Maričić *et al.*, 2019; Tingbani *et al.*, 2019; Estevão *et al.*, 2020; Kuc-Czarnecka, Lo Piano and Saltelli, 2020; Valášková *et al.*, 2020; Tauringana *et al.*, 2021; Qian *et al.*, 2022). Quite a few publications have specifically focused on the Trading Across Borders (TAB) component of the Doing Business index (e.g. Morris and Aziz, 2011; Corcoran and Gillanders, 2015; Jitmaneeroj, 2016; Calatayud, Mangan and Palacin, 2017; Jovanovic and Jovanovic, 2018; Wang, Kang and Valentine, 2020; Kumari and Bharti, 2021). TAB specifically quantifies the cost and the time needed at each country to export the product of comparative advantage for a given country (i.e. as this is determined by the largest export value) and to import an equivalent containerised shipment (The World Bank, 2019; The World Bank, 2023b).

The use however of the TAB index in the context of this study could be problematic for the following reasons:

- In 2015-2017 period, the World Bank proceeded with a major update on the methodology of the index (The World Bank, 2022a) which led to rapid changes on the scores of certain countries, and primarily for the 2015 score. For instance, the UK’s score increased by only 0.27% between 2012 and 2014 then jumped by 6.26% between 2014 and 2015 and finally recorded no change until 2020, as illustrated in Figure 4.10:

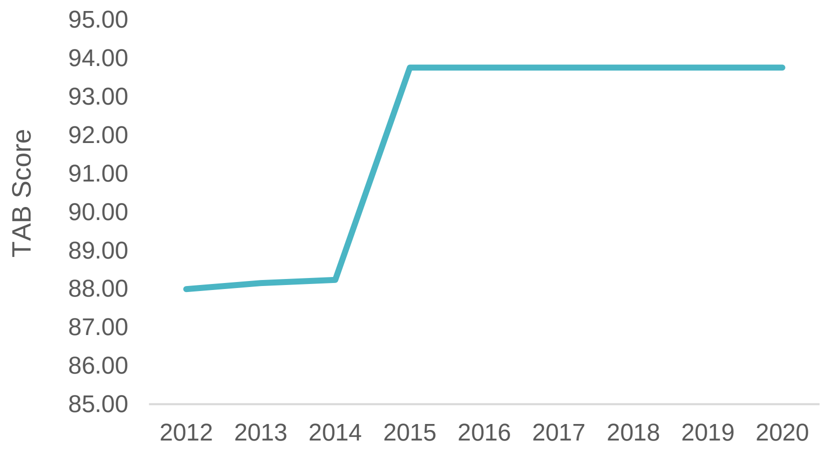

Figure 4.10 – UK's TAB score per Year

This may have a trivial impact in cross-sectional studies (i.e. with a single year time horizon) since all countries will be assessed on the same base. However, this may be challenging for the statistical inference in longitudinal studies such as this research. It is possible that an econometric model would interpret the change between 2014 and 2015 as an actual major improvement on the trade facilitation performance of certain countries. Thus, it is likely that the results may be inconsistent.

- Most importantly, in November 2021, the World Bank announced the discontinuation of the index following a major internal investigation which revealed that the 2018 and 2020 scores and methodology had been manipulated to reflect higher scores for specific countries (The World Bank, 2021). Despite the effort made by the World Bank to shed light on the events that led to the distortion of the index as well as the update of the corresponding scores, the discontinuation of the index may raise concerns regarding the validity of the methodology (at least for some of the reported years) and thus the credibility of the results.

A few publications have also utilised the Trade Freedom Index (e.g. Zibaie and Sheikh, 2009; Lourey, 2010; Hussain and Haque, 2016; Rafiei Darani and Asghari, 2018; Sishi *et al.*, 2020; Kamel, 2021; Iuga, 2022) which is issued by The Heritage Foundation, a think tank based in Washington. The Heritage Foundation compiles on an annual basis the Economic Freedom index which comprises 4 pillars: (1) Rule of Law; (2) Government Size; (3) Regulatory Efficiency; and (4) Open Markets. Each pillar comprises 3 indices. Trade Freedom is included in the Open Markets pillar along with the Investment Freedom and the Financial Freedom indices (The Heritage

Foundation, 2022a). Trade Freedom in particular is reported annually for over 180 countries and synopsises both tariff and non-tariff barriers. Tariff barriers are calculated as the average of the applicable tariffs on a country's imports, weighted by the share of imports for each good category (The Heritage Foundation, 2022b). Non-tariff barriers correspond to the assessment of restrictions that may hinder the imports and exports of a country, such as:

- Quantity restrictions (e.g. import quotas, embargoes etc.)
- Regulatory restrictions (licensing, packaging, sanitary and phytosanitary standards etc.)
- Customs restrictions (e.g. advance deposit requirements, customs clearance procedures etc.)
- Direct government intervention (e.g. subsidies, competition policies etc.) (The Heritage Foundation, 2020b)

This research opts to utilise the Trade Freedom index for quantifying Trade Facilitation in a given country as a variable that may influence its selection by the carriers for a direct connection for the following reasons:

- the use of the index by previous peer-reviewed publications
- the wide coverage of the index for over 180 countries
- the consideration by the index of both tariff and non-tariff barriers which suggest that the index may provide a comprehensive proxy for the burden that a carrier may (or may not) face by calling at a specific country.

Additionally, a thorough review of each report (following the approach previously adopted for the LPI publications) provides important insights regarding the period that the scores effectively cover. Evidently, the report and the scores of a given year are mainly based on the available data of the previous year (The Heritage Foundation, 2013; The Heritage Foundation, 2020a). Thus, the reported scores of each year actually correspond to the industry's perception for the previous year. This has been taken into consideration by this research (i.e. 2013 data by the Heritage Foundation is used for 2012 inference, 2014 data by the Heritage Foundation is used for 2013 inference and so forth).

Figure 4.11 illustrates a comparison of the UK's Trade Freedom score with the average, minimum and maximum global Trade Freedom score for each year of the examined period. Notably, the minimum score (0.00) corresponds to North Korea for all years between 2012 and 2020:

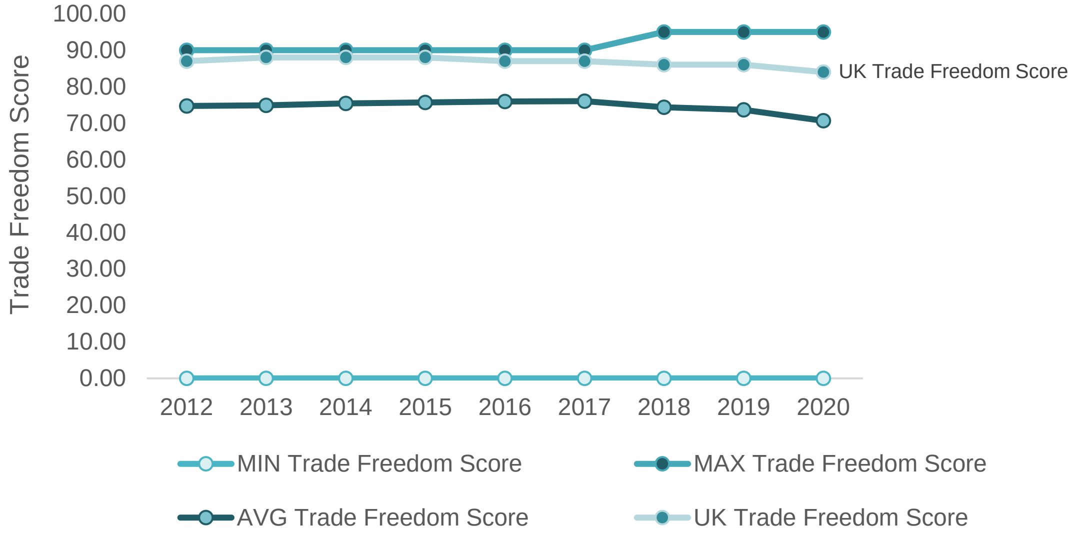

Figure 4.11 – Trade Freedom Score per Year

4.4.8 Trade Flow

The analysis of Trade Flow as a variable aims to shed light on whether the exchanged TEU volume has a significant impact towards the initiation, establishment, or termination of a direct connection between trading countries in container shipping. Since this research aims to assess those variables that promote – or equally discourage – direct connections specifically between trading countries, the bilateral trade flow is considered as a variable of major importance. Hence, the selection of the appropriate metric is extensively scrutinised.

Several scholars within the maritime transportation research field have based some of their research on the open-source trade data of the COMTRADE database by the United Nations (e.g. Lee and Lee, 2012; Calatayud, Mangan and Palacin, 2017; Fugazza and Hoffmann, 2017; Lin and Huang, 2017; Hoffmann, Saeed and Sødal, 2020; Saeed and Cullinane, 2021). The researcher wished to explore whether the analysis of the examined topic could also be based on COMTRADE data regarding bilateral container trade between countries.

Before collecting the relevant COMTRADE data with regard to the trade flows between countries, the research filters for those commodities that have a medium to high probability to be transported in a container box, following the list suggested by Calatayud, Mangan and Palacin (2017). The aforementioned list which comprises 79 categories (UN Harmonized System) of goods is then scrutinised with the intention of further enhancement. The corresponding findings from the literature review suggest the addition of category 61 (Apparel / Clothes) in accordance with Wilmsmeier, Hoffmann and Sanchez (2006). Respectively, categories 31 (Fertilisers) and 99 (Unspecified commodities) are eliminated in accordance with Bertho, Borchert and Mattoo (2016). The final set comprises 78 categories of goods as those listed in the UN Harmonized System (HS) at level 2 (Figure 4.12). The full final list can be found in Appendix C. The data is then extracted by utilising the Application Programming Interface (API) service (United Nations, 2021) of the COMTRADE webpage with the generous support of the United Nations Statistics Division. The researcher contacted the corresponding department via email. The United Nations Statistics Division responded by providing a permission for unlimited use of the API for the period of one month in order to support the development of this research. All available data for 169 potential trade partners was then downloaded. This corresponds to 14,196 possible country combinations for each year within the targeted period of the research analysis (2012-2020). Following the example of Wilmsmeier and Martínez-Zarzoso (2010) and with the aim to make meaningful comparisons between consecutive years, the corresponding trade data is deflated. This is implemented by using the respective UNCTAD's Consumer Price Index (CPI) annual growth rate indicator (UNCTAD, 2022a) with 2012 as a starting point, given the research period (2012-2020).

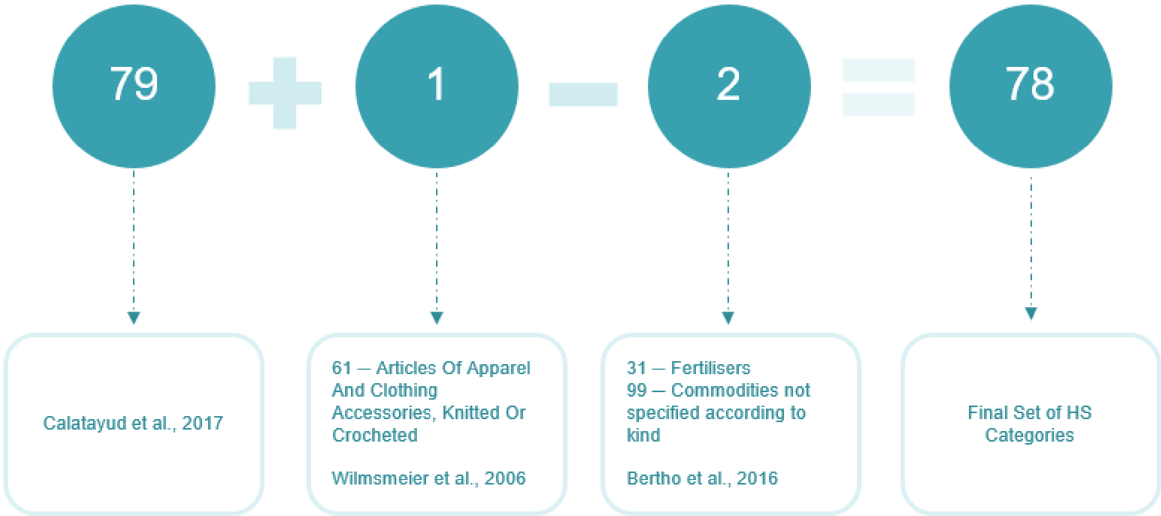

Figure 4.12 – Structuring the containerisable trade flows dataset

However, at this stage the research questions whether those 78 HS categories can accurately describe the *containerised* flows (i.e. those cargo categories that are indeed traded in containers), rather than the *containerisable* flows (i.e. those cargo categories that are likely to be containerised) between countries. Effectively, it is questioned whether the proposed list is able to (a) efficiently capture the overall container volume of a country for timeseries analysis and (b) efficiently approximate the bilateral container volume exchanges between countries. Specifically, the following questions are examined to that end:

Q1 – Can the accuracy of the proposed set of 78 HS categories be tested quantitatively?

Q2 – Is the proposed set of 78 HS categories an appropriate approach for timeseries at country level?

Q3 – Is this set of HS categories optimised or a subset may increase the accuracy of the approximation?

Q4 – Can an optimised HS set at global level be regarded as a good predictor of TEU volume at country level?

Q5 – Is there an HS set which can be regarded as a good predictor of bilateral TEU volume exchanges between countries?

The objective of each question as well as the corresponding results and the conclusion of this analysis (all of which will be detailed in the following Sections) are illustrated in Figure 4.13:

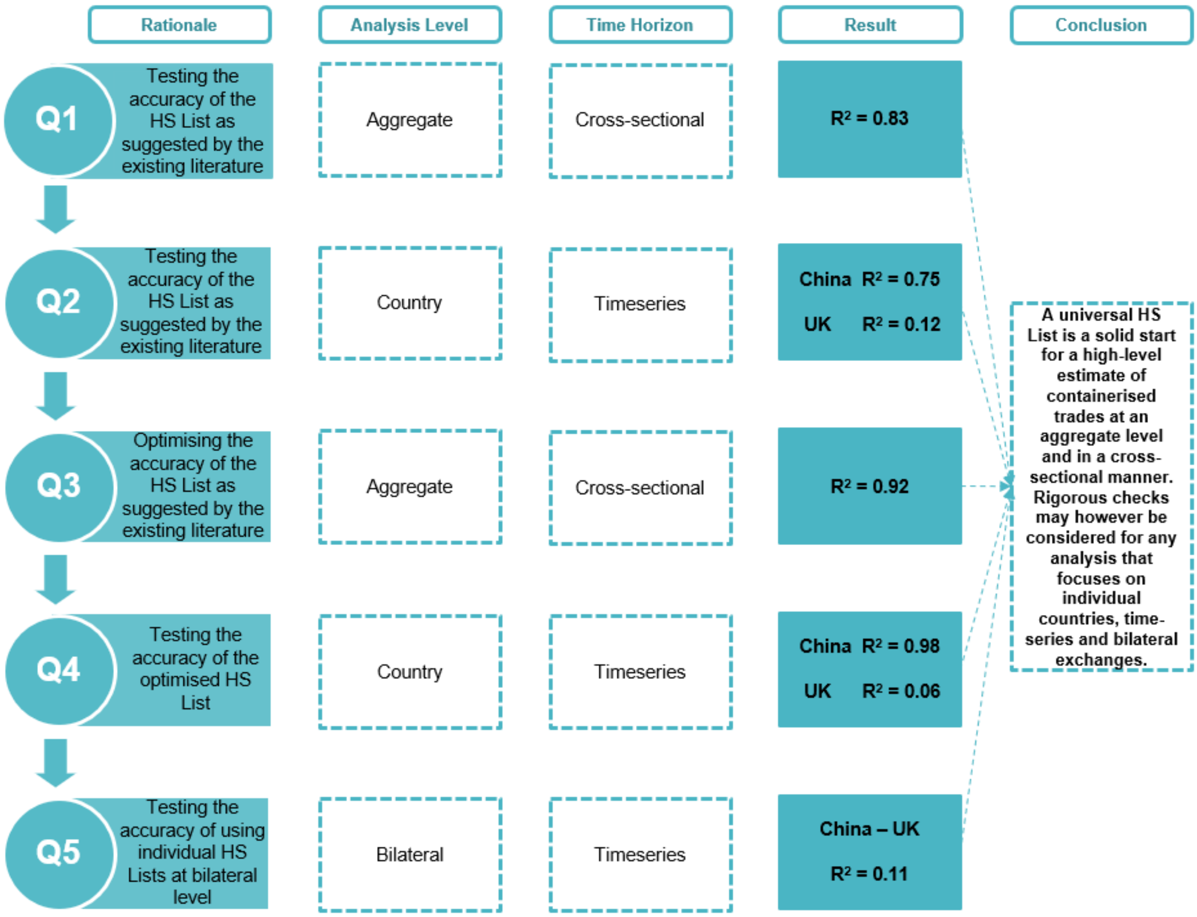

Figure 4.13 – Testing the use of Trade Value (USD) as an indicator of container volume (TEU)

Q1 – Can the accuracy of the proposed set of 78 HS categories be tested quantitatively?

In order to address Q1 and thus to quantitatively test the accuracy of the proposed HS categories in describing the corresponding volume in TEU, the trade data by COMTRADE is combined with the corresponding UNCTAD data regarding the volume in TEU by country (UNCTAD, 2022b). A basic linear regression model is compiled in Microsoft (MS) Excel. The model aims to regress TEU volume (y) on Trade Value (x), using the latest point of the research period (2020) as a reference year. The regression is compiled at aggregate level and is specifically based on the set of the countries that report data both in COMTRADE (78 selected commodities, data as per October 2021) and UNCTAD (TEU) databases for 2020 (64 countries).

The result of the model is illustrated in Figure 4.14:

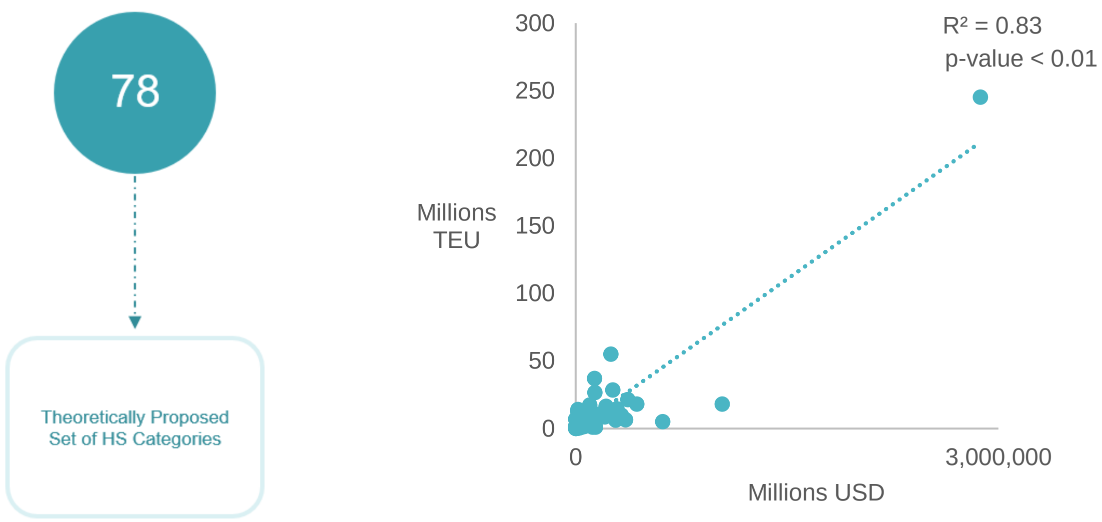

Figure 4.14 – Regression of 2020 Aggregate Trade Value (USD) on TEU based on the theory-based HS List

Thus, using 2020 as a reference year, it is confirmed ($R^2 = 0.83$) that the theory-based set of 78 HS categories can explain a considerable share of the data variance at cross-sectional level (i.e. for a single year) for a large group of countries. However, it is worth noting that the high end of the regression line corresponds to China which shows the impact and the importance of that country for the global container trade and likely drives the relatively good fit in Figure 4.14. As an experiment, in Figure 4.15 China is removed from the dataset:

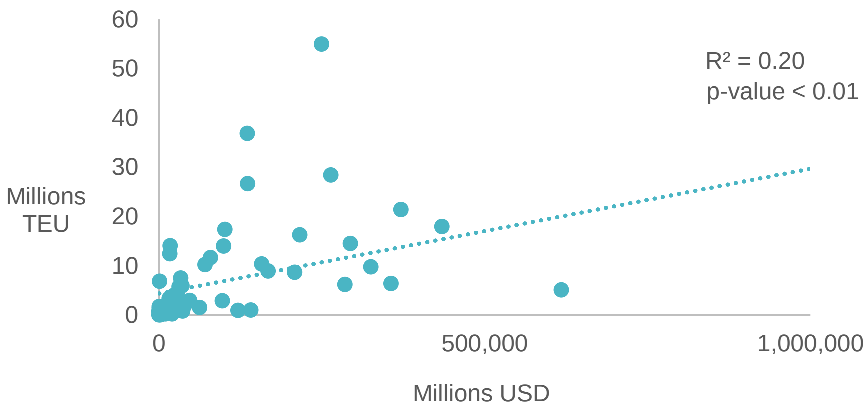

Figure 4.15 – Regression of 2020 Aggregate Trade Value (USD) on TEU based on the theory-based HS List, *excluding* China

The removal of China leads to a considerable drop ($R^2 = 0.20$) of the data variance that may be explained by the theory-based set of 78 HS categories. China's high TEU exchanges and diverse range of commodities, which dominate global trade, disproportionately affect the global model. Undoubtedly, it is meaningful to consider China in any dataset that analyses the global container shipping network. Nevertheless, the very important influence that this country has on the above result probably indicates that the use of a global HS list may be questionable if it used to describe the containerised volume of other countries in the network. This point is thoroughly examined below (see *Q2, Q4* and *Q5*).

Additionally, at this stage it is unclear whether this HS set is appropriate for timeseries analysis or adequately optimised.

Q2 – Is the proposed set of 78 HS categories an appropriate approach for timeseries at country level?

In order to address Q2, a basic linear regression model is compiled in MS Excel. Specifically, the model aims to regress TEU volume (y) on Trade Value (x), across the period 2012-2020 by utilising China and the UK as reference cases (Figure 4.16 and Figure 4.17, respectively).

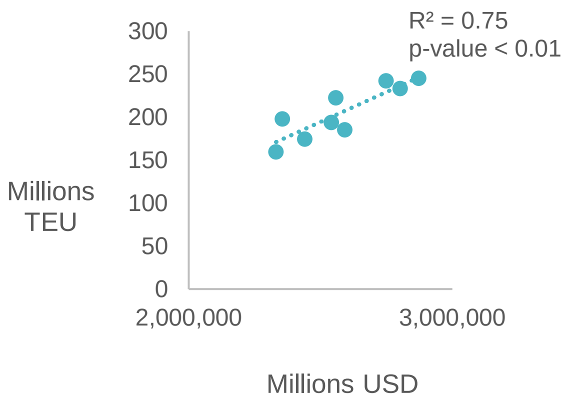

Figure 4.16 – Regression of 2012-2020 Trade Value (USD) on TEU based on the initial HS List, China – World

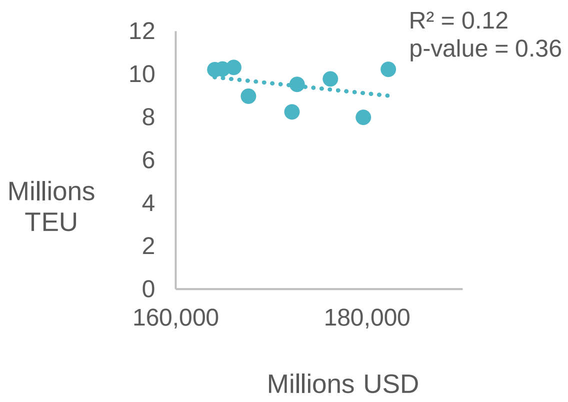

Figure 4.17 – Regression of 2012-2020 Trade Value (USD) on TEU based on the initial HS List, UK – World

As Figure 4.16 suggests, the R^2 score for China is 75% which corresponds to a substantial drop compared to the cross-sectional score of 83% that was calculated at global level in Q1. Although the two scores are by definition non-comparable directly, it could be expected that if the initial list of the 78 HS categories can largely explain a great deal of the data variance at aggregate level then it should work adequately well for China as well. The latter is a central node of the global containerised trade network and thus a global HS list is largely expected to be representative for the country and to yield a very good fit. Thus, this result is slightly alarming.

As Figure 4.17 suggests, the regression may actually work very poorly for a country such as the UK. Should a researcher aim to approximate the corresponding UK container trade volume on a timeseries basis, the respective R^2 score of 12% indicates that filtering the trade data based on the suggested list may not yield an accurate result. Additionally, Trade Value as an independent variable is not statistically significant anymore (p-value = 0.36). Thus, the proposed set of 78 HS categories may result in a fairly accurate result at a cross-sectional / aggregate level (see Q1) but evidently may start to become problematic when the intention is to work on timeseries and across different countries. It is possible then that the proposed list can be scrutinised and optimised accordingly.

Q3 – Is this set of HS categories optimised or a subset may increase the accuracy of the approximation?

In order to address Q3, all different combinations of HS categories should be checked regarding their ability to explain the variance of the data and thus their explanatory power to approximate volume in TEU given the corresponding Trade Value. A complete check should ignore the theory-based HS list of 78 categories and rigorously allow the data to suggest a new list. Furthermore, a complete check would involve the assessment of all possible combinations by single HS categories, pairs, triples and so forth. Should we have only 4 HS categories this method would demand 15 calculations (Figure 4.18, left panel). Since HS list contains 99 categories this would translate into a very large number of calculations and thus the corresponding computation becomes a very demanding task for conventional computers (Figure 4.18, right panel):

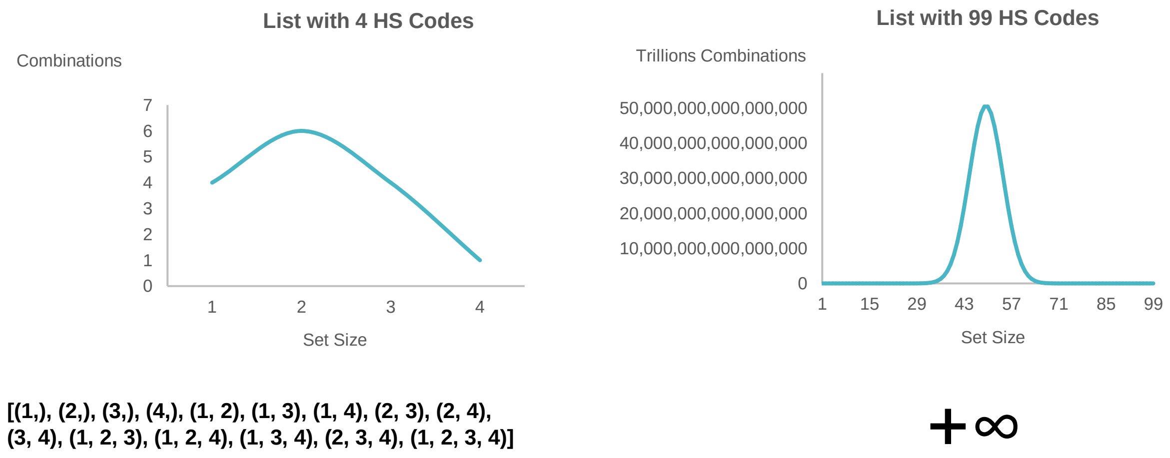

Figure 4.18 – Complexity of calculations by list size

In order to reduce the complexity of this computation, the different HS categories are divided in batches (1-10, 11-20, 21-30, …, 91-99). The division in batches allows the creation of all possible combinations of HS categories only within each batch. In turn, this drastically decreases the complication of the required calculations.

The next step requires an iterative process that allows the following:

(1) To create all possible combinations of HS categories within each batch

(2) To calculate the total of the respective linear regressions

e.g.

x: Trade Value in 2020 per country if only HS categories 1 and 2 are selected

y: TEU per country in 2020

then

x: Trade Value in 2020 per country if only HS categories 1, 2 and 3 are selected

y: TEU per country in 2020

The process continues until all combinations within a batch are tested. The combination of the HS categories which yields the higher R^2 score is stored.

(3) Once the optimal combination within each batch is identified, the algorithm proceeds to the next batch until all batches are examined accordingly.

The optimal combination within each batch is illustrated in Figure 4.19. The process yields 22 HS categories as good candidates for the approximation of the respective TEU volume. This *Batching* process is executed in Python and utilises the Linear Regression library of the scikit-learn package (Pedregosa *et al.*, 2011). An iterative process such as the proposed exercise may however be prone to overfit the data. Overfitting in data science is described as the tendency of a statistical model to fit exactly the training data and thus to start capturing the *''noise''* of the analysed dataset (IBM, 2021). As a result, an overfitting model can neither capture the actual trend of the dataset nor generalise when it is fed with unseen data thus its results may be questionable (*ibid*). In order to avoid this occurrence, it is advisable to split the data into a *''training''* set and a *''test''* set (*ibid*). The training set is used for allowing the model to understand the underlying structure of the dataset. During this process the test set is kept hidden. Following the completion of the training process, the test set is then used to check whether the model can sufficiently perform on unseen data and thus make accurate predictions if it is exposed to unseen (i.e. *''real world''*) data. Although the exercise that this Section undertakes does not essentially aim to build a predictive algorithm, the adoption of the training / test rationale is deemed as appropriate in order to promote a more rigorous effort towards a robust result. The training / test rationale is also adopted in all of the following regressions of this Section (see Appendix D for further details).

As previously mentioned, the Batching process does not make any pre-assumptions on the HS categories that should be considered as proper commodities for containerised trade but rather allows the data to directly advise the suitable HS categories.

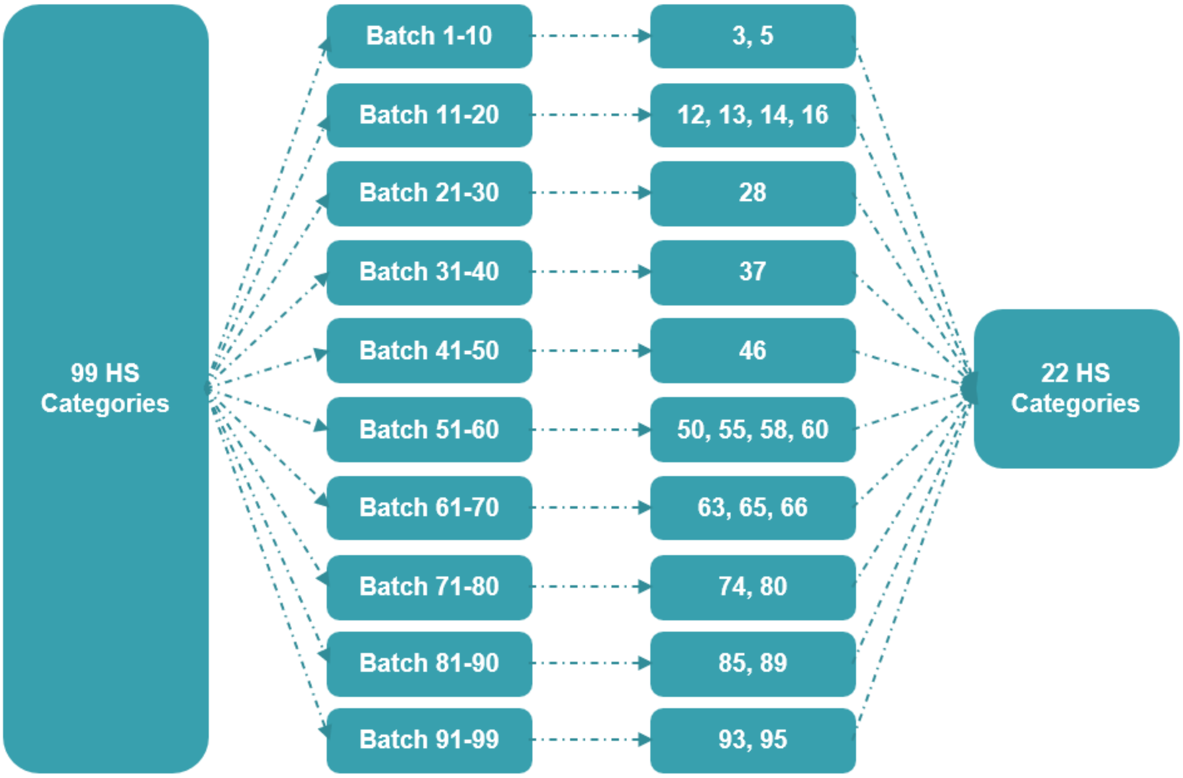

Figure 4.19 – Batching process

The substitution of the initial set of the theory-based 78 HS categories with the new set of the 22 identified HS categories yields an increase of the corresponding R^2 score from 83% to 91% (Figure 4.20). Hence, the initial set of 78 HS categories can evidently be further optimised. The initial set seemingly included HS categories which distorted the effort to associate trade data (expressed in USD value) with actual volume (expressed in TEU) and focusing on a subset of the initial set may yield a higher accuracy.

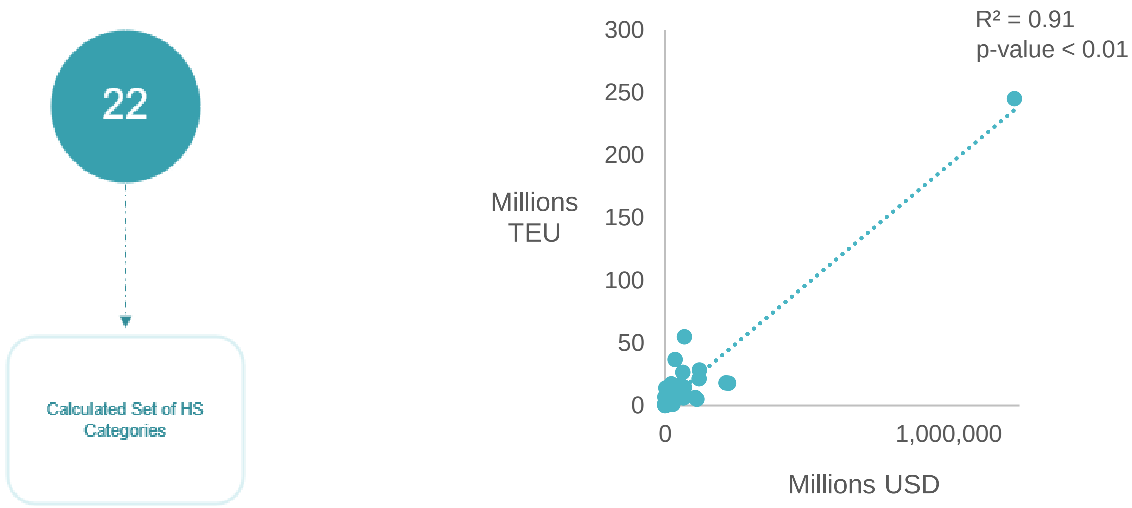

Figure 4.20 – Regression of 2020 Aggregate Trade Value (USD) on TEU based on Calculated HS List

However, this new list of 22 HS categories cannot be regarded as optimised at this stage either. Effectively, this list includes the best regressors (HS categories) of each batch unified all together in a single list. The integration in a single list does not automatically ensure that if the separate categories of each batch are combined then the enhanced list is also the optimal combination across all categories. For instance, the new list of those 22 HS categories suggests 3 HS categories that have not been identified by the theory as medium to high containerisable commodities (i.e. HS 12 – Oil seeds and oleaginous fruits, HS 28 – Inorganic chemicals and HS 74 – Copper and articles thereof).

Hence, it is likely that the combination of only specific HS categories of the new list can further increase the accuracy of the respective calculation. In order to address this challenge, this research strives to calculate all possible combinations of the identified 22 HS categories. However, the respective exercise is also computationally challenging since over 4 million linear regressions would have been required. Thus, at this stage a *Sampling* method is deemed as necessary in order to test whether the list is indeed optimised or could be further refined (Figure 4.21):

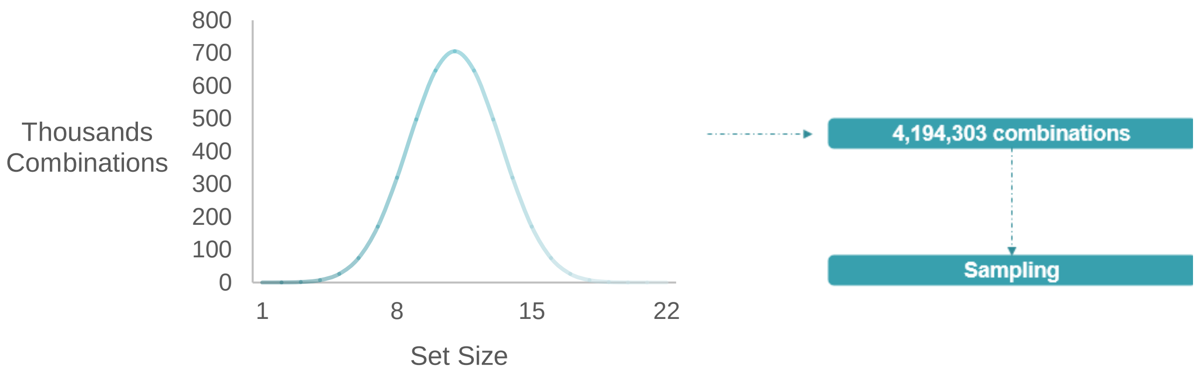

Figure 4.21 – Complexity of calculations for list with 22 HS Codes

Instead of running over 4 million linear regressions, this research tests whether performing 100,000 linear regressions could yield an informative result. This *Sampling* exercise is also executed in Python, following the same approach and software packages as previously described. However, for this exercise an additional step is added that allows the following:

1. To take random samples (i.e. random combinations of all 22 HS categories). This exercise employs the *random* module (Van Rossum, 2020) in Python. One function of this module (*random.randint*) is employed to return a random integer given a range of integers (i.e. any number within the range 1-22). Another function is then employed (*random.sample*) to utilise this integer in order to randomly select the corresponding HS categories from the list of the 22 HS categories. Following the same logic as before, each selection is used to filter the trade data only for the selected HS categories and regress the corresponding TEU volume (y) over the respective Trade Value (x). In every run, the corresponding R^2 is calculated and stored.

2. To repeat the above process 100,000 times and retain this selection with the highest R^2 among all sample combinations.

The execution of this exercise indeed revealed that the suggested list of the 22 HS categories can also be further refined and optimised to finally include only 10 HS categories while marginally boosting the respective R^2 score from 91% to 92% (Figure 4.22):

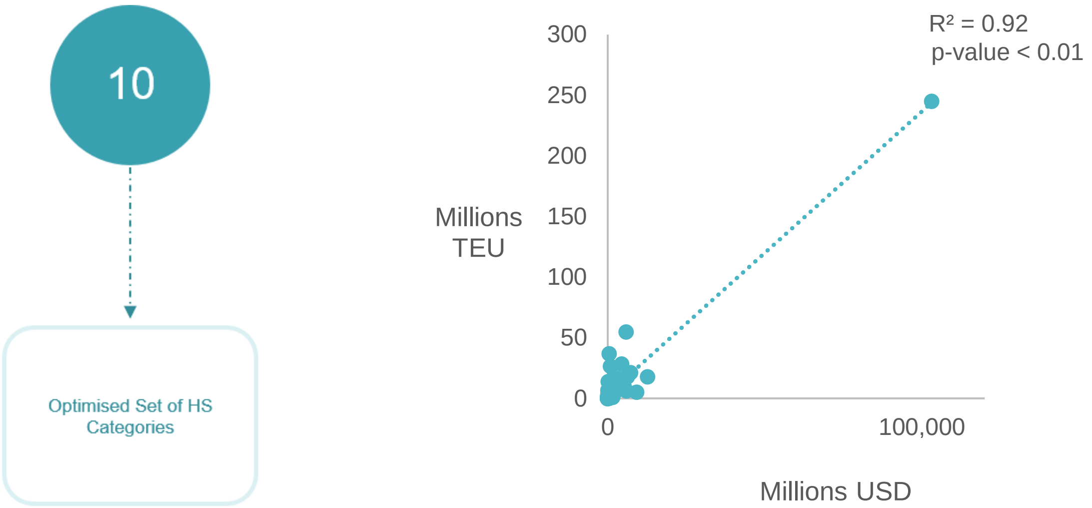

Figure 4.22 – Regression of 2020 Aggregate Trade Value (USD) on TEU based on Optimised HS List

Notably, all those 10 HS categories are also included in the theory-based initial list. It is also worth noting that the high end of the regression line corresponds to China which shows the impact and the importance of that country for the global container trade. Overall, the results suggest that this is potentially an optimised HS list which can be used to filter COMTRADE data accordingly and approximate global TEU volume based on Trade Value for a single year.

Q4 – Can an optimised HS set at global level be regarded as a good predictor of TEU volume at country level?

In order to address Q4, the suggested list of the 10 HS categories should be checked against the actual container flows of specific countries. Effectively, this exercise aims to test whether a seemingly optimised HS list, which can generalise with high accuracy the association between Trade Value (x) and container volume (y) when accounting for a wide set of countries, can also be employed to accurately describe the relationship between Trade Value and container volume of individual countries. Hence, the COMTRADE database is accordingly filtered using only the suggested 10 HS codes and a linear regression is performed. This exercise utilises the actual TEU volume between 2012-2020, using once more China and the UK as reference cases. The results are illustrated in Figure 4.23 and Figure 4.24, respectively:

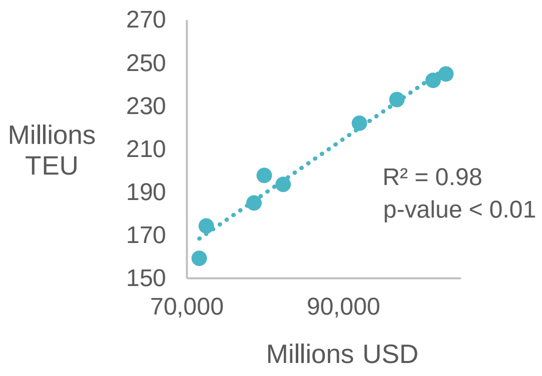

Figure 4.23 – Regression of 2012-2020 Trade Value (USD) on TEU based on Optimised HS List, China – World

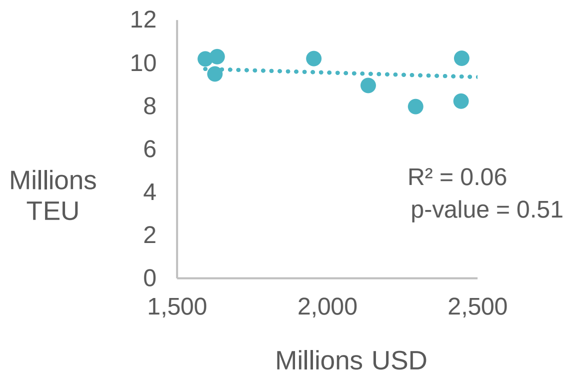

Figure 4.24 – Regression of 2012-2020 Trade Value (USD) on TEU based on Optimised HS List, UK – World

As underlined in Q2, China is at the epicenter of the global containerised trade and thus a global HS list – provided that it is thoroughly refined – is largely expected to be representative for the country and to yield a very good fit. Essentially, certain countries may partially skew the data towards the list that fits their individual characteristics. This may be alarming though since the trade mix of other countries may have a substantially different base. The latter is confirmed when the corresponding R^2 of the UK is examined. The very poor fit of the latter (R^2 = 6%) along with the fact that Trade Value became statistically insignificant (p-value = 0.51) suggests that a list which greatly describes the association of Trade Value (x) with actual volumes in TEU (y) at global level may occasionally be an inadequate solution when the aim is to approximate this association at the individual country level.

This is evidently a logical outcome since each country has a unique list of commodities that reflects its trade mix. The latter is in accordance with trade theory which suggests that different countries export different commodities based on their comparative advantage while also reaping the benefits of localised specialisation (Krugman, 2010). The latter allows countries to reap the benefits of their *''inherent advantages''* and achieve increasing returns through economies of scale (*ibid*). Consequently, any generalisation towards the use of a global HS list as a relevant approximation of the actual containerised trade flows for individual countries should be adopted with caution.

In order to test the hypothesis that distinct countries may be characterised by distinct HS lists, the processes of *Batching* and *Sampling* – as those were previously described – are applied separately for China and the UK. This attempt yields interesting results (Figure 4.25 and Figure 4.26). As expected, there is barely an improvement for China (0.4% at the third decimal) but there is a significant improvement for the UK. This suggests that the optimised list at global level is not necessarily a panacea for estimating the TEU volume at country level and each country should be examined separately. The proposed HS set for China corresponds to HS categories that are all included in the theory-based initial list. The same applies for the UK as well with the exception of HS 12 – Oil seeds and oleaginous fruits category. Interestingly, Oil seeds and oleaginous fruits may be a containerisable category as well and in fact it is identified by Lloyds List and MDS Transmodal (2017) as one of the Top 10 TEU flows between Sub-Saharan Africa and Europe / Mediterranean for 2016. Thus, the optimisation process of *Batching* and *Sampling* returned a corresponding HS list for China and the UK which cannot only provide a good estimate of the actual TEU volume but it also includes HS categories that can be in principle regarded as containerisable, in line with the existing literature.

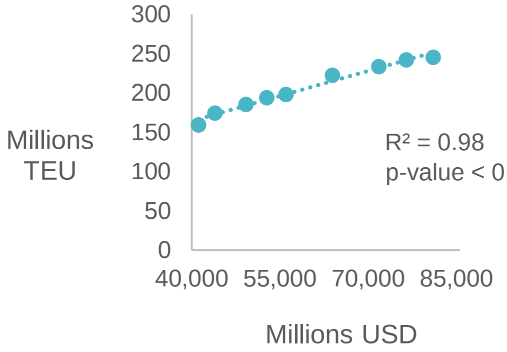

Figure 4.25 – Batching - Sampling: China – World 2012-2020

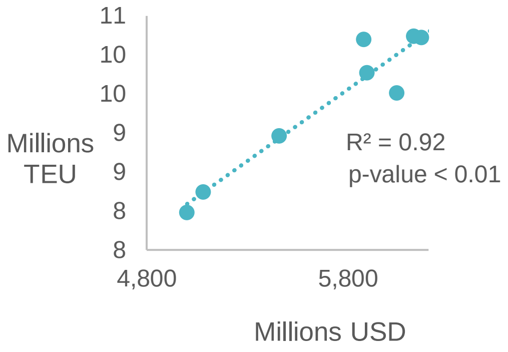

Figure 4.26 – Batching - Sampling: UK – World 2012-2020

At this stage, a sense-check is advisable before further proceeding with the analysis. According to UNCTAD (2022c), the respective TEU records are estimates based on various reputable sources and assumptions. Additionally, those records may correspond to not only imports and exports but to other container flows as well including repositioning (i.e. empty containers). Thus, until this point the corresponding calculations have regressed Trade Value (x) over both laden and empty containers. The flow of laden containers is by definition trade-driven. However, this research strives to clarify whether the use of UNCTAD TEU volumes and thus the inclusion of empty containers in the regressions can possibly distort the results.

Unfortunately, sufficient granularity regarding container data at national level is not always abundant. However, some direction regarding the reference cases of the UK and China is available:

- According to the DfT (2021c), the split of the laden / empty TEU in the UK has remained stable at a ratio of 70% / 30% between 2003 and 2020 thus covering the analysed period (2012-2020). This is an interesting indication which suggests that for a given country the proportion of empty containers increases (or decreases) in parity with the laden containers. An illustration of an updated regression for the UK is not particularly informative: laden containers represent the 70% of the overall volume and the updated regression still reflects a score of 92%, as per Figure 4.26.
- According to China Statistical Yearbook (2017) and China Statistical Yearbook (2021), the split of the laden / empty TEU in China during the analysed period (2012-2020) was also quite stable and hovered between 14%-16% (15% on average). By applying the corresponding ratio in each specific year and running again the respective regression, the following result is obtained (Figure 4.27):

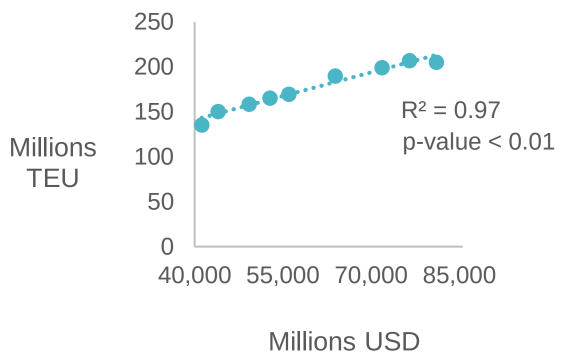

Figure 4.27 – Batching - Sampling: China – World 2012-2020, Laden Containers

The comparison of Figure 4.25 and Figure 4.27 indicates that the corresponding R^2 score barely changed from 98% to 97%. The calculation seemingly holds even by subtracting the share of the empty containers for each year.

