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An analysis of the Economic Trade and Logistic impact of digitalization throughout the supply chain

By

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Acknowledgments:

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Abstract:

With the global maritime supply chain's ever-changing nature and increasing reliance on digital technologies, one must consider digitalization's true impact. These digital technologies, such as platforms like PortXchange Tradelens, come in various forms. Through this research, my thesis aims to address and quantify the question, "What is the economic and logistic impact of countries investing in digitalization throughout the supply chain?". The significance of this research lies in the lack of current scholarly sources that have attempted to quantify the benefits of digitalization. Therefore, by quantifying the benefits, this research attempts to fill in the gap in the existing literature.

By utilizing a partial equilibrium econometric model allowing for an analysis of the economic impacts of digitalization, I attempt to quantify the impact of digital technologies. For this research, I employed the Global Simulation Model (GSIM) created by Francois and Hall (2002). The GSIM will allow for analysis of the various economic impact's digitalization has on the net welfare of a country. To ensure accurate trade data was utilized, all figures used within the trade matrix were collected from the UNCOM trades database. Furthermore, the conversion method created by ECROYs (2015) was used after the model results were gathered to convert trade values into TEUs and tons, respectively.

To simulate the effects of digitalization on a country's economy, I created a non-tariff measure (NTM) quantifying the positive impact on efficiency based on case studies on ports using digital technologies. Furthermore, to showcase the effects of countries that were lagging in implementing these technologies, a negative NTM was created. After creating a holistically optimistic scenario where all countries, including the laggers, benefited from the scenario, a scenario that utilized the negative NTM was also formed. Once the GSIM was run, I analyzed the changes in net welfare seen in these countries, converting the final results to showcase the effects in terms of TEUS and bulk tons transported.

This research found that digitalization does have significant positive impacts on the maritime supply chain, and the delayed adoption of these technologies has a negative effect not only on the specific lagger countries but all countries that engage in trade with them. The most significant outcomes of this study are the positive effects seen by China and the United States in exports and imports, respectively. By implementing these technologies, China is expected to see the most significant increase of all countries in both scenarios. Whereas the United States is projected to see a substantial increase in imports in both the presented scenarios. Furthermore, the negative impacts of not implementing these technologies not only affect the trade flows of the Laggers but all countries within the trade matrix.

The findings presented within this research are supported by the two pieces of literature presented within this paper, which also attempt to quantify the positive effects of digitalization by Bakari et al. (2022) and Aberdeen and Duan (2021). Furthermore, the various case studies conducted on the increase in efficiency seen through the use of digitalization further support the findings presented within this paper.

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List of Abbreviations

1PL	1st Party Logistics Providers
2PL	2nd Party Logistics Providers
3PL	3rd Party Logistics Providers
CGE	Computable General Equilibrium
GSIM	Global Simulation Model
MT	Metric Tons
NTM	Non-tariff Measure
PE	Partial Equilibrium
ROW	Rest of World
RQ	Research Question
SQ	Sub-Question
TEU	Twenty-Foot-Equivalent
UNCTAD	United Nations Conference on Trade and Development
US	United States of America
USD	United States Dollar

Chapter 1: Introduction

1.1 Background

The need to increase international supply chain efficiency and reduce congestion/ bottlenecks is more apparent, with the world being arguably as global as ever. A trend that has taken the supply chain sector by force is digitalization and the Fuse of various technologies to enhance competitiveness. Some notable innovations that are currently shaking up the very fundamentals of the workplace and, subsequently, the supply chain are smart technologies, artificial intelligence (AI), automation, cloud computing, and the Internet of Things (IoT) (Trenerry et al. 2021, p. 1). These new trends were accelerated following the aftermath of the COVID-19 pandemic due to the increasing need for a digital workspace and additional technologies to optimize workflows further (Trenerry et al., 2021, p. 1).

While some sectors, such as supply chain logistics, communications, and finance, are more willing to adopt these technologies, some sectors may be unwilling to change adversely. One sector that must be considered is the maritime industry due to the very nature of international trade and the considerable amount of goods transported by sea. According to M. Isenberg and Nagurney (2023), approximately 90% of the world's goods are transported by sea. Furthermore, we have seen a considerable increase in the number of ships, contributing to supply chain congestion and bottlenecks.

One instance of the immense strain the maritime industry and its growing capacity has put on the supply chain was seen in Egypt's Suez Canal in March of 2021. With an estimated 12% of all global trade passing through the Suez Canal, even a minor supply chain blockage can cause catastrophic monetary damage (BBC News, 2021). However, the events in the Suez Canal in March were nothing short of disastrous, with 369 ships being stuck at one point (Russon, 2021). According to Lloyd's List, the estimated trade value, which abruptly came to a halt, was valued at USD 9.6 billion, equating to 3.3 million tons of cargo per hour (Russon, 2021). Additionally, German insurer Allianz estimated that this blockage reduced annual trade growth by 0.2 to 0.4 percent (Russon, 2021). This supply chain disruption among the others not mentioned demonstrates the inherent need for digitalization throughout the supply chain.

This thesis aims to study digitalization's economic impact on a country level when these software's are implemented throughout the supply chain. The next section of the introduction will showcase the main research question alongside the sub-research questions formulated.

1.2 Main and Sub-Research questions

When considering the immense impact the digitalization trend has on the overall supply chain efficiency, this research aims to quantify the actual economic and logistic impact countries would achieve from implementing these technologies. When looking at the economic impact, I will consider the positive percentage change that digitalization has been proven to have on economies that have already been observed. Furthermore, when considering the logistic impact digitalization has had on a country level, I will focus on the maritime shipping aspect more specifically all sea-borne trade between countries, as this technological innovation affects international trade wholistically. Lastly, this research aims to tackle the actual effects of digitalization on total welfare and its impact on trade flows.

The main research question that this research aims to answer is as follows:
Main RQ: ***"What is the economic and logistic impact of countries investing in digitalization throughout the supply chain?"***

To ensure all aspects of the main research question are adequately addressed I have also devised a series of sub research questions which are as follows:

SQ 1: Which econometric model is best suited to answer the research question?
SQ 2: What role do maritime operators have in the digitization process?
SQ 3: What is the impact of countries delaying the implementation of these digital technologies?
SQ 4: How has transportation and logistics been impacted by digitalization?
SQ 5: Do countries with investments in digitalization see more cargo throughput?

1.3 Methodology

To ensure that this thesis has acquired consistent results and reached applicable conclusions, I have utilized qualitative and quantitative research methods to assess the impacts digitalization has on economies and logistics throughout the supply chain

The first methodological approach used within this research was an in-depth literature review. Firstly, I looked at what exactly digitalization consisted of and what the scope of a supply chain was in terms of this paper. Afterward, I analysed a case study on PortXchange which allowed for a closer look at the connection between digitalization, the supply chain, and use cases for digitalization within ports/ the maritime sector. To further cement the impact that digitalization has, I then turned to two additional case studies in which different digital software are utilized in ports within Italy. To further expand on the digital trend, I then analyse blockchain technology and several use cases through a review of Tradelens, a Maersk & IBM collaborative project. Additionally, I look at the various types of party logistics providers and further expand on third party logistics providers and their importance, which lays the foundation for the country selection within this research. Lastly, I review the existing literature on the impact of digitalization on international trade and economic growth. This part of the thesis is built upon existing knowledge and allows for a better understanding of the gaps in the current research and literature.

To ensure the validity of the answers to the research question, I employed an econometric model to adequately assess the economic and logistic impact of digitalization throughout the supply chain. Prior to choosing a specific model, I first compared the various types of econometric models available, including such as general equilibrium models (CGE), gravity models, and partial equilibrium trade models (PE) (Chemingui et al., 2018, pp. 8-28). After much consideration of the advantages and disadvantages of each type of model, I decided that a partial-equilibrium (PE) model would be the most suitable due to the simplicity in terms of data input compared to the elaborate information output one gets when using this type of model.

The model I have chosen for this purpose is the Global Simulation Model (GSIM) created by Francois and Hall (2002). Utilizing the GSIM, in particular, will allow for a more in-depth analysis of any changes to net welfare and the various interactions between consumer, producer surplus, and loss or gain of tariff revenue, if applicable.

To ensure that the GSIM is adequately calibrated, trade data for all the countries I have selected will have to be gathered and further refined to only account for the seabourn between the countries interacting within the matrix. Furthermore, a non-tariff measure (NTM) must be applied, which will show the positive impact that digitalization does indeed have on a country's economy. Lastly, this data will be converted to tons utilizing the conversion method based on the study conducted by ECROYS (2015).

1.4 Structure

The aim of chapter two is to establish the foundation of all existing literature on the topic at hand. The literature review covers a broad array of topics and intends to showcase what has and has not been done regarding the analysis of the effect of digitalization. Chapter three is centred around the methodology and aims to guide the readers through the differences in available econometric models and the thought process on my selection of the GSIM trade model. Furthermore, the chapter on methodology discuss the data such as the list of selected countries, how the information for the trade flows was gathered and the conversion method which will discuss the process of converting this data to tons to show the logistic impact of digitalization. Chapter four consists of the various results which I have arrived at and subsequently will provide an analysis on the outcome of this research. This chapter will allow for a more in-depth discussion on the various economic and logistic impacts seen and will allow for the effects to be quantified into hard data. Finally, chapter five consists of the conclusions this research has come to and ties together the main research question alongside the sub-research questions. Furthermore, the final chapter also consists of any limitations and suggestions for further research on this topic.

Chapter 2: Literature review

The second chapter is focused on an in-depth literature review of topics covered in my thesis. It will introduce topics such as digitalization, supply chain, the connection between the two, several case studies on digitalization to provide real-world examples of the use-case of this technology, 3rd party logistics providers, and the impact of digitalization on international trade and economic growth.

2.1 What is digitalization and the scope of the term Supply Chain?

Throughout history, many advancements have taken place intending to improve efficiency and existing systems or make our lives easier. One of the most recent impactful technological trends, digitalization, has shaped how society and firms conduct their daily business. According to Schallmo et al. (2017, p. 2), this increase in digitalization was seen in the early 2000s with the rise of online purchases and, in turn, the increased need for a more efficient supply chain. As technology advances, the very definition of digitalization also changes. Merriam-Webster defines *digitalization* as converting something to a digital form ("Definition of Digitalization," n.d.). However, a literature review conducted by Amorim et al. (2020, p. 6) defines digitalization as transforming analog data into digital language, allowing for improved business relationships between customers and firms while adding value to the economy and society.

Another definition that must be considered is that posed by Hagberg et al. (2016, p. 1); the author's definition is as follows: digitization encompasses many elements of business and everyday life, it is the transformation from analog to digital and the facilitation of new forms of value creation (Amit & Zott, 2001). With these technological advancements comes the ever-increasing pressure for firms and countries alike to utilize these technologies to improve their business and supply chains (Kohli & Melville, 2018, p. 1). Following the implementation of digitization throughout the supply chain, businesses and industries alike have seen significant increases in profitability and productivity.

Prior to further discussion on the literature on digitization in the supply chain, it is essential to establish a clear definition and understanding of what a supply chain is and the scope that the paper will deal with. Lam (2011, p. 366) defines a maritime supply chain as the activities connected to shipping services, including the planning, coordinating, and controlling of containerized cargo from origin to destination. When considering the scope of a supply chain within the rest of this paper, it is essential to note that this paper has adopted Lam's definition. However, to make it more concrete, digitalization throughout the supply chain refers to any part which adds value to the goods and services within the context of ports. Furthermore, as both the complexity of the supply chain and the ever-advancing nature of digitalization increase, the need to implement these technologies within supply chains becomes more apparent.

2.2 The connection between Digitalization and the Supply Chain, Case Study *PortXchange*

The inherent connection between digitalization and the supply chain cannot be understated. The impact of implementing these newfound technologies can be seen through widespread improvements in the efficiencies and agility that firms can see (Suvadarshini & Dandapat, 2022, p. 1). However, the implementation of these technologies comes with issues. In a case study analyzing *the* Port of Rotterdam conducted by Suvadarshini and Dandapat (2022, p. 3) to determine the effects of implementing a digital solution within the context of the port, six key issues were identified when considering whether digitalization could be successfully implemented within a maritime supply chain.

One of the first issues that can be seen is the innate lack of trust due to the sensitive nature of the data needed when digitalizing a supply chain (Suvadarshini & Dandapat, 2022, p. 3). This stems from the very nature of the maritime industry being rather conservative. Another fundamental issue is the need for more understanding of the infrastructure and systems needed to efficiently utilize these technologies (Suvadarshini & Dandapat, 2022, p. 3). Without a proper understanding of basic infrastructure and how to operate these systems, inefficiencies would run rampant and cause more harm than good. Furthermore, another challenge that may arise is the differing goals between organizations and the method of how they would like to achieve these goals (Suvadarshini & Dandapat, 2022, p. 3). When considering the difficulties caused by differing objectives, one must consider the cost associated with implementing these digital technologies and how some firms may be more inclined to implement them as they align with their goals, whereas others may not. Additionally, two points that many firms may face are the need for more existing infrastructure and resources and the lack of standardization within the field of digitalization. Lastly, one difficulty which is currently present is the unwillingness of firms to change current processes (Suvadarshini & Dandapat, 2022, p. 3).

Although the issues faced are daunting, the necessity for firms to implement these digital solutions throughout their supply chain cannot be understated. The case study on the Port of Rotterdam mentioned above is a relevant example of the benefits achieved throughout the supply chain when these technologies are implemented correctly. However, the inefficiencies of port calls and their drastic effects on the initial port call and subsequent ports must also be considered. According to Lind et al. (2019, p. 1), vessels of various types currently spend 60-70% of port time at a berth; only 40-65% is utilized for operations. This inefficiency causes delays and subsequent congestion affecting overall productivity, and the ships affected must also idle, affecting profit-generating capabilities for the firm and country. Ships, in turn, must seam faster to recoup any lost time, reducing the efficiency of the ship and incurring extra fuel costs alongside the increase in CO_2 and NO_x emissions (Suvadarshini & Dandapat, 2022, p. 2).

One solution implemented in the Port of Rotterdam is *PortXchange*, which has digitalized most of the port call operations. The result of implementing this software is as follows, the reduction of ship idle time, the ability for just-in-time (JIT) shipping, improved efficiency, improved accuracy when reporting the Estimated Time of Arrival and Departure, optimization of individual port and shipping line schedule based on real-time data and reduction of congestion (Suvadarshini & Dandapat, 2022, p. 4). However, it is essential to note that these improvements have benefited stakeholders on paper and have had tangible results. According to Suvadarshini and Dandapat (2022, p. 4), an assessment was conducted on 177 ships in the Port of Rotterdam, where it was shown that the average idle time was reduced from 47 to 32 minutes when using the platform *PortXchange*. Furthermore, the Mediterranean Shipping Company (MSc) has also reported an increase in its ship's efficiencies from 91% to 95% (Suvadarshini & Dandapat, 2022, p. 4).

2.3 Case Study of Digitalization within Ports in Italy

To build upon the foundation established thus far and further understand the benefits that digitalization has throughout the supply chain, I will analyze the case studies outlined in the paper "*Digitalization in the sea-land supply chain: Experiences from Italy in rethinking the port operations within inter-organizational relationships."* In this multi-case case study, Di Vaio and Varriale (2019) aimed to analyze the role of digital platforms in the supply chain, like the case mentioned above on the Port of Rotterdam. Analyzing their research will allow me to gain further insight into both the benefits and challenges of digitalization throughout the supply chain.

The first case study introduced is the a case titled *TPCS* , in which the port of Leghorn, Italy, implemented a digital platform with the support of European project funding (Di Vaio & Varriale, 2019, p.1). This platform supports four areas: import, export, national, and community cabotage and customs, enabling ocean carriers and shipping agents alike to automatically obtain data regarding goods, allowing them to complete forms and notices with
ease, whereas previously, both parties had to wait for data to be manually input which is also subjected to human error (Di Vaio & Varriale, 2019, p. 6). Furthermore, the TPCS system allows for the exchange of data and communication between different users within the supply chain, allowing for a simplified workflow and an overall increase in productivity in developing the port traffic (Di Vaio & Varriale, 2019, p. 6). Overall, what can be seen is similar to the Port of Rotterdam case study, where stakeholders throughout the supply chain have benefited from implementing this digitalization.

The second case study introduced is the case titled *GAIA* , in which both the Italian and Greek governments subsidized this digital platform in the port of Levante because of the imminent need to reduce the time and paper used in the information management process among port users (Di Vaio & Varriale, 2019, p. 7). The advantages seen from implementing the *GAIA* system were observed as a tangible reduction in time of management processes, ease of integration of other digital systems, and the increased traceability of traffic flows (Di Vaio & Varriale, 2019, p. 7). According to Di Vaio and Varriale (2019, p. 7), the overall benefits of the *GAIA* system are spread throughout all users of this platform.

Similarly, to the *TPCS* and the case of the Port of Rotterdam, it is apparent that digitalization throughout the supply chain has a positive impact on various users, including an overarching positive economic benefit from the subsequent increase in productivity. As technology continues to advance, the evidence presented by the cases analyzed thus far highlights the importance of digitalization and its overall positive effect on the economy through improvements in productivity on a business-by-business level.

2.4 Benefits of digitalization in international logistics and Blockchain technology

When considering the benefits of digitalization throughout the supply chain, the inherent role international logistics plays must be addressed. This is due to a concept known as globalization. Globalization can be defined as "the increased flow of goods, services, capital, people, and ideas across international boundaries (Cote, 2021). However, it has been argued that the world has turned to regionalization rather than globalization due to rising global geopolitical tensions (Altman, 2023). According to the data gathered by Altman (2023), the growth of global trade flows strongly refutes the claim that the internationalization of trade moved to more domestic activities. Instead, it has become more complex, requiring more collaboration between countries (Altman, 2023).

According to Bardakçi (2020, p. 13), one benefit seen on the international stage is the increase in convenience when transporting goods internationally. This conclusion is further supported by the *TPCS, GAIA*, *and Port of Rotterdam* case mentioned above, in which their finding on the benefits of digitalization independently reaches a similar conclusion. Furthermore, within his research, Bardakçi has also concluded that the need to focus on digitalization is crucial to be competitive in the global market, and by not doing so, a country's global competitiveness is reduced, giving an advantage to those more advanced countries (Bardakçi, 2020, p. 2). The primary aim of this thesis is to conduct an empirical analysis that would further contribute to and confirm the findings that came from the research described above.

Blockchain-based technology is another significant advancement in technology that could further contribute to digitalization throughout the supply chain. Blockchain is a database that virtually records transactions and ownership of assets; the key feature of this technology is the security of data recorded within this database (*IBM*, n.d.). The key security function utilized on the blockchain is the constant recording of all transactions and the inability for any altering of the database once a transaction is added (*What Is Blockchain Technology? - IBM Blockchain* | (*IBM*, n.d.). One use case that could benefit the supply chain and increase productivity is the nearly instantaneous transfer of ownership/data from one party to another.

Furthermore, in a factor analysis and survey conducted by Yang (2019, p. 8), it was found that blockchain technology could alter the way business is conducted within the maritime industry. For example, previously, paperwork and other customs documents, all done by hand, can now be done on a digital platform, enhancing both the speed and the security of cross-border trade (Yang, 2019, p.8). Additionally, Yang (2019, p.8) found that from a managerial perspective, blockchain further advances the underlying technologies utilized in maritime shipping and the accompanying supply chains, digitalizing them, resulting in lower cost, faster transit times, and increased efficiency and predictability. Although Yang's study provides valuable insight into the benefits of blockchain technology and the possible results of digitalization, it is limited by the lack of real data showcasing these findings.

2.5 Tradelens Case Study, the viability of blockchain on a global scale?

To further analyze the practical use of blockchain technology and the overall benefits digitalization has on the supply chain, I will analyze several of the Tradelens case studies. However, before deviling into the use cases of Tradelens, it is essential to know what exactly this platform is. Founded by Maersk and IBM, the Tradelens platform was a blockchain solution with the ultimate goal of digitalizing the global supply chain and ensuring true information and collaboration throughout the maritime industry (TradeLens Core | Data, Documents and Analytics, n.d.). Some key features which Tradelens boasted are real-time data and document sharing, transport insight with data directly from the source, and continuous data improvement ensuring only accurate and complete data was being shared (TradeLens Core | Data, Documents and Analytics, n.d.).

The features mentioned had tangible results; one notable case study by TradeLens was how Puma could increase import efficiency with container release notifications using this platform (Puma, n.d.). First, Puma identified an issue: the lack of automated alerts in their primary port in Bremerhaven, Germany, when containers were available for pickup (Puma, n.d.). This lack of alerts led to Puma's in-house customs department spending nearly 2 hours a day checking the status of these containers either by email, carrier's webpages, or phone calls (Puma, n.d.). These inefficiencies were not only time-consuming but also costly for Puma. After identifying this issue, Puma reached out to Tradelens, who set them up with partner access on Tradelens to the terminal in Bremerhaven, allowing for real-time email notifications when containers were released (Puma, n.d.). Puma immediately realized several benefits, such as increased visibility throughout the supply chain, proactive notifications reducing the risk of detention and demurrage costs, and improved ability in resource planning and internal customer service (Puma, n.d.). This case study conducted by TradeLens showcases the real benefits of the digitalization of the supply chain, whether through blockchain technologies or other more advanced technology currently available.

Another case study conducted by TradeLens on Syngenta, a global agtech company, further showcases the benefits of digitalization and its impact on efficiency at a firm's level. The challenge Syngenta faced is the steep amount of paperwork required to comply with regulations when importing cargo from South Korea into Bangladesh and the fact that it is a manual, paper-based process (Expediting Import Documentation, n.d.). However, using TradeLens, Syngenta could digitalize all documents required in the process and the accompanying workflow, ensuring everything was securely shared with only the relevant parties to the transaction (Expediting Import Documentation, n.d.). The benefits which Syngenta realized validated those seen by Puma above. Syngenta was able to eliminate the risk of demurrage and detention charges, reduce the risk of inventory spikes or delayed cargo; the documentation process was shortened by 10 to 14 days, and an overall increase in productivity, allowing customers to receive their products faster (Expediting Import Documentation, n.d.). This case study further proves the real-life benefits firms can realize when parties throughout the supply chain utilize these digital technologies.

However, blockchain specifically comes with issues, as realized by the study conducted by Yang and TradeLens. According to Yang (2019, p. 8), although blockchain technology has considerable benefits, some limitations include the increased need for coordination between multiple parties, government support, and the rather immature state of this specific technology. Furthermore, the announcement of the closing of TradeLens has also hampered this digital space because many saw the big names behind this platform and were certain it would be there for the long haul (TradeLens | Supply Chain Data and Docs, n.d.). Nevertheless, the significant impact TradeLens has had cannot be understated, and the closing of this platform was not due to a lack of results but rather a lack of global industry collaboration (Hershko, 2023). These cases on blockchain technology are significant for the research presented within this thesis as it highlights the actual effects of digitalization when implemented correctly, the overall effect on a firm-to-firm basis, and ultimately in later chapters, the economic impact on a country level.

2.6 3rd Party Logistic Providers

Another important aspect that must be considered is 3rd party logistic providers (3PL) and their role in the supply chain. Firstly, it is essential to define what a 3PL provider does and the scope in this paper. In a study utilizing theoretical definitions, an analysis of the European 3PL industry, and innovation issues, the following definition of 3PL companies was developed: activities performed by a logistic service provider on behalf of a shipper and at least include transportation (Sweeney & Evangelista, 2005). Furthermore, it is essential to distinguish between the different party logistic providers and how they impact supply chains. First, I look at 1st party logistic providers (1PL), in which the company itself has complete control of the logistics process from start to end-user, including the crewing and equipment needed to handle in-house logistics (Party Logistics, n.d.). 2nd party logistic providers (2PL) is where a company would hire a separate carrier rather than handle the carriage of goods themselves, thus allowing for economies of scale (Party Logistics, n.d.). 3PL is outsourcing most of the logistics to a contracted provider who further offers additional services throughout various parts of the supply chain (Party Logistics, n.d.). When discussing party logistics, it is worth noting that this paper refers to 3PL more specifically within the context of the maritime industry.

Digitalization and third-party logistics performance: Exploring the roles of customer collaboration and government support by Zhou et al. (2023) further solidifies digitalization's impact on 3PL providers and, subsequently, the supply chain. Within this paper, the authors conducted an empirical analysis of the results of survey data conducted on 235 3PL firms within China (Zhou et al., 2023, p. 1). As evidenced in previous case studies in this thesis, the benefits of digitizing the supply chain cannot be understated. However, Zhou et al. (2023, p. 4) further elaborate on them, stating that this decrease of information uncertainty throughout the supply chain, thus helping information processing in uncertain environments. Additionally, digitalization allows for a more transparent supply chain and a new way to identify bottlenecks (Zhou et al., 2023, p. 5). Furthermore, through this added transparency, these 3PL companies can identify changes in customer demand, allowing them to shift their resources to meet their needs better and ultimately achieve better service and financial performance (Zhou et al., 2023, p. 7). Zhou et al. (2023, p. 16) conclude their findings by stating that through survey data, digitalization does indeed have a positive effect on 3PL performance; when 3PL providers have increased customer collaboration, both financial and service performance are boosted, and investments in digitalization provide a competitive advantage for these 3PL providers. This section is vital to my thesis as it demonstrates the importance of 3PL providers and their impact on the supply chain and, subsequently, the financial performance of firms.

2.7 Impact of Digitalization on International Trade and economic growth

Another important aspect of this thesis is digitalization's impact on international trade and, subsequently, the economy. According to Robinson et al. (2023), international trade can be defined as the transfer of goods, capital, and services between countries. Furthermore, it is important to note that economic growth will be gauged by the increase in *Gross Domestic Product (*GDP). GPD is the final market value of all goods and services produced within a country (Taylor & Mankiw, 2017).

In a studying conducted by Salahuddin et al. (2015, p. 8) using an autoregressive distributed log (ARDL), it was found that there is a significant correlation between internet use, financial development, and economic growth in the long run. The paper "*The Impact of Digitalization and Trade Openness on Economic Growth: New Evidence from Richest Asian Countries*" by Bakari et al. (2022) further builds on this correlation by providing empirical data proving a correlation between the abovementioned factors. Within this paper, Bakari et al. (2022, p. 7) utilize both a static gravity model and a random-effect gravity model to determine several factors' effects on economic growth. It is important to note that within their study, the results of the random-effect gravity model were retained as the model showed to be more robust after testing (Bakari et al., 2022, p. 8). The factor of primary focus which I will consider is the percentage effect digitalization has on economic growth. According to Bakari et al. (2022, p. 8), it was found that a 1% increase in digitalization results in a 0.013093% increase in economic growth. The results of their analysis are crucial for this thesis as they provide hard data on the actual effects of digitalization on the economy.