Practically, this is not a surprising result: the fact that (almost) identical results are obtained is probably grounded on the fact that as trade imports / exports grow (for certain HS categories), the empty containers that those may generate / require also grow. For instance, if a country with growing container imports cannot progressively generate larger export volumes to fill the empty containers (i.e. once the goods that those were carrying as laden imports have been discharged) then the number of those empty containers may continue growing almost proportionally with the laden imports. In other words, as long as the composition of an economy does not fundamentally change over the years, the use of container records that include repositioning figures should not significantly distort the calculations.

Overall, the use of Trade Value (x) can explain a significant amount of TEU volume (y) variance at country level but this may require the use of an optimised HS set per individual country.

Q5 – Is there an HS set which can be regarded as a good predictor of bilateral TEU volume exchanges between countries?

In order to address Q4, a simple theory is tested: if one can approximate the HS lists that accurately describe the TEU volume of two countries, then the union of those lists could potentially be used to accurately approximate the bilateral TEU exchanges based on the bilateral Trade Value.

With the aim to test this theory a new linear regression is performed, utilising the bilateral Trade Value between China and the UK and the corresponding actual TEU volume for the period 2012-2020. Trade Value is again extracted from the COMTRADE database as previously described. The corresponding TEU volume data is downloaded from the publicly accessible domain of the UK Department for Trade (DfT). The latter shares a publicly available annual report as well as the corresponding data[10] regarding all of the UK's maritime trade activity. The data includes containerised trade exchanges with all of the UK's trade partners reported in TEU.

Figure 4.28 and Figure 4.29 illustrate the comparison of two different attempts:

(1) Figure 4.28 illustrates the test of the abovementioned theory. The distinct HS lists of China and the UK – as those were compiled while addressing Q4 – are merged into a new enhanced list. The new list is then used to filter COMTRADE data for the corresponding trade exchanges (Reporter: China – Partner: UK) for the targeted period (2012-2020). The respective TEU volume

[10] Data up to 2020 is available at https://www.gov.uk/government/statistics/port-freight-annual-statistics-2020

(y) is then regressed on the extracted Trade Value (x). This exercise results again in a poor fit (R^2 = 11%) and statistical insignificance for Trade Value, suggesting that the simple union of the individual HS lists of two trading countries is not an adequate solution for the approximation of their bilateral TEU trade.

(4) Figure 4.29 illustrates the subsequent step, following the poor results of the joined HS list. The processes of *Batching* and *Sampling* are once more applied. *Batching* and *Sampling* consider bilateral Trade Value per year (2012-2020) as a potential regressor (x) and examine its ability to fit the corresponding TEU volume (y). The result is a brand new list with a quite decent R^2 score of 88%. Notably, the proposed HS set corresponds to HS categories that are all included in the theory-based initial list of 78 HS categories.

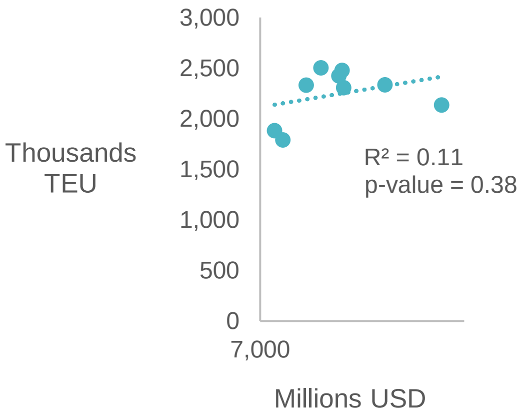

Figure 4.28 – Union of individual Optimised Lists China – UK 2012-2020

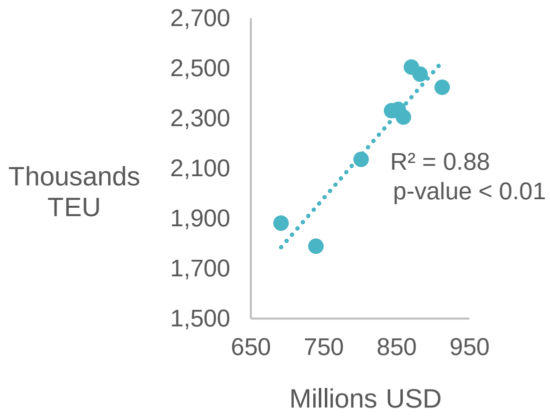

Figure 4.29 – Batching – Sampling: China-UK 2012-2020

Hence, there can be a set of HS categories which can describe with high accuracy the bilateral TEU volume exchanges between countries, but this demands the availability of actual past figures expressed in TEU in order to be identified and optimised.

Overall, addressing the abovementioned 5 questions leads to a general conclusion which can be summarised as follows:

- The initial list of 78 HS categories as suggested by the literature is a solid start for a high-level estimate of containerised volumes based on Trade Value at an aggregate / global level.

- A further and more detailed estimate of the individual volumes at country level may require a rigorous process that takes into consideration the individual characteristics of each country's trade composition.
- The proposed process of Batching and Sampling is seemingly a fairly accurate and efficient process to estimate the corresponding TEU volume given the Trade Value (USD) at country level.
- However, the HS list that may be used to project the bilateral TEU volumes between countries A and B is a distinct new list. The latter corresponds to those HS Categories that are unique for the containerised trade relationship of countries A and B.

Subsequently, it is evident that although the process of utilising COMTRADE data in container transport studies can be very accurate if filtered thoroughly, the use of the data to approximate the bilateral TEU exchanges between trading countries may be questionable.

The researcher also reached out to the UNCTAD inquiring whether there is any ongoing effort that also utilises COMTRADE data and can complement this research. Indeed, UNCTAD has capitalised on the recent update of the trade reporting guidelines which suggests that bilateral trade flows should be reported by the mode of transport (i.e. sea, air, rail, road, and others) and in conjunction with the World Bank has developed a new dataset of increased granularity regarding the cost of the bilateral trade (Barnat *et al.*, 2020). This dataset provides a great visualisation of trade flows per selected HS categories between trade partners and by mode of transport. However, the supporting data is not available yet for timeseries since only 2016 data has been processed and future expansion is expected to incorporate any available data from 2016 onwards only. Moreover, the dataset reports overall seaborne trade flows in values rather than in TEU and filtering for containerisable / non-containerisable commodities is still needed.

Thus, the need for accurate bilateral container trade is effectively one of the reasons supporting the choice of a case study for an individual country that directly reports its containerised trade in TEU (such as the UK). Subsequently, the corresponding metric that is eventually selected for the description of the UK's containerised exchanges with other trading countries, is the respective volume reported in TEU by the DfT (regardless of the commodity inside the containers). The dataset includes all containerised flows (imports / exports) with over 150 recorded trade partners on an annual basis and fully covers the targeted period (2012-2020). The data is accordingly filtered to exclude empty containers. As suggested by DfT (2022), the weight of the containers correspond to the actual weight of the carried cargo thus an empty container has a respective weight equal to zero. This allows for filtering of the data accordingly in order to include only laden containers. As shown on Figure 4.30, DfT has reported a continuous containerised trade flow with the overwhelming majority of the UK's trade partners (i.e. for 9 consecutive years) while other countries are either relatively new partners or have mostly recorded sporadic volume exchanges with the UK:

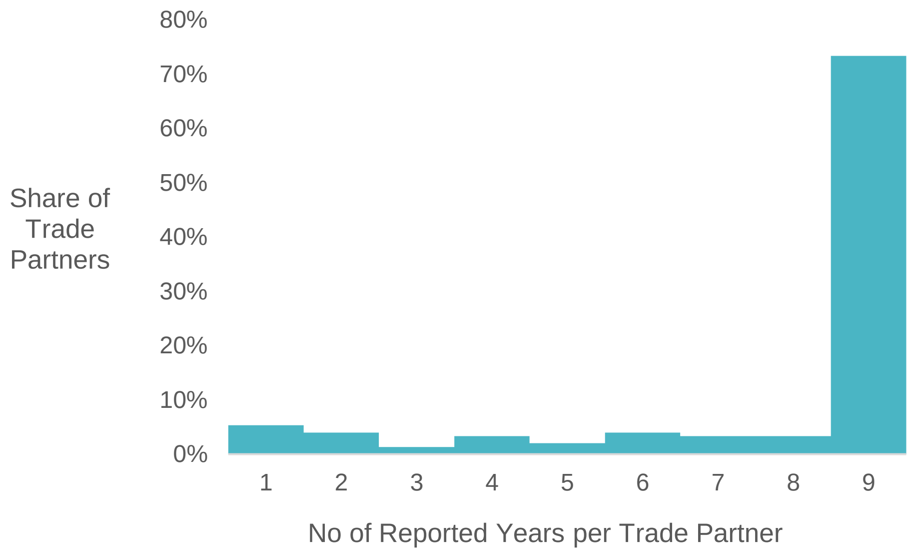

Figure 4.30 – Share of Trade Partners per No of Reported Years

4.4.9 Trade Imbalance

Since Trade Flow is measured based on the DfT records regarding containerised trade flows, the corresponding Trade Imbalance is given by the difference between UK exports and imports to / from each trading country in the dataset. A positive value for trade imbalance indicates that the UK exports more laden TEU than it imports from a given country and vice versa. In container shipping a negative balance in container flows usually corresponds to importing a large amount of laden container boxes and exporting a smaller amount of laden boxes plus a substantial amount of empty container boxes. The repositioning of empty boxes is a costly process for carriers and inflates the container box management cost (Imai, Shintani and Papadimitriou, 2009). During the examined period (2012-2020), the UK recorded its largest deficit (i.e. more imports to the UK) with China and its largest surplus (i.e. more exports from the UK) with Germany (Figure 4.31).

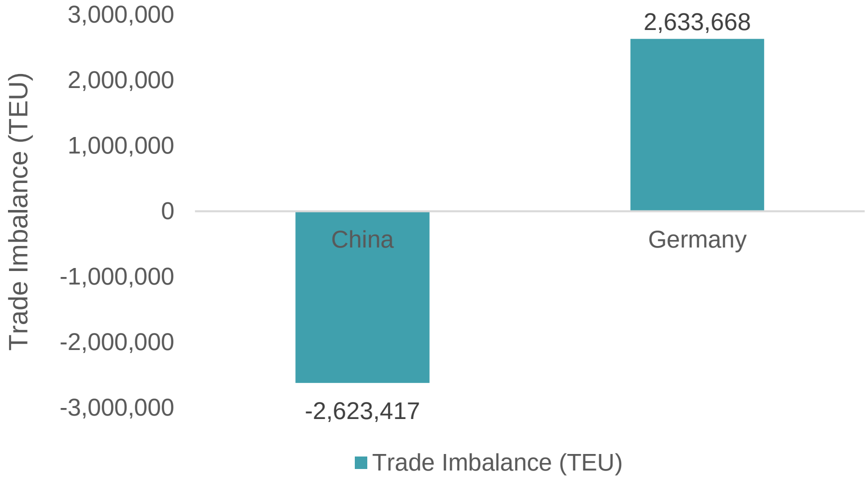

Figure 4.31 – UK Trade Imbalance in containerised flows with top importer and exporter

During the same period, the UK continuously recorded a deficit regarding its overall TEU exchanges with other trading countries:

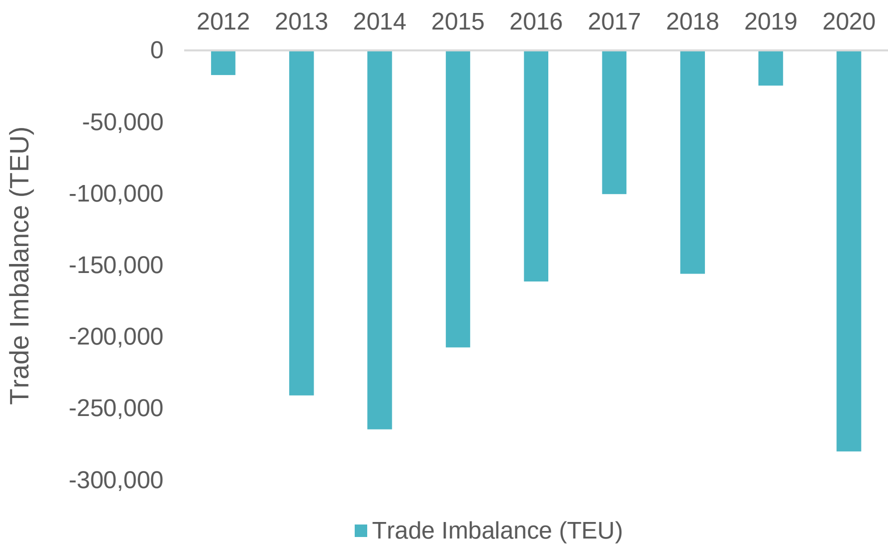

Figure 4.32 – UK Containerised Trade Imbalance during 2012-2020

4.5 Data Preprocessing

The raw data from the various sources, databases and indices has to be processed accordingly in order to meet the purpose of the analysis. The majority of the data processing is undertaken using scripts written in Python programming language as well as in MS Excel sheets, compiled by the researcher for the needs of this research analysis.

4.5.1 Trading Countries

A major step towards the compilation of the analysis dataset is the identification of those trading countries which are regarded as most relevant to the research. Therefore, the containerised trade dataset by the DfT is filtered accordingly, as follows:

1. The recorded volume under ‘*’Unspecified’’* country grouping is removed from the dataset.
2. The recorded volume under ‘*’United Kingdom (inc CHI & IOM)*’’ country grouping is removed from the dataset since it corresponds to the UK’s domestic traffic which is out of the research scope.
3. The recorded volume under ‘*’Antarctica’’*, ‘*’Asuncion’’*, ‘*’Falkland Islands’’*, ‘*’Hungary’’* and ‘*’Norfolk Island’’* country groupings is removed from the dataset since it corresponds to entities which are not states / countries or are landlocked and thus are not included in the Bluewater database. The removed volume corresponds to only 0.001% of the overall volume exchanges throughout the examined period.
4. ‘*’Philipsburg’’* and ‘*’Sint Maarten (Dutch Part)*’’ are merged under *Sint Maarten* trade partner since (a) Philipsburg is a port located in the Dutch Part of Sint Maarten and (b) Bluewater database lists the corresponding port of call as "*St Maarten-Philipsburg*".
5. Regarding the recorded volume under the country grouping of the ‘’*Netherlands Antilles’’*, additional processing is applied. ‘’*Netherlands Antilles’’* is the name of the former constituent country of the Kingdom of the Netherlands which comprised the islands of Aruba, Bonaire, Curacao, Saba, Saint Eustatius, and Sint Maarten (which corresponds to the south part of the Saint-Martin Island while the north part is an overseas territory of France). The Netherlands Antilles were dissolved to separate autonomous entities on October 10th 2010 (Britannica, 2022b). Hence, this naming is currently obsolete, and institutions have commonly abandoned its use. For instance,

UNCTAD used to report an LSCI score for the Netherlands Antilles only until 2011 and then proceeded to produce a separate score for each of the aforementioned countries. DfT reports separately Aruba which – at this stage – is retained as a distinct trade partner. DfT also reports separately Sint Maarten (Dutch Part) and Philipsburg which have been merged under Sint Maarten and retained as a distinct trade partner, as previously described. However, DfT provides no further split for the rest of the former *''Netherlands Antilles''* (i.e. (a) Bonaire, Saint Eustatius and Saba and (b) Curacao) but rather reports a single figure under their former collective naming. Consequently, the corresponding volume under this naming is disregarded. In any case, the disregarded cargo under the naming of the *''Netherlands Antilles''* corresponds only to 0.001% of the total reported containerised exchanges throughout the examined period.

6. At the final stage, a last filter is applied. As previously stated in Section 3.1, the existing literature has interchangeably used terms such as *''countries''*, *''economies''* and *''partners''* to describe the corresponding international trade relationships. In the context of this research, the term *''country''* refers to territories with political independence (The World Bank, 2022b) controlled by their own government (Britannica, 2022a). Correspondigly, the term *''trade partners''* considers only what can generally be termed *''politically independent''* countries. Thus, for consistency, the recorded volume under *''Aruba'', ''Bermuda'', ''British Virgin Islands'', ''French Polynesia'', ''Gibraltar'', ''Guadeloupe'', ''Guiana'', ''Martinique'', ''Mayotte'', ''New Caledonia'', ''Puerto Rico'', ''Reunion'', ''Sint Maarten'' and ''Virgin Islands (USA)''* country groupings is removed from the dataset since it corresponds to states with no political independence (U.S. Department of State, 2022). The removed volume corresponds to only 0.03% of the overall volume of exchanges throughout the examined period. Hong Kong (China, Hong Kong SAR) is retained in the dataset as it is evaluated as an important case in the context of this research, in particular because of (a) Hong Kong's distinct importance for the global container shipping trade; (b) Hong Kong's colonial ties with the UK.

Following the above processing, the final dataset comprises 136 countries which were actively trading container volumes with the UK during the period spanning 2012 to 2020 (Figure 4.33):

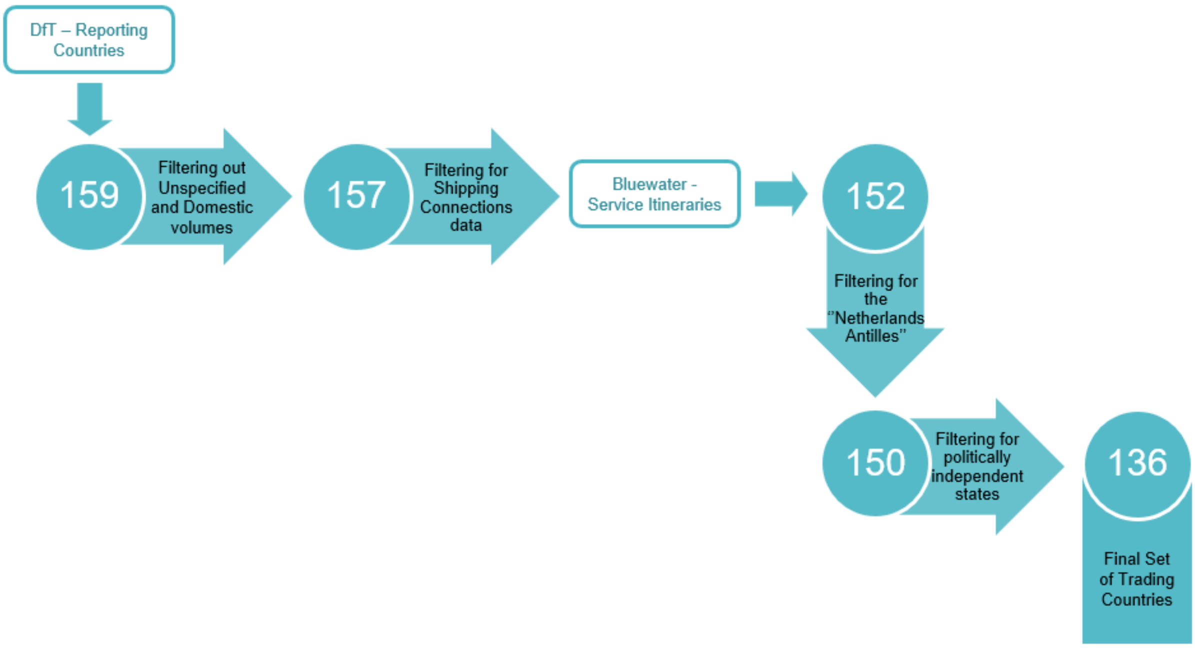

Figure 4.33 – Structuring the analysed trading countries dataset

4.5.2 *Container Shipping Connections*

COMPAIR data is respectively scrutinised to yield the maximum of available recorded connections between trading countries. Initially, all unique service itineraries available on the database between 2012-2020 are extracted. This includes varying itineraries of the same service as well, in order to capture all possible variations. Those variations effectively correspond to periodic additions or exclusions of port calls. The list of the connected ports is then converted to a list of connected countries. For each Year (Y), the characterisation of the connection type followed the notation illustrated in Figure 4.34. The term *'Y-1'* refers to the previous Year (Y):

Existing connections	→	Connections accumulated from Y-1
New Connections	→	Connections initiated during Y
Terminated Connections	→	Connections deactivated during Y
Active Connections	→	Existing Connections + New Connections

Figure 4.34 – Connection Types per Year (Y)

The development regarding the connections between the UK and its trading partners (countries) in containerised shipping over the years is illustrated in Figure 4.35:

Figure 4.35 – Number of country-pair direct shipping connections per year

The overall development of shipping connections between the UK and trading countries per year is illustrated separately for each type of connection in Figure 4.36:

Figure 4.36 – Number of country-pair direct shipping connections per year and type of connection between the UK and trading countries

However, as previously stated this research focuses on analysing the establishment of direct shipping connections not between any two countries but specifically between trading countries. Thus, once all recorded shipping connections are extracted from the COMPAIR database, a cross-check with the recorded trade connections (i.e. the exchanged TEU flows between countries) is needed. Those trade connections were extracted from the DfT database in the previous step.

The purpose of this exercise is to remove all unnecessary *'noise'* caused by shipping connections that evidently were established before the inauguration of any trade flow exchanges between countries. This filter aims to remove all direct shipping connections between the UK and those countries which progressively recorded bilateral trade flows but only following the establishment of a direct shipping connection. Such a development implies that those countries became trade partners only by capitalising on the establishment of the shipping connection, whereas the aim of this research is to examine how countries which already have a trade relationship may eventually be awarded with a direct shipping connection. Indeed, as also underlined by Fugazza and Hoffmann (2017), trade flows may influence shipping connectivity, but shipping connectivity may also impact trade flows, raising a possible issue of simultaneity or reverse causality. Hence, this exercise serves the purpose of – at least to a certain extent – removing obvious issues caused by reverse causality. This is managed by considering the timing of the shipping connection which is cross-checked against the corresponding timing of the respective trade flows.

By applying a respective formula in MS Excel it is however observed that the dataset does not include any relevant occurrences with the single exception of Aruba. The latter was indeed connected directly with the UK in 2017 while there were previously no container volumes recorded between the two partners. The respective containerised trade flow begun only in 2018. Nevertheless, Aruba is not part of the final dataset as it does not constitute a politically independent state (see point 6 of Section 4.5.1).

Since the research is organised on an annual basis, there is however a possibility of reverse causality within the same year. For instance, a country A had recorded no volume exchanges with the UK until December 2014. Then, a coincidental direct connection between the two countries was established in February 2015 leading to the initiation of bilateral volume exchanges in June 2015. Consequently, the utilised dataset would just reflect a simultaneous direct connection and trade relationship for 2015. Such an occurrence is also tested in MS Excel. Yet, it is found that there are no simultaneous establishments of both trade relationships and direct shipping connections for any of the years and trading countries. This check is also performed for year 0 of the study (2012) by thoroughly examining whether countries that were already directly connected with the UK had indeed containerised volumes in 2011. This exercise returns the same outcome as before and there are seemingly no reverse causality issues in the utilised dataset.

The above process is illustrated in Figure 4.37 and although it does not result in any material alteration of the initial dataset, it verifies that the employed dataset is indeed a relevant basis for the examination of the variables that influence the direct connectivity between trading countries.

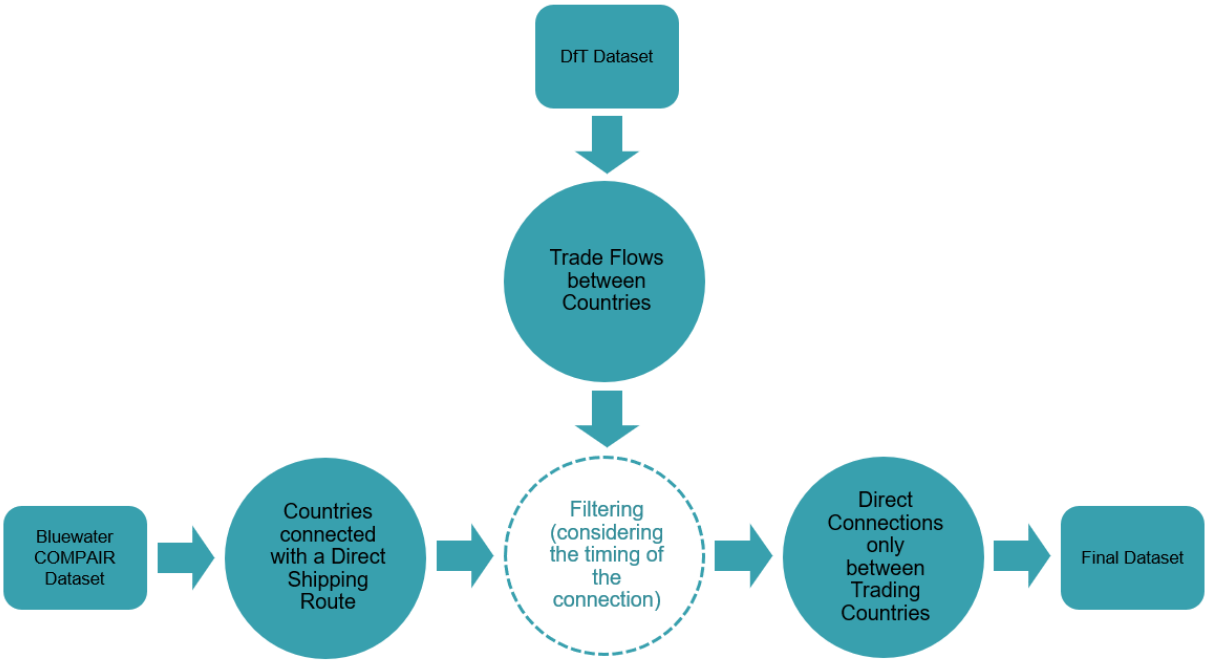

Figure 4.37 – Final Dataset filtering

4.6 Data Completeness

According to Jakobsen *et al.* (2017), in a dataset where missing data accounts for over 5% of the total then any statistical inference may be biased. It is then advisable that the analysis may proceed with a '’*complete case analysis*'' approach (i.e. by taking into consideration only those cases for which data is available across all variables) only when the 5% threshold is not violated otherwise enhanced data strategies (e.g. data interpolation, single imputation or multiple imputation) are deemed as necessary before proceeding with statistical inference (*ibid*).

The majority of the variables (6 out of 9) within the dataset that this research employs have no missing values with the exception of Trade Facilitation, Reefer Cargo and

Logistics Performance. Nevertheless, the overall missing data corresponds to only 2.92% of the total. Thus, this research may proceed with a complete case analysis approach and still provide unbiased results since the proportion of the missing data is negligible. The concept of data missingness is also discussed in Section 5.6.

4.7 Applicable Modelling Approaches

According to Baltagi (2005 p1) *''the term "panel data" refers to the pooling of observations on a cross-section of households, countries, firms, etc. over several time periods. This can be achieved by surveying a number of households or individuals and following them over time''.* Thus, the clustering of the data at a pair-wise level and its analysis over time classifies the analysis of this research as a panel data analysis.

Further to the analysis of repeated observations over time, another core characteristic of panel data is the unobserved time-invariant heterogeneity (StataCorp., 2021a). In the context of this research this would correspond to the *''inherent propensity''* (*ibid*) of certain countries to connect with the UK due to specific characteristics such as their geographical position or their overall propensity to trade their products and that both of those characteristics may remain constant over time and impact the probability of connecting directly with the UK. Those unobserved characteristics may potentially be correlated to the amount of containerised cargo that traders in either country are willing to exchange and thus affect the establishment of a direct connection.

The various applicable models are categorised based on the assumptions that are made regarding the time-invariant individual heterogeneity in the analysed data. If it is assumed that there is no unobserved individual heterogeneity, the panel structure collapses and a *Pooled* model may be employed. On the contrary, if it is assumed that there is indeed unobserved individual heterogeneity in the analysed data, the established modelling approaches of panel models are either a *Fixed effects* or a *Random effects* model. Additionally, a C*orrelated Random effects* model may also be employed which effectively is a synthesis of the *Fixed* and *Random* effects approaches.

The characteristics of the abovementioned models as well as the statistical tests that allow for the selection of the correct model and its corresponding robustness are detailed in Appendix E.

4.8 Concluding Remarks

This Chapter described the data collection process which underpins the research and discussed the overall thought process regarding the compilation of the main dataset which this research employed.

Firstly, the selection of the UK as a case study was justified. The characteristics of the UK may yield fruitful results since the country can allow the examination of all selected variables based on credible data while the UK is also regarded a major trading and well-connected node of the container shipping network. Secondly, this Chapter emphasised on the process of selecting that set of variables which can support a robust analysis. This research does not proceed with a random selection of variables for modelling but rather revisits the findings of the SLR and filters the pre-identified variables based on the principles of Causal Inference theory. Thirdly, this Chapter outlined the metrics which will be employed for quantifying the selected variables, justified the appropriateness and applicability of each metric and extensively scrutinised the selection of the appropriate metric for Trade Flow. Fourthly, this Chapter presented the refining of the main dataset of countries which will be utilised throughout this research and assessed the corresponding data completeness. Lastly, this Chapter discussed the applicable modelling approaches for the utilised dataset.

The next Chapter will proceed with detailing the statistical analysis employed in this research and the corresponding quantification of the selected variables.

Chapter 5. Quantification of the selected variables

5.1 Introduction

This Chapter proceeds with the statistical analysis of this research and corresponds to Phase 2 of the research (see Section 3.12). The analysis is conducted in Stata software (Release 17) (StataCorp., 2021d). Stata is a statistical package which is widely used in research and it is supported by detailed documentation (including mathematical grounding and practical examples). The software also offers supportive material for further comprehension of the applicable methods and most importantly provides a rich suite of estimators that are specifically designed to accommodate panel data models. A number of alternative statistical packages were also reviewed (e.g. SPSS) and it was concluded that Stata offers the most appropriate suite of solutions for answering the research questions.

In this Chapter, Section 5.2 proceeds with the model preparation which involves variable rescaling, Section 5.3 provides a descriptive analysis of the data, Section 5.4 experiments with the various model specifications that may be applicable for the employed data, Section 5.5 proceeds with the selection of the model that this research finally utilises, Section 5.7 tests the robustness of the selected model, Section 5.8 undertakes a marginal effect analysis, Section 5.9 corresponds to the analysis of the long-established connections and finally Section 5.10 comprises the concluding remarks of this Chapter.

5.2 Model Preparation

Model coefficients (or margins in the case of non-linear models such as probit and logit models) indicate the expected impact that an incremental change of a certain independent variable is anticipated to have in the outcome. However, depending on the scale of the independent variable, this incremental change may effectively be small or even negligible which in turn may reduce the interpretability of the model and its results (SCC, 2023). Variable rescaling may assist to counter this problem (*ibid*).

In the context of this research, Trade Flow for example is reported in TEU and may correspond to a few million TEU for a given country in a year. Reporting a corresponding change of 1 unit (TEU) as a driver of the probability that two countries may be directly connected is not expected to be meaningful. Simultaneously, other independent variables are reported in a much smaller scale. For instance, Reefer Cargo is reported as a decimal number within the range 0 and 1 (see Section 4.4.6). With the aim to provide meaningful and comparable results, the research proceeds to rescale certain variables as per below:

- Trade Flow, Trade Imbalance: original values divided by 10,000
- Connectivity, Trade Facilitation: original values divided by 10
- Reefer Cargo: original values multiplied by 100

This procedure does not change the statistical significance of the margins but only their interpretation. For instance, instead of analysing the impact that an increase of 1 TEU in bilateral trade may have to the probability of establishing a direct connection between two trading countries, the model will calculate the impact of an increase of 10,000 TEU in a given year and so forth.

Following the variable rescaling, the organisation of the data in panels is executed via the use of the *xtset* command in Stata. In general, the *''xt''* prefix denotes a panel-type command in Stata. A unique identification number is generated and assigned to each country (country_id) and the corresponding data of each country for years 2012 to 2020 is clustered accordingly:

```
. xtset country_id year

Panel variable: country_id (strongly balanced)
 Time variable: year, 2012 to 2020
         Delta: 1 unit
```

Figure 5.1 – Panel Data declaration in Stata

The corresponding Stata command that is illustrated in Figure 5.1, reflects that the data is clustered by country and year and that it is strongly balanced. In panel data parlance, this means that there are no missing years for the model variables (i.e. the corresponding values are observed for all years within the period 2012-2020). The

Delta value corresponds to 1 unit which indicates that the data is observed on annual basis.

5.3 Descriptive Statistics

Prior to the commencement of the core statistical analysis, it may be useful to proceed with a basic descriptive analysis of the data. Descriptive statistics provide insights on the basic features of an employed dataset and provide useful summaries (Mishra *et al.*, 2019) which in turn assists on the further understanding of the available data.

The *xtsum* Stata command returns a summary statistics table of all variables (Table 5-1):

Variable	Observations	Mean	Std. dev.	Min	Max
Trade Flow	1,224	6.59	22.92	0.00	250.42
Trade Imbalance	1,224	-0.12	4.84	-52.99	40.49
Connectivity	1,224	2.88	2.59	0.09	15.95
MSR Routing	1,224	0.26	0.44	0	1
ECA Routing	1,224	0.11	0.32	0	1
Colonial Ties	1,224	0.32	0.47	0	1
Trade Facilitation	1,165	7.53	1.12	3.30	9.50
Reefer Cargo	1,132	25.45	9.30	5.94	57.45
Logistics Performance	1,053	2.95	0.58	1.60	4.23
Direct Connection	1,224	0.49	0.50	0	1

Table 5-1 – Summary statistics

The summary provides various insights into the employed data. For instance, across the period 2012 to 2020, Trade Flow between the UK and trading countries varied from 0 to 250.42 (i.e. 2,500,420 TEU). Additionally, the mean value of Trade Imbalance was negative (-0.12 or 1,200 TEU) which indicates that over the period 2012 to 2020 the UK generally imported more TEU than it exported to the countries in the data. Furthermore, the UK's trade partners appear to be quite heterogeneous across all continuous variables (Trade Flow, Trade Imbalance, Connectivity, Trade Facilitation, Reefer Cargo, and Logistics Performance) which is reflected in the wide range between minimum and maximum values for most of them. Finally, the mean of the dependent variable (Direct Connection) provides an indication that there was probably a balance between the number of the countries that were directly and indirectly connected to the UK over the analysed period.

The *xttab* Stata command (Table 5-2) also returns a summary statistics table of all variables but allows for a deeper analysis. Apart from the overall statistics which are reported in Table 5-1, the *between* and the *within* statistics are also displayed. In panel data parlance, those describe the variation across (between) different panels and within panels, respectively (Wooldridge, 2010). As illustrated in Table 5-2, the between values are calculated by comparing the corresponding figures across countries (e.g. see column Observations – Trade Flow, n = 136) while within values are calculated by comparing each individual country to itself across years (e.g. see column Observations – Trade Flow, T = 9). A closer observation of Table 5-2 indicates that across all variables, between variations are larger than within variations (see column St. Dev.). This indicates that if two countries are randomly selected from the data, the difference in the value of a given variable between them is expected to be larger than the difference for the same country when the respective values of two randomly selected years are compared (StataCorp., 2022f).

Variable	Variation	Mean	Std. dev.	Min	Max	Observations
Trade Flow	overall	6.59	22.92	0.00	250.42	N = 1224
	between		22.80	0.00	224.23	n = 136
	within		3.03	-38.76	32.78	T = 9
Trade Imbalance	overall	-0.12	4.84	-52.99	40.49	N = 1224
	between		4.60	-29.15	29.26	n = 136
	within		1.55	-23.96	17.67	T = 9
Connectivity	overall	2.88	2.59	0.09	15.95	N = 1224
	between		2.57	0.34	14.39	n = 136
	within		0.38	1.42	4.86	T = 9
MSR Routing	overall	0.26	0.44	0.00	1.00	N = 1224
	between		0.41	0.00	0.89	n = 136
	within		0.17	-0.63	0.37	T = 9
ECA Routing	overall	0.11	0.32	0.00	1.00	N = 1224
	between		0.31	0.00	1.00	n = 136
	within		0.04	-0.11	0.89	T = 9
Colonial Ties	overall	0.32	0.47	0.00	1.00	N = 1224
	between		0.47	0.00	1.00	n = 136
	within		0.00	0.32	0.32	T = 9
Trade Facilitation	overall	7.53	1.12	3.30	9.50	N = 1165
	between		1.05	5.08	9.17	n = 131
	within		0.39	4.10	9.50	T-bar = 8.89
Reefer Cargo	overall	25.45	9.30	5.94	57.45	N = 1132
	between		8.94	11.83	49.47	n = 135
	within		3.20	5.00	45.86	T-bar = 8.39
Logistics Performance	overall	2.95	0.58	1.60	4.23	N = 1053
	between		0.57	2.03	4.17	n = 117
	within		0.12	2.46	3.35	T = 9
Direct Connection	overall	0.49	0.50	0.00	1.00	N = 1224
	between		0.47	0.00	1.00	n = 136
	within		0.19	-0.40	1.38	T = 9

Table 5-2 – Summary statistics (between/within)

Further granularity may be provided by utilising the *xttab* Stata command specifically for the dependent variable (Direct Connection), as illustrated in Table 5-3:

Direct Connection	Overall		Between		Within
	Frequency	Percent	Frequency	Percent	Percent
0	620	50.65	82	60.29	84.01
1	604	49.35	79	58.09	84.95
Total	**1224**	**100**	**161 (n=136)**	**118.38**	**84.47**

Table 5-3 – Summary Statistics, Direct Connection

The outcome of the *xttab* Stata command indicates the following:

- The Overall values summarize the data in terms of country-years (StataCorp., 2022f). Thus, the table indicates that the data includes 1224 country-years (i.e. 136 countries multiplied by 9 years) for which indirect connections correspond to 50.65% of the total and direct connections to 49.35% of the total. This is in line with the conclusion made previously (see Table 5-1) that there was probably a balance between the number of the countries that were directly and indirectly connected to the UK over the analysed period.

- The Between values provide a breakdown in terms of countries rather than in country-years (StataCorp., 2022f). Thus, the table indicates that 82 (60.29%) countries at some point in time between 2012 and 2020 were not directly connected to the UK compared to 79 (58.09%) countries that at some point were directly connected to the UK. This results in a grand total of 161 while the analysed countries are only 136. This finding indicates that at some point in time between 2012 and 2020 a number of countries changed their connection status to the UK from direct to indirect and vice versa.

- The Within values is a measurement of stability and return the fraction of the time that a country remained directly connected (or not) to the UK (StataCorp., 2022f). Thus, the table indicates that if a country was not awarded with a direct connection to the UK then it remained unconnected for the 84.01% of the time within the 2012-2020 period. Respectively, if a country was awarded with a direct connection to the UK then this connection remained open for the 84.95% of the time.

  The Total Within value is the weighted average of the Within percentages normalised by the Between frequencies, calculated as ((82 x 84.01) + (79 x 84.95)) / 161 and depicts the overall stability of the Direct Connection variable (StataCorp., 2022f). This in turn indicates that the connection status of a given country (i.e. directly or indirectly connected to the UK) was infrequently changed.

Finally, the *xttrans* Stata command provides information regarding transition probabilities between two consecutive years (i.e. how a categorical variable may change over time) (StataCorp., 2022f). In Table 5-4, rows depict the initial values and columns the final values (*ibid*):

Direct Connection	Direct Connection		
	0	**1**	**Total**
0	95.83	4.17	100
1	3.17	96.83	100
Total	**50.18**	**49.82**	**100**

Table 5-4 – Transition Probability, Direct Connection

Thus, the table indicates that 95.83% of the countries which were not directly connected to the UK in a given year largely remained with no direct connection to the UK in the next year and only 4.17% managed to obtain a direct connection. Respectively, only 3.17% of the countries which were directly connected to the UK in a given year lost their direct connection in the next year and 96.83% of them retained their direct connection.

Those figures confirm the conclusion on the discussion of Table 5-3. The employed data indicates that the analysed countries largely enjoyed a degree of stability once they had managed to directly connect to the UK. On the contrary, those countries that were not directly connected to the UK hardly proceeded to alter their connection status.

This finding may underline the importance of this research. The analysis of the variables that drive direct connections may assist towards the deeper understanding of (a) the dynamics that keep an established direct connection open and (b) the dynamics that assist a country to overcome the norm and to connect with a targeted trade partner. In other words, the analysis may indicate which variables may be important for a country in order to sustain its connectivity to international markets or most importantly in order to alter its status when it aims to achieve connectivity to targeted trade partners. The latter may potentially enhance its trade performance and thus prosperity.

5.4 Model Specification

At this stage, the research explores various specifications that are applicable in panel data analysis, as those are outlined in Appendix E. As discussed in Appendix E, it is advisable that a statistically-sound process should be followed for the selection of the applicable model. Both Hausman and Mundlak tests require the comparison of a

Fixed Effects and a Random Effects model (see Appendix E). However, since under a Fixed Effects approach there is no available probit model (see Appendix E), the research commences the analysis with logit specifications. However, logit and probit may interchangeably be applied in certain circumstances since – because of their similar function – *''it is very difficult to differentiate between the two models''* (Kissell, 2021).

5.4.1 Random Effects Model

Following the rationale described in Appendix E, a corresponding Random Effects (RE) model is compiled in Stata. The output is presented in Table 5-5:

Random-effects logistic regression						Number of obs = 949
Group variable: country_id						Number of groups = 114
Random effects u_i ~ Gaussian						Obs per group: min = 2 avg = 8.3 max = 9
Integration method: mvaghermite						Integration pts. = 12
						Wald chi2(9) = 57.13
Log likelihood = -164.92						Prob > chi2 = 0.00
Direct Connection	Coef.	Std. err.	z	P>z	[95% conf. interval]	
Trade Flow	3.18	0.60	5.35	0.00	2.02	4.35
Trade Imbalance	2.19	0.90	2.45	0.01	0.44	3.95
Connectivity	2.16	0.45	4.84	0.00	1.28	3.03
MSR Routing	-1.59	0.98	-1.62	0.11	-3.51	0.33
ECA Routing	-3.64	2.01	-1.81	0.07	-7.59	0.31
Colonial Ties	0.55	1.10	0.50	0.62	-1.61	2.72
Trade Facilitation	0.31	0.37	0.85	0.40	-0.41	1.03
Reefer Cargo	0.13	0.05	2.81	0.01	0.04	0.23
Logistics Performance	0.23	1.04	0.22	0.82	-1.81	2.27
_cons	-13.47	3.86	-3.49	0.00	-21.04	-5.90
/lnsig2u	2.59	0.34			1.91	3.26
sigma_u	3.65	0.63			2.61	5.11
Rho	0.80	0.05			0.67	0.89
LR test of rho=0: chibar2(01) = 151.84						Prob >= chibar2 = 0.000

Table 5-5 – Random Effects model specification, Stata output

As discussed in Appendix E, in a non-linear model coefficients are non-informative, and the analysis of the corresponding margins is advisable. Additionally, a detailed analysis of the notation is available in Appendix F. However, a few items in Table 5-5 may be highlighted:

1)

a. rho: denotes the intraclass correlation and effectively reflects how much of the variance at individual country level (i.e. panel) is attributed to the unobserved time-invariant component (i.e. if rho is equal to zero then a pooled approach can be employed).

b. LR test of rho, Prob >= chibar2: denotes a likelihood-ratio test for which the null hypothesis is that rho is equal to zero. The corresponding p-value is compared to a predetermined alpha value which is typically set to 5% (0.05) (i.e. coefficients with a p-value of less than 0.05 are considered to be statistically significant). Occasionally, 1% (0.01) and 10% (0.10) thresholds may also be considered.

   Thus, a Pooled Model approach (see Appendix E) is not considered an advisable specification for the analysed data since rho is not equal to zero and Prob >= chibar2 = 0.000

2)

a. Number of obs / groups: denotes the total number of cases (i.e. rows) / total number of panels (i.e. countries) considered by the model. This corresponds to those groups for which Stata has adequate data across variables and years in order to proceed with a robust inference (StataCorp., 2022f).

   Thus, a Random Effects model considers 114 groups (i.e. countries) on its calculation.

3)

a. Wald chi2: denotes the value of a Wald chi-square statistic which tests whether at least one of the independent variables' coefficient is not equal to zero.

b. Prob > chi2: denotes the probability to encounter a value of the abovementioned Wald chi-square statistic which is as high as the calculated figure or even more. The null hypothesis is that all coefficients are simultaneously equal to zero.

Since Prob > chi2 = 0.00 the null hypothesis is rejected and the employed set of variables form a meaningful and insightful model.

5.4.2 Fixed Effects Model

Following the rationale described in Appendix E, a corresponding Fixed Effects (FE) model is compiled in Stata. The output is presented in Table 5-6:

Conditional fixed-effects logistic regression						Number of obs = 193
Group variable: country_id						Number of groups = 22
						Obs per group:
						min = 7
						avg = 8.8
						max = 9
						LR chi2(7) = 39.08
Log likelihood = -63.93						Prob > chi2 = 0.00
Direct Connection	Coef.	Std. err.	z	P>z	[95% conf. interval]	
Trade Flow	2.13	0.87	2.46	0.01	0.43	3.82
Trade Imbalance	2.01	1.33	1.51	0.13	-0.60	4.61
Connectivity	1.10	0.55	2.01	0.05	0.03	2.18
MSR Routing	-0.58	1.69	-0.34	0.73	-3.89	2.73
ECA Routing	0.00	(omitted)				
Colonial Ties	0.00	(omitted)				
Trade Facilitation	0.61	0.54	1.12	0.26	-0.45	1.66
Reefer Cargo	0.14	0.06	2.38	0.02	0.02	0.25
Logistics Performance	0.31	1.43	0.22	0.83	-2.49	3.12

Table 5-6 – Fixed Effects model specification, Stata output

As discussed in Appendix E, if the outcomes within a panel (i.e. for a given country over the period 2012-2020) do not change then they provide no information, and the fixed effects model simply drops those cases. Indeed, in Table 5-6 it is shown that the model considers only 22 groups in its calculation. In other words, this model specification considers only those 22 countries for which the direct connection status with the UK fluctuated between 0 and 1 within the analysed period. On the contrary, any country that was uninterruptedly connected directly to the UK for the full period (2012-2020) or any country that was never directly connected to the UK within the same period is simply discarded.

Additionally, as also discussed in Appendix E, the Fixed Effects model eliminates the time-invariant random component of the model along with any other time-invariant variable (observed or unobserved) thus the time-invariant coefficients of a model cannot be estimated (StataCorp., 2021b). Indeed, in Table 5-6 it is shown that no calculation is provided for ECA Routing and Colonial Ties (MSR Routing varies since its introduction begins in 2013 for certain countries, see Section 4.4.5).

5.5 Model Selection Process

As proposed in Appendix E, the research proceeds with Hausman and Mundlak tests in order to identify the applicable model for the analysis.

5.5.1 Hausman Test

Following the process described in Appendix E, a comparison between the FE and the RE models is performed in Stata. The output of the calculation is shown in Table 5-7 which is followed by the corresponding statistical test:

Variable	(b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
Trade Flow	2.13	3.18	-1.06	0.63
Trade Imbalance	2.01	2.19	-0.19	0.98
Connectivity	1.10	2.16	-1.05	0.32
MSR Routing	-0.58	-1.59	1.01	1.38
Trade Facilitation	0.61	0.31	0.29	0.40
Reefer Cargo	0.14	0.13	0.00	0.03
Logistics Performance	0.31	0.23	-0.08	0.98

Table 5-7 – Hausman test, Stata output

b = Consistent under H0 and Ha; obtained from xtlogit.

B = Inconsistent under Ha, efficient under H0; obtained from xtlogit.

Test of H0: Difference in coefficients not systematic

chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B) = 15.67

*Prob > chi2 = **0.0283***

Since the test value (Prob > chi2) is lower than 0.05, the null hypothesis is rejected and the use of a Fixed Effects model is suggested.

5.5.2 Mundlak Test

Following the process described in Appendix E, the applicability of a Random Effects instead of a Fixed Effects model is further tested through a Mundlak test. Prior to the performance of the test the group mean values of the time-varying regressors are calculated (i.e. denoted with the ''m_'' prefix below):

.test m_tradeflow m_tradeimbalance m_connectivity m_msrrouting m_tradefacilitation m_reefercargo m_logisticsperformance

(1) [connection] m_tradeflow = 0
(2) [connection] m_tradeimbalance = 0
(3) [connection] m_connectivity = 0
(4) [connection] m_msrrouting = 0
(5) [connection] m_tradefacilitation = 0
(6) [connection] m_reefercargo = 0
(7) [connection] m_logisticsperformance = 0

chi2(7) = 15.69
Prob > chi2 = ***0.0281***

Since the test value is lower than 0.05, the null hypothesis is rejected and the use of a Fixed Effects model is suggested. This result is in accordance with the Hausman test as well.

5.5.3 Correlated Random Effects Model

The implementation of Hausman and Mundlak tests indicates that the unobserved time-invariant random component of the model is likely related to the regressors thus the *''random effects assumption*'' (see Appendix E) cannot hold. Hence, both tests suggest the adoption of a Fixed Effects model.

However, in the context of this research, a Fixed Effects approach is likely to be problematic for the following reasons:

- As indicated in Section 5.4.2, the Fixed Effects model considers only 22 groups in its calculation. Thus, this approach neglects the information held by a substantial part of the data while the statistical inference based on such a low number of countries may be questionable.

- As also indicated in Section 5.4.2, the Fixed Effects model does not provide any estimation regarding Colonial Ties and ECA Routing. Thus, this approach does not allow a complete statistical examination of the targeted variables and effectively limits the ability of the analysis to provide a full answer to the research questions.
- Finally, as indicated in Table 5-2, between variations across all variables are a larger than within variations. Hence, as discussed in Appendix E, when there is more variation between than within panels, a Fixed Effects estimator is not expected to be very efficient and a Random Effects model is preferable (Cameron and Trivedi (2010), as cited in Hoffmann, Saeed and Sødal, 2020).

Thus, this research employs a Correlated Random Effects (CRE) model which is effectively a synthesis of the Fixed and Random Effects approaches (Wooldridge, 2013b). This approach allows a statistical inference which (a) considers an enhanced sample compared to a Fixed Effects model; (b) includes the full set of the independent variables; and (c) employs the *''random effects assumption''* but in a statistically robust manner (see Appendix E).

The corresponding CRE specification follows equation (E-14), it is implemented with the *xtprobit* (RE estimator) command in Stata and incorporates the group mean values of the time-varying regressors that were calculated for the needs of the Mundlak test (see Section 5.5.2). Moreover, as suggested by Wooldridge (2013a), the CRE specification may include a dummy variable for each year of the analysis as extra controls. The use of those controls aims to capture any residual (i.e. unmeasured) effect of other time-varying elements – in case those have been overseen – as to absorb any temporal trends in the analysed data. Stata drops the first year (i.e. 2012) in order to use it as a reference for comparison. Consequently, the interpretation of the corresponding coefficients (and margins) may describe the difference in the expected value of the dependent variable (i.e. Direct Connection) between a given year and the reference year.

Finally, StataCorp. (2021c) suggests that the reliability of a respective command in Stata may be sensitive to the number of the integration points that are used for the numerical calculations. By default, 12 integration points are implemented. With the aim to increase the trustworthiness of the model and by experimenting with the corresponding *quadchk* command in Stata, it is observed that the CRE results stabilise with the use of 60 integration points (i.e. no variable shows a relative difference of over 0.0001 or 0.01%) (StataCorp., 2022b). Hence, this level is finally adopted for the CRE specification (Table 5-8). The output of the quadrature check in Stata is available in the Appendix G (Table G. 1).

Random-effects probit regression						Number of obs = 949
Group variable: country_id						Number of groups = 114
Random effects u_i ~ Gaussian						Obs per group:
						min = 2
						avg = 8.3
						max = 9
Integration method: mvaghermite						Integration pts. = 60
						Wald chi2(24) = 229.75
Log pseudolikelihood = -154.64						Prob > chi2 = 0.00
Direct Connection	Coef.	Robust std. err.	z	P>z	[95% conf. interval]	
Trade Flow	1.85	0.55	3.39	0.00	0.78	2.92
Trade Imbalance	1.02	0.81	1.25	0.21	-0.57	2.61
Connectivity	0.63	0.47	1.34	0.18	-0.29	1.56
MSR Routing	-0.48	0.63	-0.76	0.45	-1.71	0.76
ECA Routing	-1.36	1.53	-0.89	0.38	-4.35	1.64
Colonial Ties	0.63	0.77	0.83	0.41	-0.87	2.14
Trade Facilitation	0.22	0.34	0.64	0.53	-0.45	0.88
Reefer Cargo	0.09	0.04	2.21	0.03	0.01	0.17
Logistics Performance	0.71	1.15	0.62	0.54	-1.54	2.97
m_Trade Flow	-0.22	0.37	-0.60	0.55	-0.96	0.51
m_Trade Imbalance	0.44	1.07	0.41	0.68	-1.66	2.54
m_Connectivity	1.53	0.69	2.21	0.03	0.17	2.89
m_MSR Routing	-1.76	1.38	-1.28	0.20	-4.47	0.94
m_Trade Facilitation	-0.29	0.43	-0.66	0.51	-1.14	0.56
m_Reefer Cargo	0.01	0.07	0.19	0.85	-0.12	0.15
m_Logistics Performance	-0.93	1.45	-0.64	0.52	-3.78	1.92
Year						
2013	-0.12	0.35	-0.34	0.73	-0.81	0.57
2014	0.22	0.54	0.42	0.68	-0.84	1.28
2015	0.33	0.55	0.61	0.54	-0.74	1.41
2016	0.46	0.62	0.74	0.46	-0.75	1.67
2017	0.72	0.66	1.10	0.27	-0.57	2.01
2018	0.38	0.63	0.60	0.55	-0.86	1.62
2019	-0.22	0.62	-0.35	0.72	-1.43	1.00
2020	-0.09	0.62	-0.15	0.88	-1.30	1.12
_cons	-7.54	3.84	-1.97	0.05	-15.06	-0.03
/lnsig2u	1.52	0.38			0.78	2.26
sigma_u	2.14	0.40			1.48	3.09
Rho	0.82	0.06			0.69	0.91

Table 5-8 – Correlated Random Effects model specification, Stata output

It is worth highlighting a number of items in Table 5-8:

- The CRE model considers 114 groups (countries) compared to the Fixed Effects model which considers only 22. The CRE specification considers as many groups as the Random Effects model, but the use of the latter cannot be statistically justified.
- The CRE models return results for all variables including the time-invariant variables (Colonial Ties, ECA Routing) that the Fixed Effects model cannot estimate.
- The rho value is 0.82 which means that 82% of the individual level (i.e. country level) variance is attributed to the unobserved time-invariant component. Wooldridge (2013a) suggests that a pooled approach may also be considered over a CRE probit specification – allowing the relaxation of the serial independence assumption (see Appendix E) – although the pooled approach is not as efficient as the CRE probit model. However, since rho in Table 5-8 differs substantially from zero, the CRE specification reconfirms that a Pooled Model approach is not advisable for the analysed data.

Thus, the CRE specification is adopted as the core model specification of this research. As discussed, a CRE model is effectively a synthesis of the Fixed and Random effects approaches. In the context of this research, a CRE specification is not only a statistically robust process but ultimately represents a *''workable solution''* for the answer to the research questions. The identification of workable solutions through synthesis is at the heart of this research which follows the philosophy of Pragmatism (see Section 3.12).

5.6 Data Missingness

Stata software by default considers for further analysis *only* those rows of the dataset that have complete data and may return enough information for statistical inference. In the context of this research, the values of one or more of the abovementioned variables for certain countries, may be missing for the full period of the study and thus Stata excludes those countries from the analysis. Thus, although the analysis started with 136 countries and the missing data is overall negligible (see Section 4.6), the pattern of the missing data and the software setup eventually dictate the analysis of 114 countries. Adopting a strategy to account for the missing data and achieve full data completeness is generally appealing. However, prior to such a decision a detailed understanding of the underlying missing data mechanism is needed (Jakobsen *et al.*, 2017). Several imputation methods could be considered including:

- Single imputation: missing values are replaced based on a certain rule (e.g. mean value, last observation carried forward etc.) (Jakobsen *et al.*, 2017) thus imputation largely corresponds to interpolation and analysis of the filled-in data (Baltagi, 2005). Those methods employ strong assumptions (e.g. a missing value is identical to the last observed value) and cannot capture the actual variability of the data.
- Maximum likelihood techniques: missing values are replaced by models which *''operate by estimating a set of parameters that maximize the probability of getting the data that was observed''* (Newman, 2003 p332). Those methods in certain circumstances may be quite informative but more often than not cannot be supported by the needed theory and most importantly software (Williams, 2021).
- Multiple imputation: missing values are projected by a relevant model *M times* thus providing *M complete datasets* and following an analysis over all datasets, average values are obtained along with the corresponding errors (Rubin, 1977; Rubin, 1987). The process is referred as being based on *''Rubin's rules''*.

In the context of this research, single imputation for the missing metrics is likely a method that will unavoidably add bias. For instance, the missing values of Trade Facilitation or Logistics Performance across all years for those countries with missing values cannot be filled with the last observed value or any observed value as by definition there are no observed values for this variable (i.e. missing data cases for those variables correspond to countries with no data across 2012-2020). Additionally, assuming the mean value of those variables based on the existing data of other countries is not plausible: all countries with missing data would then assume the same score while those metrics are by definition generated based on the heterogeneity that characterises each country. Respectively, single imputation for Reefer Cargo raises a conceptual issue: the process would unreasonably generate data for Reefer Cargo for those years that certain countries – according to the Bluewater database – did not accommodate any container services (i.e. there was no deployed capacity of container vessels that could be used for reefer cargo).

The completeness of data regarding Trade Facilitation, Reefer Cargo and Logistics Performance through multiple imputation or maximum likelihood techniques may also raise conceptual, practical and statistical issues:

- Conceptual issues:
    a. Reefer Cargo: as mentioned above, for certain countries that their participation in the container shipping network was not observed (based on the available data) in the early years of the study (e.g. Albania 2012-2018), imputation would introduce a score which in the real world was not defined. Thus, at least for Reefer Cargo those methods would not assist either.
- Practical issues:
    a. Regarding Maximum Likelihood techniques for missing data, a range of statistical packages including Stata have not introduced the respective tools that can cope with non-linear panel data models (Williams, 2021) such as the specification that is employed in this research.
    b. Regarding Multiple Imputation, post estimation analysis (such as use of margins and the corresponding plots) on imputed datasets may also be problematic. Specifically, the corresponding documentation by Stata warns that predicted values such as margins are not expected to yield correct outputs and it is actually debatable if there can be any outputs at all (StataCorp., 2023b). It is also equally debatable whether Rubin's rules are applicable on non-linear setups (Williams, 2021).

    Thus, the quality and depth of the corresponding econometric analysis is expected to be questionable in the context of this research.
- Statistical issues:
    a. Multiple Imputation (as well as Maximum Likelihood techniques) are based on the assumption that data are Missing-at-Random (MAR) and in that case the missing data can be predicted based on the observed

data and variables (Jakobsen *et al.*, 2017). In the context of this research, it is unlikely that e.g. the Logistics Performance score of a country could be predicted by variables such as Trade Flow, Trade Imbalance or Colonial Ties since those correspond to the record of a country with reference to the UK (i.e. Trade Flow with the UK is not expected to explain the global perception regarding the LPI performance of a given country). Equally, ECA Routing and MSR Routing or Reefer Cargo are unlikely to be good predictors of Logistics Performance. The only logical associations could partly be with Connectivity but more likely with Trade Facilitation.

However, the question is under which circumstances the missing data of a variable such as Logistics Performance are MAR?

Based on the relevant example by Williams (2021) and assuming an association between Logistics Performance and Trade Facilitation, data are MAR if the probability of missing Logistics Performance values depends on Trade Facilitation, but within each Trade Facilitation group (e.g. low-scoring countries – 25th percentile), the probability of missing Logistics Performance values does not depend on Logistics Performance itself. In other words, low-scoring countries regarding Trade Facilitation may be more likely to have missing data for Logistics Performance. However, within this group of countries (i.e. low-scoring on Trade Facilitation), low-scoring Logistics Performance countries are no more likely to be missing Logistics Performance values than are high-scoring Logistics Performance countries of the same group (under MAR assumption). For instance, Barbados and Angola belong to the 25th percentile (as per Figure 5.2) with regard to Trade Facilitation, scoring 60 and 66 (average value across 2012-2020), respectively. Barbados has no reported score for Logistics Performance (i.e. no LPI score by the World Bank) while Angola has the highest Logistics Performance score of this group. MAR data assumption would suggest that the probability of missing a Logistics Performance score for Barbados is no more likely compared to Angola. This cannot be definitely concluded since LPI data for Barbados is not observed and thus it cannot be fully assessed whether Barbados is equally likely to have missing Logistics Performance data as Angola (Newman, 2003). However, the methodology of LPI may also provide some clarification: the index is constructed based on a global survey where international logistics providers opine on the *''friendliness''* of the countries with which those providers specifically trade (The World Bank, 2023a). It can then be assumed that there is no representative feedback by the survey participants for Barbados (and relevant countries) to provide a (statistically robust) LPI score because the participants do not trade with Barbados as they do with Angola. Thus, within the same Trade Facilitation group of countries, a specific country may be more likely to have missing Logistics Performance data than others which may violate the MAR assumption. The same rationale applies for the assessment of the Trade Facilitation MAR assumption which is likely also violated.

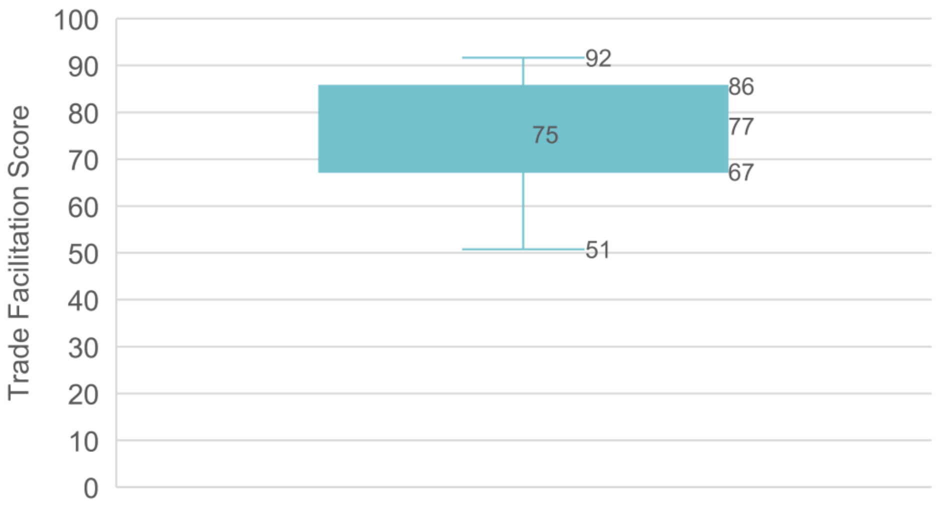

Figure 5.2 – Trade Facilitation (Average Score per Country) Boxplot

b. It is advisable that a multiple imputation model may include all or as many variables as possible with complete data (StataCorp., 2023b). As mentioned above though, a very small fraction of the variables seems to be relevant for predicting the missing values of Logistics Performance (and Trade Facilitation, respectively). Although the rationale of Multiple Imputation under Rubin's rules accounts for errors by repeating the process multiple times, the small fraction of relevant predictors could potentially raise methodological issues and introduce more bias than it resolves.

In conclusion however, none of the above techniques are deemed applicable in the context of this research. This research acknowledges both the possible bias concerns for proceeding with the analysis of 114 out of 136 trading partners of the UK as well as the available (but not necessarily applicable in this research) methods to tackle this issue. It is worth mentioning though that proceeding with the remaining complete cases is expected to be problematic in datasets where the remaining cases are not representative of the population of interest (StataCorp., 2023b). In the context of this research the population of interest are the trading partners of the UK (i.e. those countries that have exchanged container volumes with the UK during the period 2012-2020). The countries that are not considered in the final analysis correspond overall to only 1.15% of the traded container volume (TEU). Hence, those countries are not regarded as pivotal for the analysis and it is anticipated that their exclusion does not introduce a material amount of bias to the results.

5.7 Robustness Checks

5.7.1 Non-stationarity

The stationarity of the data in Stata can be checked with the use of the *xtunitroot* command which supports various *''unit root''* tests. Those tests examine the hypothesis that an analysed timeseries may be an autoregressive process with a root (of a corresponding polynomial) equal or close to unity (Koenker and Xiao, 2004). Specifically, the established tests are designed to statistically examine whether the mean and variance of a dataset change over time by testing the null hypothesis that the panels contain a unit root (StataCorp., 2022c). The command supports various types of tests grounded on the work of Levin, Lin and James Chu (2002), Harris and Tzavalis (1999), Breitung (2001); Breitung and Das (2005), Im, Pesaran and Shin (2003), Hadri (2002) as well as Choi (2001) for Fisher-type tests. Due to a few missing datapoints (see Section 4.6), only Im–Pesaran–Shin (Im, Pesaran and Shin, 2003) and Fisher-type (Choi, 2001) tests are considered as applicable by Stata for the analysed data (StataCorp., 2022c).

This research proceeds with a Fisher-type test. The latter is preferable over an Im–Pesaran–Shin test (Im, Pesaran and Shin, 2003) since it may provide a more holistic conclusion (StataCorp., 2022c). This is due to the fact that the test is effectively a meta-analysis process which combines multiple p-values from independent tests with the aim to provide an overall statistical result. A relevant approach was originally suggested by R.A. Fisher and thus the corresponding process is called a Fisher-type test (*ibid*). In panel data analysis, the Fisher-type process performs a unit-root test per panel and then combines p-values to a single test statistic. The test specifically combines the results of 4 distinct tests as those were proposed by Choi (2001). The null hypothesis of the test is that all panels contain a unit root. The fact that the null hypothesis is filtered through 4 different tests makes the selection of a Fisher-type test a rigorous and robust choice (StataCorp., 2022c). A Fisher-type test is a combination of multiple results and in practice it actually utilises an underlying statistical process to calculate the results such as the *augmented Dickey-Fuller* test (ADF) which tests the null hypothesis that a variable derives from a unit-root process (i.e. the variable is not stationary) (StataCorp., 2022a).

The ADF process includes in the calculation the differenced values of the variables to account for any serial correlation between years (StataCorp., 2022a). Hence, the Fisher test assumes that the datapoints are the outcome of an autoregressive process which means that a variable x_t derives from its value in t-1 plus a random shock (i.e. error term) (StataCorp., 2022c). Thus, a *lag* option is also required in *xtunitroot* command to account for the order of the applied differencing in the variables. This research proceeds with first differences (i.e. 1 lag) but extends to test the outcome for second differences as well (i.e. 2 lags).

Finally, if the examined variable has a non-zero mean (i.e. varies over time) the use of the *drift* option should be considered when executing the *xtunitroot* command (StataCorp., 2022c). In the parlance of stationarity in time-series, a variable x_t is considered to follow a *''random walk with drift''* when its value may drift upward or downward compared to its own lagged value x_{t-1} (Gujarati, 2004). Indeed, Nelson and Plosser (1982), as cited in Hyndman *et al.* (2008) suggested that macroeconomic data are likely to exhibit the behaviour of a random walk with drift. Macroeconomic data refers to aggregate values of economic indicators (e.g. at country level) (Hill, 2001) such as the metrics employed in the model of this research (e.g. Trade Flow, Trade Facilitation etc.). Drift is essentially a constant shift which may be upwards or downwards (Gujarati, 2004) but follows a consistent direction within the context of random variations. By including the drift option on the xtunitroot test, the test adjusts for any deterministic change (drift) that may be present in the series. Following on from the consideration of the drift, the test then examines the residual part of the series for stationarity. In the context of this research, the value of the time-varying variables (Trade Flow, Trade Imbalance, Connectivity, Trade Facilitation, Reefer Cargo, and Logistics Performance) is expected to change over time thus a drift option is included in the unit root test command.

The full results for Trade Flow using 1 lag are displayed in Table 5-9. All 4 processes (Inverse chi-squared, Inverse normal, Inverse logit t, Modified inv. chi-squared) test the null hypothesis that the corresponding data is non-stationary. The respective p-values present compelling evidence to reject the null hypothesis thus Trade Flow is stationary with 1 lag and a drift term included.

Table 5-10 and Table 5-11 include the results for all variables with 1 and 2 lags, respectively as well as a drift term included. The results reconfirm that the employed data is stationary and the modelling effort can proceed with no further adjustments.

Fisher-type unit-root test for Trade Flow Based on augmented Dickey–Fuller tests			
H0: All panels contain unit roots Ha: At least one panel is stationary	Number of panels = 136 Number of periods = 9		
AR parameter: Panel-specific	Asymptotics: T -> Infinity		
Panel means: Included			
Time trend: Not included			
Drift term: Included	ADF regressions: 1 lag		
		Statistic	**p-value**
Inverse chi-squared (266)	P	658.47	**0.0000**
Inverse normal	Z	-11.79	**0.0000**
Inverse logit t (669)	L*	-12.69	**0.0000**
Modified inv. chi-squared	Pm	17.02	**0.0000**
P statistic requires number of panels to be finite. Other statistics are suitable for finite or infinite number of panels.			

Table 5-9 – Fisher Unit-root test, Trade Flow (1 lag), Stata output

Variable	**Unit-root test**							
	Inverse chi-squared		**Inverse normal**		**Inverse logit t**		**Modified inv. chi-squared**	
	Statistic	**p-value**	**Statistic**	**p-value**	**Statistic**	**p-value**	**Statistic**	**p-value**
Trade Flow	658.47	**0.0000**	-11.79	**0.0000**	-12.69	**0.0000**	17.02	**0.0000**
Trade Imbalance	711.23	**0.0000**	-13.53	**0.0000**	-14.68	**0.0000**	19.30	**0.0000**
Connectivity	578.41	**0.0000**	-11.60	**0.0000**	-11.47	**0.0000**	13.14	**0.0000**
Trade Facilitation	455.22	**0.0000**	-7.17	**0.0000**	-7.19	**0.0000**	9.18	**0.0000**
Reefer Cargo	562.38	**0.0000**	-13.55	**0.0000**	-13.49	**0.0000**	15.99	**0.0000**
Logistics Performance	762.99	**0.0000**	-17.39	**0.0000**	-18.61	**0.0000**	24.45	**0.0000**

Table 5-10 – Fisher Unit-root test results (1 lag)

Variable	**Unit-root test**							
	Inverse chi-squared		**Inverse normal**		**Inverse logit t**		**Modified inv. chi-squared**	
	Statistic	**p-value**	**Statistic**	**p-value**	**Statistic**	**p-value**	**Statistic**	**p-value**
Trade Flow	478.86	**0.0000**	-6.99	**0.0000**	-7.15	**0.0000**	9.35	**0.0000**
Trade Imbalance	518.88	**0.0000**	-9.18	**0.0000**	-9.34	**0.0000**	11.09	**0.0000**
Connectivity	474.37	**0.0000**	-8.14	**0.0000**	-8.01	**0.0000**	8.68	**0.0000**
Trade Facilitation	389.22	**0.0000**	-5.77	**0.0000**	-5.72	**0.0000**	6.46	**0.0000**
Reefer Cargo	418.93	**0.0000**	-9.02	**0.0000**	-8.68	**0.0000**	9.21	**0.0000**
Logistics Performance	466.71	**0.0000**	-10.97	**0.0000**	-10.65	**0.0000**	11.04	**0.0000**

Table 5-11 – Fisher Unit-root test results (2 lags)

5.7.2 Multicollinearity

As discussed in Appendix E, severe multicollinearity in a model results in biased estimates and the corresponding correlations between the employed variables should be checked accordingly.

The respective process in Stata can be performed via the *estat vce, corr* command. The objective of this check is to depict whether there is a strong (positive or negative) correlation between any two variables. This piece of analysis focuses on the 9 selected variables (i.e. Trade Flow, Trade Imbalance, Connectivity, MSR Routing, ECA Routing, Colonial Ties, Trade Facilitation, Reefer Cargo, and Logistics Performance) and the outcome is illustrated in Table 5-12:

e(V)	Trade Flow	Trade Imbalance	Connectivity	MSR Routing	ECA Routing	Colonial Ties	Trade Facilitation	Reefer Cargo	Logistics Performance	_cons	Insig2u
Trade Flow	1.00										
Trade Imbalance	0.64	1.00									
Connectivity	-0.22	-0.27	1.00								
MSR Routing	0.16	0.26	-0.32	1.00							
ECA Routing	-0.41	-0.21	-0.03	0.06	1.00						
Colonial Ties	-0.14	-0.25	0.11	-0.21	0.04	1.00					
Trade Facilitation	0.16	0.24	0.10	0.24	-0.05	0.08	1.00				
Reefer Cargo	-0.15	-0.31	0.54	-0.18	-0.04	0.24	-0.10	1.00			
Logistics Performance	-0.04	0.04	-0.26	-0.27	-0.37	0.16	-0.30	-0.13	1.00		
_cons	-0.04	-0.04	-0.29	0.18	0.38	-0.37	-0.48	-0.30	-0.52	1.00	
Insig2u	0.40	0.30	0.14	-0.03	-0.40	-0.19	0.40	-0.03	0.03	-0.37	1.00

Table 5-12 – Correlation matrix of coefficients of xtprobit model, Stata Output

The only pair of variables that returns a notable correlation is Trade Flow – Trade Imbalance. This is largely expected and easily explained: as discussed in Sections 4.4.8 and 4.4.9, Trade Flow is measured based on the DfT records (TEU) and the corresponding Trade Imbalance is given by the difference between UK exports and imports to / from each trading country in the dataset. Thus, Trade Imbalance is a direct product of Trade Flow and it thus expected to be directly influenced by the respective Trade Flow value. However, as it is depicted in Figure 5.3, by looking into the Trade Flow – Trade Imbalance data of the 10 countries that recorded the highest number of TEU exchanges with the UK, the relationship between the two variables is not always straightforward. For instance:

- the country with the largest Trade Flow (China) corresponds to a negative Trade Imbalance for the UK;
- the largest positive Trade Imbalance for the UK corresponds to a country (Germany) which does not record one of the highest Trade Flow values;

- among the 10 countries analysed in the graph, the UK records negative Trade Imbalance with 6 of them and positive with 4 of them.

Thus, Trade Flow and Trade Imbalance – although they are generated by the same source of data – may follow distinct patterns per trading country. A high value of Trade Flow may indicate either a high or a low Trade Imbalance. This in turn can also be either positive or negative depending on the nature of the trade dynamics that characterise a bilateral trade relationship.

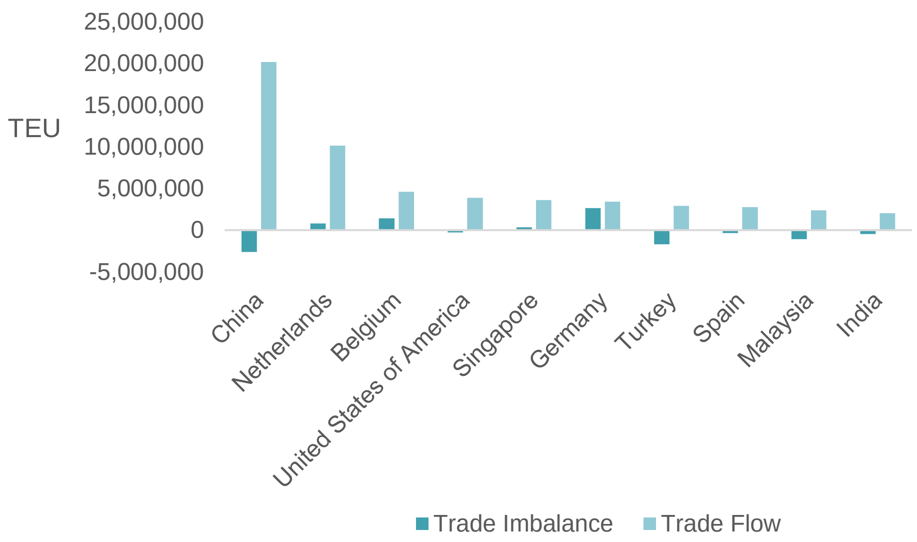

Figure 5.3 – Trade Flow/Trade Imbalance of the Top10 UK trade partners (2012-2020)

Overall, the corresponding score is not particularly strong (0.64). This level does not exceed the empirical threshold of 0.70 (Alnıpak, Isikli and Apak, 2021). Hence, it is not expected that one variable can essentially be predicted by the other (Johnston, Jones and Manley, 2018). Thus, both Trade Flow and Trade Imbalance are retained in the model and overall this research proceeds with no further concerns regarding multicollinearity.

5.7.3 Endogeneity

As discussed in Appendix E, Fugazza and Hoffmann (2017) underlined that Trade Flow may influence the establishment of a Direct Connection between countries but a Direct Connection may in turn also influence the Trade Flow between the countries. This may raise a possible issue of endogeneity (simultaneity) since the impact of an independent variable (Trade Flow) on the dependent variable (Direct Connection) is modelled but it is suspected that the same independent variable may also be –

partially – determined by the dependent variable. As also suggested in Appendix E (and thoroughly analysed in Section 4.5.2) this is seemingly not a concern for this research based on the manual check of the employed data. However, Fugazza and Hoffmann (2017) raised an important point which should be scrutinised through a statistical check as well.

This research attempts to address this point with the use of instrumental variables (IV) (see Appendix E). Thus, the aim is to find one or more variables which are related to the independent variable x_i (Trade Flow) that may be endogenous and not directly related to the dependent variable y (Direct Connection) but only through x_i (Hill *et al.*, 2021). Although this is not always a straightforward exercise, the analysis that was synopsised in Table 4-1 and depicted in Figure 4.5 may be quite indicative. Specifically, in Table 4-1 it is stated that according to Vidya and Taghizadeh-Hesary (2021) an increase in GDP per Capita – as a measure of economic development and prosperity – can boost bilateral trade (Trade Flow) between trading countries. The corresponding relationship was depicted in Figure 4.5 as follows:

Figure 5.4 – GDP per Capita as Instrumental Variable

Thus, an increase in GDP per capita may assist to boost Trade Flow which in turn may encourage the establishment of a Direct Connection between the UK and a given trade partner. Based on the causal assumptions of this research, GDP per Capita may only impact Direct Connection via Trade Flow. Since this research takes into consideration both exports and imports from / to the UK it may be logical to include the GDP per Capita development over the years at both ends of a bilateral relationship between countries. Thus, the instrumental variables that may assist to test for endogeneity are *GDP per Capita Partner* and *GDP per Capita UK*. Hence, this research proceeds to build a system of two equations:

- on the first equation Trade Flow is a dependent variable with GDP per Capita Partner and GDP per Capita UK as explanatory variables.
- on the second equation – which has so far been the core specification of this research (see Table 5-8) – Trade Flow is an explanatory variable of Direct Connection (dependent variable).

In order to fit this system of equations, a model that can support the use of instrumental variables in a panel probit setup is needed. This research proceeds to employ the Conditional Mixed-Process Model (CMP) in the Stata suite as proposed by Roodman (2011). CMP is a flexible setup that can estimate a broad family of models. Those include the estimation of models for which simultaneity may be present, but the use of instrumental variables allow the compilation of a two-stage recursive set of equations (*ibid*) as the abovementioned system. The flexibility of the CMP model is deemed useful for this research for an additional reason. Sometimes the values of certain parameters are not readily available in Stata and they have to be retrieved or manually computed (Buis L., 2011). However, the CMP model has among other attributes the power to retrieve a particular computation that is very useful in addressing the endogeneity issue that this research wishes to examine.

CMP can specifically:

- fit a system of equations that may include endogenous variables with the use of instruments and then calculate the *rho (*denoted by the Greek letter *''ρ'')* value. The latter effectively corresponds to the correlation of errors between the first equation (i.e. dependent variable: Trade Flow) and the second equation (i.e. dependent variable: Direct Connection) (Roodman, 2011).

- report the *atanhrho* value: this effectively is a transformation of the *rho* parameter. The calculation of transformed parameters assists in providing the model with valid values on its search for convergence (Buis L., 2011; Roodman, 2011). For example, the value of a standard deviation should be a positive number thus a logarithmic transformation may be followed (Buis L., 2011). Respectively, the correlation coefficient *rho* is commonly transformed into its inverse hyperbolic tangent by utilising Fisher's *z* transformation (*ibid*):

$$z = 1/2\,[\ln(1 + \rho) - \ln(1 - \rho)] \qquad (6\text{–}1)$$

  In Stata this is calculated as z = atanh(ρ) and displayed as atanhrho (or atanhrho_12 in CMP output).

This value effectively reports whether there is a correlation between the errors of the two equations as discussed and implemented by various researchers (e.g. Ji, Ranjan and Burton, 2016; Ramírez-Alesón and Fernández-Olmos, 2020; Li *et al.*, 2022). In other words, after specifying and fitting a CMP model that addresses the needs of this exercise, if the p-value of the atanhrho is statistically significant then the errors are correlated and the corresponding variable under examination is regarded as endogenous. On the contrary, if the corresponding p-value of the atanrho parameter is not statistically significant then the model suggests that the corresponding variable (i.e. Trade Flow) is not endogenous.

Despite the great flexibility and usefulness of the CMP model for testing a potential issue of endogeneity in this research, the applicability and the accuracy of the CMP model is checked prior to its adoption for the continuation of this exercise. Specifically, the CRE model (XT CRE) that has so far been adopted as the core specification (see Table 5-8) is replicated under a CMP setup (CMP CRE). The comparison of the corresponding margins (see Appendix E) and p-values for the employed variables is illustrated on Table 5-13. The margins of the various specifications that have been discussed in this Chapter or could be applicable in the context of this research are further discussed in Section 5.8.

Variable	Margins		p-values	
	dy/dx		P>z	
	XT CRE	CMP CRE	XT CRE	CMP CRE
Trade Flow	0.13	0.13	**0.00**	**0.00**
Trade Imbalance	0.07	0.08	0.21	0.19
Connectivity	0.05	0.05	0.18	0.21
MSR Routing	-0.03	-0.03	0.45	0.43
ECA Routing	-0.08	-0.07	0.38	0.34
Colonial Ties	0.05	0.04	0.41	0.44
Trade Facilitation	0.02	0.02	0.53	0.53
Reefer Cargo	0.01	0.01	**0.03**	**0.04**
Logistics Performance	0.05	0.05	0.54	0.54
m_Trade Flow	-0.02	-0.01	0.55	0.62
m_Trade Imbalance	0.03	0.03	0.68	0.67
m_Connectivity	0.11	0.11	**0.03**	**0.01**
m_MSR Routing	-0.13	-0.11	0.20	0.20
m_Trade Facilitation	-0.02	-0.02	0.51	0.51
m_Reefer Cargo	0.00	0.00	0.85	0.82
m_Logistics Performance	-0.07	-0.08	0.52	0.49
Year				
2013	-0.01	-0.01	0.73	0.73
2014	0.02	0.02	0.68	0.69
2015	0.02	0.02	0.54	0.54
2016	0.03	0.03	0.46	0.45
2017	0.05	0.06	0.27	0.26
2018	0.03	0.03	0.55	0.54
2019	-0.01	-0.01	0.72	0.73
2020	-0.01	-0.01	0.88	0.89

Table 5-13 – Margins Comparison of XT CRE and CMP CRE models

The results show that the corresponding margins and p-values are very similar with trivial differences for only a few of the variables on the second decimal. Additionally, both setups return the same set of statistically significant variables (i.e. Trade Flow, Reefer Cargo and Mean Connectivity). For those variables, both the displayed margins and p-values between the two models are identical. Thus, this research proceeds to utilise CMP for the further examination of a possible endogeneity problem regarding Trade Flow.

The corresponding specification of the CMP model which utilises GDP per Capita Partner and GDP per Capita UK as instruments is depicted in Table 5-14. At the bottom of the table, the additional equation which models Trade Flow as a function of GDP per Capita is depicted. The corresponding p-value of atanhrho (atanhrho_12) is 0.92 (> 0.05) thus not statistically significant. Hence, the CMP specification suggests that – at least for the modelled dataset – Trade Flow is not endogenous, and the core specification may return consistent estimates.

CMP IV Regression						
Direct Connection	Coef.	Robust std. err.	z	P>z	[95% conf. interval]	
Trade Flow	1.56	5.20	0.30	0.77	-8.64	11.76
Trade Imbalance	0.80	3.07	0.26	0.79	-5.22	6.83
Connectivity	0.49	2.40	0.20	0.84	-4.21	5.19
MSR Routing	-0.37	1.79	-0.20	0.84	-3.88	3.15
ECA Routing	-1.18	4.20	-0.28	0.78	-9.40	7.05
Colonial Ties	0.57	2.72	0.21	0.84	-4.77	5.90
Trade Facilitation	0.18	0.62	0.29	0.77	-1.03	1.39
Reefer Cargo	0.08	0.22	0.35	0.73	-0.36	0.52
Logistics Performance	0.71	1.12	0.63	0.53	-1.49	2.91
m_Trade Flow	-0.21	0.87	-0.24	0.81	-1.90	1.49
m_Trade Imbalance	0.42	1.37	0.31	0.76	-2.26	3.11
m_Connectivity	1.36	3.94	0.35	0.73	-6.35	9.08
m_MSR Routing	-1.67	5.87	-0.28	0.78	-13.17	9.83
m_Trade Facilitation	-0.23	0.69	-0.33	0.74	-1.59	1.13
m_Reefer Cargo	0.01	0.13	0.11	0.91	-0.24	0.27
m_Logistics Performance	-0.98	1.31	-0.75	0.45	-3.56	1.59
Year						
2013	-0.12	0.29	-0.42	0.67	-0.70	0.45
2014	0.17	0.92	0.18	0.85	-1.64	1.97
2015	0.24	1.45	0.16	0.87	-2.60	3.07
2016	0.35	1.69	0.21	0.84	-2.97	3.67
2017	0.57	2.27	0.25	0.80	-3.88	5.02
2018	0.28	1.40	0.20	0.84	-2.46	3.01
2019	-0.21	0.85	-0.25	0.80	-1.88	1.45
2020	-0.10	0.62	-0.17	0.87	-1.32	1.11
_cons	-6.51	27.73	-0.23	0.82	-60.86	47.85
Trade Flow						
GDP per Capita_Partner	0.00	0.00	2.31	0.02	0.00	0.00
GDP per Capita_UK	0.00	0.00	1.86	0.06	0.00	0.00
_cons	-3.33	1.74	-1.91	0.06	-6.74	0.09
/lnsig_1_1	0.57	3.31	0.17	0.86	-5.93	7.06
/lnsig_2	3.13	0.36	8.67	0.00	2.43	3.84
/atanhrho_12	-0.65	6.18	-0.11	0.92	-12.77	11.46

Table 5-14 – CMP IV model specification, Stata output

5.8 Margins

Based on the theoretical background that is provided in Appendix E, the corresponding margins (i.e. average marginal effects) are reported in Table 5-15. This includes the respective margins of various specifications that have so far been discussed (i.e. XT Logit FE – Model 1, XT Logit RE – Model 2, XT Probit RE – Model 3), the core model specification of this research (XT CRE – Model 4) as well as its equivalent via an additional estimator (CMP CRE – Model 5). This research also experimented with an additional approach by building upon Figure 4.5. The latter depicts the causal assumptions of this research and is effectively a path diagram which denotes the assumed relationships between the employed variables. According to Harrison, Stephan and Friston (2007) path analysis or Structural Equation Modelling (SEM) is a multivariate statistical technique that can be utilised to test hypotheses regarding the interactions between variables and estimate the coefficients of each path. SEM models in Stata can be solved either by compiling the corresponding model via a standard command or by directly drawing the respective path diagram in the incorporated *Builder* tool which executes the model graphically (StataCorp., 2022j). Probit models and multilevel models such as the specifications that this research employs are specifically solved by the Generalised Structural Equation (GSEM) command in Stata.

The reason for compiling GSEM specifications in this research is two-fold: (a) to test whether the results of an additional estimator are similar to the respective results of the discussed specifications and (b) to test whether the modelling effort may also be graphically approached. The corresponding path diagram that is compiled and utilised by the GSEM Builder is available in Appendix H. Overall, the analysis considers 3 GSEM models: GSEM RE – Model 6, GSEM CRE – Model 7, and GSEM CRE_G – Model 8 (the abovementioned graphical approach):

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	**XT Logit FE**	**XT Logit RE**	**XT Probit RE**	**XT CRE**	**CMP CRE**	**GSEM RE**	**GSEM CRE**	**GSEM CRE_G**
Trade Flow	0.04	**0.14**	**0.14**	**0.13**	**0.13**	**0.14**	**0.13**	**0.13**
Trade Imbalance	0.03	0.09	0.09	0.07	0.08	0.09	0.07	0.07
Connectivity	0.02	**0.09**	**0.10**	0.05	0.05	**0.10**	0.05	0.05
MSR Routing	0.00	**-0.06**	**-0.06**	-0.03	-0.03	**-0.06**	-0.03	-0.03
ECA Routing	(omitted)	**-0.11**	**-0.11**	-0.08	-0.07	**-0.11**	-0.08	-0.10
Colonial Ties	(omitted)	0.02	0.02	0.05	0.04	0.02	0.05	0.05
Trade Facilitation	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.02
Reefer Cargo	0.00	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Logistics Performance	0.01	0.01	0.01	0.05	0.05	0.01	0.05	0.05
m_Trade Flow				-0.02	-0.01		-0.02	-0.02
m_Trade Imbalance				0.03	0.03		0.03	0.03
m_Connectivity				**0.11**	**0.11**		**0.11**	**0.11**
m_MSR Routing				-0.13	-0.11		-0.13	-0.13
m_Trade Facilitation				-0.02	-0.02		-0.02	-0.02
m_Reefer Cargo				0.00	0.00		0.00	0.00
m_Logistics Performance				-0.07	-0.08		-0.07	-0.07
2013				-0.01	-0.01		-0.01	-0.01
2014				0.02	0.02		0.02	0.02
2015				0.02	0.02		0.02	0.02
2016				0.03	0.03		0.03	0.03
2017				0.05	0.06		0.05	0.05
2018				0.03	0.03		0.03	0.03
2019				-0.01	-0.01		-0.01	-0.02
2020				-0.01	-0.01		-0.01	-0.01

Core Specification **p<*0.05**

Table 5-15 – Margins per Model Specification

A detailed discussion regarding the margins and the meaning of the results is conducted in Chapter 7. However, it is appropriate to highlight a number of items in Table 5-15 at this juncture:

- XT Logit FE: ECA Routing and Colonial Ties margins are omitted since the corresponding coefficients are also omitted (see Section 5.4.2). Additionally, no variable returns a statistically significant margin which reconfirms that a Fixed Effects specification may not be an informative option for this research (see Section 5.4.2).

- XT Logit RE / XT Probit RE: the models return almost identical results for the corresponding margins – as anticipated – since both Probit and Logit models are described by the same form (see Appendix E).

- XT CRE: the model represents the core specification of this research and introduces the estimates for the group mean values of the time-varying regressors as well as the year effects (see Section 5.5.3). The margins of the group mean values may be interpreted as the contextual effects (Appendix E).

- CMP CRE: the model returns margin results which are very similar to the core specification, as previously mentioned (see Section 5.7.3).
- GSEM RE: the model returns identical margin results to the XT Probit RE.
- GSEM CRE: the model returns identical margin results to the XT CRE.
- GSEM CRE_G: the model returns almost identical margin results to the XT CRE / GSEM CRE. A few trivial differences are rooted in the slightly different underlying mechanism that is used for the notation of the binary variables in Builder tool and subsequently the estimation of the margins.
- Notably, the introduction of the CRE approach decreases the magnitude and the statistical significance of Connectivity, MSR Routing and ECA Routing as those are estimated in the RE specifications. This suggests that controlling for a potential relationship between the regressors and the time-invariant unobserved heterogeneity through the CRE framework (Appendix E) may be of pivotal importance from an econometric perspective. This is particularly evident in the case of *Connectivity* and mean Connectivity (*m_Connectivity*). The fact that the latter is statistically significant in a CRE framework while the former is no longer statistically significant indicates that Connectivity may be influenced by time-invariant unobserved factors (e.g. geography). Those factors should be taken into account, as neglecting them could potentially introduce bias to the results.

As discussed in Appendix E, the analysis returns the average marginal effect for each variable. Only 3 variables consistently return a statistically significant result (at 5%): (a) Trade Flow; (b) Reefer Cargo; and (c) m_Connectivity (Mean Connectivity). A more detailed interpretation of the marginal results and their ramifications is given in Chapter 7. However, as an indication at least for the variables with statistically important marginal effects, a swift interpretation may be provided at this point as well.

Hence, the respective marginal effects suggest that the conditional probability for a country of connecting directly to the UK (XT CRE specification – Model 4):

- Increases by 13% when the Trade Flow between the two countries increases by 10,000 TEU.

- Increases by 1% when the RCI score of a country increases by 1%.
- Increase by 11% when the mean Connectivity of a country (i.e. mean LSCI score) increases by 10 points.

A full display of the XT CRE specification – Model 4 margins is provided in Table 5-16:

Variable	dy/dx	Standard Error	z	P>z	95% Confidence Interval	
Trade Flow	**0.13**	**0.04**	**3.08**	**0.00**	**0.05**	**0.22**
Trade Imbalance	0.07	0.06	1.25	0.21	-0.04	0.19
Connectivity	0.05	0.04	1.28	0.20	-0.02	0.12
MSR Routing	-0.03	0.04	-0.80	0.42	-0.11	0.05
ECA Routing	-0.08	0.07	-1.13	0.26	-0.22	0.06
Colonial Ties	0.05	0.06	0.81	0.42	-0.07	0.16
Trade Facilitation	0.02	0.02	0.64	0.52	-0.03	0.06
Reefer Cargo	**0.01**	**0.00**	**2.08**	**0.04**	**0.00**	**0.01**
Logistics Performance	0.05	0.08	0.62	0.53	-0.11	0.21
m_Trade Flow	-0.02	0.03	-0.58	0.56	-0.07	0.04
m_Trade Imbalance	0.03	0.08	0.41	0.68	-0.12	0.18
m_Connectivity	**0.11**	**0.04**	**2.56**	**0.01**	**0.03**	**0.19**
m_MSR Routing	-0.13	0.10	-1.29	0.20	-0.32	0.07
m_Trade Facilitation	-0.02	0.03	-0.67	0.51	-0.08	0.04
m_Reefer Cargo	0.00	0.00	0.19	0.85	-0.01	0.01
m_Logistics Performance	-0.07	0.11	-0.63	0.53	-0.27	0.14
2013	-0.01	0.02	-0.34	0.74	-0.06	0.04
2014	0.02	0.04	0.42	0.68	-0.06	0.09
2015	0.02	0.04	0.61	0.54	-0.05	0.10
2016	0.03	0.04	0.76	0.45	-0.05	0.12
2017	0.05	0.05	1.12	0.26	-0.04	0.15
2018	0.03	0.04	0.62	0.54	-0.06	0.11
2019	-0.01	0.04	-0.35	0.73	-0.10	0.07
2020	-0.01	0.04	-0.15	0.88	-0.09	0.08

Table 5-16 – Margins of the Core Specification (XT CRE)

5.9 Characteristics of the long-established connections

In the context of this research, the establishment of a direct connection refers to the initiation and continuation of an international shipping link between two trading countries. The modelling effort has so far assessed how the selected variables may affect the binary response of the estimator (i.e. 0 for a non-active direct connection or 1 for an active direct connection between two trading countries) for a given year. Thus, the displayed results primarily indicate what may influence the initiation (or the termination) of a direct connection. Nevertheless, the factors that allow the continuation of a direct connection in the long-run between certain country pairs may also be examined.

It can be hypothesised that two trading countries may be opportunistically connected directly by the carriers or be awarded with a connection that cannot be sustained for a number of consecutive years whereas other countries may manage to be consistently and uninterruptedly connected throughout multiple years or even for the full duration of the analysis (2012-2020). As illustrated in Figure 4.35, for a given year the active direct connections between the UK and the various countries include those connections that continue from the previous year plus the ones which are initiated within the running year. However, during a given year a number of direct connections may also be terminated. Hence, at this stage the analysis strives to understand whether the underlying dynamics that characterise the direct connections that last for longer periods are considerably different from those dynamics that characterise the direct connections that may last for shorter periods of time.