Another piece of literature that further substantiates the role digitization has on international trade and economic growth is "*International Trade and economic growth in Africa: The Role of the digital economy*" by Abendin and Duan (2021). Within this paper, the authors focus on digitalization's role and its effects on Africa. This is done as an empirical estimation strategy to determine the significance levels of digitalization in influencing international trade and, subsequently, economic growth in Africa (Abendin & Duan, 2021, p. 7). According to Abendin and Duan (2021), the findings show that digitalization is, in fact, beneficial for the African economy, having a positive and significant impact on economic growth (Abendin & Duan, 2021, p. 14). Furthermore, it was also found that trade alone leads to a decrease in economic growth in Africa; however, trade was found to have a positive and significant impact on economic growth when paired with digitalization (Abendin & Duan, 2021, p. 15).

Additionally, the authors found that digitalization's influences on trade led to positive economic growth in Africa by 0.0490% and 0.0473% for the random and fixed model effects, respectively (Abendin & Duan, 2021, p. 17). This study is significant for this thesis because it shows digitalization's differing effects on different economies. We can see from the Bakari et al. (2022) paper that within the subset of the *Richest Asian Countries*, digitalization leads to positive economic growth of 0.013093%. In contrast, the paper by Aberdeen and Duan (2021) showcases a slightly larger positive economic growth of 0.0490% in Africa, where digitalization is not fully matured yet. The research within this thesis plans to fill the gaps and analyze the effects of digitalization throughout the supply chain in various countries I have selected.

2.8 Government's role in Digitalization

Another consideration that must be made is whether governments subsidize and are in favour of digitalization. Through digitalizing various sectors, these government agencies can better provide services for citizens and businesses alike regardless of any budget restraints faced or other complex challenges which may arise (Corydon et al., 2016, p. 3). Within this part of the literature review, I will discuss various examples of governments and their respective investments in digitalizing their economies. However, it is important to differentiate that these investments do not correspond with digitalization within the supply chain. Instead, this section is used to showcase the various government stances on this matter.

According to Corydon et al. (2016, p. 5), to ensure better relations between a government and its citizens and businesses within the respective country, they should first digitize services which would significantly increase satisfaction, generating support for further digitalization. One instance of this highlighted within the McKinsey article is an initiative set forth by the United Kingdom in which they digitalized 25 fundamental services to garner support for future projects further (Corydon et al., 2016, p. 5). Another relevant example is Singapore's investment in digital sign-on systems allowing residents to access services from over 60 agencies (Corydon et al., 2016, p. 5). These various examples display the differing levels of digital investments countries make depending on the needs of their citizens and businesses.

An important aspect of the government's role in digitalization is the facilitation of digital transformation through the use of subsidies. Utilizing subsidies can allow various sectors which previously may not have been able to implement these digital technologies implement them and thus gain a competitive advantage. Furthermore, one must consider the effects that companies using digital technologies have on the overall economy of a country due to the increased efficiency and, subsequently, revenue generated which contributes to the GDP of the respective country.

One case study conducted by Zhao et al. (2023) utilizes an empirical analysis to determine the incentive effects that subsidies have on the digitalization of manufacturing companies in China. To date the Chinese government has passed several attractive tax policies alongside government subsidies which allow them to effectively incentivize companies to digitally transform and implement these technologies (Zhao et al., 2023, P. 2). Within this study it was found that government subsidies could indeed encourage digitalization through special subsidies specifically for private firms which allows for a lessened pressure regarding funding and other elements (Zhao et al., 2023, P. 16). Furthermore, through conducting a heterogeneity analysis on various enterprises on various factors such as age, scale and ownership were able to analyse these variables and the effect and subsequently the significance of digitalization on each of them respectively (Zhao et al., 2023, P. 12). It was found that the positive impact of subsidies on digitalization is more significant for private firms, have a larger production scale, established earlier and located in developed areas (Zhao et al., 2023, P. 16).

However, two policy recommendations by Zhao et al. (2023, p. 17) showcase the need for more extensive policies to encourage digitalization further. One suggestion was to create an evaluation system that would allow for analysis of the level of innovation of these firms and grant these subsidies to firms that meet a certain level, thus maximizing the utilization of these grants (Zhao et al., 2023, P. 17). Additionally, the authors recommend that governments use these subsidies as a tool which would strengthen the digital landscape (Zhao et al., 2023, P. 17). Furthermore, this tool would allow governments relieve financial constraints faced by these firms while ensuring they can further digitalize their processes (Zhao et al., 2023, P. 17).

This section is vital to my research as it shows the role the government can play in digitalization throughout the supply chain. I consider this when creating scenario two, which will be discussed in Chapter 3. The following section will discuss whether or not foreign direct investment (FDI) is viable in the various sectors.

2.9 Foreign Direct Investment or Private Investment and Geopolitics

Amidst the ever-changing dynamic of geo-politics, it is important to consider the changing relationship between the various governments around the globe. Although in a perfect world, the most effective thing to do would be to ensure that all supply chains are optimized and fully digitalized. The reality is that direct investments in other countries' digital sectors can be seen as a risk to national security, depending on the evolving nature of different countries' relationships. This section assesses whether allowing FDI in other countries' technological sectors is viable.

Recently in a move anticipated by many, United States President Joe Biden restricted private equity and venture capitalist from investing in Chinese firms in three specific sectors semiconductors, quantum information technologies, and artificial intelligence (Freifeld et al., 2023). This ban aims to protect the national security interests of the US by preventing the advancement of the Chinese military rise. It aims to ensure that the US's domestic industry thrives (Freifeld et al., 2023). Although this thesis does not focus on semiconductors or the military aspect of digital technology precisely, these recent developments show the hesitancy of FDI in specific sectors due to the various uses for different digital technologies and the reality that there are various other factors to consider when looking considering the government's stance on FDI in the digital technology space.

Following this move by the US, the European Commission has also stated that they will further analyze the ban on investments in China as it is important for the European Union's (EU) own economic security (Chee, 2023). The EU plans to limit exports and the overall outflow of technologies that could be used for nefarious reasons by China in direct response to the US FDI ban (Chee, 2023). This reactionary response perfectly showcases the changing dynamic of geo-politics, which must be considered when creating scenarios for the GSIM. However, this is not to say that global FDI is not crucial to port infrastructure and other aspects of the global network which make up the maritime industry.

According to the United Nations Conference on Trade and Development (UNCTAD, 2022), global FDI inflow has risen 64% in 2021 to a staggering US$1.6 trillion. Furthermore, FDI inflow to developed countries has more than doubled to 133%, and the outflow of FDI from developed economies has more than tripled (UNCTAD, 2022). When considering the maritime industry, we must take into account the vast network of ports and infrastructure needed to ensure efficient operations and that, more often than not, these large maritime operators such as Maersk, CMA, and MSC are the ones who are contributing through FDI to ensure these infrastructures are indeed sufficient for their operations. Although my thesis does not do a deep dive into FDI or private investments, they are worth taking a look at as they are still a crucial point that might be developed and research further in future studies. The next section aims to highlight maritime operators' various investments and innovations in digitalization.

2.10 Maritime Operators investments in Digitalization

Another important aspect that is considered throughout this research is the importance of maritime operators and their investments in digitalization. As seen in previous sections, these investments are made in many ways, from software/platforms like *PortXchange* and *Tradelens.* The main objective of this section is to showcase the various investments made by different maritime operators and how these strategic decisions allow for increased efficiency and visibility throughout the supply chain. To achieve this, I will analyze the different digital solutions the top 3 leading maritime operators provide according to alpha liners public top 100 list (*PublicTop100*, n.d.).

The first industry player which I will analyze is considered a household by many, Maersk. Being at the forefront of innovation, this company often sets the standard as to the industry norm. Offering a wide array of digital solutions, Maersk has tailored its online services to ensure that customers and the entire shipping process are as streamlined as possible. Some of the solutions offered are as follows:

Data Integration: Maersk data integration allows for merging data from multiple sources across the supply chain, increasing efficiencies and visibility (Data Integrations, n.d.). Furthermore, through this integration and subsequent automation of data flows, the risk of errors is decreased, and a further reduction of costs is achieved (Data Integrations, n.d.).

Maersk App: The app developed by Maersk allows for updates in real-time on any delay’s pickup notifications or changes in cargo shipped with the company (Maersk App, n.d.). The ability for customers to be more readily notified of these changes in shipment status allows for a quicker turnaround time in port and subsequently increased efficiency on behalf of both Maersk, ports, and customers alike. Another notable feature of the app is the ability to see all relevant documentation for shipments in app, further streamlining the shipping process (Maersk App, n.d.).

Maersk Logistics Hub: Through the logistics hub, Maersk offers predictive analysis powered by artificial intelligence (AI), allowing for an estimated time of arrivals (ETA), vessel tracking, and several other options (Maersk Logistics Hub, n.d.). The predictive ETA system is calculated through historical information and GPS location, allowing for 45% to 60% more accurate reported time of arrivals (Maersk Logistics Hub, n.d.). Furthermore, the vessel tracking option is powered by live geo-locations on maps and allows for tracking ships in real-time with each vessel's route and subsequent destination (Maersk Logistics Hub, n.d.).

The next maritime giant I will cover has played an equally important role in the Mediterranean Shipping Company (MSC) digitalization. Currently ranked as the largest global container shipping company, it boasts a tremendous 5,209,989 TEU capacity, accounting for 19% of the global container capacity (PublicTop100, n.d.). Similar to Maersk, MSC offers a variety of digital solutions, which are as follows:

Direct Integrations: MSC offers the ability to directly integrate multiple sources of shipping data allowing for increased efficiency while reducing the risk of error (EDI And API Shipment Management - Digital Solutions | MSC, n.d.). A case study conducted on Flexport, a long-time partner of MSC, found that by utilizing this direct integration, multiple users throughout the supply chain benefited (Msc, 2022). According to MSC (2022), the streamlining of data paired with real-time shipping updates has allowed the customers shared between the companies to benefit from a less complex process overall, increasing efficiency and decreasing the strain on the customer service part of the supply chain.

MSC electronic bill of lading (eBL): MSC offers the eBL, historically a document transferred by hand and often takes weeks to receive. This digital innovation, also seen on Tradelens, offers several benefits (Electronic Bill of Lading (eBL) - Simple Digital Solutions | MSC, n.d.). The most notable draw is the increased efficiency and, subsequently, the cost saved by implementing this eBL. Through the digitalization of this process, the current workflow is effectively streamlined without disrupting the status quo of other equally essential workflows (Electronic Bill of Lading (eBL) - Simple Digital Solutions | MSC, n.d.). Furthermore, it allows quicker payment times due to a prompter receipt of the eBL (Electronic Bill of Lading (eBL) - Simple Digital Solutions | MSC, n.d.). Lastly, the reduction in administrative workload and the complete removal of all courier fees not only saves costs but also ensures the parties can safely and securely exchange data using MSC's blockchain platform (Electronic Bill of Lading (eBL) - Simple Digital Solutions | MSC, n.d.).

Smart Containers: Another digital solution offered by MSC is the ability to trace your shipment remotely individually and all associated information, such as door status, temperature, and position, allowing for increased visibility and subsequently streamlining the decision-making process associated with shipping (Smart Containers - Track & Monitor Shipments Remotely | MSC, n.d.). Paired with this offering is the ability to receive personalized alerts notifying the respective parties through the supply chain in the event of delays during transit and delivery timing (Smart Containers - Track & Monitor Shipments Remotely | MSC, n.d.). Utilizing this data allows for customers to reduce operating costs overall and share important information to all relevant parties (Smart Containers - Track & Monitor Shipments Remotely | MSC, n.d.).

CMA-CGM is another prominent player in the maritime industry, contributing significantly to the digital landscape. Following the digital trend that has taken the shipping industry and the globe by storm, CMA, like many other maritime operators, has invested significantly to ensure a streamlined process for all parties involved. To ensure the process is as efficient for end-users as possible CMA-CGM has complied their digital solutions all into a mobile app which has several functions.

Mobile App: The key functionalities offered through this app is the ability to see all relevant import and export documents and digitalizes the BL completely allowing for any correction to be made to those documents when applicable (CMA CGM | My CMA CGM, n.d.). Additionally, this app allows users to track shipments in real time and gives a centralized view of all relevant information regarding an individual shipment (CMA CGM | My CMA CGM, n.d.). Using this information, parties throughout the supply chain benefit from enhanced visibility and decreased delays. Information can be corrected in real-time and subsequently streamlined to any relevant parties through CMA-CGM's platform (CMA CGM | My CMA CGM, n.d.).

This section provides an overview of the different functionalities of the digital landscape the top three maritime operators have created and allows for a deeper understanding of digitization's benefits on the maritime industry. Furthermore, it showcases the collective effort of these key maritime players to improve operational efficiency, increase supply chain visibility, and allow for smoother interactions among relevant parties. This section is vital to my research as the maritime industry plays a significant role in transporting goods. The creation of the non-tariff measure seen in the upcoming methodological section is based upon the benefits realized in the maritime aspect of the supply chain.

Chapter 3: Methodology

The third chapter will discuss the various options I have considered when choosing which econometric model to use. To ensure that a robust model was chosen I will discuss the different models currently available alongside the advantages and disadvantages of each of them. Furthermore, the aim is bridging the gap between the theoretical concepts and empirical research covered in the literature review and will allow me to lay the foundation for the subsequent chapter on results and analysis of the data. Lastly, the methodology section aims to provide instill confidence in the readers that the correct model and proper steps were indeed followed.

3.1 Various Econometric Models

Before selecting the appropriate econometric model, it is essential to understand the various available models to ensure that the chosen model is optimal for this research. This research aims to convey the various changes to net welfare prompted by a positive change in nontariff measures resulting from digitalization throughout the supply chain in several countries. These welfare effects are showcased through changes *in Consumer Surplus, Producer Surplus, Tariff Revenue, National Welfare,* and *World Welfare* (Chemingui et al., 2018, p. 6). The econometric models available which I have considered are as follows: computable general equilibrium models (CGE), gravity models, and partial equilibrium trade models (PE) (Chemingui et al., 2018, pp. 8-28).