Ultimately, this Section aims to provide an answer to RQ3: *What are the factors that characterise the long-established connections?*

5.9.1 Model Approach

A prerequisite to answer RQ3 is the classification of the examined countries into (a) those countries that manage to uninterruptedly (i.e. for consecutive years) connect directly with the UK in the long-term and (b) those countries that did not manage to uninterruptedly connect directly with the UK in the long-term. In turn, this research needs to firstly define how many years within the examined period (2012-2020) may correspond to a long-term timespan. The distribution of the countries in the dataset based on how many consecutive years they managed to retain a direct connection with the UK is depicted in Figure 5.5:

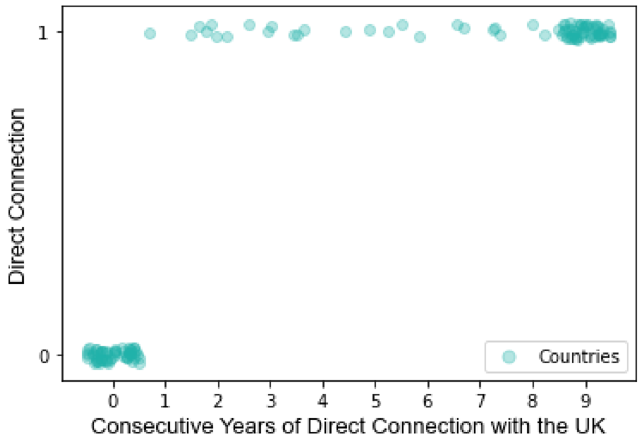

Figure 5.5 – Distribution of Countries per Consecutive Years of Direct Connection with the UK

Apparently some countries did not directly connect with the UK at all, some countries maintained a connection throughout the full period of 9 years, and finally some countries were connected with the UK for various time intervals spanning from 1 to 8 years. Several groupings may be qualitatively proposed based on human intuition (e.g. three groupings of 3 years each, 2 groupings by splitting the examined period in 2 halves etc.) but this may be a random and largely subjective approach which may not be true to the data. Hence, how can the classification of the countries may be suggested by the data itself?

This corresponds to a common research problem which effectively aims to cluster together datapoints with similar characteristics (Saeed and Cullinane, 2021). In general, there is no algorithm that is universally and objectively regarded as the most appropriate clustering method (*ibid*). Following Ducruet, Rozenblat and Zaidi (2010) and Wang *et al.* (2018a) this research proceeds with clustering by utilising the k-means algorithm. The k-means algorithm is probably one of the most well-established clustering methods based on iterations over *centroids* (Savaresi and Boley, 2004). Effectively the algorithm defines various centroids as the centres of a number of theoretical clusters and utilises the Euclidean distance as a measure of similarity between observations (Wang *et al.*, 2018a). In other words, the algorithm classifies each observation in a corresponding cluster along with other observations with similar distance from the cluster centre.

In this research, the k-means clustering algorithm is executed in Python and utilises the *KMeans* library of the scikit-learn package (Pedregosa *et al.*, 2011). The below examples depict the classification of the observations in a case where the number of the clusters (k) is randomly set to 1 and 3, respectively:

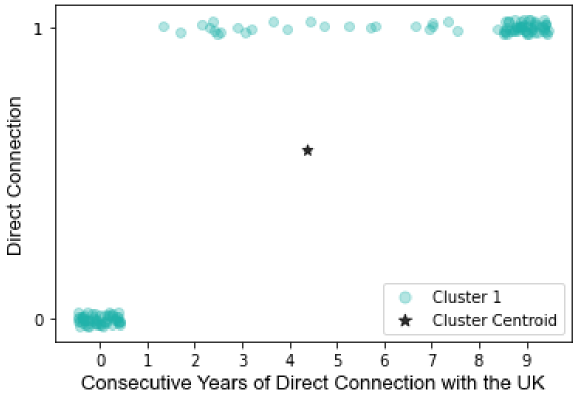

Figure 5.6 – Clustering with 1 centroid

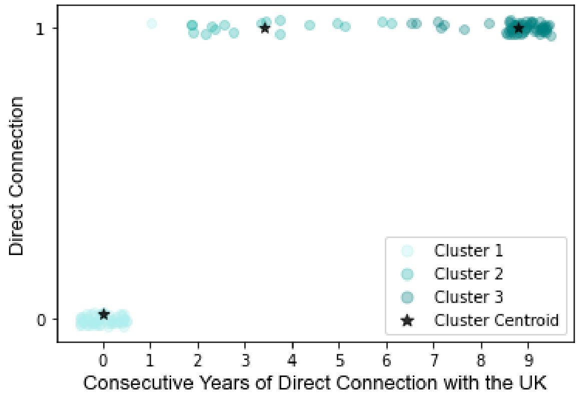

Figure 5.7 – Clustering with 3 centroids

The k-means algorithm is widely recognised and implemented as an unsupervised machine learning method. The latter refers to those machine learning algorithms that are able to identify patterns and groupings in the data without prior human guidance or intervention (Delua, 2021). Although the number of the clusters may sometimes receive a form of initialisation (Sinaga and Yang, 2020) the selection of the clusters number may be optimised using the underlying data and its characteristics for guidance rather than hypothesizing and objectively selecting a number. A quite common empirical method for the optimisation of the clusters number based on the data is the *elbow* method. This method suggests that an algorithm iterates over a specified number of potential clusters k and during each iteration it calculates the sum of squared errors (SSE) as a measure of distance between each observation (data point) in a cluster and the corresponding centroid of the cluster (Shi *et al.*, 2021). This is followed by a plot of SSE against the respective k number (*ibid*). The plot is anticipated to depict a change of the SEE value depending on k and at some point to record a dramatic reduction, representing the optimum k number (Yahyaoui and Own, 2018). The point where the plot begins to flatten effectively indicates that the clusters until that point are still quite heterogeneous and this point corresponds to the *''elbow''* of the plot (Ketchen and Shook, 1996).

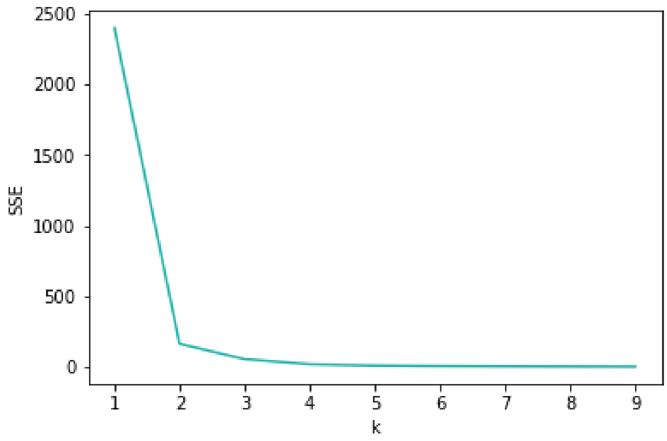

Figure 5.8 – SSE value per Number of k (clusters)

As it is illustrated in Figure 5.8, the elbow spot for the analysed data corresponds to k = 2. Hence, the data suggests that the various countries may belong to 2 clusters. The *fit_predict()* option of the KMeans library further suggests that Cluster 1 and Cluster 2 correspond to those countries that were directly connected to the UK for up to 4 years and then for 5 to 9 years, respectively. Thus, the core specification of the model may now be used to calculate the corresponding margins for the two clusters and to compare any distinct differences.

5.9.2 Results

In order to calculate the corresponding margins per cluster, a respective binary variable is generated which functions as an index and classifies each country into its suggested cluster. Then, the results are obtained by recalculating the margins of the core model specification over the cluster index. Stata can distinctly return the corresponding margins of each group in a single command. This effectively disaggregates the results that were previously obtained (see Table 5-13 and Table 5-15) by explicitly focusing on the dynamics that characterise each cluster.

As it is displayed in Table 5-17, depending on the variable the difference of the margins between clusters may be considerable (e.g. Trade Flow) or negligible (e.g. Trade Facilitation). As before, only 3 variables consistently return a statistically important result (at 5%): (a) Trade Flow; (b) Reefer Cargo; and (c) m_Connectivity. The development of the marginal effects by year for those variables are displayed in Figure 5.9, Figure 5.10 and Figure 5.11, respectively (Cluster 1 = Short-term, Cluster 2 = Long-term).

Variable	Direct Connection Cluster	dy/dx	std. err.	z	P>z	[95% conf. interval]	
Trade Flow	1	**0.19**	0.07	2.83	**0.01**	0.06	0.33
	2	**0.09**	0.03	2.86	**0.00**	0.03	0.15
Trade Imbalance	1	**0.11**	0.09	1.21	0.23	-0.07	0.28
	2	**0.05**	0.04	1.26	0.21	-0.03	0.13
Connectivity	1	**0.07**	0.05	1.26	0.21	-0.04	0.17
	2	**0.03**	0.02	1.26	0.21	-0.02	0.08
MSR Routing	1	**-0.04**	0.05	-0.84	0.40	-0.15	0.06
	2	**-0.02**	0.03	-0.75	0.46	-0.09	0.04
ECA Routing	1	**-0.10**	0.07	-1.43	0.15	-0.23	0.04
	2	**-0.07**	0.07	-0.89	0.37	-0.21	0.08
Colonial Ties	1	**0.07**	0.09	0.79	0.43	-0.11	0.25
	2	**0.03**	0.04	0.86	0.39	-0.04	0.10
Trade Facilitation	1	**0.02**	0.04	0.64	0.52	-0.05	0.09
	2	**0.01**	0.02	0.63	0.53	-0.02	0.04
Reefer Cargo	1	**0.01**	0.00	1.96	**0.05**	0.00	0.02
	2	**0.00**	0.00	2.08	**0.04**	0.00	0.01
Logistics Performance	1	**0.07**	0.12	0.61	0.54	-0.17	0.32
	2	**0.03**	0.05	0.64	0.52	-0.07	0.14
m_Trade Flow	1	**-0.02**	0.04	-0.57	0.57	-0.10	0.06
	2	**-0.01**	0.02	-0.58	0.56	-0.05	0.03
m_Trade Imbalance	1	**0.05**	0.11	0.41	0.69	-0.18	0.27
	2	**0.02**	0.05	0.42	0.68	-0.08	0.12
m_Connectivity	1	**0.16**	0.07	2.27	**0.02**	0.02	0.30
	2	**0.07**	0.03	2.72	**0.01**	0.02	0.13
m_MSR Routing	1	**-0.19**	0.15	-1.25	0.21	-0.48	0.11
	2	**-0.08**	0.06	-1.32	0.19	-0.21	0.04
m_Trade Facilitation	1	**-0.03**	0.04	-0.68	0.50	-0.12	0.06
	2	**-0.01**	0.02	-0.65	0.52	-0.06	0.03
m_Reefer Cargo	1	**0.00**	0.01	0.19	0.85	-0.01	0.02
	2	**0.00**	0.00	0.19	0.85	-0.01	0.01
m_Logistics Performance	1	**-0.10**	0.16	-0.62	0.54	-0.41	0.21
	2	**-0.04**	0.07	-0.66	0.51	-0.18	0.09
2013.year	1	**-0.01**	0.03	-0.33	0.74	-0.07	0.05
	2	**-0.01**	0.02	-0.34	0.74	-0.04	0.03
2014.year	1	**0.02**	0.05	0.42	0.68	-0.08	0.13
	2	**0.01**	0.03	0.41	0.68	-0.04	0.06
2015.year	1	**0.03**	0.06	0.61	0.54	-0.08	0.14
	2	**0.02**	0.03	0.61	0.54	-0.04	0.07
2016.year	1	**0.05**	0.07	0.76	0.45	-0.08	0.18
	2	**0.02**	0.03	0.75	0.45	-0.04	0.08
2017.year	1	**0.08**	0.08	1.12	0.27	-0.06	0.23
	2	**0.03**	0.03	1.10	0.27	-0.03	0.09
2018.year	1	**0.04**	0.07	0.62	0.54	-0.09	0.17
	2	**0.02**	0.03	0.61	0.54	-0.04	0.08
2019.year	1	**-0.02**	0.05	-0.35	0.73	-0.13	0.09
	2	**-0.01**	0.03	-0.35	0.73	-0.07	0.05
2020.year	1	**-0.01**	0.06	-0.15	0.88	-0.12	0.10
	2	**0.00**	0.03	-0.15	0.88	-0.07	0.06

p<*0.05

Table 5-17 – Margins by Cluster

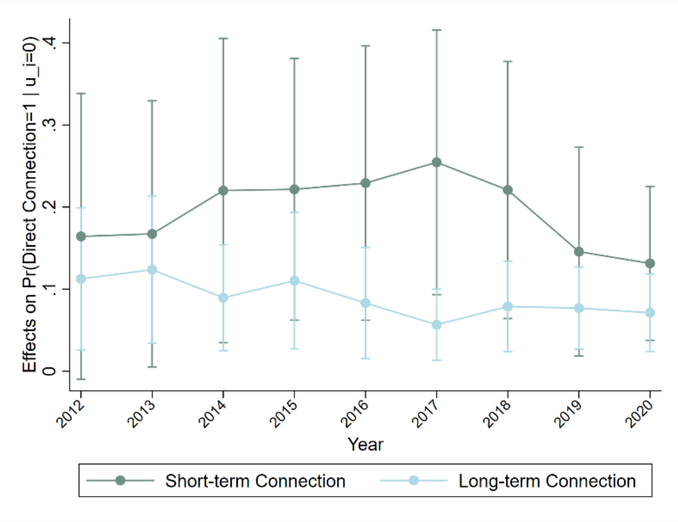

Figure 5.9 – Margins by Cluster, Trade Flow

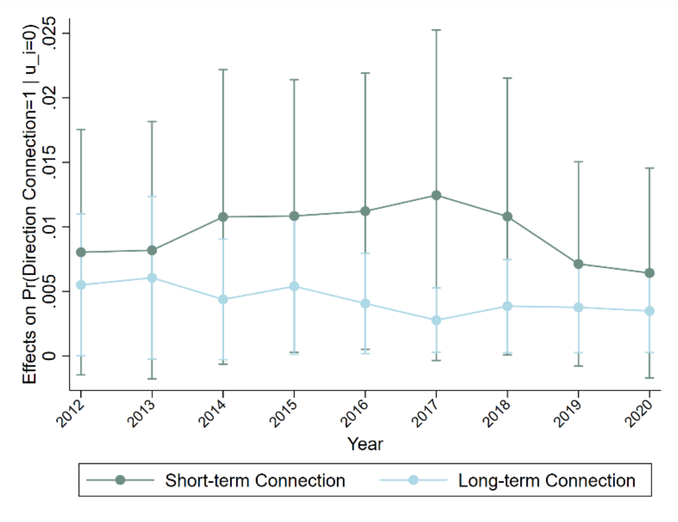

Figure 5.10 – Margins by Cluster, Reefer Cargo

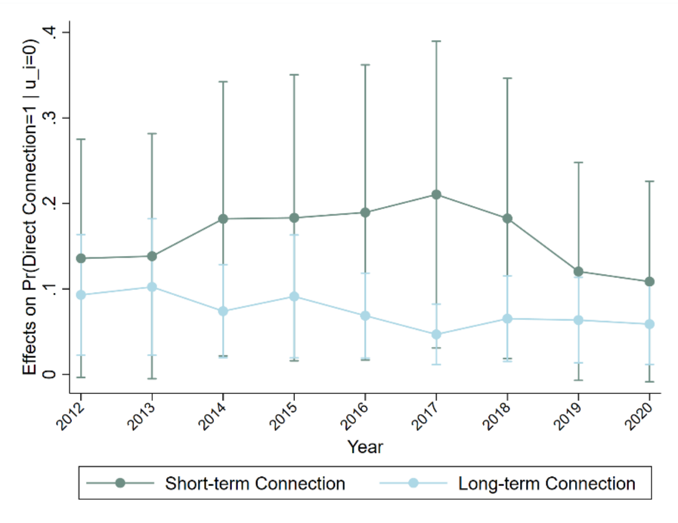

Figure 5.11 – Margins by Cluster, m_Connectivity

As previously noted, a more detailed interpretation of the marginal results and their ramifications is given in Chapter 7. However, as an indication at least for the variables with statistically important marginal effects, the following may be highlighted:

- the marginal effects by cluster for all 3 variables (Trade Flow, Reefer Cargo and m_Connectivity), show a delta between the values of the two clusters which intensifies in 2013-2014, peaks in 2017 and then gradually decreases until 2020.

- on the peak of the delta in 2017, the marginal effects for Cluster 1 / Cluster 2 (Short-term Connection / Long-term Connection) are 25% / 6% for Trade Flow, 1.2% / 0.3% for Reefer cargo and 21% / 5% for m_Connectivity, respectively.

  This for instance means that the conditional probability for a country of connecting directly to the UK, increases by 25% when the Trade Flow between the two countries increases by 10,000 TEU for Cluster 1 (Short-term Connection) and by only 6% for Cluster 2 (Long-term Connection). The latter may indicate a considerable difference on the dynamics that characterise the probability of a country to connect with the UK depending on the nature and the longevity of their bilateral shipping connection relationship. For instance, the long-established connections are seemingly less sensitive to marginal TEU volume fluctuations.

5.10 Concluding Remarks

This Chapter proceeded with the statistical analysis of the study which corresponds to Phase 2 of the research.

Following on from the model preparation and a descriptive analysis of the employed data, the research proceeded with the application of Fixed and Random effects model specifications. The corresponding statistical tests indicated that a Fixed Effects model should be preferred. Nevertheless, the analysis outlined the reasons why such a model specification may not be an informative solution for this research and respectively highlighted the reasons why the employment of a Correlated Random Effects model is likely the most workable and statistically robust solution for this research.

Furthermore, the Chapter thoroughly scrutinised the robustness of the selected model against non-stationarity, multicollinearity and endogeneity. The analysis suggested that the selected model specification holds. Then, the Chapter continued with the marginal effect analysis which informed about the statistical significance of three variables: Trade Flow, Reefer Cargo and m_Connectivity (Mean Connectivity). Finally, this Chapter also explored the characteristics of the long-established connections by conducting a cluster analysis for direct connections which were active in either the short-term or the long-term. The latter did not imply any difference with regard to the variables of statistical significance but provided some insights such as that long-established connections are seemingly less sensitive to marginal TEU volume fluctuations.

Following on from the analysis and the model results, the next Chapter proceeds with Phase 3 of the research where the results are cross-checked with practitioners with the aim to validate the employed model.

Chapter 6. Model Validation

6.1 Introduction

This Chapter proceeds with the validation of the statistical analysis of this study and corresponds to Phase 3 of the research (see Section 3.12). As discussed in Section 3.12, Phase 3 aims to investigate if "*the data are telling you what you think they are telling you*" (Saunders, Lewis and Thornhill, 2007a p139). This research has adopted a case study approach, focusing on the development of the direct connections of the UK with its trading partners (countries). As noted in Section 2.2.4, a case study may employ a triangulation method (i.e. the utilisation of different data collection techniques within a single study with the aim to cross-check and validate conclusions and findings such as the test of quantitative data via semi-structured interviews) (Saunders, Lewis and Thornhill, 2007a). Thus, in this Chapter the research tests qualitatively whether the findings of Chapter 5 are meaningful in the real world by considering the statistical results through the eye of practitioners via semi-structured interviews.

In this Chapter, Section 6.2 justifies the use of semi-structured interviews as an appropriate step towards the validation of the numerical findings of the analysis, Section 6.3 outlines the theoretical framework upon which the semi-structured interviews are conducted in this research, Section 6.4 presents the characteristics of the interviews participants, Section 6.5 discusses the outcome of the interviews, Section 6.6 tests whether an update of the employed model is deemed as necessary based on the interviews, Section 6.7 capitalises on the collected feedback and explores the predictive capabilities of the model and Section 6.8 comprises the concluding remarks of this Chapter.

6.2 Semi-structured Interviews Background

An interview is essentially *''a purposeful discussion''* (Kahn and Cannell, 1957 as cited in Saunders, Lewis and Thornhill, 2007b), commonly assisting a researcher to further explore any causal relationships between identified variables (Saunders, Lewis and Thornhill, 2007b). In the context of this research, interviews may serve the purpose of validating the numerical findings of the analysis, cross-check whether statistical significance may imply causal patterns in the real world and potentially enrich or fine-tune the core model. According to Saunders, Lewis and Thornhill (2007b) interviews may be categorised as follows:

- structured: following a pre-set questionnaire with no deviation from the coded steps and with the aim to collect quantifiable data.
- semi-structured: following a list of themes and questions which however may be altered, omitted or most importantly enhanced in order to allow the further exploration of the discussed topic, based on the flow of the discussion and the ''*organisational context''* within the interview takes place.
- unstructured (or in-depth): following an informal setup on which there is no list of themes and questions, and the interviewees may openly share their ideas, beliefs and opinions around a topic.

This research opts for a semi-structured interview approach since (a) there is a need for a predetermined set of themes / questions (i.e. with a clear purpose to collect the practitioners' opinions regarding the identified variables) and (b) there is simultaneously a need for flexibility which may allow for follow-up questions. This may assist on further exploring the perspectives of the practitioners about the drivers of direct connections between countries.

Additionally, semi-structured interviews are suitable when a researcher may wish to allow the discussion to explore areas that may have not yet been considered in the analysis or where the questions may be of complex or open-ended nature (Saunders, Lewis and Thornhill, 2007b). Phase 3 of this research effectively explores a possible enhancement of the existing model. This exploration may require a setup that is built upon quite specific but open-ended questions thus semi-structured interviews present an ideal platform for this phase of the research.

6.3 Semi-structured Interviews Framework

Although semi-structured interviews provide a flexible platform for the collection of setup qualitative data, the existing literature provides little guidance regarding a corresponding methodological approach. However, Kallio *et al.* (2016) conducted a systematic review that led to a respective framework and it is based on a phasal approach. This research proceeds to adopt the five phases of the suggested framework by Kallio *et al.* (2016), as follows:

1. *Identifying the prerequisites for using semi-structured interviews*: this phase requires a justification by the researcher regarding the applicability and suitability of a semi-structured interview as a method that serves the objectives of the research.

   In the context of this research, the methodological appropriateness of semi-structured interviews was discussed in Section 6.2.

2. *Retrieving and using previous knowledge*: this phase aims to secure a solid understanding of the examined topic which may be based on previous knowledge as well as empirical analysis.

   In the context of this research, the semi-structured interviews have been based on the statistical analysis of empirical data (Chapter 5) which in turn has been grounded on the findings of the SLR (Chapter 3).

3. *Formulating the preliminary semi-structured interview guide*: this phase involves the formulation of a guide which is based on the main themes that the interviewer wishes to address as well as follow-up questions which will allow the interviewees to elaborate on their perceptions. According to Kallio *et al.* (2016), it may be advisable that the interviewer focuses primarily on main themes and use only a limited number of follow-up questions as *''gentle nudges''* which allow the interviewer to further explain the concept to the participants, seek for clarification where needed and address specific areas of particular interest.

   Following on from Phases 1 and 2, Phase 3 strives to validate the findings of the research elicited up to this point and – if needed – to update and enhance the model. In parallel, Phase 3 may also assist on the deeper understanding of the broader topic under investigation by capitalising on the domain knowledge of the interviewees. Thus, the aim of this exercise is to question whether the model is a relevant representation of the real world (i.e. whether the statistical specification considers meaningful variables) and also how specific underlying mechanisms of interest (i.e. characteristics of long-established connections, the role of policy) may also impact direct connections.

The interview questions (i.e. Themes and Follow-up questions) have been accordingly filtered through a corresponding checklist as suggested by Collis and Hussey (2014). This checklist provides a systematic way of securing the seamless flow of the anticipated discussions while also considering those questions which serve the research objectives. Specifically, according to Collis and Hussey (2014) the questions that are finally included in the interview should share the following characteristics:

a. the anticipated answer should provide information regarding an aspect of the research questions.

b. the majority of the interviewees should be able to interpret the questions in the same way.

c. the majority of the interviewees should have enough information in order to provide a relevant answer.

d. the majority of the interviewees should have the willingness to answer the questions.

e. the questions should be asked to all interviewees (or a pre-defined subset).

In the context of this research, the preliminary guide of the semi-structured interviews includes the below main themes and follow-up questions:

Themes

- Which of the listed variables do you think are likely to drive the establishment of direct connections between trading countries?
- Are there any variables that are likely to drive the establishment of direct connections between trading countries which are not already listed?
- Could long-established connections between trading countries be driven by different variables compared to connections that last for shorter periods?
- Are there any specific actions that policy-makers may raise in order to encourage more direct calls at a country or the establishment of a direct call between two trading countries?

Follow-up Questions

- Would you agree that Trade Flow, Reefer Cargo or mean Connectivity (m_Connectivity) may be more important compared to the rest of the listed variables?
- If there are any missing variables which you think should be considered in the analysis can you please elaborate on the respective mechanism that highlights their importance?
- Are there any particular attributes that characterise the country-pairs with long-established connections?

The abovementioned Themes and Follow-up Questions match the criteria set by the checklist of Collis and Hussey (2014). The last Theme could theoretically be targeted only to policy-makers but practically if it is addressed to a broader base of participants then even more fruitful results may be extracted.

4. *Pilot testing the interview guide*: this phase aims to ensure that the content of the interviews adequately covers the needs of the research and to utilise any possible feedback in order to reformulate the structure of the interview. A pilot interview may be conducted as internal (i.e. with other members of the research team), expert assessment (i.e. with specialists who are external to the research team) or field-testing (i.e. with one of the selected interviewees). According to Kallio *et al.* (2016), the field-testing pilot interview is most commonly used. In the context of this research, a pilot testing is indeed conducted in the form of field-testing and the collected feedback from the first interview is intended to be used for possible adjustments, accordingly.

   Hence, following on from the first interview, the collected feedback indeed led to an adjustment of the abovementioned Themes. Specifically, after addressing with the interviewee which of the listed variables may be considered as the main drivers for the establishment of direct connections between trading countries, the need for the inclusion of an additional Theme arose, as follows:

   Are any of the listed variables seemingly irrelevant regarding the establishment of a direct call between two trading countries?

   This addition is grounded on the fact that the first interviewee challenged the relevance of the MSR Routing as a contributing factor and suggested that –

unless the focus of the study is China and not the UK – this variable may be dropped. This addition also matches the criteria set by the checklist of Collis and Hussey (2014) and is thus considered for the complete interview guide.

5. *Presenting the complete semi-structured interview guide*: this phase proceeds with the presentation of the applied interview guide. The latter corresponds to the questions structure and aims to enhance the reproducibility of the research by future studies. This structure is essentially a refined version of the preliminary guide that has been compiled on the previous step. In the context of this research, the questions structure of the employed semi-structured interviews is shown on Table 6-1. In line with Kallio *et al.* (2016), Follow-up Questions are kept to a minimum and are considered only for those Themes that a further clarification is deemed appropriate.

#	Themes	Follow-up Questions
1	Which of the listed variables do you think are likely to drive the establishment of direct connections between trading countries?	Would you agree that Trade Flow, Reefer Cargo or mean Connectivity (m_Connectivity) may be more important compared to the rest of the listed variables?
2	Are there any variables that are likely to drive the establishment of direct connections between trading countries which are not already listed?	If there are any missing variables which you think should be considered in the analysis can you please elaborate on the respective mechanism that highlights their importance?
3	Are any of the listed variables seemingly irrelevant regarding the establishment of a direct call between two trading countries?	-
4	Could long-established connections between trading countries be driven by different variables compared to connections that last for shorter periods?	Are there any particular attributes that characterise the country-pairs with long-established connections?
5	Are there any specific actions that policy-makers may raise in order to encourage more direct calls at a country or the establishment of a direct call between two trading countries?	-

Table 6-1 – Semi-structured Interview Guide

6.4 Semi-structured Interviews Participants

This research proceeds to consider a diversified mix of participants in order to ensure that the model has been adequately scrutinised and assessed by practitioners with different perspectives. According to Adams (2015) there are three different groups which may be deemed appropriate as participants in semi-structured interviews:

1. *Administration:* those include *''front-line''* staff as well as managers of the delivered program.
2. *Program Recipients:* those include beneficiaries or clients of the delivered program.
3. *Interested Parties:* those include any other contributors and direct / indirect stakeholders of the program.

In the context of this research, the examined program is effectively the establishment of a direct connection between two trading countries. Consequently, carriers may be considered as Administration, freight forwarders (and cargo owners) as Program Recipients and policy-makers as one of the Interested Parties. Thus, this research proceeds to conduct five interviews in total and includes the following participants for conducting the semi-structured interviews:

- Three executives from leading carriers (MSC, Maersk and CMA-CGM Group): the participants have been working (or have a background) on the development of new services and the assessment of existing itineraries (i.e. executives from *Product*, *Ocean Fulfillment* or *Voyage Assessment* departments).
- One executive from a leading freight forwarding company (Kuehne+Nagel): the participant has been working in the *Ocean Procurement* department while also having a background in *Trade* departments for leading carriers.
- Two executives from the DfT: the participants are senior operational research executives with background on maritime transport modelling including complex systems and environmental studies.

Since this research focuses on understanding the factors that are considered important by the carriers, the opinion of personnel that work for leading container shipping organisations is invaluable and thus the major share of the participants corresponds to carriers' executives. However, this research considers an important addition is the input of the carriers' clients as well (i.e. freight forwarders) since it is likely that the decisions made by the carriers are largely driven by their clients' requests. Finally, since this research focuses on the UK and its connections with other countries, it is deemed relevant to also explore the perspective that policy-makers (e.g. DfT) may have towards direct connections and the respective contributing factors.

As discussed in Section 3.12, the researcher is of the view that the collected and analysed data can be a pragmatic manifestation of the real world and can provide a representative demonstration of the mechanisms that shape the structure of the shipping network. Thus, the purpose of the semi-structured interviews is a rigorous sense-check of the modelling effort by selected practitioners. Given the focus of Phase 3, the selection of the interviewees is strategically designed to obtain high-quality insights rather than targeting a large number of respondents for a form of statistical validation. The five interviewees represent the three largest container shipping companies, a top global forwarder, and a key policy-maker from the UK. These participants are targeted for their extensive market knowledge and their ability to provide a comprehensive critique of the research's analysis. Since the selected stakeholders are at the forefront of the industry trends and policies, their feedback regarding the model may provide adequately high credibility to the findings. Therefore, the number of interviews is regarded as both sufficient and appropriate to confirm the model's validity, given the high level of expertise and representativeness of the interviewees.

6.5 Semi-structured Interviews Results

Following Collis and Hussey (2014), the collected qualitative data can be *''coded''* into emerging patterns and topics which share common attributes. The corresponding coding of the collected qualitative data into subsets provides a link between the gathered information and the interpretation of this information by the researcher (Collis and Hussey, 2014). All interviews addressed each of the predefined five Themes but quickly converged into three main Discussion Topics:

1. Appropriateness of the selected variables: corresponds to the part of the discussions which focused on which of the selected variables may be pivotal for the establishment of direct connections.

2. Completeness and relevance of the model specification: corresponds to the part of the discussions which focused on whether there are any variables that should be added or respectively dropped from the model.

3. Assessment of underlying mechanisms: corresponds to the part of the discussions which focused on whether drivers of long-established connections differ from the connections which last for shorter periods and whether policy-makers can somehow promote direct connections.

The summary of the interviews pattern is illustrated in Figure 6.1:

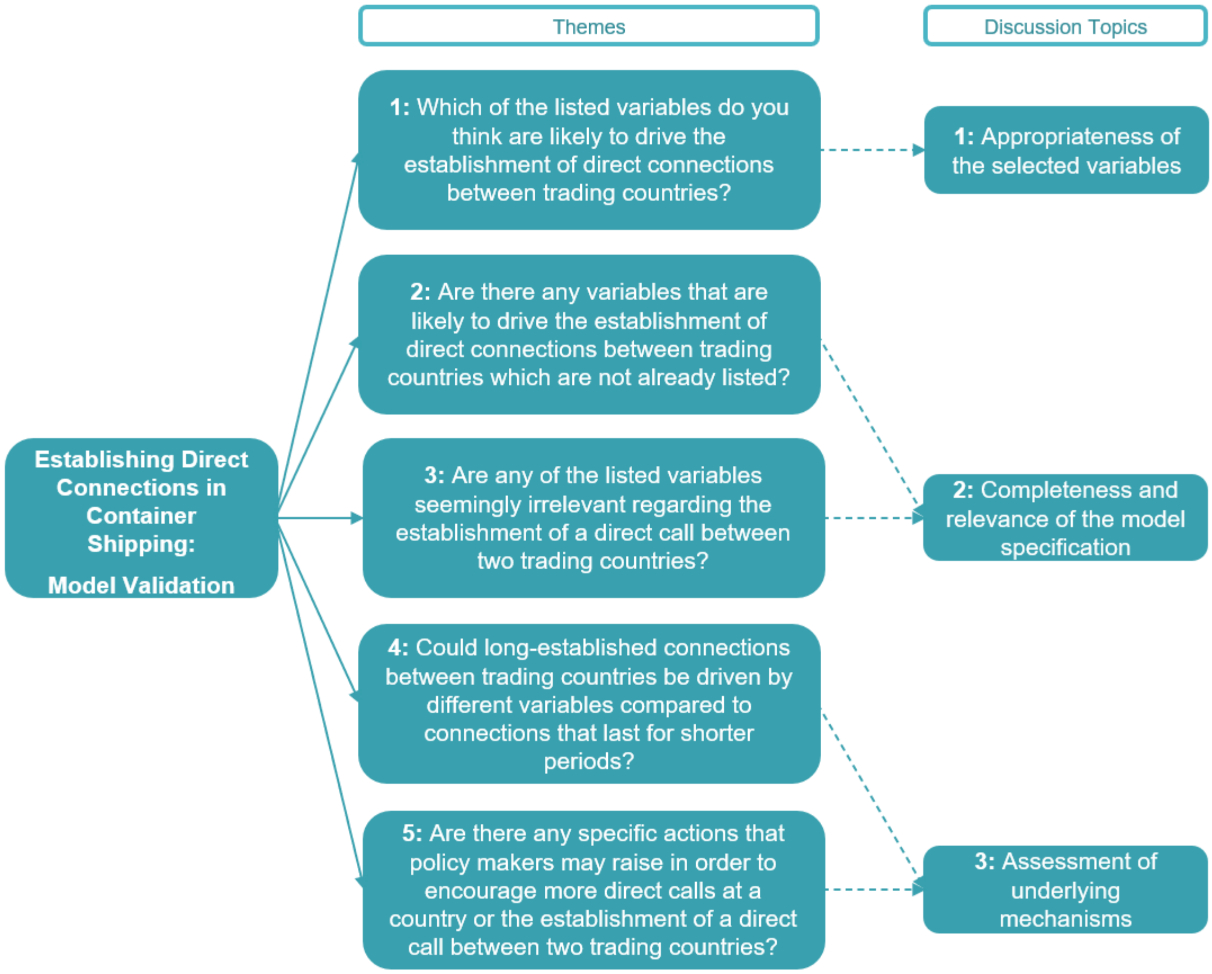

Figure 6.1 – Themes and Discussion Topics of the Interviews

Discussion Topic 1: Appropriateness of the selected variables

Overall, the interviewees confirmed the appropriateness of the selected variables and commented that all important drivers of direct connections have been included in the model.

Specifically, the interviewees noted that Colonial Ties may still be important nowadays but for certain geographies and particular carriers only thus it seems logical that the model returns a relatively low score (marginal effect) for this variable. One interviewee for instance highlighted the importance of Africa or the Caribbean for CMA-CGM due to the historical ties of France with certain countries. Colonial Ties may be actually considered as a main driver for the initiation of a direct connection only in the case that no other carrier connects two given countries. In any other case, Colonial Ties may rather be a reason for the continuation of an already available connection.

Regarding Connectivity, the participants essentially recognised its importance but mainly highlighted the fact that usually it is Trade Flow that drives the corresponding developments. The statistical significance of Mean Connectivity (i.e. the conditional probability for a country of connecting directly to the UK when Mean Connectivity increases) was broadly recognised as a logical outcome. However, most of the interviewees also suggested that this may hold for some but not necessarily all countries. A direct connection between two countries is assisted by the network trends but it is fundamentally grounded on the mentality and the commercial decisions of the local businesses at the end markets which fuel the supply and demand dynamics.

ECA Routing was recognised as a ‘*’pain’’* for carriers and certainly as a variable which they factor in during their cost calculations for calling at a corresponding country within a respective designated area. However, ECA cost is expected to be covered by the freight rates – under the proviso that the corresponding Trade Flow level can generate an adequate level of revenue which is higher than the respective cost – and the relevant surcharges, although at times the enforcement and collection of a fuel surcharge depends on the market’s dynamics.

Logistics Performance was also highlighted for its importance and specifically most of the participants underlined that indeed it is not only the competitiveness of the ports and terminals that carriers may examine, but also the intermodal capabilities of a country as well and specifically the respective rail freight options. Nevertheless, it was also highlighted that although Logistics Performance is diligently reviewed by carriers perhaps it is not necessarily regarded as a key variable for carriers’ decisions. Otherwise – according to the majority of the interviewees – the expansion of the West Africa market would have never happened due to difficulties with roads, customs, cross-border moves, equipment returns and warehousing. Carriers may risk a connection should Trade Flow be promising and if the operational situation becomes problematic they will then review and potentially interrupt the link. Carriers may also focus on the expected progress and thus continuous improvement regarding Logistics Performance is primarily examined for the assessment of a given country.

A few of the interviewees commented that MSR Routing seems theoretically relevant but may not be directly applicable in practice. One of the interviewees suggested that this may be important but found the negative sign of the coefficient slightly confusing. However, an interesting explanation was suggested by the same interviewee: there is a good chance that certain carriers do not want to encourage connections between nodes that support this kind of initiative. The reason is that certain countries (and ports) may be generously supported (e.g. via rebates) by the initiative and those ‘’*interactions’’* may signal problems with the level of competition at a country. On the contrary, another interviewee suggested that the negative sign of the coefficient is probably random or plainly signals that carriers do not see much potential regarding exchanges between the UK and other countries along the MSR (apart from China).

Reefer Cargo was praised for its importance because of its considerably high revenues for the carriers and it was noted that this type of cargo may be periodically based on (upcoming) consumer trends (e.g. avocados). However, the interviewees also highlighted that Reefer Cargo dominates very well-defined routes – for which customers push carriers for direct calls – and does not apply globally. The availability of reefer equipment is a core factor for the viability of a connection between countries and a long season of continuous perishable cargo flow is needed to justify a direct connection. Thus, Reefer Cargo is deemed important but can be regarded as a standalone factor of a direct connection for limited markets only (e.g. Central and South America). Two of the interviewees suggested that this is probably the reason for the low value of the corresponding variable score (1% – see Section 5.8).

Trade Facilitation was generally regarded as a strong contributing factor which may encourage or equally discourage the establishment of a direct connection between trading countries. The interviewees suggested that the main concern around Trade Facilitation is essentially the absence of trade restrictions such as sanctions and embargoes but may also consider currency exchange policy and local taxation. In fact, an interviewee underlined that freight forwarders may push carriers for the establishment of a direct call even if the Logistics Performance of a country is poor but Trade Facilitation is arguably satisfactory. However, freight forwarders would not push for a direct call in a country with poor Trade Facilitation (unless the corresponding volume is considerable).

In particular, all interviewees highlighted the importance of Trade Flow with three of the participants sharing the expression *''Trade is King''.* Trade Flow attracts progressively additional carriers since when the competition begins to call at a country then most of the players tend to also provide the same geographical coverage and harmonise their offer with the market standards. The interviewees unanimously suggested that Trade Flow is the most pivotal item of a checklist that a decision-maker considers. A robust Trade Flow may most importantly be a standalone factor towards the establishment of a direct connection since it may push carriers to tolerate the poor performance of any of the other variables. For instance, strong Trade Flow can justify the initial risk of calling directly at a country with poor Logistics Performance or seemingly problematic Trade Facilitation or even absorb the higher cost of an ECA Routing.

Finally, Trade Imbalance was only briefly discussed by most of the interviewees. There was largely a consensus that – although it can be a concern – it matters primarily for those trade routes for which it incurs costs that cannot be covered by the revenue that the headhaul Trade Flow secures.

In summary, Discussion Topic 1 highlights (a) the overall appropriateness of the selected variables and (b) the very significant importance of Trade Flow as the most salient contributing variable.

Discussion Topic 2: Completeness and relevance of the model specification

None of the interviewees suggested that any important variables have been excluded from the specification. This was however a topic which was scrutinised by the interviewer with the aim to stress-test the logic of the model and thus other possibly latent drivers were accordingly introduced. Specifically, the causal assumptions of this research were displayed to the interviewees (Figure 4.5) to cross-check if there may be any disagreement by the interviewees regarding the compilation of the final list of the employed variables.

One of the participants commented that the existence of an Affiliated Terminal is often a motivation for the carriers to increase their presence in a port and thus a country. However, the interviewee proceeded to explain that the existence of an Affiliated Terminal at a country increases the deployment of the vessels and thus the corresponding Connectivity. In turn, the latter provides more options and accessibility for that specific country which may indirectly boost its Direct Connections with other countries (in line with Table 4-1 and Figure 4.5). Specifically, the interviewee utilised the case of the UK as an example and suggested that operating an affiliated terminal at a given country in Africa would not be enough to trigger a direct connection with the UK. However, if the corresponding country gradually manages to increase its Connectivity and become a more important node in the container shipping network then this should attract the interest of progressively more carriers. Nevertheless, in this example the substantial importance of Trade Flow was once more highlighted as the ultimate driver towards a direct connection.

The role of geopolitics was also discussed by one interviewee but to the extent that geopolitics can raise a dramatic action such as severe sanctions or embargoes. The interviewee questioned whether this dimension is considered by the corresponding Trade Facilitation metric. Indeed, Trade Freedom considers both tariff and non-tariff barriers (including restrictions and embargoes) thus this nuance has been taken into consideration by the model.

Additionally, DfT also underlined that in the future the green agenda may increasingly be of definitive importance for the establishment of direct connections and specifically through the concept of *''green corridors''.* The latter corresponds to *''a European concept denoting long-distance freight transport corridors where advanced technology and co-modality are used to achieve energy efficiency and reduce environmental impact''* (Carballo-Penela *et al.*, 2012 p765). This idea was initially introduced in 2006 and – although it was eventually embraced by the European Commission – it primarily examined rail, inland and short-sea shipping initiatives (Carballo-Penela *et al.*, 2012). The concept draw great attention and it was essentially revisited by the shipping community following the signing of the *Clydebank Declaration*, an initiative led by the UK and signed by other 23 countries (Getting to Zero Coalition, 2021). The declaration states that the signatories would aim for the establishment of a green corridor between two ports and aim to expand to six ports by the end of 2025 by revisiting the regulatory frameworks and raising actions including information sharing, infrastructure development and the provision of incentives (DfT, 2021a). The report by Getting to Zero Coalition (2021) further promoted this initiative and since then the concept has seemingly gained increased momentum compared to the previous years with possible extension towards deep-sea connections and thus links between remote countries. However, as also discussed with DfT, this concept is still in its infancy and was essentially not a driver of direct connections between countries for the period that the model examines (2012-2020).

On the contrary, two of the interviewees suggested that although they do not consider MSR Routing as totally irrelevant, the variable could potentially be disregarded: it may mean very little to carriers unless those are based in China. This dimension is examined in Section 6.6 below. Additionally, the same interviewees also commented that ECA Routing may lose its importance if carriers impose bunker surcharges in order to recover the corresponding cost or *‘’hide’’* the cost in the freight rates. The latter is subject to the market momentum and the relative negotiating power of the carriers at a given period. Additionally, if another carrier offers a direct connection with a country located within an ECA, other carriers will most likely follow: it could be more costly for a carrier to provide limited geographical coverage and longer transit times compared to the competition than assuming (either fully or partially) the cost of burning more expensive fuel. Thus, those interviewees suggested that ECA Routing as a variable may at times play a limited role towards the establishment of direct shipping connections and – although it is more relevant than MSR Routing – its removal could also be an option. This dimension is also examined in Section 6.6 below.

In summary, Discussion Topic 2 highlights (a) the overall completeness and relevance of the model and (b) the option to potentially remove MSR Routing or MSR Routing along with ECA Routing from the list of the employed variables.

Discussion Topic 3: Assessment of underlying mechanisms

Two underlying mechanisms were investigated during the interviews. Specifically, the researcher strived to verify (a) whether the results from the analysis in Section 5.9.2 with regard to long-established connections are in line with the understanding of the practitioners and (b) whether policy-makers may somehow drive the establishment of direct connections.

Regarding long-established connections, the interviewees verified that the same dynamics that characterise short-term connections largely dictate the long-established connections. Unanimously, the participants however underlined that it is the stability of the Trade Flow which practically establishes a connection between two countries in the long-term. Additionally, the participants suggested that there should be no disruptions such as embargoes which can terminate *''almost overnight''* a long-established and robust connection and respectively no dramatic deterioration of a country's Logistics Performance. Long-established connections are to a certain extent ''*self-sustaining''*: large carriers tend to have presence everywhere – if possible – thus only under certain circumstances will they drop a call that they have established. Moreover, the interviewees suggested that country-pairs with smaller bilateral flows are more exposed to fluctuations if the trade relationship is not stable. The same applies for Reefer Cargo.

Regarding possible actions that policy-makers may introduce in order to entice direct calls by carriers, the interviewees suggested that Trade Facilitation is usually a primary objective. Carriers need a friendly business environment including reasonable port tariffs and the minimum of bureaucracy but also flexible taxation and – if possible – stable exchange rates. Furthermore, policy-makers should focus on providing the most modern and efficient infrastructure possible. The participants however once more emphasised on the crucial role of Trade Flow and its importance for the carriers. Thus, although a focus by policy-makers on Trade Facilitation and Logistics Performance is usually in scope, a few participants suggested that possibly the main effort by governments and officials should be towards the stimulation of local production and consumption in order to allow a robust Trade Flow.

In summary, Discussion Topic 3 highlights that (a) long-established and short-term connections are largely governed by the same dynamics but the former are specifically characterised by the stability of the exchanged volumes and (b) policy-makers may also focus on initiatives towards the enhancement of Trade Flow rather than solely monitoring variables such as Trade Facilitation and Logistics Performance.

6.6 Model Update – Sensitivity Analysis

As previously discussed, this Chapter strives to sense-check the modelling effort and to essentially investigate *if "the data are telling you what you think they are telling you"* (Saunders et al., 2007a p139). According to Wooldridge (2013b), a competent empirical research should include a *sensitivity analysis* which largely corresponds to the estimation of the original model and then its sensible modification with the aim to test whether the main conclusions hold. Thus, this Section utilises the feedback that has been collected by the participants of the semi-structured interviews in order to modify accordingly the core specification of this research (see Model 4 – Table 5-15) and conclude on its compatibility with the real world.

The outcome of the semi-structured interviews with regard to the setup of the model (i.e. the employed variables) may be synopsised as follows:

- The interviewees suggested that in their view there are no missing variables from the core specification.
- However, two interviewees suggested that MSR Routing is perhaps a variable that could be dropped and should this be possible they may also consider dropping ECA Routing as well.

The latter may suggest the re-estimation of the model by removing the respective variables although this dimension was proposed by only two participants. Table 6-2 displays the core specification (see Model 4 – Table 5-15) along with two variants: Model 4a which does not include MSR Routing and Model 4b which does not include neither MSR Routing nor ECA Routing. The displayed results correspond to the respective margins in order to provide a basis for comparison between the different specifications:

Model	(4)	(4a)	(4b)
Variable	XT CRE	XT CRE_a	XT CRE_b
Trade Flow	**0.13**	**0.12**	**0.12**
Trade Imbalance	0.07	0.08	0.08
Connectivity	0.05	0.04	0.04
MSR Routing	-0.03	-	-
ECA Routing	-0.08	-0.06	-
Colonial Ties	0.05	0.02	0.03
Trade Facilitation	0.02	0.02	0.02
Reefer Cargo	**0.01**	**0.01**	**0.01**
Logistics Performance	0.05	0.05	0.05
m_Trade Flow	-0.02	-0.01	-0.02
m_Trade Imbalance	0.03	0.03	0.03
m_Connectivity	**0.11**	**0.10**	**0.10**
m_MSR Routing	-0.13	-	-
m_Trade Facilitation	-0.02	-0.02	-0.01
m_Reefer Cargo	0.00	0.00	0.00
m_Logistics Performance	-0.07	-0.08	-0.10
2013	-0.01	-0.01	-0.01
2014	0.02	0.01	0.01
2015	0.02	0.02	0.02
2016	0.03	0.03	0.02
2017	0.05	0.05	0.05
2018	0.03	0.02	0.02
2019	-0.01	-0.02	-0.02
2020	-0.01	-0.01	-0.01

Core Specification	**p<*0.05**

Table 6-2 – Model Sensitivity Analysis

The results suggest that the exclusion of MSR Routing and ECA Routing across both Model 4a and Model 4b:

- does not alter the sign of any of the variables
- does not alter the statistical significance of any of the variables
- does not substantially alter the magnitude of any of the variables.

  With regard to the variables of statistical significance, Trade Flow and m_ Connectivity show a minor decrease of 0.01 while Reefer Cargo remains the same.

  With regard to the rest of the variables only minor changes (0.01 to 0.03) are respectively observed (e.g. ECA Routing decreases by 0.03 for Model 4a).

Thus, no alarming changes are observed by incorporating the feedback from the semi-structured interviews into the model. The signs, the significance and the magnitude for the majority of the variables remains the same and overall the main conclusions of the analysis seemingly hold. This sensitivity analysis suggests that the core specification of this research is evidently a trustworthy representation of the real world and no further update of the specification is required.