CGE models are based upon an ex-ante approach, meaning quantifying the implications of a new policy (Chemingui et al., 2018, p. 26). These models are based on computer simulation and output data allowing users to explore how different sectors interact within a single economy, the interlinking of different economies, and how resources are best allocated to optimize economic activities (Chemingui et al., 2018, p. 26). CGE models are typically utilized to analyze the full impact of trade policy changes on a larger scale by implementing databases with a proven theoretical foundation (Chemingui et al., 2018, p. 26). Furthermore, the ability to quantify the true macroeconomic and environmental effects of these trade policies has popularized CGE models (Chemingui et al., 2018, p. 26). Although the complexity of the CGE model is what popularized it, the time needed to adequately set up, calibrate and properly quantify these macro-economic changes is why it is unsuitable for this research due to time constraints.

According to Chemingui et al. (2018, p. 28), in applied trade analysis, the gravity model has become a fundamental econometric tool necessary to analyze several economic outputs adequately. More specifically, the gravity model analyzes bilateral trade flows between two countries. This model states that the country's GDP represents the trade flow between two countries and is inversely related to the distance between the two, a substitute for transportation costs (Chemingui et al., 2018, p. 28). Furthermore, the gravity model also considers various variables, including "common language, colonial links, contiguity, monetary and trade agreements" (Chemingui et al., 2018, p. 28). Considering the different factors the gravity model accounts for, and its status within the applied trade analysis community, it is a high-quality model that must be considered for this research. However, similar to the CGE model mentioned above, the complexity of this model and the time required to set up and calibrate it adequately makes it unsuitable for this thesis.

Lastly, we arrive at the partial equilibrium trade model, also referred to as the homogenous product model. Contrary to the other trade model presented thus far, the PE trade model only considers the effects of a given policy in the markets directly affected and is built upon the assumption of "Ceteris Paribus" (Rationale for Partial Equilibrium Modeling, n.d.). Furthermore, the analysis does not consider the different markets at play in these differing economies (Rationale for Partial Equilibrium Modeling, n.d.). While some may consider the limited perspective a disadvantage, it will enable a more detailed analysis (Rationale for Partial Equilibrium Modeling, n.d.). An additional advantage to using a PE trade model is the minimal data requirements compared to the other models proposed above (Rationale for Partial Equilibrium Modeling, n.d.). Furthermore, this minimal data requirement is advantageous due to the time constraints faced while devising this thesis.

Although each econometric model has its advantages and disadvantages and allows for a different type of analysis, I believe the PE trade model will suit this thesis best. The reasoning for this decision is that a PE model will better allow me to showcase the actual effects of digitalization throughout the supply chain on a country's net welfare. This is because PE models do not reflect the various markets at work in these economies. Furthermore, I believe a PE model is the most suitable for this thesis as it more closely adheres to the schedule and time restraints faced when gathering data and ultimately calibrating/running the chosen model. More specifically, to answer my research question, "***What is the economic and logistic impact of countries investing in digitalization throughout the supply chain"*** I will utilize the PE trade model – *The Global Simulation Model* (GSIM).

3.2 The Global Simulation Model: GSIM

Developed by Francois and Hall (2003, p. 2), the GSIM is a PE trade model to simulate global, regional, and unilateral trade policy changes and be innately industry-focused but global in scale. Furthermore, it is noted that by utilizing the GSIM model, one may derive the interactions between trading partners, consumer surplus, exporter gain, importer gain, and any changes in tariff revenue if applicable (Francois & Hall, 2003, p. 2). Additionally, it is essential to understand the different assumptions at play when using the GSIM. Firstly, it is assumed that there is national product differentiation meaning imports are indeed imperfect substitutes for each other (Francois & Hall, 2003, p. 3). This assumption is important because it means that the goods in the model still fulfill the same needs of the customers. Additionally, Francois and Hall (2003, p. 3) assume that aggregate demand elasticities are constant. Lastly, import supply within the model is classified by supply elasticities (Francois & Hall, 2003, p. 3). Prior to discussing data and, subsequently, the results, it is crucial to discuss the specifics of the GSIM to gain a better understanding of how I arrived at the results presented.

Perhaps one of the most important aspects of the GSIM model is the elasticities to being. The primary assumption that Francois and Hall (2003, p. 3) make is that within each importing country *v*, import demand in category *I* of goods from country *r* is a function of industry prices and total costs on the category. The first equation introduced to us is as follows (Francois & Hall, 2003, p. 5):

$$(1)\ M(i,v),r = f\ (P(i,v),r\ ,P(i,v),s\neq r\ ,y(i,v))$$

- $y(i,v)$ = Total expenditure on imports of *i* in country *v*
- $P(i,v),r$ = Internal price for goods from region *r* within country *v*
- $\mathbf{P}(i,v),\ s \neq r$ = Price of other varieties

Next, we are given the equations for national demand and supply, which are as follows:

$$(2)\ P(i,v),r = (1+t(i,v),r\ )Pi,r\ ^{*}= T(i,v),r\ Pi,r\ ^{*}$$

- ***P****(i,v),r* = Internal price for the same goods
- ***P****i,r** = Export price received by exporter *r* on world markets
- **T =** 1 + t signifies the power of the tariff
- t(i,v), r = proportional markup achieved by the tariff

$$(3)\ Xi,r = f\ (Pi,r^{*})$$

- X*i,r* = Country X's exports to industry *i*
- P*i,r** = Export price received by exporter r on world markets

Now we move on to the equations for two different types of elasticities utilized to calibrate the GSIM model (Francois & Hall, 2003, p. 11). Equation 4 below showcases the aggregate import demand elasticity.

$$(4)\qquad \frac{\partial M_{(i,v)}}{\partial P_{(i,v)}} \cdot \frac{P_{(i,v)}}{M_{(i,v)}}$$

- M(i,v) = Aggregate imports
- P(i,v) = Composite price

Now we look at equation 5, which represents the elasticity of export supply.

$$(5)\qquad \frac{\partial X_{(i,r)}}{\partial P_{(i,r)}{}^{*}} \frac{P_{(i,r)}{}^{*}}{X_{(i,r)}}$$

Furthermore, Francois and Hall (2003, p. 8) introduce the equations for both producer and consumer surplus. Equation 6 below showcases producer surplus, which is calculated through the approximate change in the area between the export supply curve and the price line (Francois & Hall, 2003, p. 8).

$$(6)\ \Delta PS = R0(i,r) * \frac{1}{2} * R^0(i,r,) * \hat{P}i,r,* \hat{X}i,r$$

- R^0 (i,r) = Denotes the benchmark export revenue valued at world prices (Francois & Hall, 2003, p. 8).

Francois and Hall (2003, p. 9) now introduce the equation which represents the consumer surplus. This is represented by equation 7 below and can be defined as the change in the area between the demand curve for the composite good and good price (Francois & Hall, 2003, p. 8).

(7)

$$\Delta CS_{(i,v)} = \left(\sum_r R^0{}_{(i,v),r} \cdot T^0{}_{(i,v),r} \right) \cdot \left(\frac{1}{2} E_{M,(i,v)} \hat{P}_{(i,v)}{}^2 \cdot sign(\hat{P}_{(i,v)}) - \hat{P}_{(i,v)} \right)$$
$$where\ \hat{P}_{(i,v)} = \sum_r \theta_{(i,v),r} \hat{P}_r * + \hat{T}_{(i,v),r}$$

Two final equations, which also play a crucial part in the inner works of the GSIM, are shown in equations 8 and 9, respectively. Equation 8 is the calculation for the demand expenditure share at internal prices, whereas equation 9 is for export quantity shares (Francois & Hall, 2002, p. 11).

(8)
$$\theta_{(i,v),r} = \bar{M}_{(i,v),r} T_{(i,v),r} / \sum M_{(i,v),s} T_{(i,v),s}$$

(9)
$$\phi_{(i,v),r} = M_{(i,v),r} / \sum_w M_{(i,w),r}$$

Now that the inner workings of the GSIM have been discussed I will move on to the conversion method which allows me to quanitfy the true effects in terms of seabourn trade.

3.3 Conversion Method

To determine digitalization's impact on all sea-borne trade between the specified countries within the GSIM matrix, I will employ a quantitative approach to convert the change in the bilateral trade values from millions of USD into TEUS and tonnage. I have decided to utilize the conversion method because it is vital to quantify the impact digitalization has on the maritime industry because of its significant role on world trade. Furthermore, converting these trade values into tonnage and containers is vital as digitalization is a trend that can drastically increase port efficiency, as seen in the case study on PortXchange.

As described above, the conversion method is based on a study conducted by ECORYS (2015). With this study, the author aimed to investigate the impact of the Canada-EU Trade Agreement on the Port of St. John (ECORYS, 2015). Utilizing the GSIM, the authors created a trade matrix and formulated equations allowing them to convert the final values into bulk tonnages and containers (ECORYS, 2015). The formulas below display the method used in Chapter 4 to alter the final trade values at which I arrived.

Equation 10 allows me to convert the total tonnage transported in the seaborne trade. To calculate the average unit price per ton for a range of commodities, I looked at the Excel database of primary commodity prices provided by the *International Monetary Fund*. To ensure accurate results, I first took the median commodity price for all items listed for each month of 2022. Then I took the average unit price per ton throughout 2022, giving me USD 247.78 (*IMF Primary Commodity Prices*, 2021).

(10) $\frac{Change\ in\ Bilateral\ trade\ value}{Average\ unit\ price\ per\ ton} = Total\ tonnage\ transported\ by\ sea$

Equation 11 calculates the amount of containerized cargo in tons. In order to assess the degree of containerization I looked at Clarkson Shipping Review and Outlook to assess the degree of containerization. According to Clarkson (2023, p. 13), the total seaborne trade in metric tons (mt) in 2022 was 11,920. To get the degree of containerization, I utilize the Clarksons table to calculate the percentage each sector makes up of total seaborne trade. It is as follows: dry bulk 5,270 mt (44.21%), oil 3006 mt (25.22%), gas 532 mt (4.46%), chemical 369 mt (3.10%), container 1806 mt

(15.15%) and other dry 938 mt (7.87%) ("Shipping Review & Outlook," 2023, p. 13). From this data, the degree of containerization used in the conversion method is 15.15%.

(11) $Degree\ of\ containerisation\ x\ Total\ tonnage\ transported\ by\ sea = Containerized\ cargo$

Equation 12 converts containerized cargo in to TEUS.

(12) $\frac{Containerized\ cargo\ (in\ tons)}{Average\ tonnage\ per\ TEU} = Containerized\ cargo\ in\ TEU$

Lastly, equation 13 allows me to calculate the amount of bulk cargo in tons.

(13) $Total\ tonnage\ transported\ in\ seaborne\ trade - Containrized\ cargo = Bulk\ Cargo$

In the upcoming section, I will provide a comprehensive explanation which will elaborate on the methodology used to select the countries which are incorporated in the GSIM trade model.

3.4 Country Selection

The most fundamental aspect of the GSIM trade model is country selection, as it allows the user to conduct an in-depth analysis of the countries of choice. When contemplating which countries should be chosen, I considered two main aspects: the largest maritime operators and their global network/infrastructure location. These aspects are crucial to ensuring that this research stays true to its primary objective of quantifying digitalization's economic and logistics benefits throughout the supply chain. The flow of goods traded by sea is directly correlated with shipping companies, the location of their infrastructure, and, ultimately, digitalization's impact on supply chain efficiency in these countries. By considering both these aspects, I can ensure that the research is comprehensive and accurate in assessing digitalization's effects on the supply chain.

The first step to mapping out the country selection was to identify the top container and liner operators, including containerized vessels, breakbulk services, and other multipurpose cargo vessels. To ensure an unbiased, accurate, and thorough list of these operators, ranked by their percentage share of the world fleet, I utilized a list created by *Alphaliner*, which covers the top 100 operators in the world listed by TEU capacity and includes all these various types of vessels (*Top 100*, n.d.). Furthermore, it is essential to note that in the case of multipurpose vessels, reefers, roros, conbulkers, or barge carriers, A*lphaliner* calculates the TEU capacity while also taking into consideration that this cargo capacity can be used for non-containerized cargo (*Top 100*, n.d.). Additionally, before looking at the top 100 list, it is essential to note that Al*phaliner* has consolidated subsidiaries of larger companies, as seen in *Figure a* in *appendix I* allowing for a more accurate representation of the true size of the larger market players (*Top 100*, n.d.).

To ensure that the methodological approach used to select these countries was indeed rigorous I intended to capture the most market share of the world's fleet. To accomplish this, I first exported the top 100 maritime operators as seen in *Figure b* in *Appendix II* into excel and calculated the total TEU capacity of the listed vessels and from that was able to derive the percentage share of each of the companies listed. The results from this analysis and subsequently the top 16 maritime operators by share can be seen in *Figure c* below and accounts for approximately 90.430% of TEU capacity globally. However, when compiling the location of the maritime operators listed below it is important to note that *IRISL Group* was not considered as at the time of gathering data there was no publicly available site or data on its global locations. However, to ensure that the largest market share was indeed captured I instead gathered the location of the facilities for the company *X-Press Feeders Group*. It is worth noting that the percentage difference in world market share when comparing the

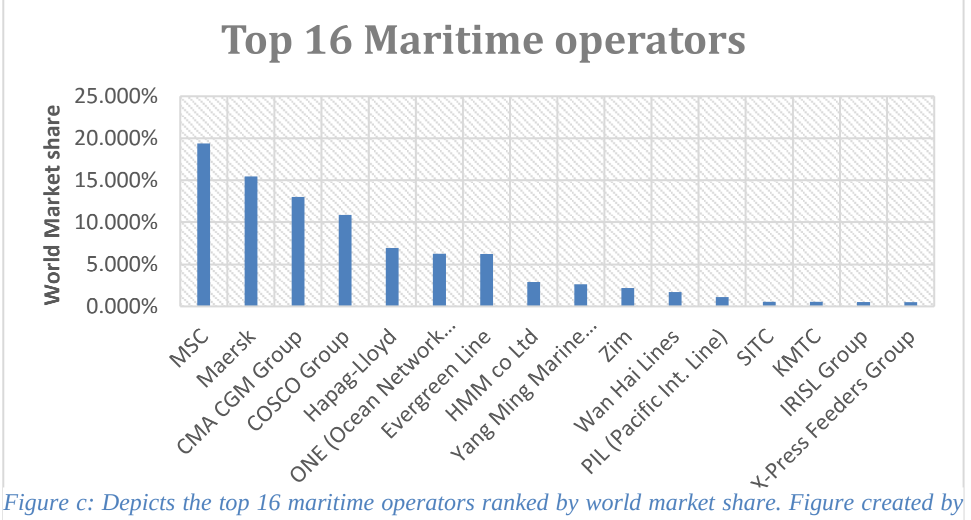


Figure c: Depicts the top 16 maritime operators ranked by world market share. Figure created by authore based on data from alphaliner.

two companies listed above is statistically insignificant, coming in at only a 0.015% difference.

The exact percentage of each companies' world market share and the TEU capacity can be seen in *table 1* below.

Company	TEU	Market Share
MSC	5,209,989.00	19.362%
Maersk	4,149,918.00	15.422%
CMA CGM Group	3,511,846.00	13.051%
COSCO Group	2,955,867.00	10.985%
Hapag-Lloyd	1,884,159.00	7.002%
ONE (Ocean Network Express)	1,681,897.00	6.250%
Evergreen Line	1,673,600.00	6.220%
HMM co Ltd	792,074.00	2.944%
Yang Ming Marine Transport Corp.	705,614.00	2.622%
Zim	578,633.00	2.150%
Wan Hai Lines	453,324.00	1.685%
PIL (Pacific Int. Line)	295,331.00	1.098%
SITC	156,231.00	0.581%
KMTC	153,261.00	0.570%
IRISL Group	137,604.00	0.511%
X-Press Feeders Group	135,517.00	0.504%
Total:	**24,474,865**	**90.956%**

Table 1 Depicts the TEU capacity alongside the market share in percentage of the top 16 maritime operators globally. Created by the author.

Based on data from: https://alphaliner.axsmarine.com/PublicTop100/

After collecting data on the top shipping companies and their global networks, I needed to accurately map the countries where each company has a significant presence. To ensure that I considered the totality of each company's global network, I consulted their respective global websites, which contained the locations of all relevant facilities. Furthermore, the first assumption of this research is that these facilities serve as digitalization hubs. To ensure each company was accurately represented, I counted all locations mentioned on each website, including ports of call, offices, agents, and miscellaneous facilities. This approach allowed me to create a comprehensive picture of each company's global reach. The results of this analysis are presented in *Appendix* III-V *Figure d-h*, which shows the top 12 countries where each of the top 15 shipping companies has facilities, followed by the percentage total of all their facilities located in the specific country. From this information, I selected the top 10 countries with the most facilities between all companies mentioned previously.

Furthermore, some exceptions were made in the selection of countries, and a group called Laggers was formed, which will be further explained in the following paragraph. This information is the foundation for the GSIM trade matrix used in this research.

The finalized country matrix can be seen in Appendix VI *Figure I* and includes the countries: China, India, Indonesia, Malaysia, Brazil, Spain, United States, Japan, Italy, Egypt, Singapore, Netherlands, Laggers, and Rest of World (ROW). It is worth noting that although both Singapore and the Netherlands have not made the top 10 countries with the most facilities, they were included in the matrix because of their front-runner stance on digitalization. Furthermore, the Laggers include Canada, the United Kingdom, and France and ROW is the rest of the world. Additionally, it is essential to note that these countries *Laggers* were solely selected based on the criteria listed above: the total number of facilities in each country. Furthermore, the results impacting ROW are insignificant as this research aims to analyse the impact on the countries mentioned explicitly within the GSIM. The following section will detail how the trade data was gathered and the methodology used to ensure only seaborne trade was represented.

3.5 Trade Data

After the country matrix was finalized, the next step was to populate the GSIM with trade data. More specifically, it will be populated with the trade data corresponding to the trade flow between the respective countries, which interact in the given cell in the matrix. To ensure accurate and reliable data, I utilized the UN Comtrade database for all trade data presented thus forth before diving into how I converted the raw trade data from solely export values to representing solely seaborne trade between the countries within the matrix. Furthermore, it is essential to emphasise that all commodities were used as I am looking at the total value for trade rather than specific HS codes Lastly, before presenting the finalized matrix populated with the adjusted trade values, it is important to discuss how the data was gathered and converted.

The first step in gathering all the relevant data was to adjust the filter of the UN Comtrade Database to ensure that only all countries would be shown as the reporters, the partner would be ROW, and the trade flow would show solely export data. The logic behind showing the global trade flows for exports was that once exported to excel, I could apply filters to ensure only the relevant country's data would be shown. Furthermore, when completing the ROW interactions, having all relevant trade data was advantageous to showcase the actual trade flows.

However, due to missing trade data, the second assumption of this research is that 2019 data would be used in place of missing 2022 information and still allow for an accurate and reliable analysis. The reasoning behind this critical assumption is that 2021 trade flows were impacted by covid, thus not representing the full potential of a country's trade. To be more specific, 2019 trade data was used for the following countries: Indonesia, Malaysia, and Laggers. Additionally, intercountry trade, such as China to China, was not considered for this research, only the bilateral trade flows hence the values of 0 for flows between the same country except in the instance of ROW and ROW. The trade matrix before the conversion of only seaborne trade can be seen in *Appendix VI, Figure j*.

After aggregating all relevant trade flows and ensuring they consisted of the export values only, I converted the matrix to represent solely seaborne trade. With ships delivering over 80% of world trade, accurately representing this within my research is essential (Review of Maritime Transport 2022, n.d.). To accomplish this, we come to the third assumption my research was based upon; that the value of seaborne trade between countries currently sits between 70-90% depending on if they are connected by land borders, accounting for the overall distance between the countries interacting with each other. The matrix containing the percentage of seaborne trade between the two interacting countries can be seen in *Appendix VII Figure k*.

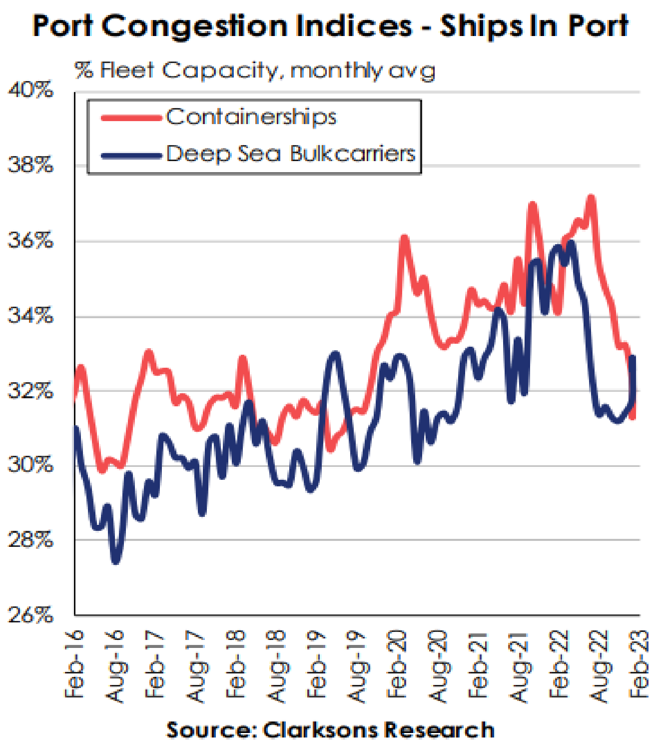
The final step in completing the trade matrix was ensuring that only the portion of trade between two countries transported by sea remained. To accomplish this, I took the trade matrix before conversion as seen in Appendix VII, Figure j. I multiplied those values by the respective percentage in the matrix shown in *Appendix VI, Figure k* The results produce the finalized trade matrix with only seaborne trade being represented. This finalized matrix which will be utilized in the GSIM, can be seen in *Appendix VII Figure l*. The following section will discuss the non-tariff measure I created, which will simulate the positive shock of digitalization in the supply chain, specifically at ports.

3.6 NTM Creation

The most vital aspect of the GSIM is the NTM creation and the importance weighed upon the accuracy of the data used to create it. The first step in creating the NTM used within this research was aggregating current case studies which had already calculated the tangible results of digitalizing the supply chain. To ensure accuracy, I compiled and analyzed eight separate case studies. The results are presented below in *Table 2*. The table showcases the tangible results from each case study alongside the results calculated in a positive percentage change. To quantify the increased efficiency, I first took the median percentage change from the table below, which is 30%. It is worth noting that the median was taken rather than the average as it ensures that outliers do not skew the results.

Case Study	Tangible Result	Result %	Link to Case Study
How to optimize port operation while reducing port delays	**Less Idle Time**	**15%**	How to optimize operations & reduce port delays - PortXchange (port-xchange.com)
How the Port of Algeciras reduced idle times and vessel delays	**Less Idle Time**	**40%**	How the Port of Algeciras reduced idle times and vessel delays - PortXchange (port-xchange.com)
How Shell has reduced idle time on departure by optimizing port calls	**Less Idle Time**	**20%**	How Shell has reduced idle time on departure | PortXchange (port-xchange.com)
How to reduce vessel delays on departure?	**Less Delays**	**19%**	How to Reduce Vessel Delays on departure?- PortXchange (port-xchange.com)
How Dutch wholesaler Van Den Ban eliminated $300,000 in detention and demurrage charges	**Increase in supply chain visibility**	**50%**	Eliminating D&D charges (archive.org)
Industry 4.0 in the port and maritime industry: A literature review	**Reduction of cost**	**10%**	De La Peña Zarzuelo, I., Soeane, M. J. F., & Bermúdez, B. L. (2020). Industry 4.0 in the port and maritime industry: A literature review. *Journal of Industrial Information Integration*, *20*, 100173. https://doi.org/10.1016/j.jii.2020.100173
How a shrimp exporter in India is reducing risk and saving money by going digital	**Time savings**	**86%**	Protecting fragile cargo (archive.org)
How Syngenta expedited imports with digital documents, including trade finance from HSBC	**Time savings**	**50%**	Expediting Import Documentation (archive.org)

Table 2: Created by author based on data presented in the case studies linked within table.



After conducting this analysis, it was evident that digitalization has a positive impact when implemented. However, for this research, I look to quantify the efficiency increase in port, specifically when implementing digitalization. To accomplish this task, I had to identify the percentage of the fleet capacity in ports at any given time. *Figure m* shows that the most recent percentage of ships in port at any given time is approximately 32% ("Shipping Review & Outlook," 2023).

Figure m: Depicts the percentage of the fleet capacity in ports by month. Source: Shipping Review & Outlook. (2023). Clarkson Research, ISSN 1743-7296, page. 9

The final piece of data required to create the NTM was the global median time spent in port, which allowed me to measure the percentage increase in efficiency accurately. According to UNCTAD's review of maritime transport (2022), the global median time in port for all vessel types is 1.05 days. The breakdown of each vessel type and its specific time in port can be seen in *Appendix VII Figure n*.

The formulas below showcase the method used to calculate the increase in efficiency at ports through the use of digitalization.

Equation 14 below showcase how I calculated the decreased time spent in ports utilizing the median percentage from the case studies in *Table 2* and multiplying it by the global median time in port.

Equation 14:

$$30\% \ (Median\ \%) * 1.05\ (days) = \ 0.315\ decreased\ time\ spent\ in\ ports\ (in\ days)$$

Equation 15 below shows how I calculated the true increase in efficiency by dividing the decreased time spent in ports by the percentage of ships in port as shown in Graph A above.

Equation 15:

$$\frac{0.315(in\ days)}{32\%\ (percent\ of\ world\ fleet\ in\ ports)} = 0.984\%\ increase\ in\ efficency$$

Now that I have quantified the increase in efficiency, I look at one last case study in which MSc reported an increase in efficiency of 4% at port by utilizing PortXchange (Suvadarshini & Dandapat, 2022, p. 4). For this reason, we turn to Equation 16 below, which takes the weighted average of 0.984% and the 4% reported by MSc to ensure an accurate NTM. For the equation, 0.984 has a weight of 8 because 8 case studies back it, whereas 4 has a weight of 1 because of its backing by the case study on MSc.

Equation 16:

$$\frac{(8 * 0.984\% + 1 * 4\%)}{(8 + 1)} = 1.31911\%$$

	Weighted average/ real NTM		**Real NTM for Laggers**
Percentage change in efficiency	**1.31911%**	**Percentage change in efficiency**	**1.31911%**
1 - Percentage change	**0.98681**	**Percentage change * 20%**	**0.00264**
Final NTM used in GSIM	**0.98681**	**Final NTM used in GSIM (1-percentage change)**	**0.99736**

Table 3: Created by author based on equations above.

As seen in *Table 3*, after calculating the positive percentage change in efficiency, I transformed it into the NTM, which will be used for the countries listed. For the countries excluding Laggers and ROW, the final NTM used in the GSIM is 0.98680. However, in the case of this research, the fourth assumption made is that the Laggers will reap 20% of the benefits of digitalization even without full implementation because of the advancements other countries have made.