6.7 Exploring the potential predictive power of the model

The nature of a semi-structured interview allows for open-ended questions as well as the discovery of areas that may have not yet been anticipated (Saunders, Lewis and Thornhill, 2007b). During the general discussion of the modelling effort, one of the participants showed a particular interest regarding the mechanics of the model. Following on a short explanation of the *xtprobit* model rationale, the interviewee questioned whether the model could assist in predicting any changes on the network. Specifically, the interviewee asked if the model could be used at the beginning of a year (e.g. early 2020, at the outbreak of COVID-19 crisis) to predict whether a given country is anticipated to be directly connected with the UK that year (i.e. by providing as input certain values for the independent variables). The latter essentially posed an intriguing challenge to the model capabilities.

As discussed in Section 3.12, this research strives to understand the underlying relationships between variables by studying the statistical correlation (or the causal patterns) of the gathered data. Thus, according to Shmueli (2010) the corresponding analytical effort belongs to the type of *explanatory modelling*. The latter differs significantly from the type of *predictive modelling* which is designed to predict new or future observations (*ibid*). Explanatory modelling focuses on minimising bias in order to represent as accurately as possible an underlying mechanism or theory while predictive modelling focuses on balancing between bias and variance (often by sacrificing theoretical accuracy) in order to achieve the most accurate predictions (*ibid*). Subsequently, the architecture of those two modelling efforts (including the selection of the employed variables) may be substantially different (*ibid*). However, Shmueli (2010) highlighted that an explanatory model may strengthen its validity by demonstrating a degree of predictive power. This may be achieved by adopting the approach of *data partitioning* (*ibid*) which corresponds to the training / test data split that was introduced in Section 4.4.8.

Essentially, the aim of the exercise that was suggested by the interviewee would necessitate running an estimated model for the period 2012-2019 and then use any random values for the independent variables in 2020 in order to make predictions. However, the advantage of the data partitioning is that the estimated model for 2012-2019 can utilise the actual 2020 values of the independent variables, make predictions for the value of the dependent variable (i.e. Direct Connection) in 2020 and then cross-check those predictions with the actual 2020 values of the holdout dataset. Hence, this task may be specifically tackled as an *out-of-sample* prediction problem. The latter is based on ''*using the first part of a sample to estimate the parameters of the model and saving the latter part of the sample to gauge its forecasting capabilities. This mimics what we would have to do in practice if we did not yet know the future values of the variables''* (Wooldridge, 2013b p659).

Stata allows the calculation of the *predicted probability of a positive outcome* with a corresponding command. Specifically, following on the re-estimation of the core specification for years 2012-2019, the below command is executed:

predict probhat_20 if year == 2020, pr

This command returns the probability of a positive outcome (i.e. probhat_20 shows how probable a Direct Connection with the UK may be for each country in 2020) by taking into consideration the corresponding random effects for each panel (StataCorp., 2023a). The execution of this command returns predictions for 109 counties (i.e. if a country has any missing value(s) on any of the independent variables for 2020, Stata cannot generate a prediction).

The predicted probability of a positive outcome is a decimal number between 0 and 1. The task of the evaluation of a predictive binary model is essentially to assess whether the observations can be correctly predicted (Wooldridge, 2013b). A binary predictor y_i may then be equal to 1 (i.e. Direct Connection) if the predicted probability is larger than 0.50 or 0 (i.e. no Direct Connection) otherwise (*ibid*). For instance, a predicted probability of 0.65 suggests that according to the model the corresponding country has a 65% predicted probability to be directly connected to the UK in 2020. Based on the 0.50 threshold this country is more likely than not to be directly connected to the UK in 2020 and is allocated in Class 1 (i.e. Direct Connection). This value is then compared to the actual connection status of the examined country in order to verify whether the model managed to make a correct prediction. A relevant example (i.e. the ten first countries by alphabetical order) is displayed in Table 6-3. For instance, all countries in Table 6-3 were correctly classified with the exception of the Bahamas and Benin:

Country	Year	Probability of Positive Outcome	Predicted Class	Actual Class
Albania	2020	0.04	0	0
Algeria	2020	0.21	0	0
Angola	2020	0.39	0	0
Argentina	2020	0.91	1	1
Australia	2020	0.94	1	1
Bahamas	2020	0.59	1*	0*
Bahrain	2020	0.18	0	0
Belgium	2020	1.00	1	1
Benin	2020	0.18	0*	1*
Brazil	2020	1.00	1	1

*False Classification

Table 6-3 – Probabilities and Classification Example

The cut-off value of 0.50 is commonly used for classification problems but may be altered under certain circumstances. If for example Class 1 (i.e. Direct Connection) corresponds to only 5% of the data then the threshold could be substantially decreased otherwise Class 1 would be hardly predicted (Wooldridge, 2013b). Nevertheless, this is anticipated to cost the misclassification of a significant amount of Class 0 predictions (*ibid*). As it was displayed in Table 6-3 – across all years – Class 0 corresponds to 50.65% and Class 1 to 49.35%. Although a differentiation of this split may be possible specifically for 2020, both classes are seemingly well-represented across the examined dataset thus this exercise proceeds with the default 0.50 threshold for classification.

A classification problem utilises four basic numbers (Singh *et al.*, 2021):

1. True Positive (TP): the number of countries which had a Direct Connection with the UK in 2020 and were correctly allocated to Class 1.

2. True Negative (TN): the number of countries which had no Direct Connection with the UK in 2020 and were correctly allocated to Class 0.

3. False Positive (FP): the number of countries which had no Direct Connection with the UK in 2020 but were incorrectly allocated to Class 1.

4. False Negative (FN): the number of countries which had a Direct Connection with the UK in 2020 but were incorrectly allocated to Class 0.

Those numbers are then used to compile the main metrics that are commonly used for the evaluation of the predictive power of a binary model (Singh *et al.*, 2021; Grandini, Bagli and Visani, 2020; Bej *et al.*, 2021):

- **Accuracy** = (TP + TN) / (TP + FP + TN + FN)

  This metric denotes the ratio of the correctly classified countries (TP + TN) to the total number of countries (TP + FP + TN + FN).

  This metric answers the question: *What proportion of the predictions was correct?*

- **Precision =** TP / (TP + FP)

  This metric denotes the ratio of the correctly classified countries with a Direct Connection to the total number of countries predicted to have a Direct Connection.

  This metric answers the question: *What proportion of Positive (P) predictions was actually correct?*

Sensitivity (or Recall) = TP / (TP + FN)

  This metric denotes the ratio of the correctly classified countries with a Direct Connection to the total number of countries that actually had a Direct Connection.

  This metric answers the question: *What proportion of TP was correctly identified?*

- **Specificity** = TN / (TN + FP)

  This metric denotes the ratio of the correctly classified countries with no Direct Connection to the total number of countries that actually had no Direct Connection.

  This metric answers the question: *What proportion of TN was correctly identified?*

- **F1 Score** = (2 * Precision * Sensitivity) / (Precision + Sensitivity)

  This metric is suggested by the literature if the Classes (i.e. 0, 1) are imbalanced (i.e. the vast majority of the cases belongs to either Class 0 or 1). In this case, there is a risk of misrepresentation for the minority Class. F1

Score is the harmonic mean of Precision and Sensitivity and practically penalises the model if either Precision or Sensitivity is low. Hence, F1 Score sheds light on any predictive weakness of the model and essentially provides a more holistic assessment of the predictive performance of the model.

The predictive performance of the model is accordingly displayed on Table 6-4:

Actuals		Predictions		Out-of-Sample Prediction Metrics	
P	63	**TP**	57	**Accuracy**	94%
N	46	**FP**	1	**Precision**	98%
		TN	45	**Sensitivity**	90%
		FN	6	**Specificity**	98%
P + N	109	**Total**	109	**F1 Score**	**94%**

Table 6-4 – Out-of-sample prediction results

Thus, overall the model performs quite well across all metrics. The lowest score is recorded for Sensitivity since the model incorrectly suggests that 6 countries (Benin, Côte d'Ivoire, Iceland, New Zealand, Norway, and Senegal) were not directly connected to the UK in 2020 while the actual data suggests the opposite (i.e. FN = 6). The detailed observation of the characteristics of those countries does not reveal any clear pattern that suggests the reason for their misclassification. However, it can be noted that those countries managed to retain their direct connection with the UK although they recorded relatively low exchanged volumes with the UK in 2020 and no or negative growth compared to 2019. The calculation of the corresponding F1 Score is deemed appropriate since for 2020 the split between the classes is slightly imbalanced. The respective result (94%) suggests that the model manages to successfully address the intriguing challenge that was set by one particular interviewee during the interviews.

Hence, although the modelling effort primarily serves the explanatory orientation of this research, the core model specification is also able to display a reasonably strong predictive capacity, at least for the task that it was challenged to perform (i.e. 2020 predictions). Inevitably, the out-of-sample exercise utilises the actual values of the employed variables in order to make predictions and cross-check those results against the actual values. However, a model which has proved its predicting ability provides a certain level of confidence that it can possibly predict future connections quite accurately if the input is valid.

6.8 Concluding Remarks

This Chapter proceeded with the model validation which corresponds to Phase 3 of the research.

Following on from an introduction to the theoretical background of the semi-structured interviews, the applicability of a relevant approach for this research was justified. Then, the setup of the semi-structured interviews according to the needs of this research was presented, followed by the results of the discussions with the interviewees. The semi-structured interviews highlighted that a) the model has overall considered the right mix of variables; b) trade is the main driver of direct connections; c) long-established and short-term connections are largely driven by the same dynamics; and d) policy-making efforts – among other actions – may emphasise on the improvement of the underlying economic dynamics of a country. Additionally, this Chapter investigated whether the main conclusions of the model hold through a sensitivity analysis and then explored the predictive power of the model. Those processes suggested the overall relevance of the model to the practice as well as its potential capability to accurately predict direct connections.

The next Chapter will explore the role of each variable under certain conditions towards the establishment of direct connections between trading countries.

Chapter 7. Further exploration and discussion of the role of individual variables

7.1 Introduction

In Chapter 3, the SLR of this research identified 23 factors (variables) that the literature has discussed as potential drivers for the establishment of direct connections between trading countries. The list of those 23 variables was further filtered in Chapter 4 through the framework of Causal Inference and a final list of 9 variables were identified as the basis for the statistical analysis of this research.

In Chapter 5, the statistical analysis of this research quantified the importance of the identified variables and indicated that only 2 of those variables consistently return a statistically significant result (at 5%): (a) Trade Flow and (b) Reefer Cargo. The employed statistical framework of the Correlated Random Effects (CRE) further indicated the statistical significance of m_Connectivity (Mean Connectivity). The significance of a statistical result suggests that an estimate is not attributed to randomness (Britannica, 2023b), reflects the mathematical importance of an analysed variable and is measured by the value of a test statistic (Wooldridge, 2013b). However, an analysis may also inform on the practical (or economic) significance of an estimate which is measured by the sign and magnitude of the estimate (*ibid*). The latter allows for a discussion regarding the possible direction of a policy (e.g. the improvement of a country's Trade Facilitation score) (*ibid*).

In Chapter 6, the statistical findings of this research were qualitatively cross-checked with the views of selected practitioners. With the aim to further understand the relevance of the model to the real world and thus its practical significance, the discussion with the practitioners explored their views regarding all employed variables, irrespective of their statistical significance. This research utilises the UK as a targeted sample and accepts that between different regions, carriers and routes there might be distinct dynamics that shape the competitive environment in container shipping (see Section 3.12). Thus, although those variables with statistical significance in this research have been highlighted and thoroughly discussed, it has been deemed appropriate to explore the possible practical significance of all employed variables which may have an augmented role under different contexts.

The methodological triangulation of this research confirmed the very substantial importance of Trade Flow (i.e. a statistically significant variable) towards the establishment of Direct Connections between trading countries. Reefer Cargo (i.e. also a statistically significant variable) was also deemed important but the practitioners suggested that it may be regarded as a standalone driver of a direct connection for limited markets only, as opposed to Trade Flow. Finally, the practitioners also indicated that the rest of the employed variables (i.e. statistically insignificant variables) may only be partly important and under certain conditions.

Hence, a relevant question arises:

What precisely is the importance of Trade Flow for an average country and under which conditions would other covariates also have an impact on the establishment of a Direct Connection?

In order to answer the above question, Chapter 7 revisits the employed dataset in order to quantitatively explore and discuss the following two points:

1. The importance of Trade Flow (Section 7.3): this effort attempts to define the impact of different Trade Flow values towards the establishment of a Direct Connection with the UK (e.g. at which Trade Flow value (TEU) the probability of a Direct Connection is more likely for an average country or alternatively for a country which scores very low on the rest of the covariates).

2. The importance of the remaining covariates under certain conditions (Section 7.4): this effort builds upon the previous findings and accepts that Trade Flow is the core driving force of a Direct Connection. However, this effort further explores how the probability of a Direct Connection with the UK changes by keeping the TEU volume at a fixed level while experimenting with selected reference values for each of the other covariates (e.g. how the probability of a Direct Connection changes for an average country with a fixed Trade Flow value when its Connectivity is evaluated at various reference values of LSCI etc.).

The focus of the following exploration and discussion of the role of individual variables is displayed in Figure 7.1:

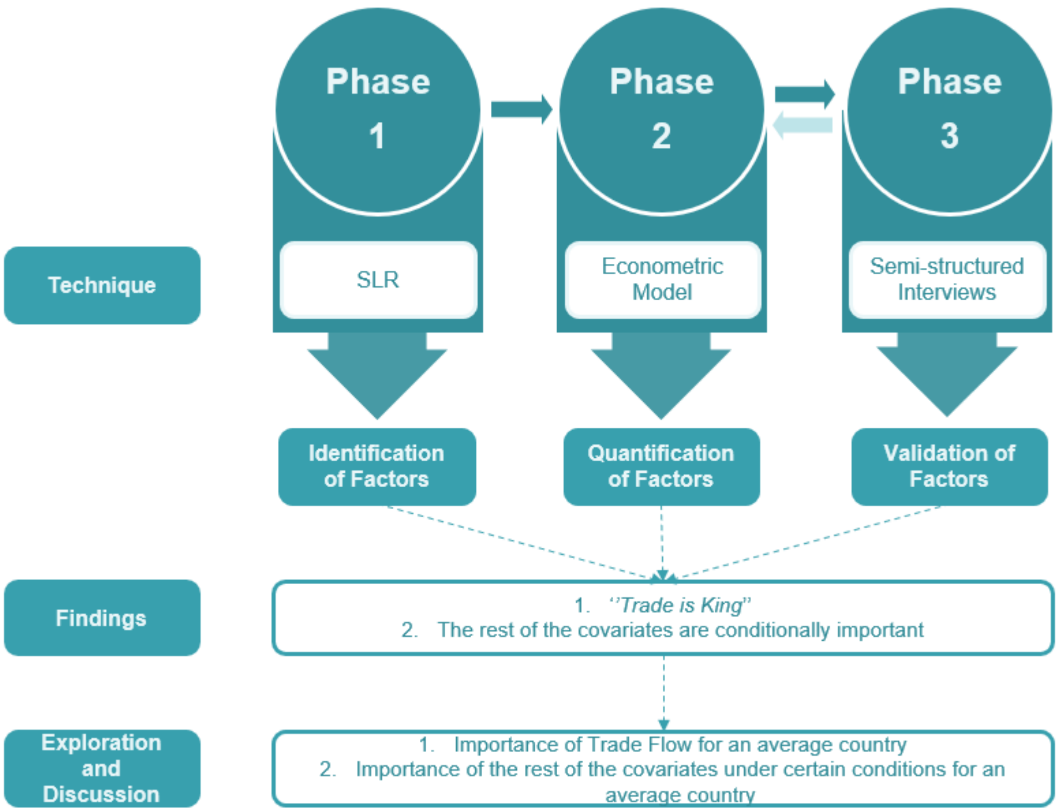

Figure 7.1 – Focus of the exploration and discussion of the role of individual variables

In this Chapter, Section 7.2 outlines the approach of the subsequent analysis and discussion, Section 7.3 discusses the importance of Trade Flow while Section 7.4 discusses the importance of the remaining covariates under certain conditions, and finally Section 7.5 comprises the concluding remarks of this Chapter.

7.2 Approach

The following exploration and discussion of the individual variables' role utilises the *margins* command in Stata and specifically the option which calculates the *predictive margins*. The latter returns *''the average predicted probability of y = 1''* thus the estimated probability that a country may be directly connected with the UK. For the purposes of this exercise, the research calculates the corresponding probability of the *average* country with the aim to provide a holistic understanding of the examined dataset. The latter is achieved by setting the controlled covariates at their mean value (Williams, 2012) while the corresponding random effect is also calculated at its mean (i.e. for an individual with $a_i = 0$, see Appendix E).

For instance, the following command estimates the predictive margin (i.e. the probability of a positive outcome – Direct Connection of a country with the UK) at the minimum, mean and maximum values of Connectivity across the examined dataset (*0.26, 3.43,* and *15.95,* respectively) when the rest of the covariates as well as the random effects are set to their mean value (i.e. *atmeans* and *predict(pu0),* respectively):

margins, *at(connectivity = (0.26 3.43 15.95))* ***atmeans predict(pu0)***

This process is executed for all covariates. The aim is to illustrate whether by adapting for instance the value of a given covariate such as Connectivity, an (average) country has a higher probability to connect directly with the UK when for the rest of the covariates that country achieves a mean score.

However, those mean values include the corresponding mean value of Trade Flow which is likely to define the above result because of its pivotal importance. Therefore, the analysis takes an additional step for each covariate and illustrates the probability of a country to connect directly with the UK when the rest of the covariates are estimated at their mean value but Trade Flow is also estimated at a lower level. The question then is will that change the importance of Connectivity? Is it in the interest of a country to score higher in terms of Connectivity when its Trade Flow is relatively low? And if yes, what is a possible threshold for the Connectivity score above which an average country may increase its probability to connect directly with the UK?

In order to arrive at a conclusion, this research proceeds to build an iterative code in Stata which returns the corresponding thresholds for each covariate. Those thresholds are specific values for each covariate where the probability of a Direct Connection with the UK surpasses the 0.50 cut-off point and indicates whether a Direct Connection becomes a favourable scenario or not. For instance, a relevant process regarding Connectivity returns a suggested threshold value of 3.41 (which is very close to the corresponding mean value 3.43). Therefore, this process suggests that for a Connectivity value over 3.41 the corresponding probability of connecting with the UK surpasses the 0.50 cut-off point and an average country is more likely to connect directly with the UK than not. The respective Stata command estimates the predictive margin as before but following the calculation of the corresponding threshold value for Connectivity (see example in Appendix I) while keeping Trade Flow and Trade Imbalance at fixed values. The utilised values of Trade Flow and

Trade Imbalance are further explained and defined – along with other individual assumptions for each covariate – in the corresponding Sections of this Chapter for each individual variable:

margins, *at(connectivity = (0.26 3.42 3.43 15.95) tradeflow = 0.71 tradeimbalance = -0.0142)* ***atmeans predict(pu0)***

7.3 The importance of Trade Flow for the Establishment of Direct Connections

As discussed in the SLR of this research (see Chapter 3) Trade Flow (i.e. the overall trade (TEU) exchanges between two countries) has been suggested by the literature as the variable with the most pivotal contribution towards the establishment of a Direct Connection between two trading countries. The statistical analysis of this research (see Section 5.8) confirmed the positive impact of the variable and highlighted its statistical significance. Finally, the discussion with the practitioners during the semi-structured interviews (see Section 6.5) suggested that Trade Flow may be considered as the actual driver of a direct connection.

In order to evaluate the importance of Trade Flow towards the establishment of a Direct Connection for an average country, its role is assessed: (a) when the values of all variables are set to their mean (Figure 7.2) and (b) when the values of all variables are set to their minimum (Figure 7.3). The latter is essentially an extension of the former point and aims to explore whether Trade Flow becomes increasingly more important when a country underperforms on the rest of the covariates.

In order to proceed with the corresponding analysis for Trade Flow, an additional assumption is needed regarding Trade Imbalance. As discussed in Section 5.7.2, Trade Imbalance is a direct product of Trade Flow thus those two values should be examined in tandem. However, for an exercise which assesses the average country this effectively suggests that for different Trade Flow levels, Trade Imbalance would remain fixed at its mean value (i.e. 1,270 TEU). In practice, this may return unrealistic Trade Flow – Trade Imbalance combinations. For instance, when Trade Flow is assessed on its minimum value (i.e. 0 TEU) Trade Imbalance should by definition also be zero and not equal to its mean value (i.e. 1,270 TEU).

Therefore, with the aim to make meaningful comparisons, this exercise proposes the ratio of the *Mean Trade Imbalance* to *Mean Trade Flow* of the examined dataset which is – approximately – equal to -0.02. The use of this ratio may essentially suggest the Trade Imbalance level that an average country is expected to record with the UK given the Trade Flow level between the two countries. For instance, if the Trade Flow between the two countries is equal to 50,000 TEU then (on average) this corresponds to a Trade Imbalance between the two countries equal to 50,000 X (-0.02) = 1,000 TEU and so forth. Trade Imbalance is respectively calculated with the use of this ratio for the rest of the discussion in this Chapter. As discussed in Section 4.4.9, during the examined period (2012-2020), the UK continuously recorded a deficit regarding its overall TEU exchanges with other trading countries. This justifies the negative sign of the ratio (i.e. -0.02) and suggests that the UK is expected to record a negative Trade Imbalance with an average country according to the employed dataset.

Regarding Figure 7.2, the displayed values of 0.00, 8.40 and 250.42 correspond to the minimum, mean and maximum values of Trade Flow for the examined dataset while the rest of the variables are set to their mean level. Respectively, the displayed value of 0.71 (i.e. 7,100 TEU) corresponds to the calculated threshold above which the probability of a positive outcome begins to surpass the 0.50 cut-off point. Hence, for the examined period (2012-2020), an average country needed to record at least 7,100 TEU exchanges in a given year in order to begin becoming an attractive option for a direct connection to the UK. The corresponding probability of a positive outcome increases progressively over that level and beyond the mean Trade Flow value of 8.40 (i.e. 84,000 TEU) an average country may be expected to secure a direct connection with the UK.

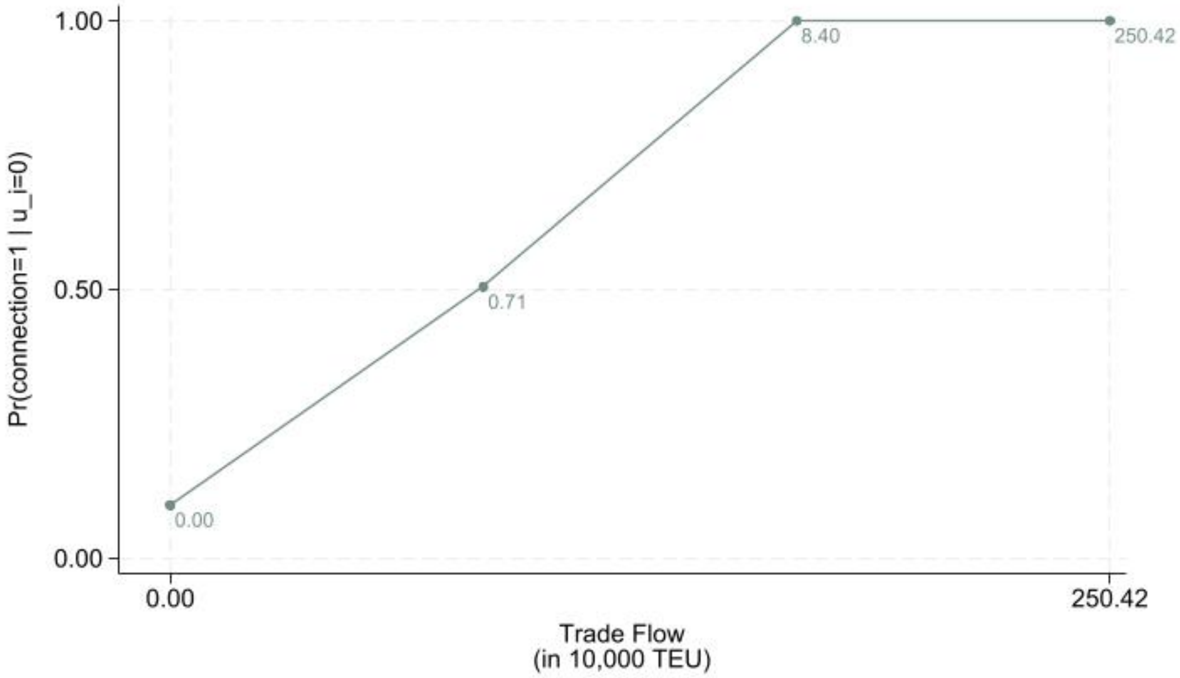

Figure 7.2 – Predictive Margins, Trade Flow (covariates set at mean value)

Regarding Figure 7.3, the displayed values of 8.40 and 250.42 correspond again to the mean and maximum values of Trade Flow for the examined dataset while the rest of the variables are set to their minimum level. Notably, the probability at the mean Trade Flow Value (8.40 or 84,000 TEU) corresponds to a value which is approximately equal to zero and suggests that the evaluation of the respective probability at that minimum Trade Flow value (i.e. 0.00 TEU) is practically meaningless: any direct connection is not likely for a relevant country which records less than 84,000 TEU of Trade Flow in a given year if the rest of the covariates are set at minimum value. Respectively, the displayed value of 11.95 (i.e. 119,500 TEU) corresponds to the calculated threshold above which the probability of a positive outcome begins to surpass the 0.50 cut-off point. Hence, it is illustrated that if a given country performs poorly on the rest of the covariates, it may need a considerably higher volume performance (compared to an average country which generates 7,100 TEU volume but scores better on the rest of the covariates) in order to start becoming an attractive option for a direct connection to the UK. Carriers may not proceed to establish a direct connection between the UK and a trading partner if the latter performs very poorly and is potentially problematic regarding the rest of the variables. Nevertheless, should the volume of the trade exchanges between the UK and a trading country be considerable then any concerns by the carriers may be alleviated by the prospect that a large Trade Flow value may offer.

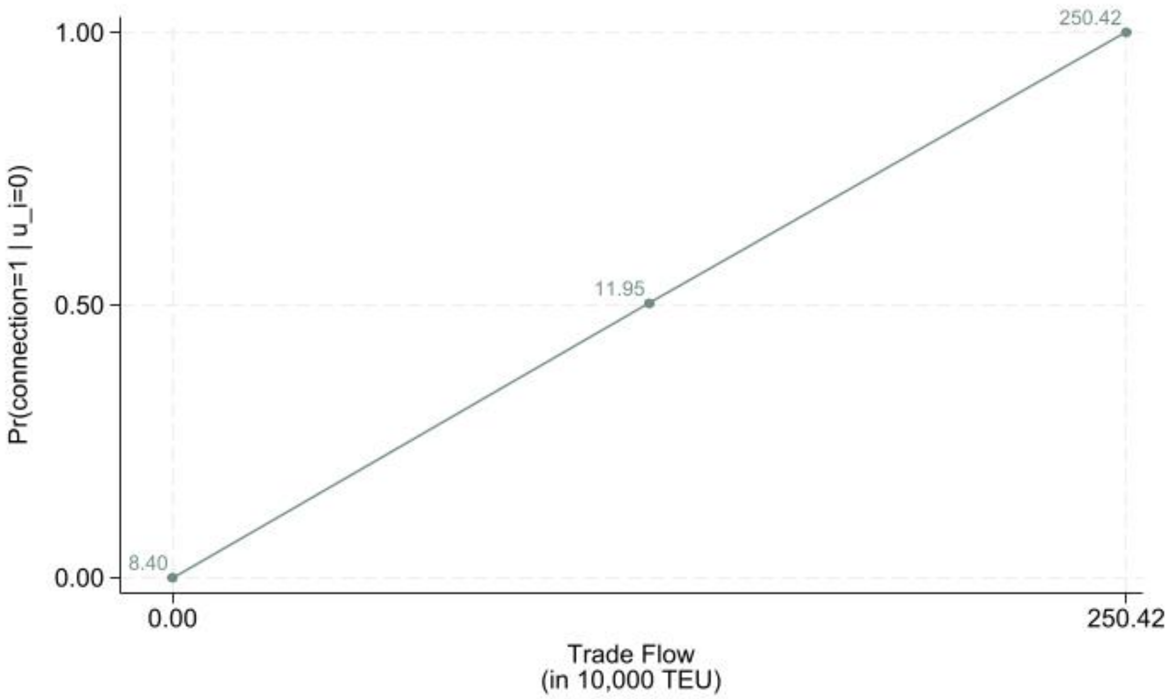

Figure 7.3 – Predictive Margins, Trade Flow (covariates set at minimum value)

The above analysis is in line with Robinson (1998) who highlighted that the consideration of a node as a direct call within a deep-sea network is initially triggered by a sustainable volume threshold which essentially satisfies the corresponding economies of scale and thus justifies a direct call by carriers. The analysis also suggests that this threshold is essentially co-defined by the performance of a country in other aspects as well. For instance, a country which scores lower than another country in terms of Connectivity or Logistics Performance may need a stronger volume performance in order to attract the interest of the carriers for a direct call. Additionally, there is a certain volume level beyond which carriers may proceed to call directly at a country purely driven by Trade Flow even if that country underperforms on other aspects.

Container shipping pursues economies of scale in order to spread more efficiently the high fixed costs of the business. High volume is of paramount importance since only the utilised slots onboard the container vessels can generate revenue. Therefore, carriers target those direct calls which can cover the cost of call and boost the utilisation of the vessel during a voyage. The robust volume performance of a country may act as an attraction for feeder services that will in turn attract more mainline vessels (Cullinane and Khanna (2000), as cited in Wang and Cullinane, 2008). Furthermore, volume drives the deployment of the fleet in certain geographies and thus the corresponding market share of a carrier. Apart from the apparent benefit of generating more revenue, a strong market share dictates the negotiating power of carriers regarding procurement (e.g. fuel, handling rates, port dues) and thus assists greatly on cost management efforts.

Carriers may monitor the economic development of various countries in order to identify opportunities for the robust flow of containers (González Laxe, Jesus Freire Seoane and Pais Montes, 2012). Volume performance may even occasionally overcome barriers set by exogenous forces such as politics and may also overcome historical political tensions (Yang, Chung and Lee, 2014). The above analysis confirms the pivotal role of Trade Flow which has been evident across all three Phases of this research: SLR, Modelling and Semi-structured interviews. Apparently, the rest of the covariates are very important but from a certain level of volume and beyond it is seemingly true what the practitioners suggested: *''Trade is King''*.

7.4 The importance of the remaining covariates under certain circumstances

7.4.1 Colonial Ties

As was discussed in the SLR of this research (see Chapter 3) Colonial Ties (i.e. whether two countries are or were in colonial relationship post 1945) has been suggested by the literature as one of those variables for which a general consensus has not been reached (see Figure 3.9). The importance of a colonial relationship between two trading countries towards the establishment of a Direct Connection has been advocated by the existing literature (e.g. Ducruet, Rozenblat and Zaidi (2010); Ducruet and Zaidi (2012)) but this can also be contradicting with the statistical analysis of certain samples pointing to the opposite conclusion (Saeed, Cullinane and Sødal, 2020). The statistical analysis of this research (see Section 5.8) confirmed the possibly positive impact of the variable but did not confirm its statistical significance. Finally, the discussion with the practitioners during the semi-structured interviews (see Section 6.5) suggested that Colonial Ties may be considered as a contributing factor of a direct connection for certain geographies and particular carriers only.

In order to evaluate the importance of Colonial Ties towards the establishment of a Direct Connection under certain conditions for an average country, the analysis explores whether (a) Colonial Ties is indeed a variable that may impact the probability of an average country to connect directly with the UK (Figure 7.4) and (b) there exists a certain Trade Flow threshold which is the minimum needed volume for an average country to be directly connected with the UK even if there is a colonial relationship between the two countries (Figure 7.5).

Regarding Figure 7.4, the graph illustrates that the probability of an average country to connect directly with the UK is indifferent to that country's colonial relationship with the UK when all of the remaining covariates are assessed at their mean value. As long as a country manages the average level of Trade Flow (84,000 TEU), it makes no difference whether Colonial Ties exist or not.

Figure 7.4 – Predictive Margins, Colonial Ties (covariates set at mean value)

Regarding Figure 7.5, the displayed value of 4,500 TEU corresponds to the calculated threshold over which the probability of a positive outcome begins to surpass the 0.50 cut-off point. In other words, it may be beneficial for a country to be in a Colonial Relationship with the UK in order to connect with it directly but a bare minimum volume is still needed for countries with former colonial relationships so as to materialise into a direct link in container shipping. Hence, based on the examined dataset Colonial Ties may not be regarded as a standalone reason for a country to connect directly with the UK when a minimum Trade Flow level is not guaranteed.

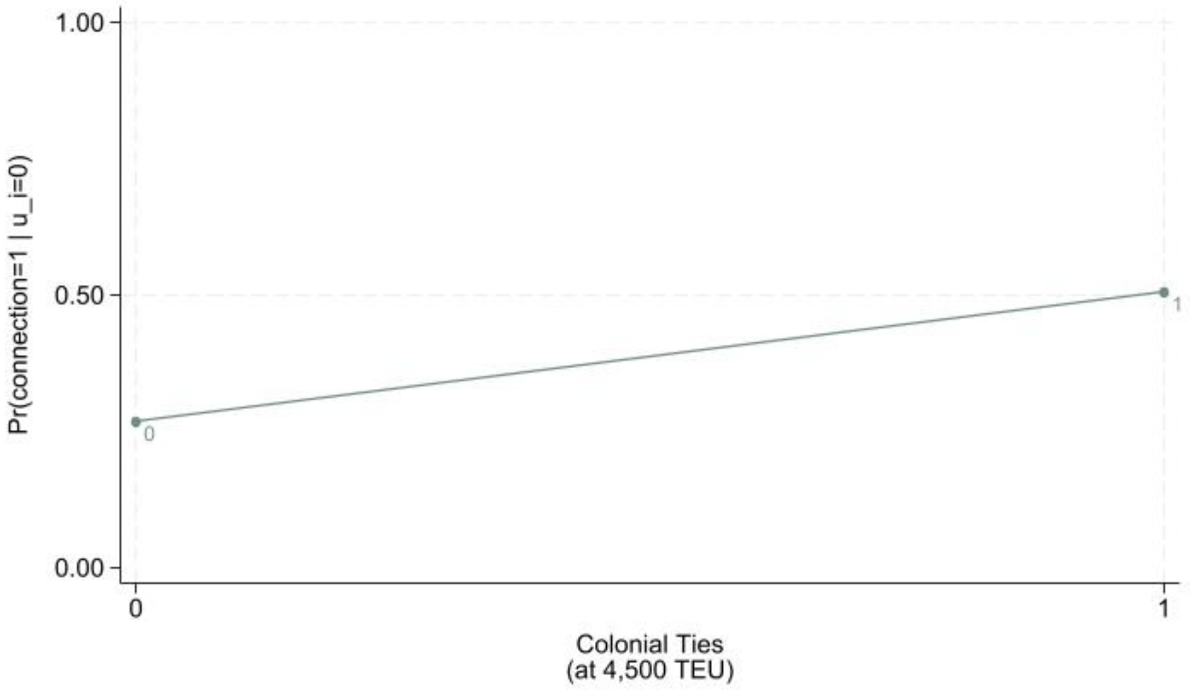

Figure 7.5 – Predictive Margins, Colonial Ties (covariates set at mean value, Trade Flow at calculated threshold value)

The examination of post-1945 colonialism refers to the relationship between various countries worldwide and the so-called modern colonial powers. The latter mainly comprise the United Kingdom, the Netherlands, Belgium, France and Portugal (Britannica, 2023a). Among those countries there is currently only a single example where a carrier may serve a *''national''* scope: CMA-CGM – France. The carrier is regularly present in former colonies such as Africa and the Caribbean. In fact, CMA-CGM was the only example that was named by the participants of the semi-structured interviews in the context of our discussion. In this case, it may be expected that certain countries may be directly called by CMA-CGM for reasons that extend beyond pure financial gains and may be partially attributed to corporate strategy and most importantly the national strategy of France. For instance, in August 2020 CMA-CGM proceeded with a substantial discount of freight rates (EUR 500 per container) for all major retailers not only in mainland France but in its overseas territories as well (Loadstar, 2020). This offer was dictated by a relevant request made by the French government to the carrier as a *''gesture''* against rising inflation which allegedly was not subsidised (*ibid*). Nevertheless, the container shipping stakeholders suggested that during periods of financial prosperity certain carriers may be *''easy political targets''* and thus may be asked to serve a certain political agenda (*ibid*). Therefore, on certain occasions countries may directly or indirectly promote the exchanges (and thus connections) with targeted trading partners. However, this is likely not a usual business model for carriers and in most of the occasions Colonial Ties is of secondary importance for the establishment of Direct Connections between trading countries, including the UK and its trading partners.

7.4.2 Connectivity

As it was discussed in the SLR of this research (see Chapter 3) Connectivity (i.e. the degree of a country's integration into the container shipping network) has been suggested by the literature as a variable the may possibly contribute towards the establishment of a Direct Connection between two countries. The statistical analysis of this research (see Section 5.8) confirmed the possibly positive impact of the variable but did not confirm its statistical significance. Finally, the discussion with the practitioners during the semi-structured interviews (see Section 6.5) suggested that Connectivity may be considered as a contributing factor of a direct connection but ultimately the Trade Flow performance of a well-connected node in the container shipping network is the underlying driver.

In order to evaluate the importance of Connectivity towards the establishment of a Direct Connection under certain conditions for an average country, its role is assessed (a) when the values of all variables are set to their mean (Figure 7.6) and (b) when the values of all variables are set to their mean and Trade Flow is set to 7,100 TEU (Figure 7.7) (i.e. the value which was identified as the minimum volume threshold for an average country in Section 7.3).

Regarding Figure 7.6, the displayed values of 0.26, 3.43 and 15.95 correspond to the minimum, mean and maximum values of Connectivity for the examined dataset. Hence, at average volume (84,000 TEU), the Connectivity score of a country is seemingly not an important factor since the probability of a positive outcome is already driven and defined by the Trade Flow volume.

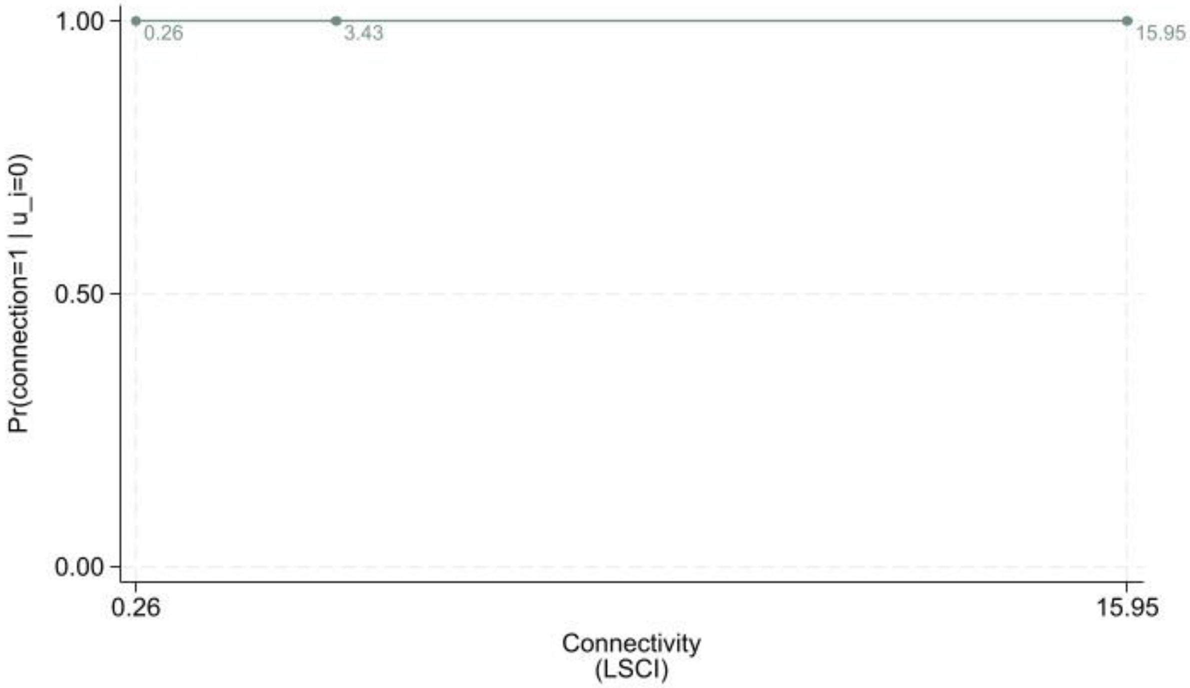

Figure 7.6 – Predictive Margins, Connectivity (covariates set at mean value)

Regarding Figure 7.7, the displayed value of 3.41 corresponds to the calculated threshold above which the probability of a positive outcome begins to surpass the 0.50 cut-off point. Hence, at a comparatively low volume (7,100 TEU), the Connectivity score of a country is seemingly a contributing factor: as the respective score grows the corresponding probability of a positive outcome also increases progressively. Thus, it is in the interest of a given country to work towards increasing its overall Connectivity score which in turn is likely to increase its probability of connecting directly with selected trading partners.

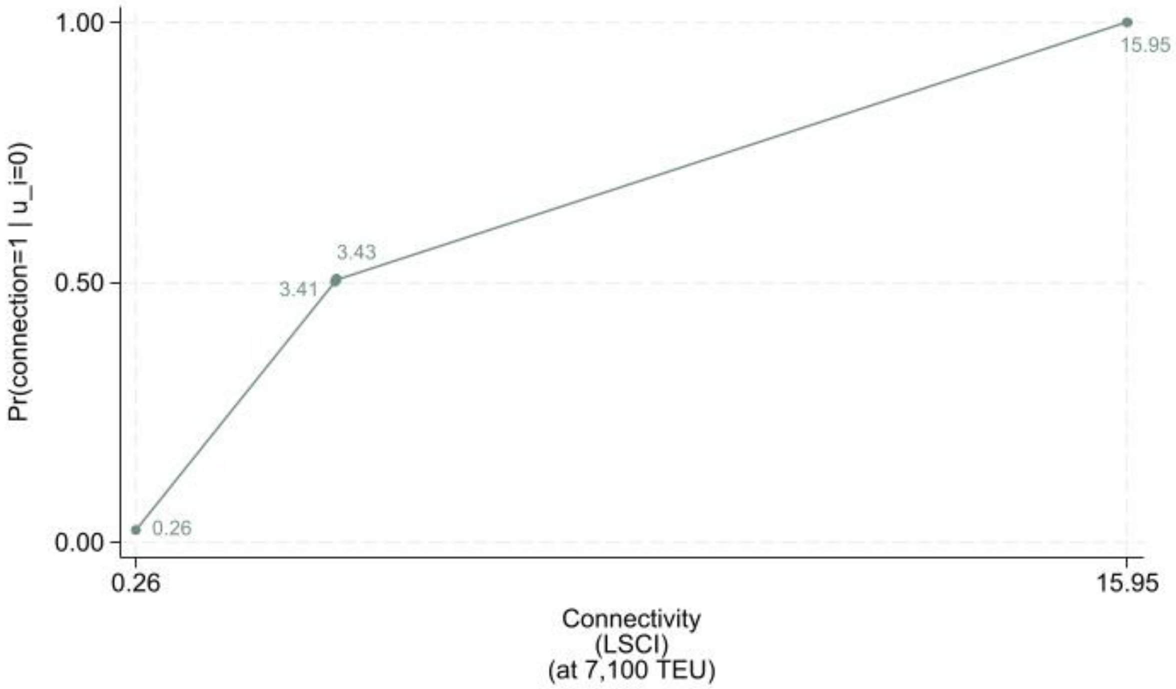

Figure 7.7 – Predictive Margins, Connectivity (covariates set at mean value, Trade Flow at calculated threshold value)

In Figure 7.6, it is illustrated that if the Trade Flow of a country is strong then Connectivity is not a game changer. Nevertheless, not all countries have the same TEU volume footprint in the container shipping network and not all trade routes are characterised by the same trade dynamics. For instance, a country which has a Trade Flow potential of 7,100 TEU may be of negligible importance if it targets the North Europe market across a major tradelane such as Asia – Europe. On the contrary, if a country with identical Trade Flow potential targets the same market across the South America / Caribbean – North Europe tradelane then it may be regarded as an attractive target for carriers. Hence, in Figure 7.7 it is illustrated that certain countries with relatively low volumes may be inclined to further develop their Connectivity score in order to connect with a country such as the UK.

As discussed in Section 3.6, the higher the connectivity of a country, as reflected by its LSCI score, the more likely it is to attract additional services which eventually will promote its better access to the international trade network (Wilmsmeier and Sánchez, 2010). This essentially suggests that whenever a country manages to attract additional container vessel calls and services, its Connectivity score is boosted and most importantly this generates a positive momentum which is likely to generate further opportunities in the future. In Section 1.1, the example of Gabon was utilised to define what is considered a direct call in container shipping and how a direct connection for example between Belgium and Gabon was established by CMA-CGM in 2019 (Figure 1.4). The establishment of a direct call at a certain country however may indeed have a broader importance than purely providing a direct link between two specific countries. Since container vessels operate in itineraries which involve multiple calls in various ports, the addition of a new port / country of call may unlock opportunities for additional country-pairs as well.

Figure 7.8 illustrates the West Africa – North Europe network of CMA-CGM as of April 2019 (the size of each node represents the corresponding deployed capacity at each country across all CMA-CGM services). Regarding the abovementioned example of Gabon and its addition in the EURAF service of CMA-CGM, the country managed for instance to connect directly with major end markets such as France and Belgium, intra-regional destinations such as Cameroon, Angola and Congo and finally with important nodes for further transhipment opportunities such as Portugal and in particular Spain (via the major hub port of Algeciras). This provides a prospect for carriers and countries to possibly pursue more cargo moves in more than one direct link. Moreover, a direct call by a carrier at a country may also increase the *Number of Common Direct Connections* which – as discussed in Section 3.11 – may also imply a higher chance of additional future connections with other countries. For instance, as per Figure 7.8, Gabon and the UK may not share a direct connection but they both connect directly with Spain, France, Belgium and Portugal and this – under certain circumstances – may encourage a future direct connection between them.

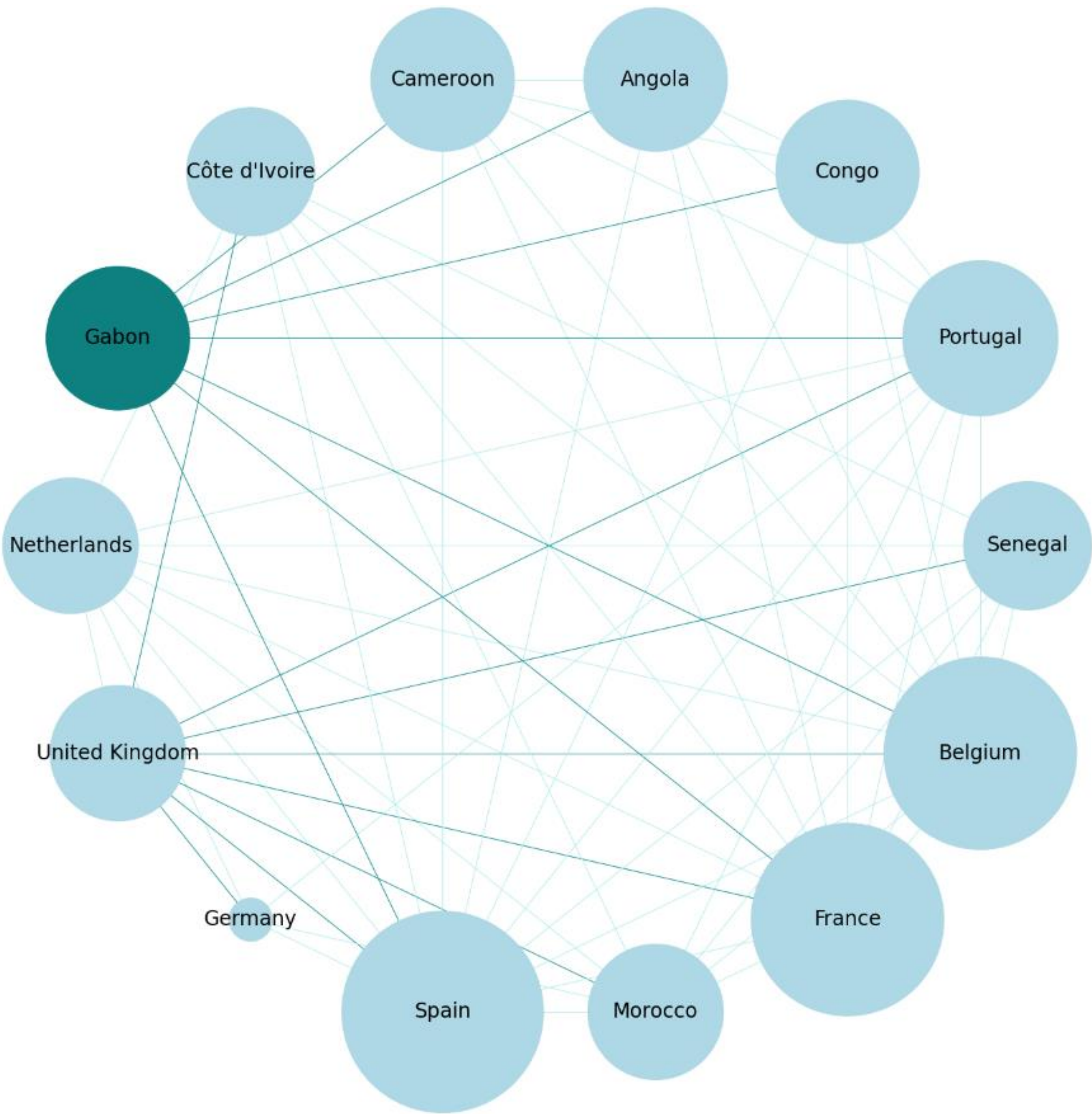

Figure 7.8 – West Africa - North Europe network of CMA-CGM (April 2019)

Thus, for a given country such as Gabon the attraction of a direct call by a container shipping service may have an incremental impact on its Connectivity but may also unlock other underlying opportunities and a recurrent boost of Connectivity. Undoubtedly, the further development of a country's Connectivity performance is heavily dependent on whether that country may capitalise on the opportunities that the carriers may provide via direct connections which in turn depends on whether the corresponding Trade Flow is robust and stable in the long-term.