For this reason, the NTM for the laggers is 0.99736, and the ROW will have an NTM of 1, which showcases no change as I am only focused on the outlined countries and the Laggers. The following section will focus on the various elasticities used within the GSIM and the relevant papers which ensure accuracy and reliability.

3.7 Elasticities

Another critical aspect of the GSIM model is the three different elasticities required to run this simulation properly. The three types of elasticizes needed are substitution, import demand, and export supply elasticity. The importance of robust elasticities must be considered as they directly impact the results of this research. Therefore, I consult academic papers on each of the elasticities mentioned above to ensure robust results.

Traditionally called Armington Elasticities, the substitution elasticity was named after Armington, who created the first theoretical model which distinguished between goods of different origins (Bajzik et al., 2019, p. 2). In a study conducted by Bajzik et al. (2019, p. 9), a sample of 3,524 estimated substitution elasticities from 42 papers were analyzed against 34 variables to ensure accuracy. From this data, the authors could estimate the Armington elasticities implied for individuals and all countries (Bajzik et al., 2019, p. 36). The different Armington elasticities used within this paper can be seen in *Appendix VIII Table 4*.

When considering the import demand elasticities, I look at a paper titled “Import demand elasticities and trade distortions” by Kee et al. (2008). The authors utilize a flexible translog GDP function in this paper to derive import demands and the associated elasticities using various prices and endowments (Kee et al., 2008, p. 3). From this research, I utilized the weighted averages for all listed countries. In contrast, the median weighted average will be used for countries which do not appear on the list and for the category Laggers and Row (Kee et al., 2008, p. 12). The import demand elasticities which I utilized within this research can be seen in *Appendix VIII Table 4*.

Lastly, I turn to a study by Tokarick (2010) on export supply elasticities. Within this study, the author utilizes a method that estimates these elasticities without using econometrics (Tokarick, 2010, p. 1). For this research, I use the export supply elasticities available from a 2008 study conducted by Broda, Limao & Weinstein where appliable; when not available, we turn to the short-run average elasticity, and for the group Laggers and ROW, I turn to the average short-run elasticity (Tokarick, 2010, p. 22). The specific export supply elasticity used within this research can be seen in *Appendix VIII Table 4*. The following section will focus on the tariff values utilized within this research.

3.8 Scenarios

Scenario 1

In the first scenario, I consider a world where digitalization has been widely implemented by all the main countries listed within the trade matrix presented earlier. In this scenario, these countries will benefit from these technologies and simulate the benefits of the positive NTM shock listed above. On the other hand, the countries that are considered laggers due to lack of facilities that can be classified as digitalization hubs will not realize the total benefits of the NTM. Instead, these countries will be presented with only 20% of the total positive shock, simulating the overall global benefits of the supply chains even when the countries in question have not implemented these technologies.

Scenario 2

	Real NTM for Laggers
Percentage change in efficiency	1.31911%
Percentage change * 20%	0.00264
Final NTM used in GSIM (1-percentage change)	1.00264

Table 5: Showcases the calculations used to formulate the NTM used for the laggers in scenario 2.

In the second scenario, I consider a world in which digitalization has still been implemented by the main countries listed within the trade matrix. These countries retain the full positive effects of the NTM created above through this implementation of technologies. However, the Laggers yet to widely implement these digital technologies within this scenario experience a negative NTM shock of -20% of the initially proposed value equalling 1.00264. *Table 5* showcases how this value was calculated.

Furthermore, this scenario attempts to showcase the adverse effects of failing to implement these digital technologies, leading to fewer vessels calling ports within the respective countries and, subsequently, a negative effect on the economies of the *Laggers* due to this decrease in trade.

3.9 Tariffs

Given the focus on NTMs rather than tariff measures, I maintain a constant bilateral trade value of 1 pre- and post-shock within both scenarios. This allows for the GSIM to simulate no change in tariff values. By simulating a no-change scenario, I can isolate and focus on the effects of the NTM proposed in section 3.6, allowing for a better analysis of its economic impact. Through this approach, I can ensure robust and accurate results, which allow for better insights into the effects of the proposed NTM. The following chapter will showcase the results and give a detailed analysis on the economic and trade impact of digitalization throughout the supply chain.

Chapter 4: Results and Analysis

This chapter will present the results from my analysis of the scenario presented within this paper. More specifically, it will detail the economic effects of digitalization, such as the changes in producer and consumer surplus and the resulting net welfare effects seen by each country. Taylor and Mankiw (2017, p. 797), defines consumer surplus as the buyer's willingness to pay minus the amount they pay. Furthermore, the authors define producer surplus as the amount the sellers are paid for the goods minus the cost of the goods (Taylor & Mankiw, 2017, p. 802). Additionally, I will cover the various percentage changes seen in exports and imports for each country and the percentage changes in both producer and consumer pricing. Afterward, I will convert the effects to showcase the various effects of digitalization on transportation. Finally, I will conduct a sensitivity analysis to showcase the robustness of the model.

To ensure transparency within this research prior to the discussion of all the results mentioned above, the assumptions I have made when utilizing this economic model are as follows:

Assumption 1: The various facilities owned by these maritime operators serve as digitalization hubs.

Assumption 2: 2019 Trade data is able to be used in place of missing 2022 data as it was not affected by covid therefore symbolized normal trade.

Assumption 3: The value of seaborne trade between countries currently sits between 70-90% depending on if they are connected by land borders, accounting for the overall distance between the countries interacting with each other.

Assumption 4: Laggers will reap 20% of the benefits of digitalization even without full implementation because of the advancements other countries have made.

4.1 Scenario 1:

Economic effects

I will first look at producer and consumer surplus to provide an accurate analysis of the net welfare effects of the scenario mentioned in this research. Typically, one would look at the change in tariff revenue; however, with no tariff changes being measured, it will not be analyzed in this paper. *Figure o,* below shows the net welfare effects of digitalization. From this figure, we can conclude that China and the United States are the biggest winners from digitalization.

Producers within China gain a massive USD 9,838.6 billion, whereas consumers gain an additional $7,089.2 billion in surplus. Overall, China aims to gain a massive economic boost, accumulating USD 16,927.8 billion in net welfare effects. This can be attributed to their extensive global economic reach trading large amounts with many countries worldwide. The United States similarly sees significant growth in both producer and consumer surplus. However, within this scenario, consumers gain significantly more seeing an additional USD 12,004.8 billion in surplus. Whereas producers still gain, however less seeing USD 5,196.8 billion in additional surplus. The United States looks to gain a whopping USD 17,201.5 billion in net welfare effects. Comparable to the significant benefits seen by China, the United States also has a global reach, both importing and exporting large amounts of goods.

The model also shows that overall digitalization has positive benefits for all countries, even Laggers, who are slow to implement this technology yet benefit from implementing these technologies in other countries. More specifically, Figure M shows Japan and Laggers benefit considerably in both consumer and producer surplus and net welfare. Japanese consumers and producers alike see nearly equal benefits, resulting in a gain of USD 3,502.9 billion and USD 3,071 billion, respectively, with Japan seeing a total net welfare gain of USD 6,573.9 billion.

Consumers within the countries label Laggers see a gain of USD 3,674.2 billion, and producers gain only USD 1,899.4 billion. However, the *Laggers* still experience a sizeable net welfare increase of USD 5,573.6 billion. This increase in net welfare seen by the *Laggers* can be attributed to the increase in efficiency seen in other countries benefiting the global supply chain as a whole. Another notable remark from the outcome of this econometric model is the small gain realized by consumers and producers alike in Egypt. Although still seeing a positive gain from digitalization, the results for consumers and producers do not see a significant change compared to those mentioned above. More specifically, consumers in Egypt realized the largest gain in surplus, gaining USD 406.5 million, whereas producers gained USD 157.3 million. Egypt seeing a net welfare gain of USD 563.9 million. Albeit smaller of a gain, it should be noted that this is due to the lesser extent of their global imports and exports. For the full values of the producer surplus, consumer surplus and net welfare for each country refer to *Annex IX Table 6.*

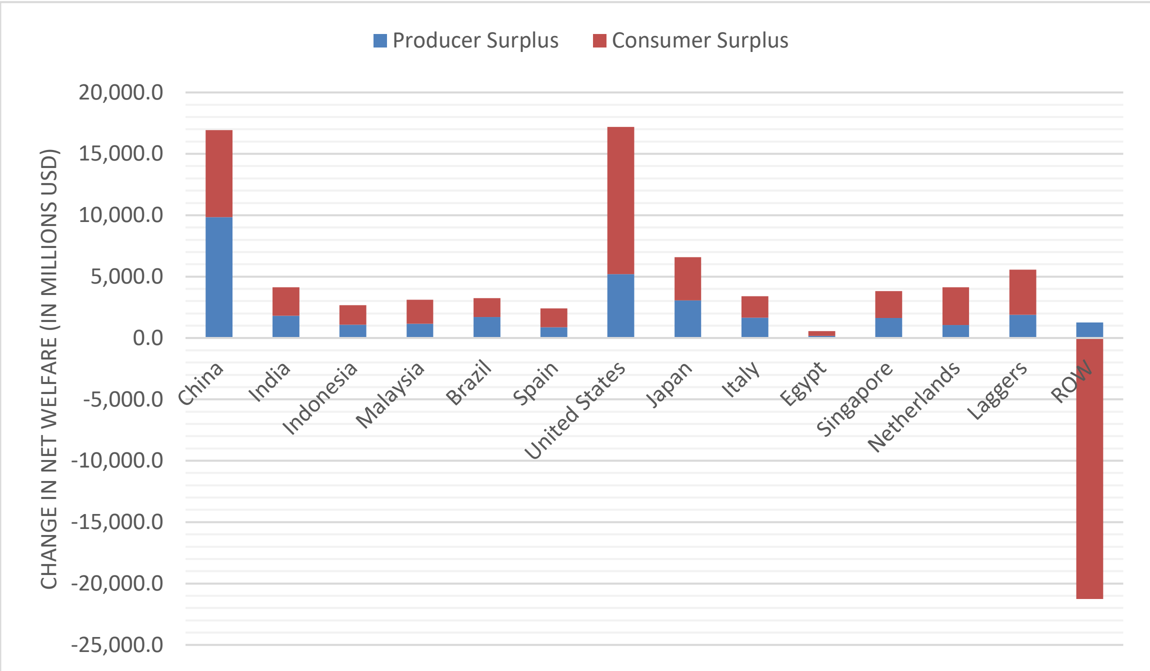


Figure o: Shows the Producer Surplus, Consumer Surplus. The sum of which equals the net welfare effects.

Now we look at the percentage change in exports and imports for total trade resulting from the model. More specifically, the biggest winners from digitalization in terms of percentage change of output are Singapore, China, India, Japan, and Malaysia. As seen in Figure M below, Singapore gains the most, with a .50% increase in output, close behind China, which sees a .49% increase. Although, it must be noted that the increase in output China sees is significantly larger due to the quantity already traded before the NTM shock. Furthermore, we see India gain a .38% increase in output, Japan .36%, and Malaysia .31%, respectively. Lastly, it is worth noting that although Laggers see a lesser benefit overall from digitalization, the 0.06% increase seen is a direct result of other countries implementing these technologies, thus spreading the benefits to other countries.

Next, I turn to the changes in import results from the post-shock of the NTM. One trend must be considered is the overall positive percentage increase seen in every country within the model. As seen in *Figure p,* below, the top 5 countries that experienced the largest growth in imports are Brazil at 2.44%, Indonesia at 2.25%, Japan at 2.06%, Malaysia at 1.98%, and India at 1.87%. What can be derived from Figure M is that through this digitization, trade is facilitated more efficiently, and countries overall see more significant gains in imports due to this increase in the efficiency of their supply chains. Furthermore, it is essential to note that, similarly to exports, Laggers continuously benefit from digitalization, albeit at a smaller rate. An important observation is that regardless of the minuscule benefits seen by the Laggers, the percentage of growth that would have been seen if they had indeed fully implemented digitization would have been significantly more. Furthermore, for a full list of all countries and their respective percentage increase for both exports and imports refer to *Annex IX Table 7*

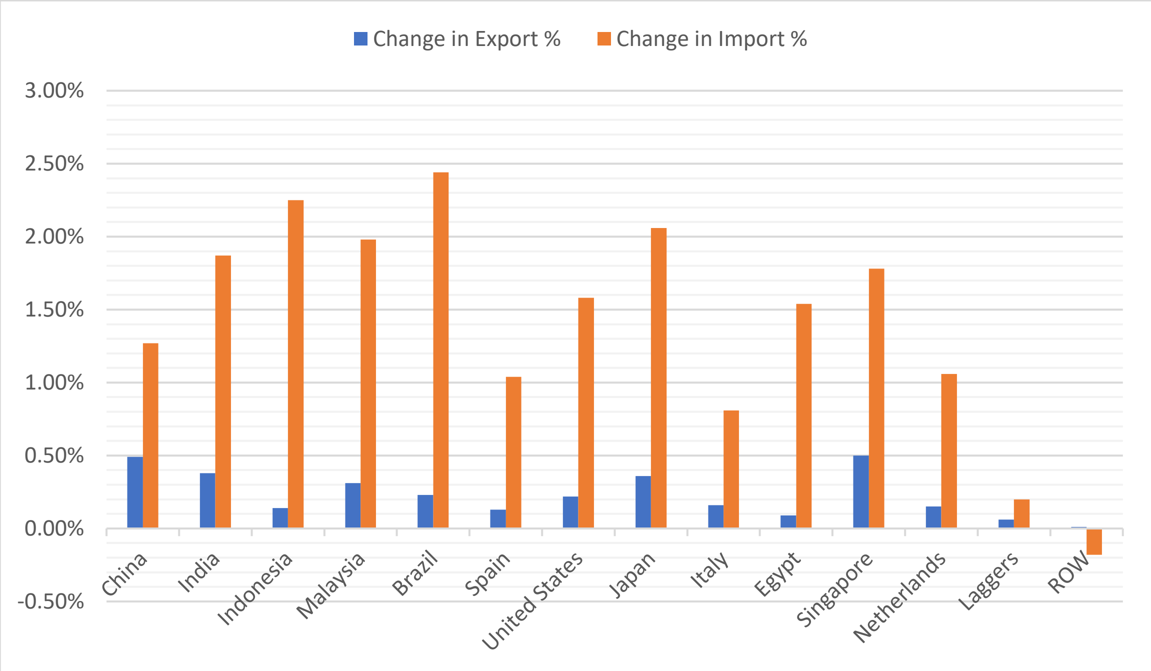


Figure p: Showcases the percentage change in exports and imports..

Lastly, I look at the percentage change in producer and consumer prices and analyse the effects of these changes. The most notable difference is that producer prices across the board increased while consumer prices decreased. This result can is also reflected in *Figure o above*, where consumers gain notably more surplus than producers. It is important to note that consumers benefit all around, with every country seeing a negative price increase. However, consumers within differing countries benefit from differing levels. As seen in *Figure q below* the countries with the most significant decrease in consumer pricing were Malaysia at -0.935%, Indonesia at -0.928, Singapore at -0.793, Brazil at -0.793, and Japan at -0.716%. On the contrary, the countries with the lowest percentage change in producer pricing were Laggers 0.062%, the Netherlands 0.076%, Spain 0.117% Italy 0.132%, and China 0.133%. Furthermore, for a list with all countries and their respective changes in both producer and consumer prices refer to *Annex X Table 8.*

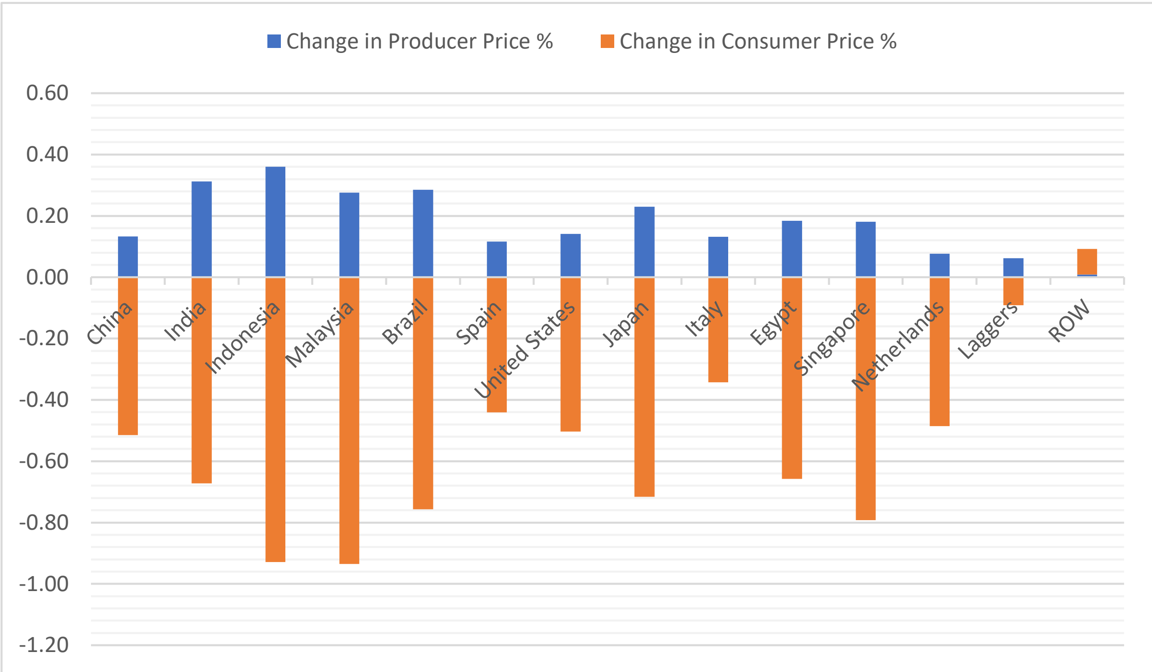


Figure q: Showcases the percentage changes in both producer and Consumer prices.

The next section will cover the transport effects of digitalization and will proceed to covert the values to both TEUS and Tonnes based on the conversion method mentioned in the methodology chapter.

Transportation effects

When considering the logistics and transportation impact of digitalization, I consider the impact of this NTM on the maritime industry as measured in TEUS and Tonnes utilizing the conversion method. This research shows that digitalization's positive impact cannot be understated. This impact is demonstrated through an increase in efficiency and subsequently equates to a short port stay for all vessels involved, including those visiting these Lagger countries. When analysing the totality of the transportation effects, I first look at the impact on the global containership industry. The conversion method calculates containerized cargo in TEUS and the bulk cargo in tonnes.

Figure r below, displays the impact in thousands of TEUs; it is worth noting that all countries have been positively impacted at varying degrees. The top five bilateral trade interactions that have been the most significantly affected are China-US showing an increase of 705,000 TEUS, China-Japan 221,000 TEUS, China-Laggers 258,000 TEUS, US-China 203,000 TEUS, and Japan-China 174,000 TEUS. In total, those countries alone have seen an increase of 1,561,000 TEUS. One trend that must be noted is that China is slated to gain significantly within every bilateral trade interaction in the top five winners. Furthermore, it is worth noting that overall, China's exports saw the largest growth of all the countries, gaining 1,397,000 TEUS traded. Additionally, the United States is slated to gain the most in imports, seeing a growth of 1,462,000 TEUS. Moreover, *Laggers* are projected a growth of 73,000 TEUS exported and 314,000 TEUS imported.

S \ D	China	India	Indonesia	Malaysia	Brazil	Spain	United States	Japan	Italy	Egypt	Singapore	Netherlands	Laggers	ROW	Total Exports
China	0	130	79	89	87	47	705	221	56	17	85	123	258	-500	1397
India	18	0	9	5	11	4	79	6	7	3	9	15	-17	-65	85
Indonesia	28	11	0	6	1	1	17	15	2	1	9	3	0	-77	16
Malaysia	47	9	6	0	1	1	24	16	1	0	23	6	0	-84	51
Brazil	89	7	3	3	0	9	36	7	5	3	7	10	-1	-125	54
Spain	11	2	0	1	5	0	23	4	31	2	1	13	9	-65	36
United States	203	56	10	17	68	28	0	100	30	7	47	74	46	-374	313
Japan	174	15	14	13	5	3	147	0	5	1	20	11	0	-223	186
Italy	26	6	1	2	8	32	83	11	0	4	3	17	11	-125	79
Egypt	2	2	0	0	0	3	2	0	3	0	0	2	0	-13	3
Singapore	118	14	33	36	3	0	50	24	1	0	0	11	1	-115	175
Netherlands	20	4	1	1	6	20	43	7	28	2	4	0	18	-74	81
Laggers	12	3	0	0	2	6	122	1	10	0	0	7	17	-108	73
ROW	-68	-7	-6	-11	-1	-13	131	-21	-17	-4	-16	-30	-27	139	49
Total Imports	680	252	151	161	195	142	1462	393	162	37	193	261	314	-1808	

Figure r: Shows the Transportation effect of digitalization. All results shown in Thousands TEUs

Considering the effects on bulk trade after the positive shock of digitalization, it is apparent that all countries that either implement these technologies or directly trade with those that have implemented them will benefit positively. As seen below in Figure s, the top five bilateral trade interactions that have seen the most significant increase are as follows, China-US 95,850,000 tons, China- Japan 30,060,000 tons, China-Laggers 35,130,000 tons, US-China 27,650,000 tons and Japan-China 23,710,000 tons. Furthermore, with this positive shock of digitalization, China would be expected to see an increase in exports of a staggering 189,960,000 tons, coming away with the most significant growth. The United States would see the largest import growth, gaining 198,800,000 tons. Furthermore, *Laggers* are projected to see a growth of 9,870,000 tons exported and 42,750,000 tons imported. Overall, the gain in total trade seen in countries in both TEUS and tonnes is directly related to the already large amounts traded before the positive shock.

S \ D	China	India	Indonesia	Malaysia	Brazil	Spain	United States	Japan	Italy	Egypt	Singapore	Netherlands	Laggers	ROW	Total Exports
China	0	1769	1071	1211	1177	639	9585	3006	762	232	1160	1672	3513	-6803	18996
India	251	0	116	71	151	56	1072	82	101	45	121	203	-234	-883	1150
Indonesia	375	153	0	81	15	19	229	205	21	12	124	35	-5	-1047	215
Malaysia	638	124	88	0	14	14	322	224	16	5	308	76	-2	-1138	690
Brazil	1217	89	38	41	0	124	493	97	62	36	99	142	-7	-1695	736
Spain	145	30	7	7	70	0	310	59	418	22	15	172	118	-885	487
United States	2765	758	142	232	920	386	0	1364	406	96	640	1002	629	-5086	4253
Japan	2371	206	184	179	72	36	2000	0	72	10	266	156	4	-3030	2528
Italy	348	82	17	22	106	438	1130	155	0	59	38	225	153	-1703	1071
Egypt	23	24	6	1	5	44	32	4	45	0	4	21	3	-171	41
Singapore	1605	191	451	491	35	6	674	321	15	5	0	147	7	-1570	2380
Netherlands	269	55	16	15	78	275	584	99	386	28	54	0	244	-1001	1102
Laggers	167	42	1	-4	26	82	1662	13	131	4	2	99	226	-1467	987
ROW	-921	-92	-83	-153	-18	-183	1788	-284	-237	-50	-214	-404	-374	1888	663
Total Imports	9254	3431	2053	2195	2652	1938	19880	5345	2199	504	2618	3546	4275	-24591	

Figure s: Showcases the transportation effects of digitalization in Tens Thousands of tonnes.

4.2 Scenario 2:

Economic effects

To ensure a holistic overview of the economic effects resulting from the modeling of scenario 2, I will begin by looking at the producer and consumer surplus. As seen below in *Figure t,* the countries implementing these digital technologies have seen a positive gain in net welfare. However, the scenario modeled shows a significant change from scenario 1, with countries seeing less of a positive gain in net welfare and *Laggers* seeing a significant shift now seeing negative net welfare.

Similarly, to the previous scenario, we see both the United States and China gaining significant net welfare. Firstly, we look at United States producers slated to gain USD 3933 million in surplus. In contrast, consumers are expected to see a larger portion of the benefits, gaining USD 10,865 million in surplus. Overall, the United States would be projected to gain the most from this scenario, gaining a total of USD 14,798 million. However, close behind, China is expected to be the second-largest winner in this scenario. Differing from scenario 1, consumers would now be projected to gain the most surplus projected to benefit USD 6,818 million, whereas producers will still reap significant benefits, gaining USD 5,602 million in surplus. Overall, China is anticipated to gain the second-largest net welfare increase, amounting to USD 12,420 million.

Additionally, the model shows the overall net welfare of Japan still increasing considerably with the country seeing the 3rd largest increase. Similarly, to the previous scenario, both Japanese consumers and producers are expected to gain a considerable amount of surplus. Consumers are estimated to see a majority share of surplus gaining USD 3,603 million, and producers gaining USD 2,958 million. Japan in total is expected to gain USD 6,561 million which is a larger net welfare increase than every country except China and the United States. Furthermore, in this scenario, we now see both Singapore and the Netherlands gain a substantial amount of net welfare. With Singapore seeing the 4th largest increase in welfare gaining a total of USD 3,794 million. Singaporean consumers are expected to see the largest increase in surplus gaining USD 2,208 million whereas producers would gain USD 1,585.7 million. Additionally, the Netherlands now sees the 5th largest increase in net welfare gaining USD 3,794.4 million. With Dutch consumers gaining a majority share of the increase in welfare seeing an increase of USD 2,940 million, and producers gaining USD 750.9 million.