7.4.3 ECA Routing

As discussed in the SLR of this research (see Chapter 3) ECA Routing (i.e. a shipping itinerary that crosses an established Emission Control Area while connecting two countries) has been suggested by the literature as a variable with a rather ambiguous impact towards the establishment of a direct connection between two trading countries (see Figure 3.9). Specifically, the existing literature suggested that although the establishment of an ECA is likely to fuel a tendency towards rerouting by the carriers, this is not regarded as a necessity for all routes (e.g. Doudnikoff and Lacoste, 2013; Schinas and von Westarp, 2017; Dithmer, Reinhardt and Kontovas, 2017b). The statistical analysis of this research (see Section 5.8) confirmed the possibly negative impact of the variable but did not confirm its statistical significance. Finally, the discussion with the practitioners during the semi-structured interviews (see Section 6.5) suggested that ECA Routing may not be considered as a major discouraging factor of a direct connection with a trading country since the corresponding cost of navigating via an ECA is expected to be covered by the freight rates (and / or the relevant surcharges). The latter however is attainable under the proviso that the corresponding Trade Flow level can generate an adequate level of revenue which is higher than the respective cost.

In order to evaluate the importance of ECA Routing towards the establishment of a Direct Connection under certain conditions for an average country, the analysis explores whether (a) ECA Routing is indeed a variable that may impact the probability of an average country to connect directly with the UK (Figure 7.9) and (b) there exists a certain Trade Flow threshold below which an average country may face difficulties to be directly connected with the UK if it is located within the boundaries of an ECA (Figure 7.10).

Regarding Figure 7.9, the graph illustrates that the probability of an average country to connect directly with the UK is not impacted by that country’s relative location (in / out of an ECA) when all of the remaining covariates are assessed at their mean value. As long as a country manages the average level of Trade Flow (84,000 TEU), it makes no difference whether a container vessel has to cross an ECA in order to directly connect the country with the UK. This is in accordance with the semi-structured interviews outcome: given enough revenue to absorb the corresponding cost, calling at a country which incurs an ECA cost is not a concern for carriers.

Figure 7.9 – Predictive Margins, ECA Routing (covariates set at mean value)

However, this possibly suggests that if a targeted country is located within an ECA then a minimum volume threshold may be a prerequisite for carriers. Regarding Figure 7.10, the displayed value of 13,500 TEU corresponds to the calculated threshold below which the probability of a positive outcome begins to drop beneath the 0.50 cut-off point. In other words, an average country which is located within the boundaries of an ECA may need a corresponding Trade Flow of above 13,500 TEU over a given year in order to achieve a direct connection with the UK. Hence, based on the examined dataset, ECA Routing may not be regarded as a standalone reason for not establishing a direct connection with the UK, provided however that a certain volume threshold is managed which allows the carriers to absorb the associated cost.

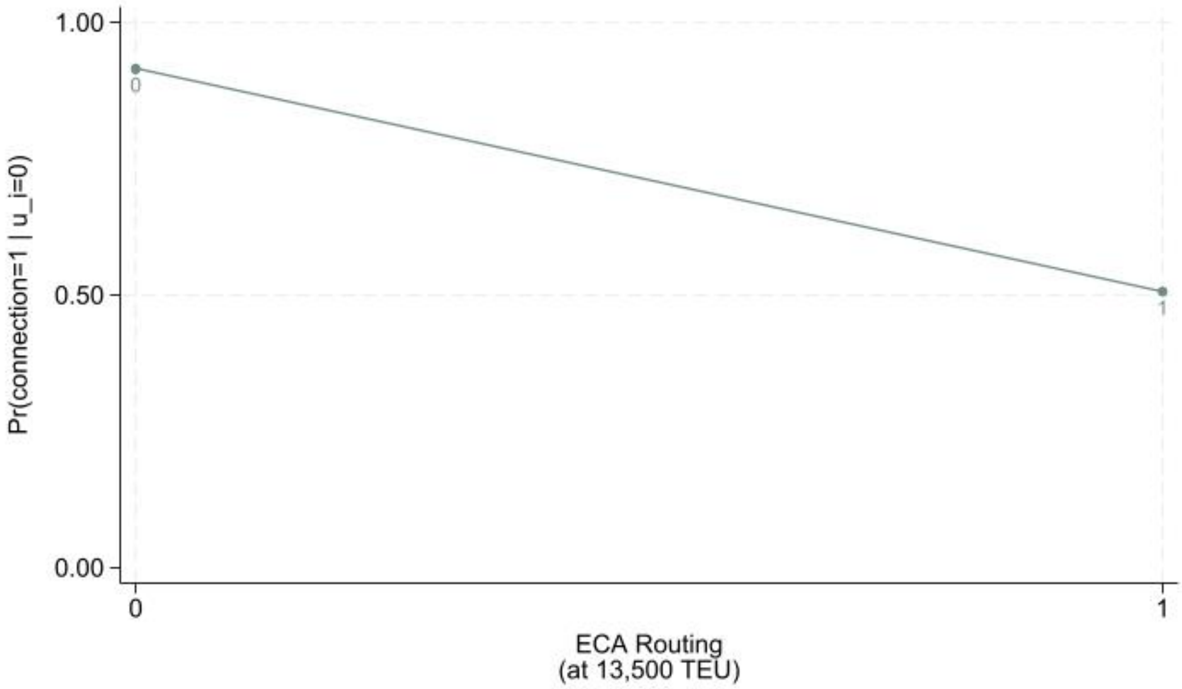

Figure 7.10 – Predictive Margins, ECA Routing (covariates set at mean value, Trade Flow at calculated threshold value)

The above findings and discussion may possibly explain – at least partially – the ambiguity found in the literature regarding the impact of the established ECAs on the routing decisions of the carriers. This ambiguity may be attributed to the fact that the existence of an ECA and the corresponding cost is only conditionally important for the carriers. Although the associated cost is likely considerable and is taken into consideration by the carriers, it may only become problematic under certain market conditions such as inadequate volume that cannot cover the associated cost. As the semi-structured interviews however also suggested, if the market momentum is favourable for the carriers they may simply pass the associated cost to their customers via a corresponding surcharge regardless of the corresponding volume. Additionally, even if the cost cannot be fully recovered, carriers may also consider the respective opportunity cost of losing market share if they do not match a certain routing which is offered by the competition and it is likely that they may evaluate that the corresponding opportunity cost supersedes the cost of burning more expensive fuel when operating within an ECA.

7.4.4 Logistics Performance

As discussed in the SLR of this research (see Chapter 3) Logistics Performance (i.e. the overall efficiency of the logistics network of a country) has been suggested by the literature as a variable the may possibly contribute towards the establishment of a Direct Connection between two countries. The statistical analysis of this research (see Section 5.8) confirmed the possibly positive impact of the variable but did not confirm its statistical significance. Finally, the discussion with the practitioners during the semi-structured interviews (see Section 6.5) suggested that Logistics Performance may be considered as a contributing factor of a direct connection but perhaps it is not necessarily regarded as a key variable for carriers' decisions if Trade Flow is promising and the Logistics Performance of a country is expected to progress.

In order to evaluate the importance of Logistics Performance towards the establishment of a Direct Connection under certain conditions for an average country, its role is assessed (a) when the values of all variables are set to their mean (Figure 7.11) and (b) when the values of all variables are set to their mean and Trade Flow is set to 7,100 TEU (Figure 7.12) (i.e. the value which was identified as the minimum volume threshold for an average country in Section 7.3).

Regarding Figure 7.11, the displayed values of 1.60, 3.00 and 4.23 correspond to the minimum, mean and maximum values of Logistics Performance for the examined dataset. Hence, at average volume (84,000 TEU), the Logistics Performance score of a country is seemingly not an important factor since the probability of a positive outcome is already driven and defined by the Trade Flow volume.

Figure 7.11 – Predictive Margins, Logistics Performance (covariates set at mean value)

Regarding Figure 7.12, the displayed value of 2.98 corresponds to the calculated threshold above which the probability of a positive outcome begins to surpass the 0.50 cut-off point. Hence, at a comparatively low volume (7,100 TEU), the Logistics Performance score of a country is seemingly a contributing factor: as the respective score grows the corresponding probability of a positive outcome also increases progressively. Thus, it is in the interest of a country with relatively low volumes to enhance its Logistics Performance.

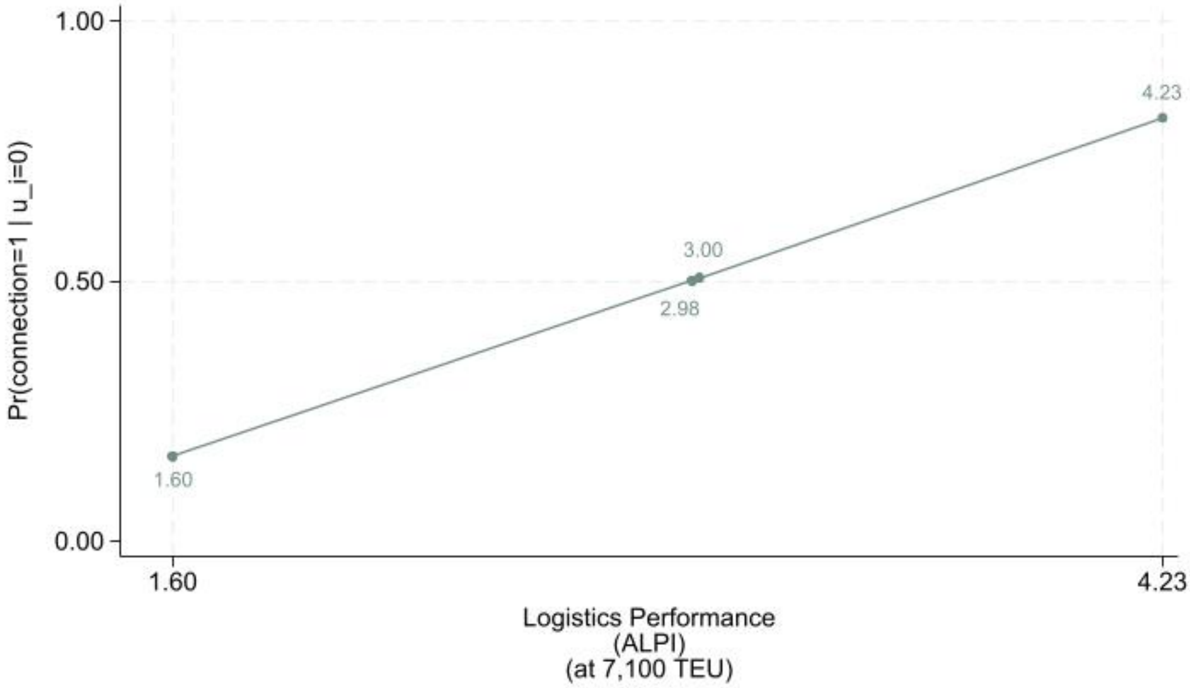

Figure 7.12 – Predictive Margins, Logistics Performance (covariates set at mean value, Trade Flow at calculated threshold value)

As discussed in the SLR of this research (see Chapter 3), if a country manages to improve its LPI score it is more likely to achieve better connectivity with targeted trade partners (Saeed and Cullinane, 2021). Additionally, deep-sea container operators consider a prosperous hinterland (in market terms) that can generate strong trade volumes a significant advantage of a node in order to be selected for a direct call (Wiegmans, Hoest and Notteboom, 2008). The above analysis as well as the findings of the semi-structured interviews essentially indicate that the Logistics Performance of a country is of secondary importance compared to Trade Flow and the former increases its importance only for low Trade Flow levels. In other words, carriers are likely to ignore a low LPI (or ALPI) score of a country if the associated volume that the corresponding country can generate is adequately attractive. Nonetheless, carriers may pay higher attention to the respective score of a country when the corresponding Trade Flow of that country is low. In that case, it may be on the interest of a given country to increase its Logistics Performance in order to compensate accordingly with regard to its attractiveness for a direct call.

Although typical interventions by national policy as well as the private sector primarily engage with the improvement of the logistics infrastructure, the long-term improvement of Logistics Performance lies on the ability of the countries to sustain a robust performance on other key attributes of the logistics ecosystem such as visibility applications that improve traceability (The World Bank, 2023a). As smart technologies that improve cargo monitoring advance, customers become more educated regarding cargo traceability which in turn assists the stakeholders across the supply chain to organise their logistics process and plan accordingly. It is thus likely that future supply chain stakeholders may demand increased traceability as a standard rather than a complementary offer and countries which invest on the whole spectrum of the LPI components may have an advantage on the container shipping network of the future.

Additionally, the magnitude of the Logistics Performance of a country may increasingly become of higher importance for certain carriers which have lately been engaged in door-to-door logistics services. Those carriers have recently adopted an integrated logistics strategy and aim to offer an end-to-end delivery service for their customers which expands from covering only the ocean leg of a container box move. Although carriers have been engaging with integrated logistics for over two decades certain companies such as Maersk have heavily invested their profits from the COVID-19 period into further door-to-door supply chain integration (Haralambides, 2023).

Specifically Maersk has announced a clear focus on such a strategy and has proceeded with targeted acquisitions globally (e.g. custom brokers, business-to-business / business-to-consumer specialists etc.) and have expanded on their air-freight offer as well (JOC, 2023). CMA-CGM has since 2019 included in its logistics portfolio CEVA Logistics, the leading European automotive specialist GEFCO, US-based Ingram Micro CLS, the parcel specialist Colis Privé, a stake in Air France – KLM and lately has proceeded to also acquire Bolloré Logistics (Alphaliner, 2023a). MSC has also been investing on its logistics, inland and air-freight network (JOC, 2023) including its latest focus on intermodal solutions in Africa via the acquisition of Bolloré Africa Logistics which is now branded as Africa Global Logistics (AGL, 2023).

COSCO has also announced its strategic decision to follow its peers into the third-party logistics (3PL) arena by establishing a distinct supply chain division (Loadstar, 2022). Hence, certain carriers may gradually increase their interest on the Logistics Performance of specific countries in order to evaluate whether those countries are prominent targets for the development of their door-to-door logistics strategies. For those strategies the evaluation of characteristics and profitability of the sea leg may correspond to only a part – albeit integral – of carriers' analysis when establishing connections between countries.

7.4.5 MSR Routing

As discussed in the SLR of this research (see Chapter 3) MSR Routing (i.e. whether two countries are connected via a shipping itinerary that crosses the Maritime Silk Road) has been suggested by the literature as a variable the may possibly contribute towards the establishment of a Direct Connection between two countries. Nevertheless, the statistical analysis of this research (see Section 5.8) indicated that – in the case of the UK – MSR Routing may have a small albeit negative effect while the analysis did not confirm the variable's statistical significance. The discussion with the practitioners during the semi-structured interviews (see Section 6.5) suggested that MSR Routing is a variable that is not always be considered in practice. Furthermore, the practitioners suggested that the negative sign of the corresponding marginal effect may reveal the overall small potential of countries along the MSR to directly connect with the UK. Finally, the practitioners suggested that the negative sign may also imply the inherent reluctance of carriers to encourage connections between nodes that support this kind of initiative because of anti-competitive implications which can be fueled by the MSR.

In order to evaluate the importance of MSR towards the establishment of a Direct Connection under certain conditions for an average country, the analysis explores whether (a) MSR Routing is indeed a variable that may impact the probability of an average country to connect directly with the UK (Figure 7.13) and (b) there exists a certain Trade Flow threshold below which an average country may face difficulties to be directly connected with the UK if it is located along the MSR (Figure 7.14).

Regarding Figure 7.13, the graph illustrates that the probability of an average country to connect directly with the UK is not impacted by that country's relative location (along the MSR or not) when all of the remaining covariates are assessed at their mean value. As long as a country manages the average level of Trade Flow (84,000 TEU), it makes no difference whether a container vessel has to utilise an MSR Routing in order to directly connect the country with the UK.

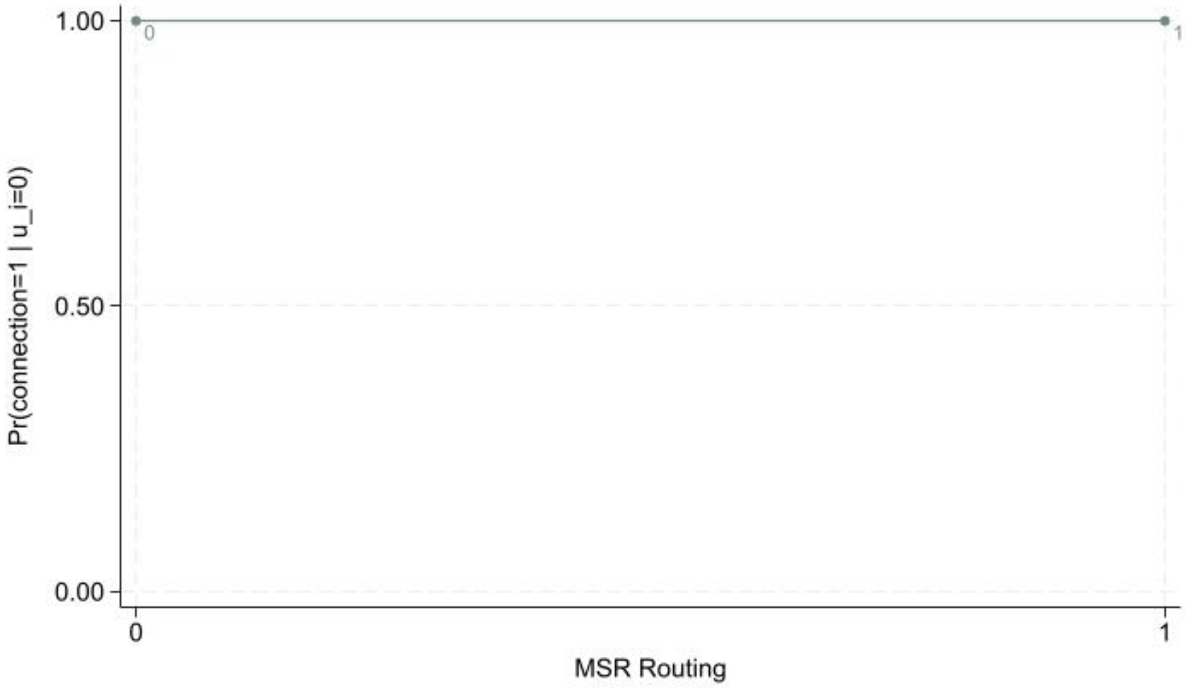

Figure 7.13 – Predictive Margins, MSR Routing (covariates set at mean value)

Under the hypothesis that the importance of MSR Routing is negligent for the carriers (either because what matters for the carriers is the volume or simply because this variable is not considered by the carriers in general) a further discussion of the impact of MSR Routing towards the establishment of a direct connection between countries is likely not important. However, under the hypothesis that carriers may explicitly tend to avoid MSR Routing connections for anti-competitive reasons then there might be a minimum volume threshold that could push carriers to overcome such reluctance. Regarding Figure 7.14, the displayed value of 8,900 TEU corresponds to the calculated threshold below which the probability of a positive outcome begins to drop beneath the 0.50 cut-off point. In other words, an average country which is located along the MSR may need a corresponding Trade Flow of over 8,900 TEU during a given year in order to achieve a direct connection with the UK. Hence, based on the examined dataset MSR Routing may not be regarded as a standalone reason for not establishing a direct connection with the UK, provided however that a certain volume threshold is managed which allows the carriers –

under the hypothesis that they take into consideration MSR Routing as a driver – to disregard any associated concerns.

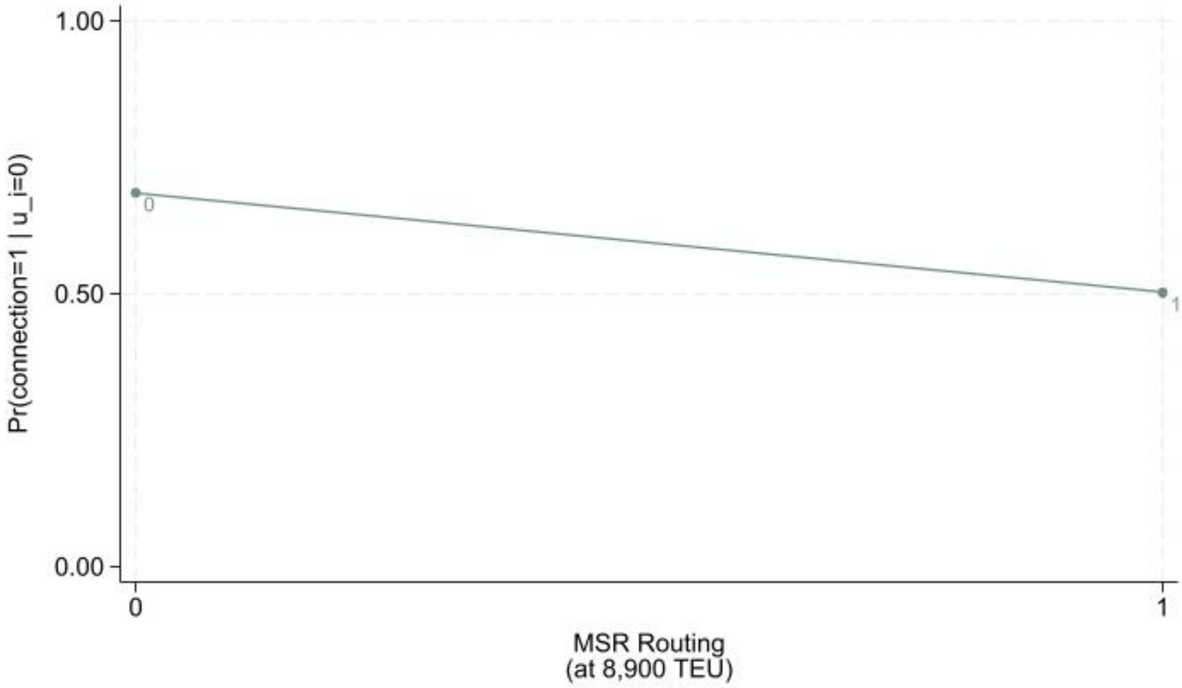

Figure 7.14 – Predictive Margins, MSR Routing (covariates set at mean value, Trade Flow at calculated threshold value)

State aid in the form of subsidies has been a concern for the stakeholders of container shipping. In 2019, the EU Commission expressed their scepticism specifically regarding certain investments of China along the MSR and directly questioned whether for instance the port of Piraeus is governed by COSCO or directly by China (JOC, 2019). According to Alphaliner (2023b), between 2010 and 2018 COSCO Shipping was subsidised with an amount of over USD 1.3 billion in the form of initiatives regarding vessel demolitions. In 2018, Maersk publicly suggested that subsidies of this kind trigger a distortion of the container market and are likely to compensate for a carrier which cannot compile a profitable business model (JOC, 2019). Thus, the negative impact of the MSR Routing because of anti-competitive concerns may be likely for the carriers – under certain circumstances – when they evaluate their options for a Direct Connection between countries. Nevertheless, even if scepticism may be in place, an adequate level of Trade Flow is seemingly able to diminish the importance of any relevant concerns by the carriers.

7.4.6 Reefer Cargo

As was discussed in the SLR of this research (see Chapter 3) Reefer Cargo (i.e. the importance of refrigerated cargo in the context of the overall containerised market of a country) has been suggested by the literature as a variable that may possibly contribute towards the establishment of a Direct Connection between two countries. The statistical analysis of this research (see Section 5.8) confirmed the positive – albeit small – impact of the variable and further suggested its statistical significance. Finally, the discussion with the practitioners during the semi-structured interviews (see Section 6.5) suggested that Reefer Cargo may be considered as a standalone factor of a direct connection for limited markets only (e.g. Central and South America).

In order to evaluate the importance of Reefer Cargo towards the establishment of a Direct Connection under certain conditions for an average country, its role is assessed (a) when the values of all variables are set to their mean (Figure 7.15); (b) when the values of all variables are set to their mean and Trade Flow is set to 7,100 TEU (Figure 7.16) (i.e. the value which was identified as the minimum volume threshold for an average country in Section 7.3) and (c) when the values of all variables are set to their mean and Trade Flow is set to its bare minimum (Figure 7.17). The justification of which volume may be regarded as the bare minimum in this case is provided later in this Section.

Regarding Figure 7.15, the displayed values of 8.80, 23.81 and 57.45 correspond to the minimum, mean and maximum values of the Reefer Cargo Index (RCI) score for the examined dataset. Hence, at average volume (84,000 TEU), the Reefer Cargo score of a country is seemingly not an important factor since the probability of a positive outcome is already driven and defined by the Trade Flow volume.

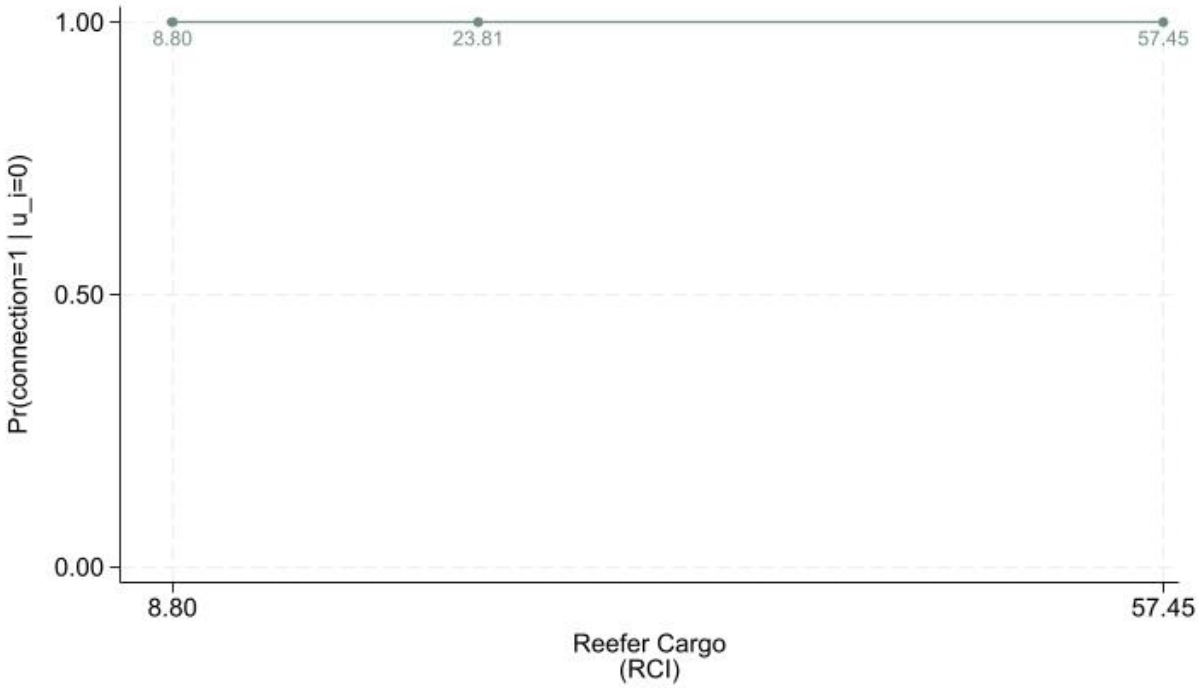

Figure 7.15 – Predictive Margins, Reefer Cargo (covariates set at mean value)

Regarding Figure 7.16, the displayed value of 23.80 corresponds to the calculated threshold above which the probability of a positive outcome begins to surpass the 0.50 cut-off point. Hence, at a comparatively low volume (7,100 TEU), the RCI score of a country is seemingly a contributing factor: as the respective score grows the corresponding probability of a positive outcome also increases progressively. Thus, it is in the interest of a country with relatively low volumes to enhance its performance on Reefer Cargo (to the extent that this can be supported by the underlying production capabilities of the country).

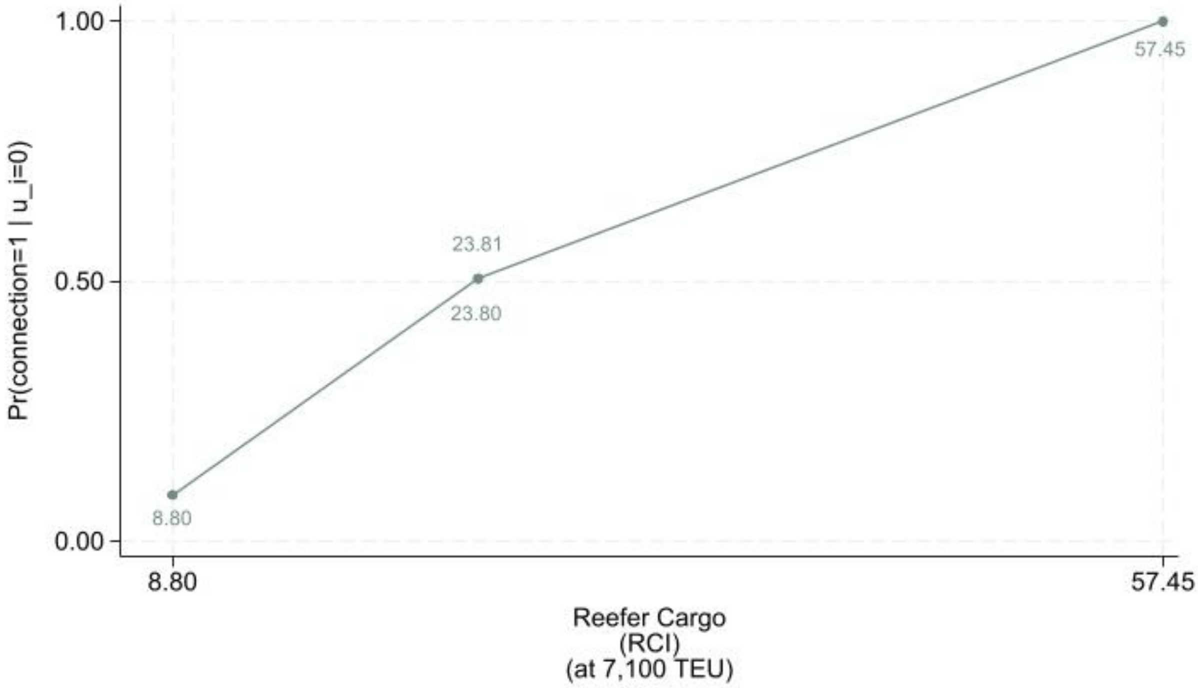

Figure 7.16 – Predictive Margins, Reefer Cargo (covariates set at mean value, Trade Flow at calculated threshold value)

However, the analysis suggested that only two of the main variables (i.e. excluding contextual effects / m_Connectivity) may have a statistical significance: Trade Flow and Reefer Cargo. Thus, it may also be meaningful to explore this threshold when even if Trade Flow is set at a minimum level, Reefer Cargo may arise as a standalone driver that may push carriers to establish a connection. The employed RCI metric in this research indicates primarily those countries which are essential for the reefer trade because they are exporters and their importance lies in the fact that their RCI score represents a strong underlying market which specialises on reefer cargo. Thus, this exercise should better target – as a reference for the minimum Trade Flow value – a country which has generally focused on exporting to the UK rather than importing. Additionally, as was suggested by the interviewed practitioners, a continuous perishable cargo flow is needed to justify a direct connection driven by Reefer Cargo. Thus, this exercise should better target – as a reference for the minimum Trade Flow value – a country which has sustained a long-established connection with the UK to avoid any opportunistic connections.

The country with relevant characteristics in the examined dataset is the Syrian Republic (Trade Flow = 0.0277 or 277 TEU and Trade Imbalance = -0.0162 or 162 TEU). The Syrian Republic managed to remain directly connected with the UK in the period 2012-2017 but lost its direct connection in the period 2018-2020. In 2018, a steep decrease on its Trade Facilitation is recorded which is most likely a reflection of the continuing unrest due to war (ongoing since 2012). Notably, in 2017 most of the variables recorded a level which was considerably lower than the overall mean value for all countries including Trade Flow, Connectivity, Trade Facilitation and Logistics Performance. However, that year the country recorded an RCI score which was considerably higher than the overall mean value for all countries (41.8 versus 23.8). Although causation is hard to be claimed this may be an indication that under certain circumstances a strong RCI of a country can be an important contributing factor for attracting direct connections. Additionally, the removal of the Latakia call from the corresponding service (NESM - Hamburg Sud) coincided with an update of the deployment profile for the service which included a 9% reduction of the available reefer plugs. This may also be an indication that until that certain point when the Syrian Republic was served by the specific service, the focus of the carriers on reefer cargo was higher compared to the follow-up period. Therefore, if the corresponding record of the Syrian Republic (i.e. Trade Flow / Trade Imbalance) is utilised as a reference level and the rest of the covariates are set to their mean value, the question is what could possibly be the threshold RCI value for a country which manages to connect directly with the UK?

Regarding Figure 7.17, the displayed values of 8.80, 23.81 and 57.45 correspond again to the minimum, mean and maximum values of Trade for the examined dataset while the rest of the variables are set to their minimum level. Respectively, the displayed value of 37.80 corresponds to the calculated threshold above which the probability of a positive outcome begins to surpass the 0.50 cut-off point. Hence, it is illustrated that if a given country performs poorly on the rest of the covariates (including Trade Flow), it may need a considerably higher RCI score compared to an average country in order to begin becoming an attractive option for a direct connection to the UK.

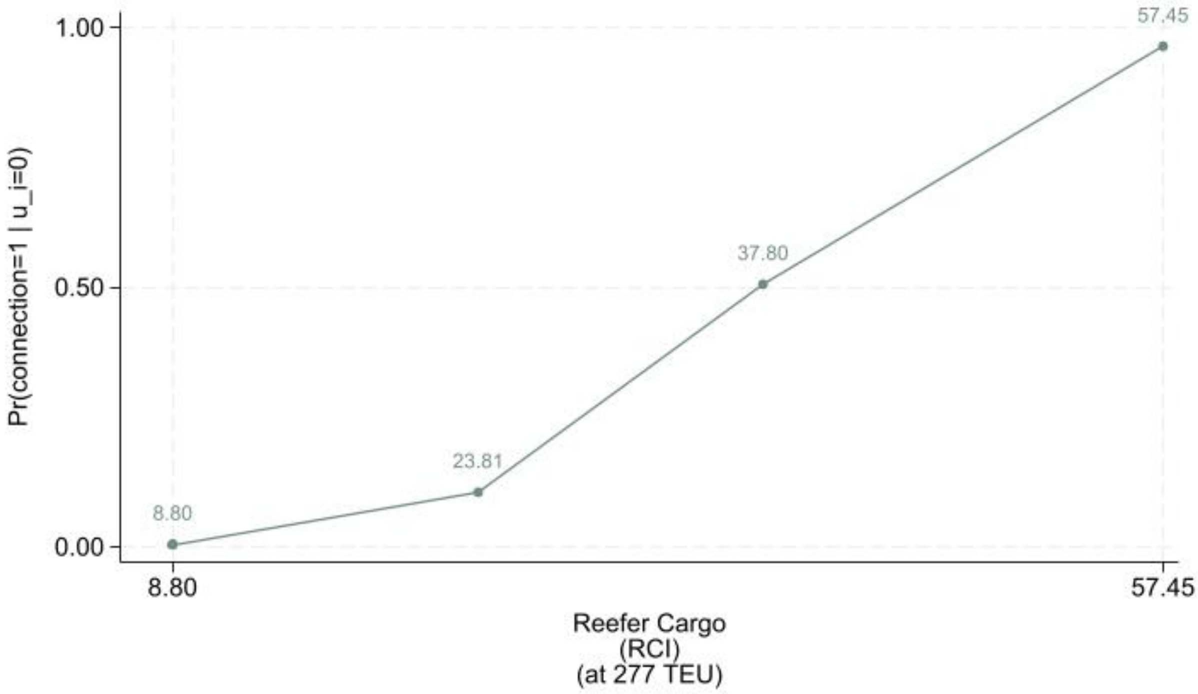

Figure 7.17 – Predictive Margins, Reefer Cargo (covariates set at minimum value, Trade Flow at fixed value)

The above analysis as well as the findings of the semi-structured interviews essentially indicate that the Reefer Cargo of a country is of secondary importance compared to Trade Flow, but under certain circumstances Reefer Cargo may also become a driver towards the establishment of a direct connection provided that the potential of the Reefer Cargo is considerably high. Nevertheless, in practice the strong potential of reefer cargo in a market is certainly an attractive attribute for carriers but may not necessarily lead to a direct connection between two countries.

Reefer Cargo may not only be seasonal but each perishable product category may also have its own unique season (ZIM, 2023). Therefore, Reefer Cargo may not act as a standalone driver of a direct connection unless the direct connection between two trading partners is also approached from a seasonal perspective. For instance, every year Hapag-Lloyd offers a direct connection (‘Cherry Express’ Far East – WCSA ‘AN1’ service) between Chile and various markets in Asia between November and January to cater for the seasonal demand for the transportation of cherries (Alphaliner, 2021).

Additionally, from an operational perspective, Reefer Cargo relies on accurate forecasts so the carriers can assign the needed capacity and act on sudden changes in the demand for the transportation of perishable cargo (ZIM, 2023). In practice, the latter may occasionally follow rapid and unexpected adaptations of the season in real time (e.g. harvest disruption due to severe weather conditions). This is in accordance with the input from the semi-structured interviews and may imply that the corresponding deployed capacity by the carriers is not only an automated reaction to the corresponding demand. The supplied reefer plugs on container vessels may also be subject to the planning ability of the carriers as well as their agility to promptly redistribute vessels and equipment according to the demand.

Specialised reefer container transportation has gradually gained market share from conventional transportation in bulk and that is rooted on tangible benefits regarding standardisation which in turn provides an edge on time reliability and flexibility (Arduino, Carrillo Murillo and Parola, 2015). In effect, the specialised reefer container transportation allows shippers and consignees of reefer cargo to reap the benefits of the fast, scheduled and geographically broad connections that the container shipping network may offer. Simultaneously, the conventional reefer fleet has been in continuous decline over the last few years, demolition levels have decreased (i.e. no upcoming fleet renewal) and newbuilding rate is not expected to adequately compensate for the decreasing footprint of the fleet (Dynamar, 2022). This trend is likely to worsen for the conventional fleet which is largely old and *''fuel-hungry''* and will likely be losing its competitive advantage to provide dedicated direct connections in the future since upcoming environmental regulations will dictate the fleet to sail at lower speeds (*ibid*). Thus, it is likely that the future demand for the transportation of reefer cargo may increasingly be fulfilled by container vessels including the niche markets that conventional reefer vessels still serve today. Under this scenario Reefer Cargo may in turn also increase its importance for the establishment of direct connections between countries within the container shipping network.

7.4.7 Trade Facilitation

As discussed in the SLR of this research (see Chapter 3) Trade Facilitation (i.e. the streamlining and improvement of trade processes in a country) has been suggested by the literature as a variable that may possibly contribute towards the establishment of a Direct Connection between two countries. The statistical analysis of this research (see Section 5.8) confirmed the possibly positive impact of the variable but did not confirm its statistical significance. Finally, the discussion with the practitioners during the semi-structured interviews (see Section 6.5) suggested that Trade Facilitation may be considered as a contributing factor of a direct connection. In fact, Trade Facilitation may often be a prerequisite unless the Trade Flow of a country is considerable and thus is expected to drive the establishment of a direct connection.

In order to evaluate the importance of Trade Facilitation towards the establishment of a Direct Connection under certain conditions for an average country, its role is assessed (a) when the values of all variables are set to their mean (Figure 7.18) and (b) when the values of all variables are set to their mean and Trade Flow is set to 7,100 TEU (Figure 7.19) (i.e. the value which was identified as the minimum volume threshold for an average country in Section 7.3).

Regarding Figure 7.18, the displayed values of 4.10, 7.60 and 9.50 correspond to the minimum, mean and maximum values of Trade Facilitation for the examined dataset. Hence, at average volume (84,000 TEU), the Trade Facilitation score of a country is seemingly not an important factor since the probability of a positive outcome is already driven and defined by the Trade Flow volume.

Figure 7.18 – Predictive Margins, Trade Facilitation (covariates set at mean value)

Regarding Figure 7.19, the displayed value of 7.55 corresponds to the calculated threshold above which the probability of a positive outcome begins to surpass the 0.50 cut-off point (i.e. the calculated threshold is equal to the mean Trade Facilitation value). Hence, at a comparatively low volume (7,100 TEU), the Trade Facilitation score of a country is seemingly a contributing factor: as the respective score grows the corresponding probability of a positive outcome also increases progressively.

Thus, as discussed below it is in the interest of a country with relatively low volumes to enhance its performance on Trade Facilitation.

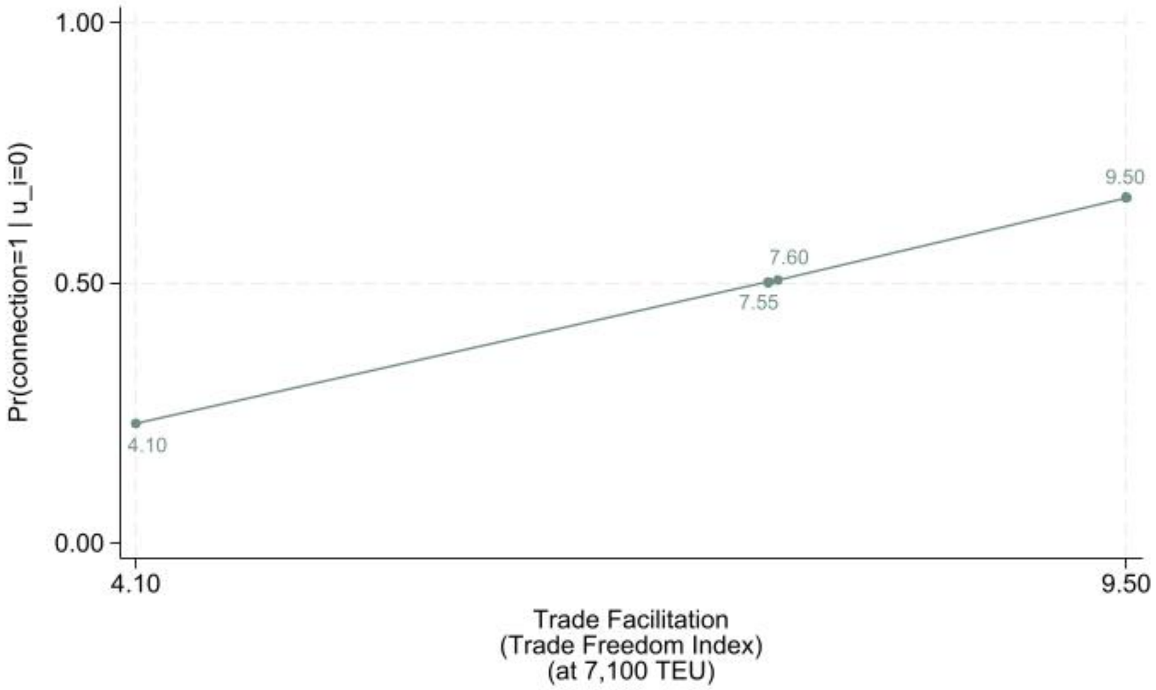

Figure 7.19 – Predictive Margins, Trade Facilitation (covariates set at mean value, Trade Flow at calculated threshold value)

Countries generally strive to simplify trade processes and reduce *''red tape''* with the aim to increase bilateral trade flows with their partners and thus become a more attractive option for calling vessels. This effort usually includes typical policy interventions such as the participation in established initiatives including WTO membership (see Section 3.9) and the adoption of the corresponding WTO Trade Facilitation Agreement (TFA). The latter entered into force in 2017 and caters for the move, release and clearance of goods, customs cooperation, and technical assistance (WTO, 2023). According to UNCTAD (2022d), the enforcement of certain established initiatives such as the TFA is however not a straightforward exercise for all countries and reportedly some countries need the assistance of specialists in order to proceed. A series of seminars and training procedures have been organised by UNCTAD with the aim to educate designated people as *national transit coordinators* to support developing and least developed countries in the implementation of WTO TFA (in particular Article 11 regarding freedom of transit) (UNCTAD, 2023). Thus, it is in the interest of the countries to appoint coordinators and adopt best practices in order to become more competent and attractive for carriers.

Carriers are generally enticed by a reasonable level of regulation that contributes towards the establishment of a well-organised but overall business-friendly framework for their operations. In other words, carriers may seek to deploy their vessels at those countries where there exists a balance between intervention by the local governments and market freedom, and prefer those countries which are characterised by policies that are neither loose nor stringent. A decisive step towards the simplification of the processes that are crucial for maritime transport may progressively include more digitalised solutions. Specifically, countries are encouraged to accelerate the practices associated with pre-arrival processing, electronic documents and payments by removing legal bottlenecks that may block the use of electronic transactions as well as support real-time analytics and digital platforms based on Automatic Identification System (AIS) data (UNCTAD, 2022d). In Section 7.4.4, it was highlighted that the carriers which are expanding into end-to-end logistics strategies are likely to progressively increase their interest in the processes that take place beyond the sea leg. For those carriers, Trade Facilitation is also likely to increase in importance since for instance costly delays attributed to the release of the cargo may be part of the bottlenecks they will be called to resolve in order to deliver the agreed door-to-door solution to their customers.

7.4.8 Trade Imbalance

As discussed in the SLR of this research (see Chapter 3) Trade Imbalance (i.e. the difference between the TEU volume of exports / imports of a country to / from the UK) has been suggested by the literature as a variable that may possibly discourage the establishment of a Direct Connection between two countries. The statistical analysis of this research (see Section 5.8) confirmed the possibly negative impact of the variable (or vice versa that as the positive imbalance increases so does the conditional probability of a direct connection) but did not confirm its statistical significance. Finally, the discussion with the practitioners during the semi-structured interviews (see Section 6.5) suggested that Trade Imbalance matters only for those routes where the revenue of the Trade Flow (laden containers) cannot compensate for the cost of repositioning a corresponding number of empty containers when trade is imbalanced.

In order to evaluate the importance of Trade Imbalance towards the establishment of a Direct Connection under certain conditions for an average country, its role is assessed (a) when the values of all variables are set to their mean (Figure 7.20) and (b) when the values of all variables are set to their mean and Trade Flow is set to designated levels which may considerably impact the corresponding costs of empty containers repositioning (Figure 7.21).

As discussed in Section 7.3, Trade Imbalance should be examined in conjunction with Trade Flow in order to provide realistic calculations. Hence, a relevant assumption should be made to outline the relationship between Trade Imbalance and Trade Flow for this exercise. Therefore, this exercise proposes the ratio of the *Mean Trade Flow* to *Mean Trade Imbalance* of the examined dataset which is – approximately – equal to 66. This ratio essentially suggests the absolute volume level (Trade Flow) that an average country is expected to exchange with the UK given the (positive or negative) Trade Imbalance between the two countries. For instance, if the Trade Imbalance between the two countries is equal to 500 TEU then (on average) this corresponds to a Trade Flow between the two countries equal to 500 X 66 = 27,618 TEU and so forth.

Regarding Figure 7.20, the displayed values of -53.00, -13.00 and 41.00 correspond to the minimum, mean and maximum values of Trade Imbalance for the examined dataset. Hence, at any of those values the corresponding Trade Flow (calculated based on the abovementioned ratio) may cover the cost that carriers could face due to repositioning of empty containers and Trade Imbalance is seemingly not an important factor since the probability of a positive outcome is already driven and defined by the Trade Flow volume.

Figure 7.20 – Predictive Margins, Trade Imbalance (covariates set at mean value)

However, if there is indeed a range of Trade Flow – Trade Imbalance combinations that can compensate for the cost of the empty containers repositioning then it is likely that there is also a range of respective combinations which may be regarded as unfavourable for the carriers. Regarding Figure 7.21, the displayed value of -0.01 corresponds to the calculated threshold below which the probability of a positive outcome begins to fall below the 0.50 cut-off point. Respectively, the displayed value of 0.01 corresponds to the calculated threshold above which the probability of a positive outcome begins to surpass the 0.50 cut-off point. Those two Trade Imbalance values correspond to Trade Flow values of approximately 7,000 TEU (6,996 and 6,930, respectively). Hence, at a comparatively low volume of approximately 7,000 TEU, the corresponding Trade Imbalance score of a country is seemingly a discouraging factor for carriers: as the respective score however falls below or surpasses those values, Trade Flow is likely to compensate for the associated costs and the corresponding probability of a positive outcome also increases progressively. Notably, the suggested level of approximately 7,000 TEU is very close to the findings of Section 7.3 which suggested that for the examined period (2012-2020), an average country needed to record at least 7,100 TEU exchanges in a given year in order to start becoming an attractive option for a direct connection to the UK. Therefore, a country which records a volume close to 7,000 TEU – either it has a positive, negative or zero imbalance with the UK – is seemingly not a good candidate for the carriers for a direct link with the UK but over 7,100 TEU any concerns may begin to ease. This level may generally be interpreted as follows: it is likely that there is a certain level of Trade Imbalance which is neither small enough in order to be ignored nor associated with a large enough Trade Flow in order to be absorbed. Thus, it is in the interest of a country with relatively low volumes to focus on primarily enhancing its trade performance (i.e. volume) rather than explicitly correcting its container trade imbalance with a targeted partner such as the UK.

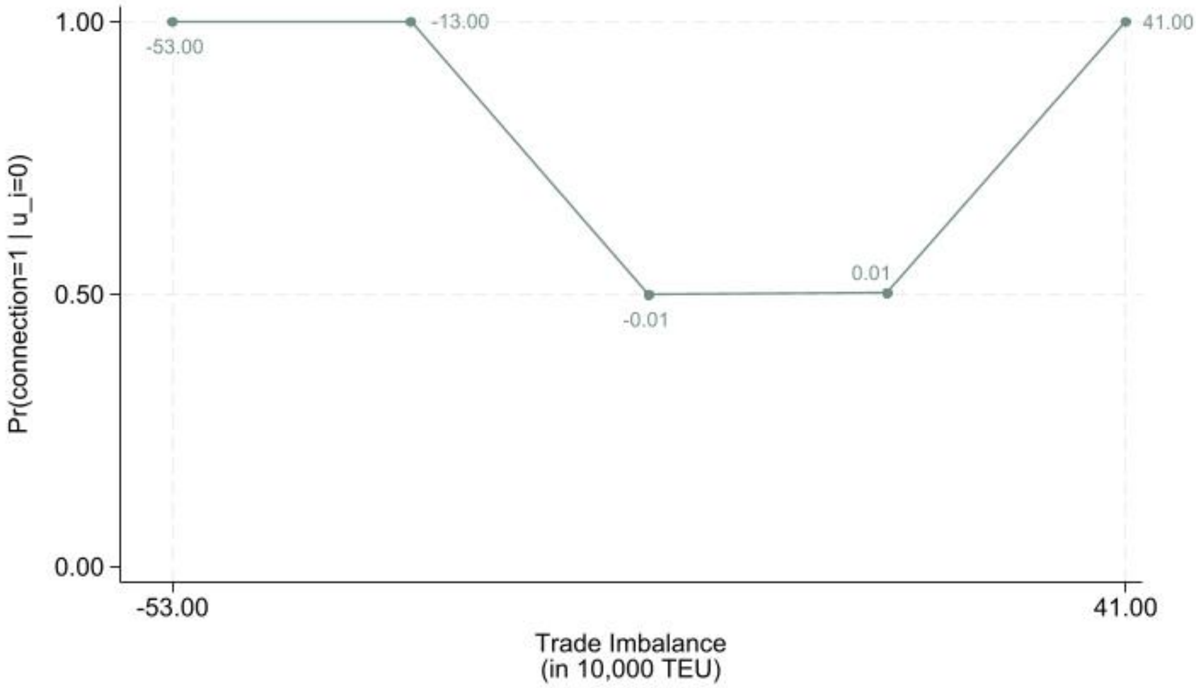

Figure 7.21 – Predictive Margins, Trade Imbalance (covariates set at mean value, Trade Flow at calculated threshold values)

The above findings are in line with the input of the practitioners who also suggested that the Trade Flow level may actually dictate whether Trade Imbalance is a concern for the carriers. Additionally, with regard to Trade Imbalance countries may not be able to directly alter their profile since trade imbalances are generally rooted on the capabilities and needs (supply / demand) of the underlying economies. The main concern of the carriers regarding imbalances is that they are often requested to call at certain places with either a strong import or export orientation and thus need to either collect a large number of empty containers after the imported cargo has been unloaded or to provide an adequate number of empty containers in order to be filled with exported cargo.

In this case at least one of the sea legs (inbound or outbound) is light in terms of vessel utilisation and thus largely problematic. Carriers strive to identify business opportunities that can alleviate this problem. For instance, in certain trade routes carriers tend to target for the weak part of the journey (i.e. backhaul trade) large quantities of recyclables (e.g. wastepaper) or specialised products that the hinterland may produce (e.g. tiles ex Spain). Hence, a country may indirectly attempt to make the conditions more attractive for the carriers in order to capitalise on any relevant opportunities. For example, in countries where containerisation is not yet fully established, governments may focus on improving the intermodal capabilities of a country and overall provide an ecosystem of facilities which encourages the transportation of certain products that are considered as good targets for backhaul trades (e.g. tiles in the above example). Hence, those commodities may be increasingly carried in containers rather than in palletised, bagged or bulk form. This may allow carriers to maximise their chances of capturing any containerisable cargo from / to a country and utilise as much as possible a number of containers that otherwise may travel empty and thus incur equipment repositioning costs.

7.4.9 Contextual and Year Effects

A core characteristic of the employed CRE model in this research is the inclusion of the following (see Section 5.5.3):

1. The group mean values of the time-varying regressors in order to secure the extraction of unbiased results which correspond to the *''contextual effects''* (Antonakis, Bastardoz and Rönkkö, 2021).
2. A dummy variable for each year of the analysis as extra controls (Wooldridge, 2013a).

The use of the group mean values of the (time-varying) variables in this research serves a very important purpose from a statistical robustness perspective but the overall practical importance of the concept may probably be of secondary interest in the context of this research. Jones and Subramanian (2019) suggested that contextual effects return *''the potential differential effect on the response from belonging to groups or contexts with different means''*. In the context of this research, contextual effects may inform on what is the expected difference on the probability of two distinct countries to connect directly with the UK when for instance they score the same in terms of Connectivity in a given year, but they belong to panels (i.e. countries) with one unit difference in their mean Connectivity. According to Bell, Fairbrother and Jones (2019), contextual effects may be useful to answer a research question regarding *''what is the effect of a (level 1) individual moving from one level 2 entity to another''*. In the context of this research, level 1 individuals are the year-country observations and level 2 entities are the corresponding groups (i.e. countries). However, as Bell, Fairbrother and Jones (2019) also highlighted, in a longitudinal study such as this research, the further exploration of the contextual effects may practically be meaningless since observations are not possible to *''move''* between panels. Indeed, in this research, the exploration of the contextual effects would correspond to the understanding of how the probability of a country to connect directly with the UK could possibly be altered if that country could *''move''* to assume the mean Connectivity score of another country.

The latter may hardly be meaningful in practice. This can possibly explain the discount of the mean Connectivity importance by the interviewed practitioners despite the targeted question they were asked by the researcher regarding this variable during the semi-structured interviews (see Section 6.5). In theory, the selection of a country as a good candidate for a direct connection with the UK based for instance on the contextual effects of the mean Connectivity would possibly suggest the following: a carrier would decide whether to directly connect country A instead of country B with the UK in 2020 while taking into consideration the difference of their mean Connectivity score over 2012-2020 and notwithstanding that the two countries have the same Connectivity score in 2020. Despite the statistical significance of the mean Connectivity, the practitioners briefly acknowledged that it is overall an advantage for a country to have a good mean Connectivity score, but this is not considered in practice as a driver towards a Direct Connection. None of the remaining contextual effects are statistically significant and were not specifically addressed with the practitioners but the concept regarding contextual effects is essentially the same. Therefore, contextual effects in this research are an integral part of a robust statistical process, but their further exploration and discussion may have limited practical importance.

The use of the year controls aims to capture any residual (i.e. unmeasured) effect of other time-varying elements – in case those have been overseen – as to absorb any temporal trends in the analysed data. The interpretation of the corresponding year effects (although none of them carry any statistical significance) may describe the difference in the expected value of the dependent variable (i.e. Direct Connection) between a given year and the reference year (2012). This may also have limited practical ramifications. For instance, the statistical analysis suggests that the conditional probability for a country of connecting directly to the UK decreased by 1% in 2013 and increased by 2% in 2014 compared to 2012 (see Table 5-15). This information may in practice only add a small value towards the deeper understanding of the drivers behind the establishment of direct connections.

Nevertheless, a theoretical discussion about year-effects in the context of this research could possibly strive to associate those periodical trends with major economic incidents or other shipping-related developments during a specific year. For instance, the largest year-effect within the examined period (2012-2020) corresponds to 2017 and indicates that during that year the conditional probability for a country of connecting directly with the UK increased by 5% compared to 2012. This peak could potentially be attributed to a massive reorganisation of the container shipping network that materialised that year. In 2017, the major shipping alliances at the time such as the Ocean Three Alliance (CMA-CGM, China Shipping and UASC), the G6 Alliance (APL, Hapag-Lloyd, HMM, MOL, NYK and OOCL) and the CKYHE Alliance (COSCO, K-Line, Yang Ming, Hanjin and Evergreen) terminated their consortium agreement while the 2M Alliance (Maersk and MSC) continued its operation. The members of the former alliances established new alliances which began their operations on the 1st of April of the same year. Therefore, it is likely that certain carriers proceeded with a significant update of their network and during that phase the newly established network provided more opportunities for certain countries to connect with the UK.

7.5 Concluding Remarks

This Chapter sought to further understand the role of each individual variable under certain conditions towards the establishment of direct connections between trading countries.

Therefore, the Chapter considered the findings of all three phases of the Research (SLR, Econometric Model, and Semi-structured Interviews) and further explored (a) the impact of Trade Flow as the main driver of direct shipping connections between trading countries and (b) the potential impact of the rest of the covariates under certain conditions. The analysis and discussion reconfirmed that from a certain level of volume and beyond *''Trade is King''* and may dictate the establishment of a direct connection even if a given country underperforms on other aspects. Nevertheless, the analysis and discussion also quantitatively indicated that it may still be in the interest of a given country to improve – when possible – its performance with regard to certain aspects (e.g. Logistics Performance, Trade Facilitation etc.) particularly when bilateral container trade exchanges are not inherently strong. Finally, this Chapter briefly discussed the practical importance and possible interpretation of the Contextual and Year Effects in the context of this research.

The next Chapter will conclude this Research and outline its overall findings, contribution to the literature, limitations and recommendations for further research.

Chapter 8. Conclusion

8.1 Introduction

This Chapter corresponds to the conclusion of this research. The aim of this research was to investigate how direct connections are established in container shipping. Accordingly, the research (a) identified a list of factors (variables) which according to the literature may contribute to the decision of liner shipping companies to connect directly a pair of trading countries; (b) quantified the contribution of selected factors; and (c) examined whether the underlying dynamics that characterise the direct connections that last for longer periods are considerably different from those dynamics that characterise the direct connections that may last for shorter periods of time.

In summary, this research concluded the following:

In the context of establishing direct connections between trading countries, liner shipping companies – under certain conditions – may consider a broad set of factors such as Colonial Ties, Connectivity, ECA Routing, Logistics Performance, MSR Routing, Trade Facilitation and Trade Imbalance. Nevertheless, Trade Flow is the decisive driver for any given country pair to have a direct connection while for a limited number of country pairs Reefer Cargo is also likely to play a substantial role. Trade Flow and Reefer Cargo are consistently important for connections that are active for both short and long periods of time, although it is notable too that long-established connections are seemingly less sensitive to marginal fluctuations in Trade Flow.

In this Chapter, Section 8.2 discusses the results for each particular Research Question; Sections 8.3, 8.4 and 8.5 outline respectively the contribution, implications and limitations of this research; Section 8.6 provides recommendations for further research; and finally Section 8.7 comprises the concluding remarks of this Chapter.

8.2 Results

The findings of this research for each particular Research Question (RQ) are outlined in Figure 8.1:

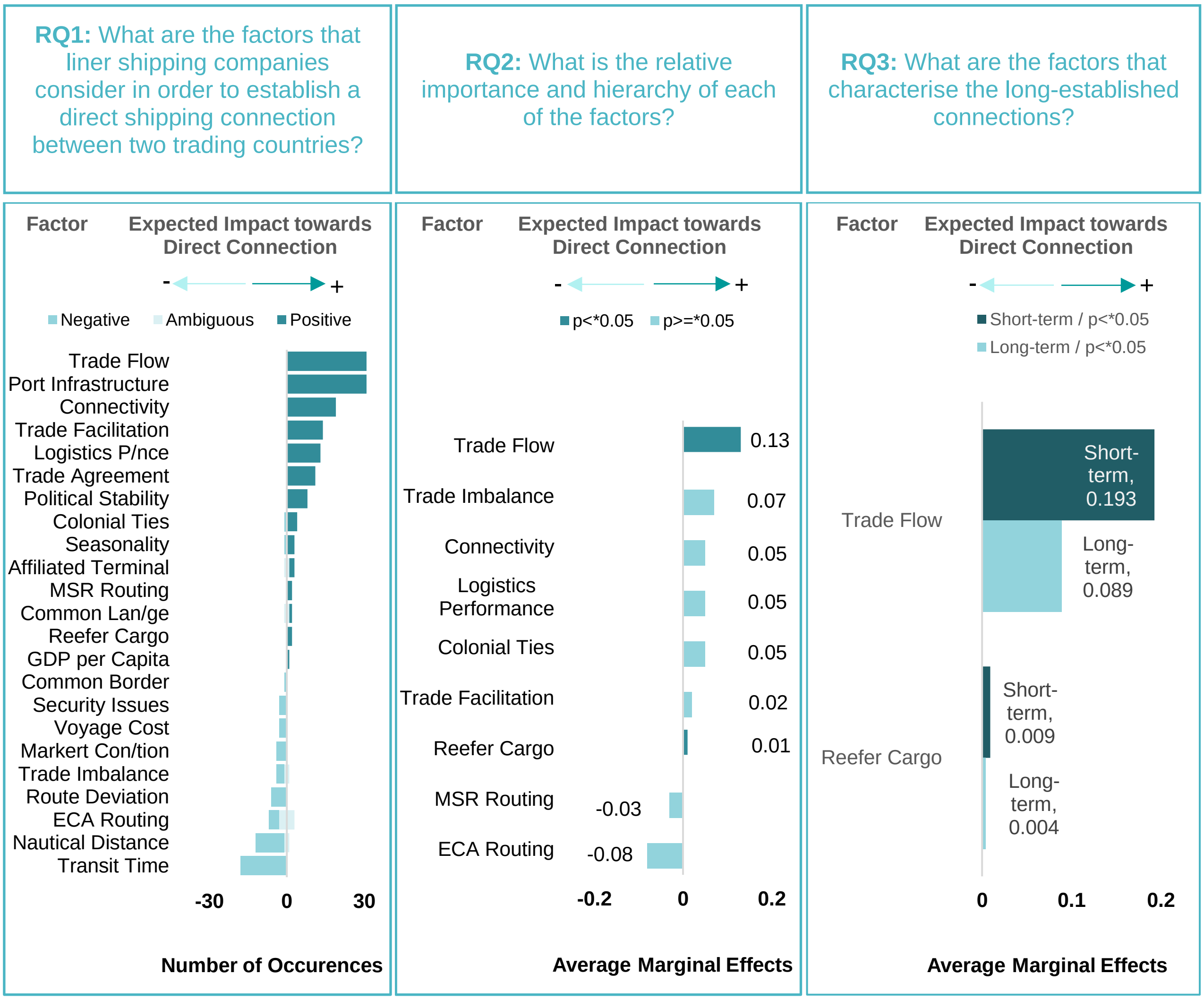

Figure 8.1 – Research Results

The average marginal effects return the impact that a change of one unit in one of the independent variables is expected to have to the dependent variable (e.g. the change of the conditional probability for a country to connect directly with the UK when the Trade Flow between the two countries increases by 10,000 TEU). The corresponding p-value is compared to a predetermined alpha value which is typically set to 5% (0.05) (i.e. coefficients / marginal effects with a p-value of less than 0.05 are considered to be statistically significant).

8.2.1 Research Question 1

- *What are the factors that liner shipping companies consider in order to establish a direct shipping connection between two trading countries?*

The first Research Question was addressed through the SLR of this research (Chapter 3). The SLR identified 23 factors (variables) as potential drivers towards the initiation, establishment, or termination of a direct connection between trading countries in container shipping (see RQ1 – Figure 8.1). Those variables were categorised into 5 Themes: (1) Shipping Network, (2) Connectivity, (3) Port Selection Criteria, (4) Trade and (5) Alternative Transport Modes with certain variables appearing across multiple Themes. For the majority of the identified variables, there has been a strong convergence regarding their potential impact (i.e. positive / negative) towards the establishment of direct connections between trading countries. However, the SLR also indicated that for a few variables some scholars have found no concrete evidence regarding their overall impact (e.g. ECA Routing) while for other variables a general consensus whether their contribution is positive or negative has not been reached in the literature (e.g. Colonial Ties).

The SLR reconfirmed the importance of factors that have traditionally been regarded as important for the establishment of direct connections between countries (e.g. Trade Flow, Connectivity, Logistics Performance, etc.). Nevertheless, the SLR also highlighted that the container shipping network may also be influenced by a broader spectrum of factors such as the environmental, geopolitical, cultural, and security-related characteristics of the shipping routes (e.g. ECA Routing, MSR Routing, Common Language, Political Stability etc.).

8.2.2 Research Question 2

- *What is the relative importance and hierarchy of each of the factors?*

Following on from the SLR and the identification of 23 variables as potential drivers for the establishment of direct connections between trading countries and before proceeding with further analysis, the research investigated whether the consideration of all identified variables was indeed an advisable and feasible approach for modelling. Therefore, the second Research Question was addressed with (a) the selection of the correct set of variables for the modelling effort of this research based on the principles of Causal Inference theory (Chapter 4); (b) the compilation of an econometric model which quantified the importance of the selected variables by utilising the UK as a case study (Chapter 5); and (c) the validation of the econometric model findings via a series of semi-structured interviews with container shipping practitioners (Chapter 6).

Specifically, this research emphasised on the process of selecting that set of variables which can support a robust analysis. Rather than proceeding with a random selection of variables for modelling, this research followed a rigorous process in order to justify which of the 23 factors (variables) identified during the SLR (Chapter 3) were likely to be of primary interest for the analysis. This process was based on the principles of Causal Inference theory and the corresponding nomenclature which suggests that a *parent* variable X causes a *child* variable Y. Hence, this research followed on from the SLR and attempted to outline all of the corresponding parent-child relationships as those have been discussed by the reviewed literature.

The econometric model of this research finally considered 9 variables as those drivers with potentially direct (causal) association with the establishment of a Direct Connection between trading countries (see RQ2 – Figure 8.1):

- Trade Flow
- Trade Imbalance
- Connectivity
- MSR Routing
- ECA Routing
- Colonial Ties
- Trade Facilitation
- Reefer Cargo
- Logistics Performance

The research further proceeded with the calculation of the corresponding average marginal effects which return the conditional probability for a country of connecting directly to the UK. In this context, the econometric model indicated the following:

- Trade Flow and Reefer Cargo have a positive and statistically significant impact on the establishment of a direct connection between two trading countries (at 5%)
- MSR Routing and ECA Routing have a negative but not statistically significant impact on the establishment of a direct connection between two trading countries (at 5%)
- Trade Imbalance, Connectivity, Logistics Performance, Colonial Ties, Trade Facilitation and Logistics Performance have a positive but not statistically significant impact on the establishment of a direct connection between two trading countries (at 5%).

The validation of the statistical findings by the practitioners confirmed the very substantial importance of Trade Flow (i.e. a statistically significant variable) towards the establishment of Direct Connections between trading countries. Reefer Cargo (i.e. also a statistically significant variable) may also be deemed important but the practitioners suggested that it may be regarded as a standalone driver of a direct connection for limited markets only (e.g. Central and South America), as opposed to Trade Flow which is considered to have a universal impact. Finally, the practitioners also indicated that the rest of the employed variables (i.e. statistically insignificant variables) may only be partly important for the establishment of Direct Connections between trading countries and under certain conditions only.

Overall, the impact of each of the employed variables towards the establishment of direct connections in container shipping between two trading countries is depicted in Figure 8.2 (i.e. direct connection between Country A and Country B versus indirect connection between Country A and Country B via a third country Z):

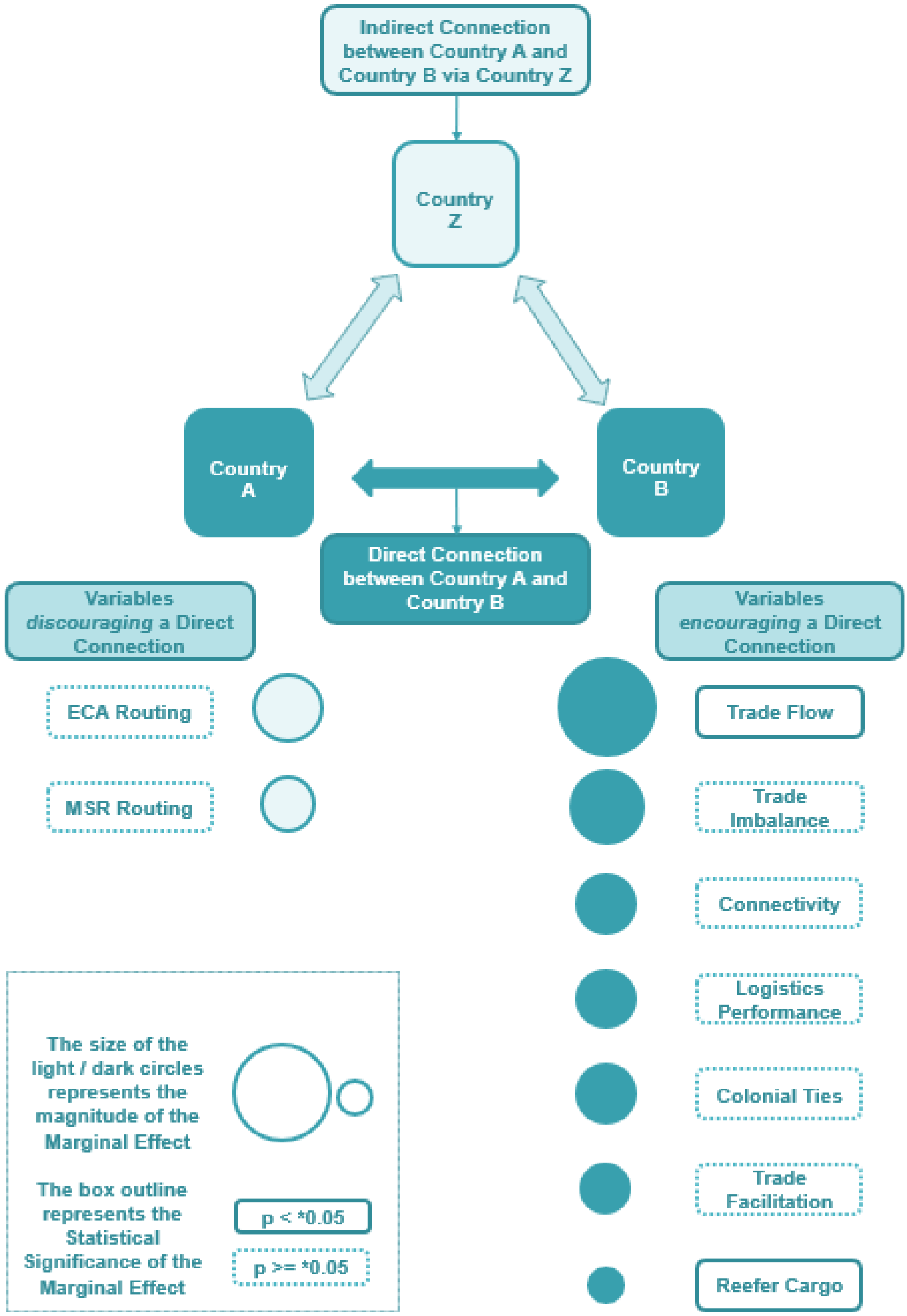

Figure 8.2 – Establishing direct connections in container shipping

8.2.3 Research Question 3

➢ *What are the factors that characterise the long-established connections?*

The third Research Question was addressed with (a) the classification of the examined countries into two clusters based on whether each country managed to uninterruptedly (i.e. for consecutive years) connect directly with the UK in the short-term or long-term (Chapter 5); (b) the recalculation of the econometric model over each cluster (Chapter 5); and (c) the validation of the econometric analysis findings via a series of semi-structured interviews with container shipping practitioners (Chapter 6).

The clustering analysis indicated that short-term and long-term direct connections correspond to those countries that remained uninterruptedly connected directly with the UK for up to 4 years and from 5 to 9 years, respectively. The associated analysis suggested that – as before – only Trade Flow and Reefer Cargo may consistently return a statistically significant result (at 5%) (see RQ3 – Figure 8.1). Furthermore, the analysis by cluster (i.e. short-term / long-term) indicated that the long-established connections are seemingly less sensitive to marginal fluctuations in Trade Flow (TEU volume). The practitioners reconfirmed the latter point: long-established connections are to a certain extent *''self-sustaining''* since carriers rarely drop a call they have established but the practitioners similarly highlighted that country-pairs with smaller bilateral flows may not manage to sustain a direct connection if the trade flow exchanges are not regular. Finally, a respective conclusion could be reached for Reefer Cargo as well but the magnitude of the variable is relatively small for both clusters (i.e. short-term / long-term). Thus, practitioners once more highlighted the importance of Reefer Cargo for niche markets but refrained from explicitly underlining a differentiation of its importance between clusters.

8.3 Contribution

The first contribution of this research corresponds to the outcome of the SLR (Chapter 3). Following on from the SLR, a framework was subsequently developed which identified and synopsised the set of factors that may determine the establishment of direct container shipping connections between trading countries, the expected impact (positive, negative or ambiguous) of each factor, the number of occurrences in the literature as well as the categorisation of the factors under the identified Themes (see Figure 3.10) . This framework can be of use to interested stakeholders across the research and policy domains who have an interest in both the establishment and continuation of direct container shipping connections between trading countries.

The second contribution of this research corresponds to the outcome of the statistical analysis (Chapter 5) and the confirmation of the respective results through the eyes of the practitioners (Chapter 6). Specifically:

- This research employed a Correlated Random Effects (CRE) model which is effectively a synthesis of the Fixed and Random effects approaches. In the context of this research, a CRE specification was not only a statistically robust process but ultimately represented a *''workable solution''* for the answer to the research questions in line with the philosophy of Pragmatism (see Section 3.12) which this research embraced. This approach allowed a statistical inference which (a) considered an enhanced sample compared to a Fixed Effects model; (b) included the full set of the independent variables; and (c) employed the *''random effects assumption''* but in a statistically robust manner (see Section 5.5.3). Subsequently, the selected approach enhanced the trustworthiness of the modelling results and may act as a proof of concept for future studies within the discipline of maritime logistics.
- This research built a bridge between *''practical theory''* and *''practical empiricism''* and following on from the modelling effort strived to confirm whether the statistical results are a close representation of the real world. Hence, by filtering the findings through the empirical knowledge of the container shipping practitioners, this research highlighted a very pragmatic conclusion: while certain variables which have been extensively discussed by the literature (e.g. Connectivity, Logistics Performance, Trade Facilitation, etc.) do matter towards the establishment of direct connections in container shipping, Trade Flow is the main driving force. This research does not advocate that trading countries should not continue their effort towards their improvement with regard to the rest of the variables. While Trade Flow is a core driving force for the establishment of direct connections between trading countries, under certain circumstances (i.e. when Trade Flow is not substantial) carriers may tend to scrutinise the effectiveness of a country with regard to other attributes such as Connectivity, Logistics Performance or Trade Facilitation (see Section 7.4). Thus, this research contributes to the literature by providing a hierarchy of the practical importance of the variables that may drive the establishment of direct connections between trading countries.

The third contribution of this research corresponds to its approach towards data collection. Following on from the identification of a broad number of suggested variables through the SLR, this research did not proceed with a bulk analysis of all variables or the selection of a random sample from those variables. On the contrary, this research followed a concrete methodology based on the established Causal Inference theory and rather focused on those variables that may reveal the true effect of the underlying drivers. This systematic process during both the literature review and the compilation of the modelling effort may provide a platform on which scholars can build upon in order to proceed with a practical and robust analysis.

Finally, the fourth contribution of this research corresponds to the quantitative check of the established practice in maritime logistics towards the approximation of container shipping trade flows and specifically how the discipline of maritime logistics understands the *containerisable* commodities (i.e. those cargo categories that are likely to be containerised) (see Section 4.4.8). The corresponding effort employed a series of tests in order to quantitatively check whether the established practice can yield informative results at cross-sectional (i.e. for a single year), timeseries and bilateral (i.e. pair of trading countries) levels and proposed a methodology (i.e. Batching and Sampling) for performing those tests. Effectively, the process suggested that if a study aims to understand the containerised footprint of a country, the corresponding trade data should be thoroughly filtered. Subsequently, the analysis provided evidence that although the process of utilising COMTRADE data (i.e. in USD value) in container transport studies can be very accurate if filtered thoroughly, the use of the data to approximate the bilateral TEU exchanges between trading countries may be questionable. Furthermore, the process advocated the delicate consideration of the differences between countries and also proceeded to follow the development of those nuances across different years. The analysis – which was fundamentally based on Ordinary Least Squares – showed why researchers should avoid the assumption that the same product categories are likely to be containerised for all countries. This work may enlighten practitioners and research and in turn allow the discipline to advance by providing accurate and tested insights on the nature of containerised freight. Therefore, analysis that informs on *containerised* rather than *containerisable* cargo may complement existing research efforts and provide a more holistic and directed set of recommendations for such contexts.

8.4 Implications for Policy and Practice

It could be suggested that to a certain extent the findings of this research simply reinforce a broadly accepted argument (i.e. the substantial role of Trade Flow / Reefer Cargo for the establishment of direct connections between trading countries). Nevertheless, the ramifications of this research's conclusions may actually derive from the underlying process which generated the respective findings.

This research explored whether there are any *''causal associations''* between specific variables and their impact to the establishment of direct connections between trading countries by compiling a causal graph before proceeding with a modelling effort. Then, since causal associations and most importantly ''*causal effects''* cannot either be truly accepted or rejected without verification by subject-matter experts (see Section 4.3.3), this research ultimately consulted practicing professionals who assessed and verified the modelling findings. Hence, on the one hand this research may have indeed confirmed what could be largely expected (i.e. the substantial role of Trade Flow / Reefer Cargo for the establishment of direct connections between trading countries). On the other hand however this research not only suggested which factors may – or may not – be theoretically important but effectively highlighted those factors that may be pivotal – and arguably causal – for directly connecting two countries. Consequently, the results may assist policy-makers in understanding the hierarchy of the policies they should promote and may also have substantial practical importance.

In the aftermath of the COVID-19 pandemic the world witnessed an unprecedented disruption of global supply chains, prolonged bottlenecks and service shortages. Those developments underlined the increasing need for countries to reduce their dependence on specific trade partners and / or seek other sources of supply. Ongoing structural adaptations of global trade including concepts such as *reshoring* and *nearshoring* (Notteboom and Haralambides, 2020) may be increasingly considered as strategies that can allow supply chain resilience to be enhanced (Notteboom, Pallis and Rodrigue, 2021). Reshoring (or backshoring) refers to the *''relocation to the home country''* and nearshoring to the *''relocation to the home region''*, as opposed to the long-established concept of offshoring which refers to the *''relocation to a region far away from the home one''* (Merino, Di Stefano and Fratocchi, 2021). Hence, as global trade may reshape to follow the paradigm of a decentralised and largely multipolar network, the deeper understanding of the factors that may allow a country to directly connect with targeted trade partners as well as the application of more accurate metrics on containerised flows can be of growing importance for both policy and practice.

8.4.1 Policy

The findings of this research (i.e. the econometric analysis in conjunction with its assessment by the practitioners), suggested that variables such as Connectivity, Logistics Performance or Trade Facilitation are unlikely to be ‘game changers’ during the decision-making process of the carriers to directly connect two countries if the bilateral Trade Flow is inherently strong. Simultaneously, the subsequent exploration and discussion of the results (see Chapter 7) underlined that this conclusion is conditional to what is regarded as *‘’strong Trade Flow’’* for a given country pair – or tradelane – and thus the remaining covariates may still be conditionally important. For instance, this research also indicated that when the bilateral Trade Flow between two countries is not inherently strong then carriers may increasingly pay attention to variables such as Connectivity, Logistics Performance or Trade Facilitation, thus the improvement on those attributes is undoubtedly within scope for policy-makers.

Therefore, the findings of this research may indicate to the policy-makers of a country how to prioritise their actions in order to achieve the establishment of direct connections with targeted trading partners. Those policy actions may begin with the deeper understanding of how important a given country may be for the carriers within the context of a targeted market / tradelane (i.e. a small country may be of negligible importance if it targets the North Europe market across a major tradelane such as Asia – Europe but if a country with identical Trade Flow potential targets the same market across the South America / Caribbean – North Europe tradelane then it may be regarded as an attractive target for carriers). Subsequently, policy may further proceed with targeted actions towards the stimulation of local production and consumption in order to maximise the corresponding Trade Flow (and Reefer Cargo to the extent that this can be supported by the underlying capabilities of the country). Finally, policy may then focus on enhancing the performance of a given country regarding attributes such as Connectivity, Logistics Performance or Trade Facilitation. The prioritisation of the respective actions may allow a well-designed policy effort based on the advantages and disadvantages of each country and depending on its individual needs and capabilities.

Respectively, such a targeted effort may also be informed by the findings of this research regarding other policy initiatives / directions that may not be worth following. For instance, at least in the case of the UK, the findings of this research indicated that it makes small difference for carriers whether a trading partner is located within an ECA Routing or along an MSR Routing or if there exist any Colonial Ties between two trading countries. Those findings are also conditional to the Trade Flow (e.g. ECA Routing may still be problematic when Trade Flow is inadequate and cannot cover the associated cost). Nevertheless, the respective findings can also provide an indication of which variables are generally not considered as pivotal for carriers in order to directly connect two countries thus those variables may not be the primary focus of policy-makers.

8.4.2 Practice

This research strived to demystify the decision-making process of the carriers with a primary focus to assist policy towards the deeper understanding of the core factors that shape the structure of the international shipping network. Nevertheless, although the policy domain may be regarded as the targeted audience, the findings of this research may also be beneficial for practice, including container shipping companies.

To begin with, the identification and quantification of the factors that encourage the establishment of direct connections between trading countries sheds light on what drives the decisions of the carriers at an aggregate level. While previous research has theoretically discussed various factors as possible drivers of direct connections, this research specifies that the main driver for the majority of the carriers is Trade Flow (and Reefer Cargo for niche markets). This may assist individual carriers in shaping their strategies by clarifying what is indeed deemed important by their competitors in general when deciding towards the establishment of direct connections.

Additionally, the classification effort in Section 6.7 provided some evidence that future direct connections between countries may be predicted quite accurately if the input is valid. Container shipping companies are exposed to severe uncertainty rooted on factors which can be endogenous (e.g. oversupply of shipping capacity) but exogenous as well (e.g. macroeconomic shocks). The corresponding predictive exercise was essentially a stress-test of the model for 2020. The latter was a year of severe uncertainty due to the impact of the COVID-19 pandemic. The successful implementation of the model may act as a proof of concept towards the possible predictability of the shipping network and provide a strong indication to carriers that uncertainty regarding future connections can potentially be manageable.

Furthermore, this research discussed the distinction between (in effect potentially) *''containerisable''* and *''containerised''* flows (see Section 4.4.8). A study which is based on containerisable flows may effectively outline and conceptualise the upside scenario for a country or country-pair (but also terminals, ports, tradelanes etc.) should all containerisable commodities be indeed containerised. Depending on the target of a study, those (conceptual) approaches may be of high importance and usefulness. While trade value however can be a good proxy for the containerisation potential of a country or country-pair, the trends that underpin trade value may not always perfectly align with the corresponding trends that underpin trade volume in container shipping. For instance, a scenario can arise where a given country pair have a large share of their bilateral trade comprising commodity *A* which is of low value but is traded in large volumes (TEU). Then, the trade activity of commodity *A* decreases (e.g. because of policy restrictions) and the bilateral trade between those countries is eventually dominated by commodity *B* which is of very high value but is traded in low volumes (TEU). An interrogation of the COMTRADE database however based purely on trade value might suggest to practicing stakeholders (e.g. a carrier or a terminal operator) that the bilateral containerisable trade between the countries is rapidly expanding underpinned by the growth in high value commodity *B*.

Scenarios such as this would be important for relevant studies that aim to advise certain stakeholders regarding investment in particular countries (such as Least Developed Countries and Small Island Developing States). The level of containerisation in some of those countries may still remain below global averages and certain potentially containerisable trade flows may still be carried as bulk / general cargo. Investment in those countries may gain from research that aims to communicate the benefits of containerisation or actions that support its facilitation and establishment. Specifically, provision of maritime logistics infrastructure and deployment of container services are all predicated on the analysis of input data on container flows that is valid rather than making general assumptions. For instance, more targeted analysis which focuses on the actual container flows may assist on studies that assess the volume potential of a brownfield or – most importantly – greenfield container terminal as well as any relevant planning actions by carriers regarding vessel deployment (i.e. vessel size / number and calling frequency).

8.5 Limitations of the Research

It could be claimed that a possible limitation of this research may be associated with data missingness. As discussed in Section 4.6, the share of the missing datapoints was negligible and concentrated around three variables:

- Trade Facilitation
- Logistics Performance
- Reefer Cargo

This was attributed to:

a) Trade Facilitation / Logistics Performance: missing observations (country-years) for those countries that The Heritage Foundation / The World Bank have not provided the corresponding values of Trade Freedom / LPI metrics.

b) Reefer Cargo: missing observations (country-years) for those countries that – according to the Bluewater database – did not accommodate any container services during a given year.

As also discussed in Section 5.6, although the analysis started with 136 countries and the missing data was overall negligible (see Section 4.6), the pattern of the missing data and the Stata software setup (see Section 5.4.1) eventually dictated the analysis of 114 countries. Several data imputation methods were reviewed and evaluated but were not deemed applicable in the context of this research due to conceptual, practical and statistical issues (see Section 5.6). Nevertheless, the countries that were not considered in the final analysis corresponded overall to only 1.15% of the traded container volume (TEU) between the UK and its trading partners (i.e. those countries that have exchanged container volumes with the UK during the period 2012-2020). Hence, those countries were not regarded as pivotal for the analysis and it was anticipated that their exclusion would not introduce a material amount of bias to the results (as is shown to be the case with the model formulated in this research).

Furthermore, as discussed in Section 6.7, Shmueli (2010) suggested that the predictive power of an explanatory model may add on its validity. The corresponding F1 Score of the model (94%) provided a certain level of evidence towards that direction. Additionally, Phase 3 of the Research and the corresponding qualitative check of the findings via the semi-structured interviews aimed specifically to filter the results through the eyes of the practitioners. The interviewees commented on the magnitude of the corresponding margins and raised no concerns. Moreover, the interviewees shared a plausible explanation regarding the marginal effect of Reefer Cargo which may potentially be regarded as low and hence raise questions. However, the practitioners underlined that Reefer Cargo may be regarded as an important variable but for very specific trading partners only. Therefore, despite the discussed limitation regarding data missingness, the modelling effort of this research provided a reasonably accurate and probably unbiased representation of the real world.

8.6 Recommendations for Further Research

The SLR of this research (Chapter 3) through its identification of the 23 factors and 5 Themes, may provide a platform for researchers to conduct further analysis into the impact of these factors in the establishment of direct shipping connections between trading countries. Although this research proposed a specific set of variables that may have a direct (causal) impact on the establishment of direct connections between trading countries, the impact of other variables may be of interest in particular contexts. As discussed in Section 4.3.1, any of the 23 variables suggested by the SLR could be selected for modelling should this be explicitly dictated by the research needs, provided though that a relevant causal graph is compiled and possible issues due to the presence of mediators and overcontrol bias are eliminated (e.g. a different modelling approach could specifically target to identify the impact of a variable such as Trade Agreement to Direct Connection etc.).

Further analysis may consider certain aspects including the following:

- Expansion to other countries as case studies – in the same fashion that this research utilised the UK – and cross-comparison of the respective findings with the outcome of this research or other relevant studies.
- Expansion towards the compilation of a global model. Despite the limitations that a global model may face (see Section 3.12), a larger dataset may be utilised for cross-comparison between extensive subpopulations. For instance, a global model may question how carriers in general decide about direct connections in Asia to South America versus Mediterranean to India Subcontinent tradelanes etc., how different may be the drivers which a global player such as MSC may consider versus an Intra-Asia specialist such as Wan Hai or SITC and so forth. Respectively, a relevant analysis may question whether the direct connections which are established by individual carriers are driven by different dynamics compared to those established by consortia and specifically the shipping alliances, how different may be the drivers between alliances and so forth.
- Expansion on the role that other identified variables may have from a geopolitical perspective (e.g. Political Stability, Security Issues etc.) provided that a relevant causal diagram may clarify which variables are included on the statistical model in order to avoid possible issues due to overcontrol bias (see Section 4.3.1). The focus on certain variables such as Political Stability may also explore the relevant aspects at bilateral level (e.g. the status of the diplomatic relations between countries, peace agreements etc.). For instance, at the time of writing, ongoing conflicts between Russia - Ukraine and Israel - Palestine may (or may not) have had an impact on direct connections between those countries and their trading partners (e.g. decreased direct connections between European countries and Russia but increased direct connections between China and Russia etc.).
- Expansion on the role of additional variables of increasing importance for future networks such as green shipping corridors. As discussed in Section 6.5, this concept is still in its infancy and was essentially not a driver of direct connections between countries for the period that this research examined (2012-2020). Nevertheless, in the future it may be of increasing interest for scholars to understand whether the green agenda can gain momentum and have a substantially important role to play along with Trade Flow.

The expansion of the utilised dataset may also in turn aid in predicting the future evolution of container shipping networks. The classification effort in Section 6.7 provided some evidence that future direct connections between countries may be predicted quite accurately if the input is valid. Future studies may aim to validate this indication by repeating the exercise for alternative and potentially larger samples (e.g. a global model). A possible aspect which could be explored may be the use of an econometric model as a baseline in order to compare its predictive power against other models which are expected to perform stronger on predictive tasks. In pursuit of that goal, machine learning techniques may also be introduced. Those efforts could expand to include various models which can be efficient with tabular data (e.g. Decision Trees, Random Forests, etc.) but may also include more complicated sequential models which can take into consideration the importance of clusters (i.e. countries) in this type of analysis (e.g. Long Short-Term Memory models).

Furthermore, the quantitative check of the established practice in maritime logistics towards the approximation of container shipping volumes (TEU) (see Section 4.4.8) may also be revisited and enhanced, as follows:

- The architecture of the employed algorithms in this research was specifically designed to examine whether there can be a UN Harmonized System (HS) subset that can explain the variance of the TEU data across the targeted period (2012-2020). Hence, the employment of a basic linear regression approach and the application of certain caveats – in order to check if there can exist a good fit of the data – were deemed appropriate as to serve the preset objective. Future work can be orientated towards a more predictive manner and examine whether more sophisticated algorithms (e.g. machine learning techniques) can provide informative results, potentially based on longer timeseries.

- This research provided some insight on how HS lists can be optimised at cross-sectional and timeseries levels but effectively suggested that the optimisation of an HS list that characterises the bilateral flows between two countries is a more demanding task that dictates the existence of some prior knowledge regarding the actual bilateral TEU flows between those two countries. The latter should not necessarily be restrictive for future research which may experiment with various techniques to fill this gap. Future approaches may for instance expand to include other explanatory variables along with the bilateral trade value that can be informative for a pair-wise analysis. Those can include the deployed capacity between two countries building upon Cerdeiro *et al.* (2020) and Wilmsmeier and Martínez-Zarzoso (2010) or even experiment with the use of the LSBCI by UNCTAD building upon Fugazza and Hoffmann (2017). To that end, future efforts may utilise any existing open-source data regarding actual TEU bilateral exchanges at country level (e.g. data by DfT in the case of the UK) and use them as an indicator or training / test set.

8.7 Concluding Remarks

The final Chapter of the study summarised the results of this research and presented the findings for each individual Research Question. Furthermore, in this Chapter the contribution, the implications for policy and practice as well as the limitations of this research were discussed. Finally, possible directions for future research were outlined.

Appendices

A. Modified CASP checklist

MODIFIED CASP CHECKLIST

Answer Notation

Y = YES
N = NO
CT = CANNOT TELL

Study Type

P = Academic paper
R = Report (working paper/report)
B = Book Section

		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Result 1
Study No	Study Type	Address a clearly focused isssue	Relevance to the synthesis	Clear research methods	Explicit data collection	Clear data analysis	Rigorous data analysis	Explicit and understandable findings	Data analysis sufficiently support findings	Adding knowledge or theory	Findings important to practice	Included in the synthesis?
1	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
3	B	Y	Y	Y	CT	N	N	Y	Y	Y	N	Y
4	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
5	P	Y	Y	Y	CT	Y	Y	Y	Y	Y	Y	Y
6	P	Y	Y	Y	CT	Y	Y	Y	Y	Y	Y	Y
7	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
8	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
9	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
10	R	Y	Y	Y	CT	CT	CT	N	Y	Y	Y	Y
11	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
12	P	Y	Y	Y	Y	Y	Y	Y	Y	CT	CT	Y
13	P	Y	Y	Y	Y	Y	Y	Y	Y	CT	CT	Y
14	P	Y	Y	CT	Y	Y	Y	Y	Y	CT	CT	Y
15	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
16	P	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N
17	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	CT	Y
18	P	Y	Y	Y	Y	Y	Y	Y	Y	CT	CT	Y
19	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
20	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Figure A. 1 – Modified CASP Checklist

B. Dimensionality Reduction Techniques

In many statistical models, composite variables are created with the aim of reducing the number of the original variables and tackle any underlying problems because of multicollinearity among the original variables (Liu *et al.*, 2022). Effectively, a composite variable is constructed by other variables which are interrelated either from a statistical or a conceptual point of view (Ley, 1972) and can synopsise the information from a group of outcomes (Liu *et al.*, 2022). The synthesis of composite variables is commonly conducted through Principal Component Analysis (PCA) and Factor Analysis (FA) techniques (Liu *et al.*, 2022):

- PCA is a statistical technique which aims to reduce the number of variables into a smaller set of representative ones (Dray and Josse, 2015) by "*geometrically projecting them onto lower dimensions called principal components (PCs)" (Lever, Krzywinski and Altman, 2017)*.
- FA is a statistical technique which aims to identify common factors that cannot be directly measured but are accountable for the correlation between variables (Kim, 2008)

C. HS2 Categories (initial set of 78 categories)

In order to economise space, certain commodity descriptions have been shortened (e.g. HS No 86):

HS No	Commodity
2	Meat and edible meat offal
3	Fish and crustaceans, molluscs, and other aquatic invertebrates
4	Dairy produce; birds' eggs; natural honey
5	Products of animal origin, not elsewhere specified or included
6	Live trees and other plants; bulbs, roots, and the like; cut flowers and ornamental foliage
7	Edible vegetables and certain roots and tubers
8	Edible fruit and nuts; peel of citrus fruit or melons
9	Coffee, tea, maté and spices
11	Products of the milling industry; malt; starches; inulin; wheat gluten
13	Lac; gums, resins and other vegetable saps and extracts
14	Vegetable plaiting materials; vegetable products not elsewhere specified or included
16	Preparations of meat, of fish or of crustaceans, molluscs or other aquatic invertebrates
18	Cocoa and cocoa preparations
19	Preparations of cereals, flour, starch or milk; pastrycooks' products
20	Preparations of vegetables, fruit, nuts or other parts of plants
21	Miscellaneous edible preparations
22	Beverages, spirits and vinegar
24	Tobacco and manufactured tobacco substitutes
30	Pharmaceutical products
32	Tanning or dyeing extracts; tannins and their derivatives; dyes, pigments, etc.
33	Essential oils and resinoids; perfumery, cosmetic or toilet preparations
34	Soap, organic surface-active agents, washing preparations, lubricating preparations, etc.
35	Albuminoidal substances; modified starches; glues; enzymes
36	Explosives; pyrotechnic products; matches; pyrophoric alloys; certain combustible preparations
37	Photographic or cinematographic goods
39	Plastics and articles thereof
40	Rubber and articles thereof
41	Raw hides and skins (other than furskins) and leather
42	Articles of leather; saddlery and harness; travel goods, handbags and similar containers
43	Furskins and artificial fur; manufactures thereof
44	Wood and articles of wood; wood charcoal
45	Cork and articles of cork
46	Manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork
47	Pulp of wood or of other fibrous cellulosic material
48	Paper and paperboard; articles of paper pulp, of paper or of paperboard
49	Printed books, newspapers, pictures and other products of the printing industry
50	Silk
51	Wool, fine or coarse animal hair; horsehair yarn and woven fabric
52	Cotton

53	Other vegetable textile fibres; paper yarn and woven fabrics of paper yarn
54	Man-made filaments; strip and the like of man-made textile materials
55	Man-made staple fibres
56	Wadding, felt and nonwovens; special yarns; twine, cordage, ropes and cables and articles thereof
57	Carpets and other textile floor coverings
58	Special woven fabrics; tufted textile fabrics; lace; tapestries; trimmings; embroidery
59	Impregnated, coated, covered or laminated textile fabrics
60	Knitted or crocheted fabrics
61	Articles of apparel and clothing accessories, knitted or crocheted
62	Articles of apparel and clothing accessories, not knitted or crocheted
63	Other made-up textile articles; sets; worn clothing and worn textile articles; rags
64	Footwear, gaiters and the like; parts of such articles
65	Headgear and parts thereof
66	Umbrellas, sun umbrellas, walking sticks, seat-sticks, whips, riding-crops and parts thereof
67	Prepared feathers and down and articles made of feathers or of down; artificial flowers
68	Articles of stone, plaster, cement, asbestos, mica or similar materials
69	Ceramic products
70	Glass and glassware
71	Natural or cultured pearls, precious or semi-precious stones, precious metals, etc
73	Articles of iron or steel
75	Nickel and articles thereof
76	Aluminium and articles thereof
78	Lead and articles thereof
80	Tin and articles thereof
82	Tools, implements, cutlery, spoons and forks, of base metal; parts thereof of base metal
83	Miscellaneous articles of base metal
84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof
85	Electrical machinery and equipment and parts thereof; sound recorders and reproducers, etc.
86	Railway or tramway locomotives, rolling stock and parts thereof, etc.
88	Aircraft, spacecraft, and parts thereof
89	Ships, boats and floating structures
90	Optical, photographic, cinematographic, measuring, checking, precision, surgical instruments etc.
91	Clocks and watches and parts thereof
92	Musical instruments; parts and accessories of such articles
93	Arms and ammunition; parts and accessories thereof
94	Furniture; bedding, mattresses, mattress supports, cushions and similar stuffed furnishings
95	Toys, games and sports requisites; parts and accessories thereof
96	Miscellaneous manufactured articles
97	Works of art, collectors' pieces and antiques

Table C. 1 – Initial set of 78 HS categories, Source: GOV.UK (2021)

D. Batching / Sampling process

During the overall process, certain actions are taken which may vary by the Question that each algorithm aims to answer:

- Q3: The training set corresponds to 60% of the data and the test set to 40% of the data. The optimised HS set is capped to a minimum of 10 categories. The reason for this choice is again rooted on overfitting avoidance: if no cap is set then the model may proceed to propose a combination of e.g. 2 HS categories as the optimum list. Under this scenario, it is likely that the model may capture spurious relationships between the Trade Value (x) of certain HS categories and TEU volume. By restricting the minimum combinations of HS categories to 10, the research applies an additional safety control: it is considerably less likely for the model to capture – at least – 10 categories that simultaneously move to the same direction as TEU volume development does compared to a combination of only 2 HS categories.
- Q4: The training set corresponds to 60% of the data and the test set to 40% of the data. In order to run an efficient training / test split that captures multiple years (i.e. train for 2012 to 2016 – test for 2017 to 2020), those HS categories with data across all years are considered. The optimised set is again capped to a minimum of 10 categories. China's batch list already returns 10 HS categories so no sampling process is applied. At this stage, although extensive action has been undertaken to tackle overfitting, an equivalent action to tackle underfitting is also raised. Underfitting in data science is described as the tendency of a statistical model to be unable to capture the structure of the training set (IBM, 2021). In the proposed model, the attention is given to the identification of an optimum set of HS categories that fits increasingly better the test data. Hence, it is likely that a set may be selected that fits excellent the data for the test years (2017-2020) although it may not be a very good fit for the training years (2012-2016). In order to avoid this occurrence, the research applies one more safety control: the model continues selecting the best fit for prediction but only for those HS categories' combinations that explain at least 75% of the training data as well. If the intention of this exercise was to purely compile a predictive model, this extra restriction may have not been deemed as vital. However, the intention of this

exercise is to identify this HS set that can describe the variance across the full period (2012-2020) thus the model should be adequately able to both capture the underlying structure and also predict.

- Q5: All above restrictions regarding training / test split, minimum available trade data, minimum HS categories' combinations and minimum R^2 for training data are applied.

E. Applicable Modelling Approaches for Panel Data

As discussed in Section 3.12, this research adopts a longitudinal approach with regard to its time horizon. This allows the research to observe the cross-sectional development of the analysed phenomenon over multiple time periods (Baltagi, 2005). In the context of this research the implementation of a longitudinal study corresponds to the analysis of the pair-wise direct shipping connections development between the UK and 136 trading countries over the period of 2012-2020. As discussed in Section 4.7, the clustering of the data at a pair-wise level and its analysis over time classifies the analysis of this research as a panel data analysis. Specifically, the analysis follows the development of the values of the 9 selected variables for each individual pair of countries over the defined period of time with the aim to measure the impact of each variable towards the establishment of a direct connection between the countries.

i. Panel Data

Panel data analysis in the Maritime Logistics field is an established econometric technique which has been applied by various scholars in studies associated with trade and connectivity. For instance, Wilmsmeier and Martínez-Zarzoso (2010) studied the determinants of the transport costs for Latin America trade from 1999 to 2004 based on relevant data of 277 trade routes and – among other findings – indicated that the geographical distance as a sole determinant of international trade is overrated, simplistic and does not reflect the actual level of access to the markets for the countries. Biermann (2012) analysed the impact of variables such as GDP, Colonial Ties and Distance on bilateral container trade flows between countries and proposed that classic approaches of gravity-type models which use great circles distance are not advisable for seaborne trade (see Section 3.9). Fugazza (2015) utilised a gravity-type panel setup of 178 countries over the period of 2006-2012 and claimed that although there is no clear causal relationship, the absence of a direct connection may account for a drop in export values of 42-55% and any additional transhipment for a drop of 20-25%. Bottasso *et al.* (2018) applied a Poisson pseudo-maximum likelihood regression on panel data for Brazilian states over the period 2009-2012 and showed that there is a positive impact of port infrastructure endowment on international trade flows which is greater for exports than imports. Hoffmann, Saeed and Sødal (2020) applied a dynamic panel model to examine how the various components of connectivity as well as distance and GDP of 142 trading countries with South Africa may affect the corresponding bilateral container trade flows. Jia, Lee Lam and Tran (2020) applied a panel regression framework for a number of port pairs aiming to assess the factors that impact the time uncertainty of a trip in container shipping. Vidya and Taghizadeh-Hesary (2021) – in a report commissioned for the Asian Development Bank Institute (ADBI) – combined network analysis with a panel regression to test the importance of infrastructure on connectivity and found a positive relationship.

A relevant sample of the panel data that this research employs is illustrated in Table E. 1. The values of the 9 selected variables (i.e. Trade Flow, Trade Imbalance, Connectivity, MSR Routing, ECA Routing, Colonial Ties, Trade Facilitation, Reefer Cargo, and Logistics Performance) for each of the countries in the sample are followed for the period 2012-2020. China and Germany are selected as the countries with the largest surplus and deficit regarding container cargo exchanges with the UK, respectively (see Section 4.4.9). For those countries, it is observed that during the examined period, a Direct Connection with the UK (i.e. the depended variable) was constantly active (i.e. flagged as 1). However, it is worth noting that for other countries such as Norway, the establishment of a Direct Connection with the UK within the examined period was more volatile (i.e. interchanging between 0 and 1).

Trading Country	Year	Trade Flow (TEU)	Trade Imb/e (TEU)	Con/y	MSR Rou/g	ECA Rou/g	Col/l Ties	Trade Fac/n	Reefer Cargo	Log/s Perf/e	Direct Con/n
China	**2012**	1881154	-265403	131.45	0	0	0	72	0.17	3.53	**1**
China	**2013**	1788804	-319216	133.8	1	0	0	72	0.17	3.53	**1**
China	**2014**	2330493	-233348	135.49	1	0	0	72	0.17	3.60	**1**
China	**2015**	2423526	-205529	140.35	1	0	0	73	0.17	3.66	**1**
China	**2016**	2504224	-268729	140.62	1	0	0	74	0.16	3.66	**1**
China	**2017**	2476706	-174196	145.1	1	0	0	73	0.15	3.61	**1**
China	**2018**	2305188	-283642	152.43	1	0	0	73	0.16	3.61	**1**
China	**2019**	2335542	-343477	155.97	1	1	0	72	0.17	3.63	**1**
China	**2020**	2135193	-529877	159.51	1	1	0	71	0.16	3.66	**1**
Germany	**2012**	264701	185164	79.47	0	1	0	87	0.18	4.08	**1**
Germany	**2013**	307804	244736	81.36	1	1	0	88	0.17	4.12	**1**
Germany	**2014**	348329	257730	82.06	1	1	0	88	0.17	4.18	**1**
Germany	**2015**	394341	303322	84.28	1	1	0	88	0.16	4.23	**1**
Germany	**2016**	511887	404883	83.94	1	1	0	87	0.17	4.23	**1**
Germany	**2017**	450033	352312	83.58	1	1	0	87	0.15	4.20	**1**
Germany	**2018**	357246	280409	83.98	1	1	0	86	0.16	4.20	**1**
Germany	**2019**	367995	289571	83.49	1	1	0	86	0.16	4.17	**1**
Germany	**2020**	427780	315540	83.62	1	1	0	84	0.16	4.15	**1**
Norway	**2012**	13272	4138	10.96	0	1	0	89	0.34	3.82	**0**
Norway	**2013**	13486	3422	10.32	0	1	0	89	0.34	3.96	**0**
Norway	**2014**	14009	1378	10.38	0	1	0	89	0.30	3.85	**0**
Norway	**2015**	13961	1096	10.72	0	1	0	88	0.46	3.73	**1**
Norway	**2016**	13116	1168	10.15	0	1	0	88	0.42	3.73	**1**
Norway	**2017**	9655	2496	8.65	0	1	0	88	0.39	3.70	**1**
Norway	**2018**	15049	3421	9.53	0	1	0	83	0.38	3.70	**0**
Norway	**2019**	10544	887	10.81	0	1	0	84	0.43	3.70	**0**
Norway	**2020**	10573	719	10.33	0	1	0	84	0.46	3.70	**1**

Table E. 1 – Panel data sample of the employed dataset

The fact that the dependent variable is binary (i.e. defined with a value of either 0 or 1) largely defines the type of the applicable econometric models for this research. This is further discussed below.

ii. Review of Applicable Models

The individual heterogeneity of the various countries cannot be captured in a classic timeseries or cross-sectional data setup which treat this unobserved random component as common for all observations, while in the cross-sectional case the static nature of the data does not allow the unobserved component to be treated as either constant or varying over time (*ibid*).

In panel data analysis, those characteristics are illustrated by the following relationship:

$$y_{it} = \beta x_{it} + a_i + \varepsilon_{it}, \quad i = 1 \ldots N,\ t = 1 \ldots T \qquad \text{(E-1)}$$

where according to Alnıpak, Isikli and Apak (2021) and StataCorp. (2021a):

- i denotes the individual panel (country) and t denotes the time periods (years)
- y_{it} denotes the dependent variable (Direct Connection) between individual (country) i and the UK at time t (year)
- x_{it} are the regressors (dependent variables) for individual (country) i at time t (year) and β denotes the corresponding coefficient of each regressor
- a_i denotes the abovementioned time-invariant individual heterogeneity (i.e. the unobserved time-invariant random component of the model)
- ε_{it} denotes any other unobserved individual component of the model which varies over time

Panel data models are classified into various groups based primarily on the assumptions that are made regarding the time-invariant individual heterogeneity a_i (effects) (Alnıpak, Isikli and Apak, 2021).

Pooled Model

A Pooled model assumes that there is no unobserved individual heterogeneity and this assumption essentially collapses the panel structure of the dataset (Biermann, 2012). Effectively, a Pooled approach assumes that the there is no significant correlation between any of the dependent variables and the error term a_i and that a_i does not exist (i.e. $a_i = 0$), as this is illustrated by the following relationship (Alnıpak, Isikli and Apak, 2021):

$$y_{it} = \beta_1 x_{1it} + \beta_2 x_{2it} + \ldots + \beta_k x_{kit} + \varepsilon_{it} \qquad \text{(E-2)}$$

The fraction of the variance at the individual level that may be attributed to a_i can be statistically tested in order to confirm whether a panel model should be adopted or a simpler Pooled approach could suffice (StataCorp., 2021c). In the context of this research a Pooled approach would assume that the parameters which dictate whether a direct connection with the UK will be established do not vary between different countries (Baltagi, 2005).

Random Effects

The key characteristic of the Random Effects model is the assumption that the unobserved time-invariant random component of the model is not related to the regressors (StataCorp., 2021b). In the context of this research this assumption would mean that each of the selected variables are not related with unobservable time-invariant factors (e.g. geography does not affect the establishment of a Direct Connection between UK and other trading countries). The unobserved time-invariant random component of the model is taken into consideration (i.e. $a_i \neq 0$) (Alnıpak, Isikli and Apak, 2021) but this *''random effect''* in accordance with the traditional panel data parlance is treated as another random variable rather than a parameter to be estimated for each individual (Wooldridge, 2010). This is illustrated by the following relationship which underlines the fact that the overall unobserved random disturbance (v_{it}) incorporates a time-invariant and a time-varying component (StataCorp., 2021b):

$$y_{it} = \beta x_{it} + (a_i + \varepsilon_{it}) = \beta x_{it} + v_{it} \qquad \text{(E-3)}$$

Respectively, the assumption that the unobserved time-invariant random component of the model is not related to the regressors (i.e. the covariance (cov)) it is called *''the random effects assumption''* in econometrics and it is illustrated by the following relationship (Antonakis, Bastardoz and Rönkkö, 2021):

$$\text{cov}\ (x_{it}, a_i) = 0 \qquad \text{(E-4)}$$

where *cov* corresponds to covariance which is a statistical measure of how much two variables change together (Weigt and Szurmant, 2013).

Probit Model (Random Effects)

As previously discussed, the dependent variable of this research is binary. A commonly applied panel model for binary variables is the Probit model. The latter is a non-linear estimator which can predict the probability that the binary variable may take one of two possible values (i.e. 1 for the existence of a Direct Connection or 0 for non-existence). The term *probit* is attributed to the seminal work of Bliss (1934a);

Bliss (1934b) and has its roots on Biology while the estimator has been widely discussed by the literature over the years (e.g. Finney, 1947; Van de Ven and Van Praag, 1981; Howard *et al.*, 1986; Geroski, 2000; Hoetker, 2007). Specifically, the Probit panel model is illustrated by the following relationship (StataCorp., 2021c):

$$f(x) = \begin{cases} 1 & \text{if } \beta x_{it} + a_i + \varepsilon_{it} > 0 \\ 0 & \text{otherwise} \end{cases} \quad \text{(E-5)}$$

The distributional assumption regarding ε_{it} is illustrated by equation (E-6) which suggests that the time-varying error component is normally distributed (i.e. follows a typical bell-shaped curve) with mean and standard deviation being 0 and 1, respectively (StataCorp., 2021c). It also assumed that ε_{it} is not dependent on past or future random disturbances (i.e. ε_{it} is serially independent) (*ibid*). Equation (E-7) suggests that the time-invariant error component is also normally distributed with mean equal to 0 (*ibid*):

$$\varepsilon_{it} \mid (x_{i1},\ldots, x_{iT}, a_i) \sim N(0, 1) \quad \text{(E-6)}$$

$$a_i \mid (x_{i1},\ldots, x_{iT}) \sim N(0, \sigma_\alpha) \quad \text{(E-7)}$$

The parameters of the Probit models are estimated by maximum likelihood. This process maximizes the likelihood that the modelled data fits the assumptions which were accepted regarding the distribution of the dependent variable (StataCorp., 2021c). The likelihood function is effectively the probability that a certain set of parameters would yield the observed data (Robinson, 2016) and the purpose of the maximum likelihood is ''*to estimate the probability distribution which makes the observed data most likely''* (Haynes, 2013).

Logit Model (Random Effects)

Another option of modelling binary variables is the Logit model. As is the case with the Probit model, the Logit model is also a non-linear estimator which can predict the probability that the binary variable may take one of two possible values (i.e. 1 for the existence of a Direct Connection or 0 for non-existence) and it is also estimated via maximum likelihood. The Logit model is described by the same form that describes the Probit model as well (see equation (E-5) (StataCorp., 2021c)). The core difference between Logit and Probit models is the distributional assumption regarding ε_{it} which in the case of the Logit model is estimated via a Logistic rather than a Normal distribution (StataCorp., 2021c). The Logistic distribution approximates very closely both the form and the shape of the bell-shaped Normal distribution (Kao, Keskin and Shang, 2022). The distributional assumptions of the Logit panel model regarding ε_{it} and a_i are illustrated by equations (E-8) and (E-9), respectively:

$$\varepsilon_{it} \mid (x_{i1},\ldots, x_{iT}, a_i) \sim \text{Logistic } (0, 1) \qquad \text{(E-8)}$$

$$a_i \mid (x_{i1},\ldots, x_{iT}) \sim N\ (0, \sigma_\alpha) \qquad \text{(E-9)}$$

Fixed Effects

In contrast to the Random Effects model, the Fixed Effects model recognises the difficulty to ignore a possible relationship of the unobserved time-invariant random component of the model with the regressors (StataCorp., 2021b). If an unobserved component is related to the regressors then ignoring this relationship would lead to inconsistent estimations and the Fixed Effects model mechanisms overcome this problem (*ibid*). In the context of this research this assumption would mean that one or more of the selected variables may be related with unobservable time-invariant factors (e.g. geography somehow affects the establishment of a Direct Connection between the UK and other trading countries). The unobserved time-invariant random component of the model is taken into consideration (i.e. $a_i \neq 0$) (Alnıpak, Isikli and Apak, 2021) but this *''random effect''* in accordance with the traditional panel data parlance is treated as a parameter to be estimated for each individual (Wooldridge, 2010). The Fixed Effect model eliminates the time-invariant random component of the model along with any other time-invariant variable (observed or unobserved) thus the time-invariant coefficients of a model cannot be estimated (StataCorp., 2021b). In the context of this research this would mean that the impact of variables such as Colonial Ties or ECA Routing could not be estimated.

Logit Model (Fixed Effects)

Under a Fixed effect approach there is no available Probit model since mathematically there is no option to eliminate from the log-likelihood function the unobserved time-invariant component a_i (StataCorp., 2021c). On the contrary, a fixed effect logit model can be specified since it is mathematically proven that the conditional distribution D (.) of the dependent variable y_{it} no longer depends on a_i once it is conditioned on the sum of the dependent variable ($\sum_{t=1}^{T} y_{it}$) (*ibid*).

This is illustrated by the following relationship:

$$D(y_{it} \mid (x_{i1},\ldots, x_{it}, a_i, \textstyle\sum_{t=1}^{T} y_{it}) \equiv D(y_{it} \mid (x_{i1},\ldots, x_{it}, \textstyle\sum_{t=1}^{T} y_{it}) \qquad \text{(E-10)}$$

The addition of the element $\sum_{t=1}^{T} y_{it}$ (i.e. the sum of the dependent variables), allows the estimation of the model without estimating a_i. This addition informs how many times a positive outcome of a given individual is observed (*ibid*). In the context of this research this would correspond to the number of years a country remained connected with the UK within the period 2012-2020.

Nevertheless, utilising the expression $\sum_{t=1}^{T} y_{it}$ imposes a restriction on the model estimation since effectively the model predicts the probability of a positive outcome of the dependent variable y_{it} at a certain year based on the available information across all years (i.e. the sum of the dependent variable) (StataCorp., 2021c). However, if a country (i) was constantly directly connected to the UK throughout the full period 2012-2020 then the conditional probability of being connected with the UK at a certain year given that it was constantly connected to the UK, is equal to 1. Respectively, if a country (i) was never directly connected to the UK throughout the full period 2012-2020 then the conditional probability of being connected with the UK at a certain year given that it was constantly not connected to the UK is equal to 0. Hence, if the outcomes within a panel (i.e. for a country (i) over the period 2012-2020) do not change then they provide no information and the Fixed Effects Logit panel model simply drops those cases since the outcome – based on equation (E-10) – is solely estimated by $\sum_{t=1}^{T} y_{it}$ and no information is returned for the impact of the estimated coefficients (StataCorp., 2021c). In the context of this research, countries such as China or Germany in Table E. 1 would be completely ignored and the model would proceed with a statistical analysis based only in cases such as Norway for which the establishment of a Direct Connection with the UK within the examined period was more volatile (i.e. interchanging between 0 and 1).

iii. Model Selection Process

The selection between a fixed or random effects model is a key step for an econometric research but there is not always a straightforward answer on which one should be preferred (Baltagi, 2005). Historically, various scholars were advocates of either the fixed effects model (see Mundlak (1961) and Wallace and Hussain (1969), as cited in Baltagi, 2005) or the random effects model (see Balestra and Nerlove

(1966), as cited in Baltagi, 2005). Additionally, other scholars have proceeded to select between those two approaches based on whether the majority of the independent variables vary within or between panels. As previously discussed, when a variable does not vary within a panel then a fixed effect model cannot be informative regarding the impact of the corresponding variables. Specifically, when there is more variation between than within panels, a fixed effect estimator is not expected to be very efficient and a random effects model is preferable (Cameron and Trivedi (2010), as cited in Hoffmann, Saeed and Sødal, 2020). Hence, sometimes the comparison regarding the variation of the variables within and between panels has been the basis of the selection between models (e.g. Hoffmann, Saeed and Sødal, 2020). However, although this is a reasonable claim, the ignorance of a possible correlation between the time-invariant random component and the regressors may lead to estimates that are inconsistent (i.e. the estimated coefficients do not approach the correct values as the sample grows) and biased (i.e. the mean value estimates of repeated sampling do not converge to the correct estimates) and a statistically-sound process should be followed for the selection of the applicable model (Antonakis, Bastardoz and Rönkkö, 2021). The literature suggests two widely-used statistical tests that allow for the selection of the correct model.

Hausman test

Hausman (1978) proposed a process to test the difference between the fixed and random effects models. The null hypothesis (i.e. H_0) of the Hausman test is that the random effects assumption holds as this is illustrated by the following relationship (Baltagi, 2005):

$$H_{0:} \operatorname{cov}(x_{it}, a_i) = 0 \qquad \text{(E-11)}$$

The Hausman test calculates the difference between the coefficients of the fixed and the random effects estimators and assumes that this is not statistically significant (StataCorp., 2021b). If H_0 is true then both fixed and random effects models are consistent but the latter is more efficient (i.e. the random effects model has a smaller standard error) and thus appropriate (*ibid*). On the contrary, if H_0 is rejected then a fixed effects model is the suggested approach.

Mundlak test

Mundlak (1978) suggested an alternative test that it is more robust than the Hausman test in case the analysed data is characterised by:

(a) Heteroscedasticity: equations (E-1) and (E-3) assume that the standard error component of the models has the same variance across time and panels (individuals) or in other words the standard errors are homoscedastic. This is probably a restrictive assumption in a panel analysis where the individuals (i.e. the countries in the context of this research) vary by size and thus may be characterised by different variation (Baltagi, 2005) or in other words their standard errors are likely to be heteroscedastic.

(b) Serial correlation within panels: from equation (E-3) it is derived that $v_{it} \equiv a_i + \varepsilon_{it}$ (i.e. the unobserved random disturbance (v_{it}) incorporates a time-invariant and a time-varying component). Since a_i is time-invariant then a part of the random disturbance v_{it} is common in every period t (year) for an individual i (country) (StataCorp., 2021a). Thus, the possibility that a *''random shock''* at time t may be correlated with a random shock at time t + k cannot be excluded (*ibid*). The assumption that random shocks throughout periods in a panel are uncorrelated may be another restrictive assumption in economic relationships since it is possible that an unobserved shock of the current period may have an impact on the behaviour of an individual for the next few periods (Baltagi, 2005) thus in other words the random disturbances are likely to be serially correlated.

In the presence of the above caveats, an alternative estimate of variance is needed that can relax the assumption of independence of the observations (StataCorp., 2022d). This alternative calculation is known as the *Huber and White* or *sandwich* estimator of variance and the corresponding errors are known as *robust standard errors* (*ibid*). For panel models, the respective calculation *''should allow for correlation of the unobserved random components to be nonzero within each group and zero across groups''* (StataCorp., 2021a). Additionally, robust standard errors may also be used to account for the potential presence of other types of model misspecification (Breinegaard, Rabe-Hesketh and Skrondal, 2017).

The Mundlak test controls for a possible correlation between a_i and the regressors x_{it} and suggests a form for their relationship. Specifically, the test proposes that ''*the* *expected value of a_i, conditional on the regressors, is a linear combination of the average per panel of the time-varying regressors''* (StataCorp., 2021b). This is illustrated by the following relationship:

$$E\,(a_i \mid x_i) = \gamma_0 + \gamma_1\bar{x}_{i1} + \ldots + \gamma_k\bar{x}_{ik} \qquad \text{(E-12)}$$

Within this framework if a_i is uncorrelated with the regressors then the following relationship has to be true (*ibid*):

$$\gamma_1 = \gamma_2 = \ldots = \gamma_k = 0 \qquad \text{(E-13)}$$

Effectively, a Mundlak test estimates a random effects model with robust standard errors which apart from the original regressors includes the mean value of each time-varying regressor at individual level ($\bar{x}_i$) and then tests the null hypothesis (H_0) that the coefficients of all $\bar{x}_i$ are different from zero (StataCorp., 2021b). The augmented equation which includes both x_i and $\bar{x}_i$ is known as the *Mundlak regression* (*ibid*).

In line with the Hausman test, if H_0 is true then a random effects model is appropriate, while if H_0 is rejected then a fixed effects model is the suggested approach.

iv. Correlated Random Effects

As previously discussed, since the Fixed Effect model eliminates the time-invariant random component of the model, the impact of certain variables cannot be estimated. This attribute of the Fixed Effect model can impose an important restriction on an econometric study that wishes to assess the importance of specific time-invariant variables. On the contrary, as discussed above, a Random Effects model does not impose this restriction but employs ''*the random effects assumption*'' (i.e. the assumption that the unobserved time-invariant random component of the model is not related to the regressors). Thus, a Random Effects approach may provide a degree of flexibility but – as previously discussed – the applicability of this approach on a dataset should be statistically tested before the model is adopted. In fact, the violation of the – testable – random effects assumption may lead to biased results and undermine the extraction of any causal interpretations (Antonakis, Bastardoz and Rönkkö, 2021).

However, the seminal work of Mundlak (1978) and Chamberlain (1980), proposed an alternative approach that is effectively a synthesis of the Fixed and Random effects approaches (Wooldridge, 2013b). Instead of assuming that a_i is not correlated with the regressors (i.e. Random Effects model) or mathematically removing a_i (i.e. Fixed Effects model), the correlation between a_i and the regressors may be modelled (*ibid*). The latter is managed by adding the mean value of each time-varying regressor at individual level ($\bar{x}_i$) (*ibid*), a process which was previously also discussed as part of the Mundlak test. In econometrics parlance, this approach is referred as the *Correlated Random Effects* (CRE) model (*ibid*).

The fact that $\bar{x}_i$ does not vary over time allows for its correlation with a_i and thus acts as a control for this part of the time-invariant unobserved heterogeneity that may be correlated to the regressors. Any remaining part of the time-invariant unobserved heterogeneity should be then uncorrelated to the regressors (Wooldridge, 2013b). Effectively, the model equation corresponds to the Random Effects model with the addition of the time-average values $\bar{x}_i$ (*ibid*). Wooldridge (2019) discussed that the CRE framework extends to non-linear approaches such as probit models as this was also previously indicated by Wooldridge (2010). Thus, equation (E-5) is respectively transformed, as follows:

$$f(x) = \begin{cases} 1 & \text{if } \beta x_{it} + \boldsymbol{\gamma}\bar{\mathbf{x}}_{\mathbf{i}} + a_i + \varepsilon_{it} > 0 \\ 0 & \text{otherwise} \end{cases} \qquad \text{(E-14)}$$

According to Antonakis, Bastardoz and Rönkkö (2021), the *γ* coefficient in equation (E-14), corresponds to the ''*contextual effect''*. The latter ''*tells how characteristics or actions of other individuals in the same context affect individual-level outcomes or, alternatively, how characteristics or actions of an individual affect the outcomes of others in the same context''* and has essentially the equivalent meaning of the ''*herd immunity''* (*ibid*). In the context of this research, this may for instance indicate how the increase of the mean Connectivity of a country across the analysed periods may affect the probability of that country to establish a direct connection with the UK in a given year.

v. Robustness Checks

Following the model compilation and the core statistical analysis, it is common for an econometric research to proceed with a set of checks. The aim of those checks is to secure the robustness of the results and to address as much as possible any limitations of the analysis (Fugazza and Hoffmann, 2017). The following robustness checks derive from relevant efforts that are common in the econometric research of the Maritime Logistics field according to the reviewed literature.

Non-stationarity

Panel data analysis is a time-series cross-sectional process. Any time-series process is regarded as stationary if its mean and variance do not change over time (Baltagi, 2011) thus in other words there is no trend or seasonality in the data. If the modelled data is non-stationary then the modelled behaviour has essentially followed a defined pattern and thus any generalisation of the results may not be accurate (Özcan and Öztürk, 2019).

The stationarity of the data can be checked via various statistical tests which belong to the family of the *''unit root''* tests and are designed to statistically test whether the mean and variance of a dataset change over time and are also applicable in panel data analysis (StataCorp., 2022c).

Multicollinearity

Multicollinearity exists when two (or more) independent variables are highly correlated in the sense that the values of one variable can essentially be predicted by the other (Johnston, Jones and Manley, 2018). Severe multicollinearity in a model results in imprecise estimation of the corresponding coefficients (Wooldridge, 2010) and the accurate estimation of the true parameters is not possible (Askin, 1982). Multicollinearity can be estimated with Pearson's correlation coefficient which measures the linear association of two variables and its value may vary between -1 and 1 (Kirch, 2008). A Pearson correlation coefficient value close to zero indicates low correlation between two variables, while a value close to 1 or -1 indicates a strong correlation between two variables (*ibid*).

In the presence of severe multicollinearity the interpretation of the model results should be neglected until a solution to the problem is provided (Daoud, 2018). The conventional way to deal with multicollinearity is to drop one of the highly correlated variables (i.e. in the case of two highly correlated variables to retain only one and so forth) or to avoid including simultaneously in the specified model those variables with high multicollinearity (i.e. with Pearson correlation coefficient value over 0.7) (Alnıpak, Isikli and Apak, 2021).

Endogeneity

Endogeneity is a situation in econometrics where the regressors are correlated with the unobserved error component (Baltagi, 2005) while the discussed models in this

Appendix assume the opposite. In general, the error component incorporates all those factors that may impact the dependent variable y but for various reasons may have not been included in the model (Hill *et al.*, 2021). If any of the regressors (explanatory variables) x_i is correlated with the error component the estimate of the corresponding coefficients will be biased (upwards or downwards) depending on the impact the *''unmodelled factors''* may have to y and their impact is captured by x_i (*ibid*). Addressing endogeneity is of paramount importance towards providing unbiased estimates (e.g. Froyen, 1974; Krugman, 1978; Villas-Boas and Winer, 1999). The latter is also applicable in panel data analysis (e.g. Hamilton and Nickerson, 2003; Wintoki, Linck and Netter, 2012).

There are two common types of endogeneity in panel data (Wooldridge, 2010):

- The regressors may be correlated with the time-invariant error component (a_i): a possible test may be an approach similar to the Mundlak regression (or Chamberlain-Mundlak) (see above). Under this framework, the time averages of the time-varying regressors are computed and included in the model. A statistical test then checks for joint significance as per equation (E-13).

- The regressors may be correlated with the time-varying error component(ε_{it}): a possible test may be to include in the model the lead values of the regressors (i.e. x_{it+1}) as well as the time averages as mentioned above. The null hypothesis would be that the lead values should be statistically insignificant.

Endogeneity may arise due to the following reasons:

- Omitted Variable(s): although the modeller wishes to include one or more additional explanatory variables this is not possible, primarily due to data unavailability (Wooldridge, 2010). In the context of this research, an endogeneity issue due to Omitted Variable could arise if for instance the direct impact of Trade Facilitation to the establishment of a Direct Connection between countries was accepted but there was no available metric to quantify this variable.

- Measurement Error: one or more of the applicable metrics is considered to be an *''imperfect measure''* of the corresponding explanatory variable (*ibid*). In the context of this research, an endogeneity issue due to Measurement Error could arise if for instance the direct impact of Trade Flow to the establishment of a Direct Connection between countries was accepted but the employed metric was not able to effectively capture the TEU exchanges between the countries (e.g. by following the methodology that was discarded for being imperfect in Section 4.4.8).

- Simultaneity: *''at least one of the explanatory variables is determined simultaneously along with y''* (i.e. the impact of x on y is modelled but it is suspected that x is also – partially – determined by y) (*ibid*). In the context of this research, the most prominent case of a suspected endogeneity issue due to Simultaneity is the one discussed in Section 4.5.2. Indeed, as Fugazza and Hoffmann (2017) underlined, Trade Flows may influence the establishment of a Direct Connection between countries but a Direct Connection may in turn also influence the Trade Flow between the countries.

  Simultaneity is harder to resolve than the previous two reasons of Endogeneity (Wooldridge, 2010). Although – as also discussed in Section 4.5.2 – this issue may not be present in the dataset employed by this research, it is worth noting that a common approach which attempts to tackle simultaneity is the use of *''instrumental variables''*. An instrumental variable z may (a) predict the endogenous variable; (b) be uncorrelated with the error component; and (c) be uncorrelated with the dependent variable (Hill *et al.*, 2021). In other words, an instrumental variable should be related to the endogenous independent variable x_i and not directly related to the dependent variable y but only through x_i (*ibid*). An instrumental variable is used to model the predicted value $\hat{x}_i$ of the endogenous variable x_i. Since the instrumental variable is exogenous to the original model, the corresponding $\hat{x}_i$ value is also exogenous and it is used instead of the original x_i variable. In the context of this research, a corresponding approach would need the identification of an instrumental variable z that is correlated to Trade Flow and does not impact Direct Connection but only through Trade Flow.

vi. Margins

A core objective of an econometric analysis is the calculation of the effect that a change in a variable of interest is expected to have on the dependent variable for the entire sample (StataCorp., 2021a). This calculation corresponds to the average marginal effect which is calculated for an individual with certain characteristics (e.g. a_i

= 0) but it can also be calculated at the mean value of all covariates (i.e. conditional effect) (*ibid*).

In general, margins correspond to calculated statistics based on the predictions of a previously fit model (StataCorp., 2022g). Margins are calculated at fixed values of certain variables and by integrating over the remaining covariates (Searle, Speed and Milliken, 1980; Graubard and Korn, 1999; Bartus, 2005; Wooldridge, 2010; Greene, 2019).

In linear relationships the coefficients of the model inform about the impact that a change of one unit in one of the independent variables is expected to have to the dependent variable and thus the coefficients match with the marginal effects (StataCorp., 2021a). On the contrary, in non-linear relationships and models (such as probit and logit), the coefficients inform only about the sign of the average marginal effect for each variable (StataCorp., 2021c). In order to obtain further information about the magnitude and the significance of the average marginal effect an extra calculation is needed:

$$\frac{\partial P\ (y_{it}=1 \,|\, x_{it}, a_i)}{\partial x_{itk}} \qquad \text{(E-15)}$$

In the context of this research equation (E-15) would be interpreted as – for example – what is the change in the conditional probability for a country of connecting directly to the UK if there have been Colonial Ties between the two countries compared to a third country which has not been in a colonial relationship with the UK. Notably, a_i is evaluated at its mean (i.e. for an individual with $a_i = 0$, see equations (E-7) and (E-9) in order to yield the corresponding average marginal effect (StataCorp., 2021c).

F. Stata Output Notation

Random-effects logistic regression						
					Number of obs = 949	
Group variable: country_id					Number of groups = 114	
Random effects u_i ~ Gaussian					Obs per group:	
					min = 2	
					avg = 8.3	
					max = 9	
Integration method: mvaghermite					Integration pts. = 12	
					Wald chi2(9) = 57.13	
Log likelihood = -164.92					Prob > chi2 = 0.00	
Direct Connection	Coef.	Std. err.	z	P>z	[95% conf. interval]	
Trade Flow	3.18	0.60	5.35	0.00	2.02	4.35
Trade Imbalance	2.19	0.90	2.45	0.01	0.44	3.95
Connectivity	2.16	0.45	4.84	0.00	1.28	3.03
MSR Routing	-1.59	0.98	-1.62	0.11	-3.51	0.33
ECA Routing	-3.64	2.01	-1.81	0.07	-7.59	0.31
Colonial Ties	0.55	1.10	0.50	0.62	-1.61	2.72
Trade Facilitation	0.31	0.37	0.85	0.40	-0.41	1.03
Reefer Cargo	0.13	0.05	2.81	0.01	0.04	0.23
Logistics Performance	0.23	1.04	0.22	0.82	-1.81	2.27
_cons	-13.47	3.86	-3.49	0.00	-21.04	-5.90
/lnsig2u	2.59	0.34			1.91	3.26
sigma_u	3.65	0.63			2.61	5.11
rho	0.80	0.05			0.67	0.89
LR test of rho=0: chibar2(01) = 151.84					Prob >= chibar2 = 0.000	

Table F. 1 – Stata Output Notation

The following explanation of the Stata's output notation is based on StataCorp. (2022h); StataCorp. (2022f); StataCorp. (2021c); UCLA (2021a); and UCLA (2021b).

- Group variable: denotes the panel level (i.e. country)
- Random effects u_i: denotes the assumption that the time-invariant component is Gaussian (i.e. normally distributed)
- Integration method: denotes the (default) integration method employed by the software (i.e. mean–variance adaptive Gauss–Hermite quadrature)
- Log likelihood: denotes the log-likelihood of the model once this has converged
- cons: the expected value of the dependent variable when all independent variables are equal to zero

- lnsig2u: denotes the log-parameterised standard deviation at panel level
- sigma_u: denotes the standard deviation at panel level
- rho: denotes the intraclass correlation and effectively reflects how much of the variance at individual level (i.e. panel) is attributed to the unobserved time-invariant component (i.e. if rho is equal to zero then a pooled approach can be employed).
- LR test of rho, Prob >= chibar2: denotes a likelihood-ratio test for which the null hypothesis is that rho is equal to zero. The corresponding p-value is compared to predetermined alpha value which is typically set to 5% (0.05) (i.e. coefficients with a p-value of less than 0.05 are considered to be statistically significant). Occasionally, 1% (0.01) and 10% (0.10) thresholds may also be considered.
- Number of obs / groups: denotes the total number of cases (i.e. rows) / total number of clusters (i.e. countries) considered by the model
- Obs per group: denotes the minimum, average and maximum number of observations per individual (i.e. country) that is considered in the calculation
- Integration pts: denotes the number of integration points (i.e. the more points the more accurate the log-likelihood estimation).
- Wald chi2: denotes the value of a Wald chi-square statistic which tests whether at least one of the independent variables' coefficient is not equal to zero.
- Prob > chi2: denotes the probability to encounter a value of the abovementioned Wald chi-square statistic which is as high as the calculated figure or even more. The null hypothesis is that all coefficients are simultaneously equal to zero.
- z , P>z: denotes the z and P>z values of a two-tailed p-value test for which the null hypothesis is that corresponding coefficient is equal to zero based on a predetermined value of alpha. Typically this value is set to 5% (0.05) and this research has adopted this level.
- 95% conf. interval: denotes the confidence interval of the coefficient estimates.

G. Quadrature Check

StataCorp. (2021c) suggests that the reliability of a respective command in Stata may be sensitive to the number of the integration points that are used for the numerical calculations. By default, 12 integration points are implemented. With the aim to increase the trustworthiness of the model and by experimenting with the corresponding *quadchk* command in Stata, it is observed that the CRE results stabilise with the use of 60 integration points (i.e. no variable shows a relative difference of over 0.0001 or 0.01%) (StataCorp., 2022b). Hence, this level is finally adopted for the CRE specification (Table G. 1):

	Fitted quadrature 60 points	Fitted quadrature 40 points	Fitted quadrature 80 points	
Log Likelihood	-154.6367	-154.6368	-154.6367	
		0.0000	0.0000	Difference
		0.0000	0.0000	Relative Difference
Direct Connection:	1.8528	1.8528	1.8528	
Trade Flow		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	1.0198	1.0198	1.0198	
Trade Imbalance		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	0.6321	0.6321	0.6321	
Connectivity		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	-0.4773	-0.4773	-0.4773	
MSR Routing		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	-1.3560	-1.3560	-1.3560	
ECA Routing		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	0.6340	0.6340	0.6340	
Colonial Ties		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	0.2154	0.2154	0.2154	
Trade Facilitation		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	0.0906	0.0906	0.0906	
Reefer Cargo		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	0.7136	0.7136	0.7136	
Logistics Performance		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	-0.2250	-0.2250	-0.2250	
m_Trade Flow		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	0.4388	0.4388	0.4388	
m_Trade Imbalance		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference

Direct Connection:	1.5313	1.5313	1.5313	
m_Connectivity		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	-1.7629	-1.7629	-1.7629	
m_MSR Routing		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	-0.2869	-0.2869	-0.2869	
m_Trade Facilitation		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	0.0132	0.0132	0.0132	
m_Reefer Cargo		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	-0.9290	-0.9290	-0.9290	
m_Logistics Performance		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	-0.1203	-0.1203	-0.1203	
2013.year		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	0.2247	0.2247	0.2246	
2014.year		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	0.3319	0.3319	0.3319	
2015.year		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	0.4578	0.4578	0.4578	
2016.year		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	0.7217	0.7217	0.7217	
2017.year		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	0.3812	0.3812	0.3812	
2018.year		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	-0.2193	-0.2193	-0.2193	
2019.year		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	-0.0928	-0.0928	-0.0928	
2020.year		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
Direct Connection:	-7.5449	-7.5449	-7.5449	
_cons		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference
/:	1.5192	1.5192	1.5192	
lnsig2u		0.0000	0.0000	Difference
		0.0000	0.0000	Relative difference

Table G. 1 – Quadrature Check, Stata Output

H. Structural Equation Model – Path Diagram

The following path diagram (Figure H. 1) depicts the graphical approach of this research of the modelling effort and has been compiled in Stata GSEM Builder. The GSEM model setup follows the logic of the core specification (CRE) and includes year effects as well as the group mean values of the time-varying regressors. The setup also indicates that a random intercept (i.e. a random effect) is considered via the latent variable *country_id.* This essentially denotes the panels (i.e. data clustering at country level) of the analysis. Finally, following on from Appendix G, the model is fitted with 60 integration points:

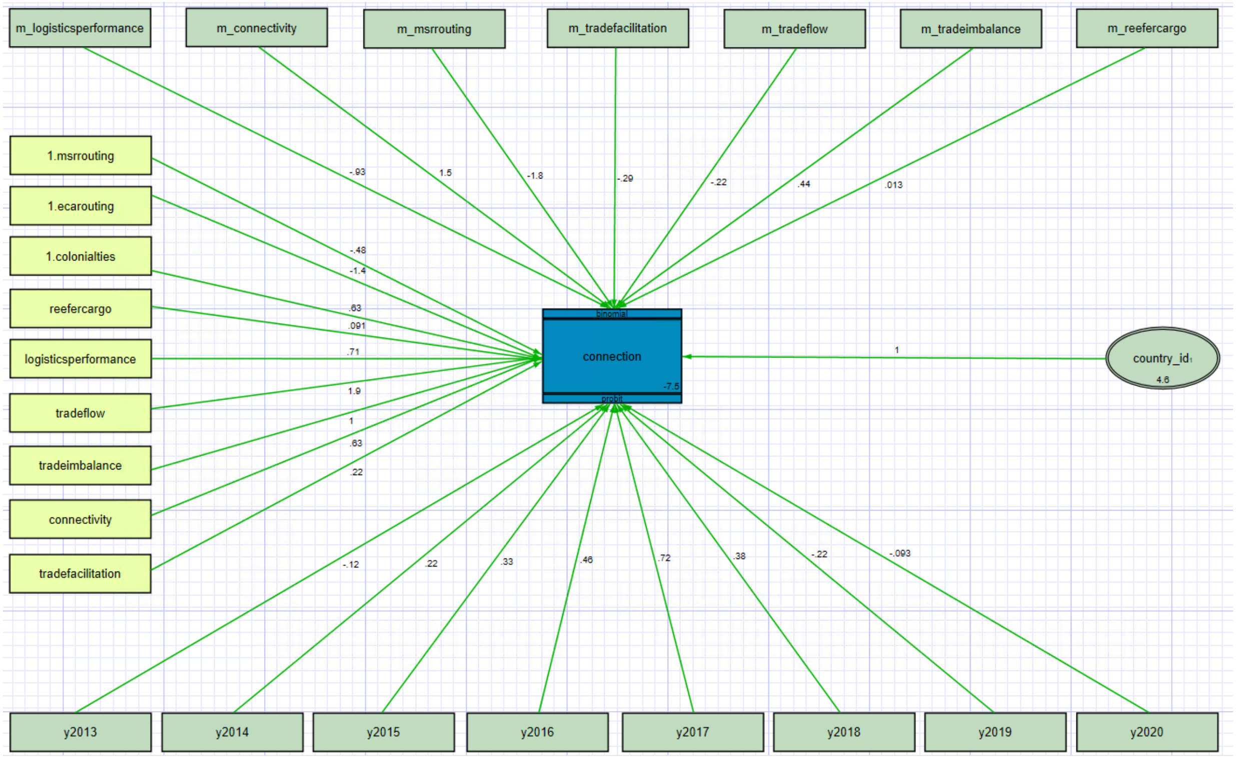

Figure H. 1 – GSEM estimator for the Core Specification

I. Predictive Margins – Iterative process / Threshold

The following code calculates the threshold value for Connectivity over which the probability of a positive outcome (i.e. Direct Connection with the UK) of an average country surpasses the 0.50 cut-off point while keeping Trade Flow and Trade Imbalance at fixed values (0.71 and -0.02 * 0.71 = -0.0142, respectively):

```
local interim_connectivity 0
local interim_tradeflow 0.71
local interim_tradeimbalance = - 0.02 * `interim_tradeflow'
local last_margin 0
local thre 0

while `last_margin' <= 0.50 {
    margins, at(connectivity = `interim_connectivity' tradeflow = `interim_tradeflow'
    tradeimbalance = `interim_tradeimbalance') atmeans predict(pu0)
     matrix results = r(table)
    local interim_margin = results[1,1]
     di `interim_margin'
    if `interim_margin' > 0.50 {
        local last_margin = `interim_margin'
          local thre = `interim_connectivity'
        break
    }
    local interim_connectivity = `interim_connectivity' + 0.010
}

di "Variable value for margin > 0.50: " `thre'
*di "This translates to ""
di "Last calculated margin result: " `last_margin'
```

Result:

Last calculated margin result: 0.50086426 for Connectivity = 3.41

A relevant process is repeated for all covariates.

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