However, the the biggest change in this scenario is the significant loss the countries labeled Laggers are projected to see. The most significantly impact group is the consumers, who are projected to realize the majority of the losses to their surplus, amounting to a staggering USD – 11,103.1 million. In contrast, producers are projected to lose USD – 1,000.6 million. The Laggers are estimated to see a staggering loss of net welfare amounting to USD – 12.103.7 million. This steep loss in surplus is attributed to the large amount of trade the Laggers engage in and the negative impact simulated due to the loss of efficiency from the lack of implementation of digitalization

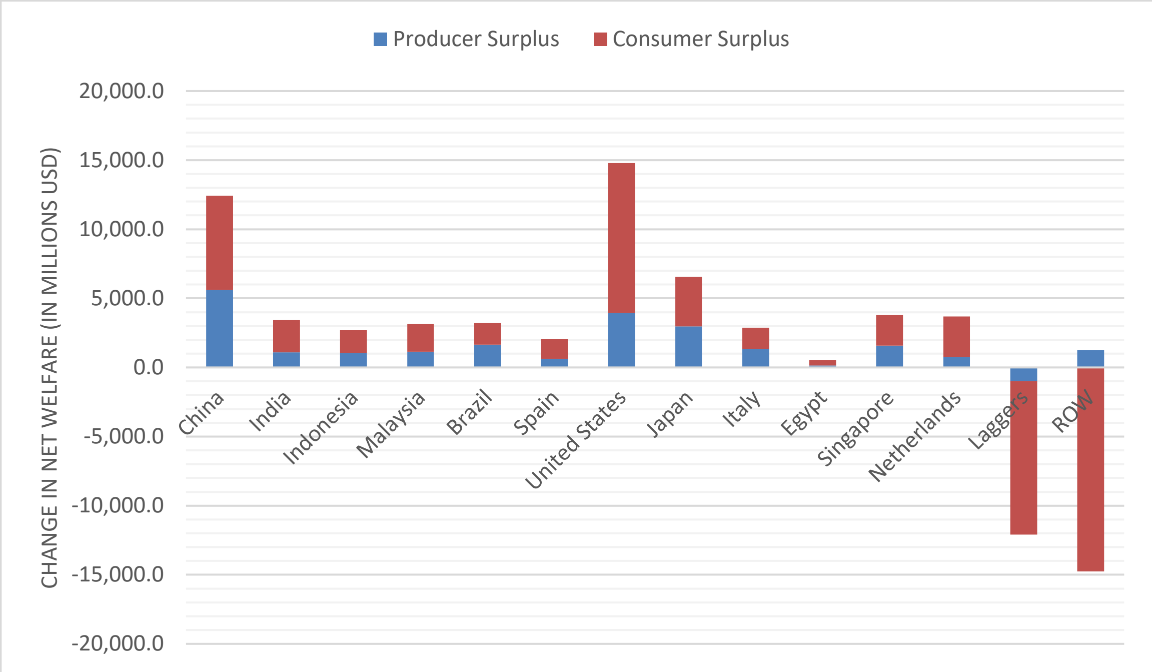


Figure t: Shows the Producer Surplus, Consumer Surplus for scenario 2. The sum of which equals the net welfare effects.

within ports. This cost can also be attributed to a loss in port traffic due to countries choosing to call ports in neighbouring countries that have implemented digital technologies and thus have faster vessel turnaround times. Furthermore, a list of all countries alongside the producer and consumer surplus and net welfare can be seen in Annex X Table 9.

Additionally, it is essential to consider the overall change in net welfare to assess each scenario properly. As seen in Table 10 below, all countries except Indonesia and Malaysia experienced an adverse change in net welfare from scenario 1 to scenario 2. More notably, the countries that experience the most significant negative change in net welfare are Laggers, China, the United States, and India. China initially saw a positive net welfare of USD 16,927 million in scenario 1; however, after the negative shock presented in scenario 2, their net welfare decreased to USD 12,420 million, seeing a significant decrease of USD -4,507 million. The country saw the second-largest net welfare decrease from scenario 1 to scenario 2. In scenario 1, the US is projected to see a positive net welfare of USD 17,201 million; however, after the negative shock of scenario 2, their net welfare to USD 14,798 million, signifying a decrease of USD -2,403 million. Furthermore, the most significant reduction in net welfare was seen by the Laggers, going from USD 4,133 million in scenario one to

USD – 12,103 million in scenario 2, signifying a decrease of USD-17,677 million. These negative changes in net welfare showcase the impact of the negative shock seen by the Laggers and its effect on the bilateral trade matrix due to this loss of efficiency and trade volume due to the failure of these countries to implement digitization.

Country	Scenario 1	Scenario 2	Change in Net Welfare
China	16,927.8	12,420.7	-4,507.10
India	4,140.2	3,435.1	-705.10
Indonesia	2,676.9	2,695.9	19.00
Malaysia	3,122.7	3,144.9	22.20
Brazil	3,257.3	3,226.0	-31.30
Spain	2,417.9	2,066.4	-351.50
United States	17,201.5	14,798.3	-2,403.20
Japan	6,573.9	6,561.9	-12.00
Italy	3,403.5	2,880.0	-523.50
Egypt	563.9	544.0	-19.90
Singapore	3,829.4	3,794.4	-35.00
Netherlands	4,133.4	3,691.0	-442.40
Laggers	5,573.6	-12,103.7	-17,677.30
ROW	-19,977.9	-13,504.3	6,473.60

Table 10: Showcases the change in net welfare between the two scenarios presented within this research.

Country	Difference in % Output between scenarios
China	-0.21%
India	-0.15%
Indonesia	-0.01%
Malaysia	-0.01%
Brazil	0.00%
Spain	-0.04%
United States	-0.05%
Japan	-0.01%
Italy	-0.03%
Egypt	-0.01%
Singapore	-0.01%
Netherlands	-0.04%
Laggers	-0.10%
ROW	0.00%

Table 11: Showcases the percentage difference between % Output between scenario 1 and scenario 2 for each country.

Now, I turn to the percentage change in both exports and imports in total trading resulting from the post shock of the NTM in scenario 2. Regarding output, the biggest winners of digitalization are Singapore, Japan, Malaysia, and China. Singapore sees the largest growth in exports, seeing a 0.49% increase, an insignificant decrease of 0.01% from the growth seen in scenario 1. Following closely behind in terms of percentage change in output, Japan saw the second-largest increase in exports, coming in at 0.35%. In contrast, in scenario 1 they saw an increase of 0.36%, only seeing an insignificant decrease of 0.01% in scenario 2. Subsequently, Malaysia sees the subsequent largest increase in exports, ranking in a percentage change of 0.30% in output compared to 0.31% in scenario 1. Furthermore, China sees the fourth largest increase in exports, coming in at a percentage change of 0.28% increase, seeing a significant decrease in output compared to scenario 1. *Table 11* above showcases the differences in percentage change in output from scenario 1 compared to scenario 2 from all countries.

Country	Difference in % imports between scenarios
China	-0.05%
India	0.01%
Indonesia	0.06%
Malaysia	0.05%
Brazil	0.05%
Spain	-0.08%
United States	-0.15%
Japan	0.06%
Italy	-0.09%
Egypt	-0.01%
Singapore	0.01%
Netherlands	-0.05%
Laggers	-0.83%
ROW	0.06%

Table 12: Showcases the percentage difference between percentage growth in imports between scenario 1 and scenario 2 for each country.

Now, I consider the percentage change in imports resulting from post-shock NTM. With the largest increase in imports in percentage change, Brazil is projected to grow by 2.49%. Following closely, Indonesia is projected to see a percentage growth of 2.31% increase in imports. Afterward, Japan is estimated to see a percentage growth of 2.12% increase in imports. Additionally, Malaysia is also projected to see a percentage growth of 2.03% increase in imports. However, it must be noted that although some countries are slated to see a bigger percentage growth in scenario 2 some countries saw a significant decrease in imports. The countries projected to see the largest decrease in imports between the two scenarios are Laggers, the United States, and Italy. Seeing the largest decrease in imports due to the negative shock of the NTM directly affecting them, Laggers are projected to lose a stagger -0.83% in imports compared to the positive shock seen in scenario 1. Whereas the United States is predicted to see a slightly smaller percentage decrease in imports, losing -0.16%

compared to scenario 1. Additionally, Italy is projected to realize a -0.09% decrease in imports in scenario 2. However, one must consider the volume that is being imported. For example, in scenario 1 the United States imported the highest volume of all countries even though they did not have the highest increase in percentage growth of imports. *Table 12* above showcases the differences in projected percentage growth of imports per country between scenarios 1 and 2. Furthermore, for a complete list of all countries and their respective percentage change for both exports and imports, refer to *Annex XI Table 13*.

Lastly, I look at the percentage change in producer and consumer prices and analyze the effects of these changes. The effects of these changes in producer and consumer prices are directly reflected in *Figure t* above. The first trend that should be noted is the overall increase in producer price except for the negatively affected group Laggers. The countries which have seen the most significant increase in producer prices were Indonesia, Malaysia, Brazil, and Japan. Expected to see the largest increase in producer price, Indonesia is projected to see a positive change of 0.35%. Brazil and Malaysia are predicted to see the same percentage change in producer price at 0.27%. The final country with a positive percentage change in producer price above 0.20% is Japan, projected to see a 0.22% increase. Furthermore, the only country expected to experience a negative percentage change in producer price is Laggers, projected to see a -0.03% decrease.

Another trend that should be noted is the all-around negative percentage change in consumer price except for Laggers, which saw an increase in consumer pricing. The countries that see the most significant benefit to consumer pricing are Indonesia, Malaysia, Singapore, and Brazil. Consumers in Malaysia are predicted to see a percentage decrease in pricing -0.96%. Following closely behind, Indonesian consumers are projected to see a percentage decrease of -0.95% in pricing. Another country anticipated to see a notable decrease in consumer pricing is Singapore at -0.79%.

Furthermore, Brazilian consumers are projected to see a significant decrease in consumer pricing at -0.77%. Similarly, to the trend seen in producer pricing, consumers in the countries that make up the Laggers are expected to see adverse effects, seeing the only increase in consumer pricing, an increase of 0.28%. *Table 14* below showcases the difference in producer and consumer pricing between the scenarios. Furthermore, for a complete list of all countries and their respective percentage change in both producer and consumer pricing, refer to *Annex XI Table 15*.

Country	Difference in Producer Pricing between scenarios	Country	Difference in Consumer Pricing between scenarios
China	-0.057	**China**	0.020
India	-0.122	**India**	-0.002
Indonesia	-0.008	**Indonesia**	-0.025
Malaysia	-0.007	**Malaysia**	-0.024
Brazil	-0.010	**Brazil**	-0.014
Spain	-0.031	**Spain**	0.037
United States	-0.034	**United States**	0.049
Japan	-0.008	**Japan**	-0.021
Italy	-0.026	**Italy**	0.039
Egypt	-0.020	**Egypt**	0.005
Singapore	-0.005	**Singapore**	-0.001
Netherlands	-0.021	**Netherlands**	0.024
Laggers	-0.093	**Laggers**	0.374
ROW	0.000	**ROW**	-0.025

Table 14: Showcases the percentage difference of both Producer and Consumer pricing between scenario 1 and scenario 2 for each country.

The next section aims to test the robustness of the model and the data alike to ensure that the results presented thus forth in this chapter are accurate and reliable.

Transportation effects

As seen in scenario 1 the conversion method was utilized to convert the final trade values into both TEU's and tonnes traded, allowing for the analysis of the maritime effect of digitalization. In scenario 2 I will highlight the still positive effects of digitalization while emphasizing the decrease in overall trade due to the negative shock simulated when trading with the Laggers. To ensure a holistic overview of the true transportation effects, I will first examine the impact on containerized trade.

Figure u below displays the impact in thousands of TEUS, with varying degrees of positive effects being displayed and the negative impact the Laggers have seen post-shock NTM. The five bilateral trade interactions that saw the largest positive impact are as follows: China-US saw 480,000 TEUS, China-Japan 153,000 TEU, the US-China 139,000 TEUS, Japan-China saw 116,000 TEUS, and Japan-US at 97,000 TEUS. The top five bilateral interactions saw a total increase of 985,000 thousand TEUS. Overall, the top five projected bilateral trade interactions are estimated to lose 576,000 TEUS as compared to scenario 1. Similarly, to scenario 1, China and the United States are projected to remain the biggest winners in terms of volume exported and imported.

However, China is projected to lose a staggering -1,120,000 thousand TEUS in both exports and imports between the two scenarios. Furthermore, the United States is estimated to see a lesser loss of -405,000 thousand TEUS due to the negative shock of the NTM. Moreover, the Laggers saw the second most significant decrease, projected to lose -951,000 thousand TEUS from scenario 1 to scenario 2 due to the negative shock of the NTM. These losses in the containerized trade showcase that the loss of direct trade with the Laggers can be attributed to the loss of efficiency and, subsequently, countries calling other ports.

S \ D	China	India	Indonesia	Malaysia	Brazil	Spain	United States	Japan	Italy	Egypt	Singapore	Netherlands	Laggers	ROW	Total Exports
China	0	90	55	62	60	33	480	153	39	12	60	86	-423	-181	525
India	14	0	6	4	8	3	57	4	6	2	7	11	-63	-26	34
Indonesia	18	7	0	4	1	1	11	10	1	1	6	2	-1	-51	10
Malaysia	31	6	4	0	1	1	16	11	1	0	15	4	-1	-55	33
Brazil	60	4	2	2	0	6	24	5	3	2	5	7	-4	-81	34
Spain	7	1	0	0	3	0	15	3	21	1	1	9	-13	-32	17
United States	139	38	7	12	46	19	0	68	20	5	32	50	-91	-190	156
Japan	116	10	9	9	4	2	97	0	4	1	13	8	-7	-145	118
Italy	17	4	1	1	5	22	55	8	0	3	2	11	-20	-68	42
Egypt	1	1	0	0	0	2	2	0	2	0	0	1	-1	-8	2
Singapore	78	9	22	24	2	0	32	16	1	0	0	7	-2	-77	113
Netherlands	13	3	1	1	4	14	28	5	19	1	3	0	-18	-35	38
Laggers	-21	-3	-1	-1	-2	-8	-23	-2	-11	-1	-5	-13	-10	76	-25
ROW	-43	-4	-4	-8	-1	-8	78	-14	-10	-2	-10	-19	34	44	32
Total Imports	432	167	102	109	131	86	872	267	95	24	127	164	-620	-829	

Figure u: Shows the Transportation effect of digitalization. All results shown in Thousands TEUs for scenario 2.

Now, I consider the impact on bulk trade after both the positive shock of digitalization and the negative effect simulated when interacting in the bilateral trade matrix with the *Laggers*. *Figure v* displays the impact of the digitalization in tens of thousands of tons. Furthermore, the positive benefits of digitalization should be considered, even with the adverse effects being reflected in the overall drop in both exported and imported goods. The top 5 bilateral trade interactions projected to see the biggest increase in thousands of tonnes are as follows: China-US 64,570,000 tons, China-Japan 20,590,000 tons, US-China 18,650,000 tons, Japan-China 15,650,000 tons and Japan-US gaining 12,980,000 tons. Overall, the five top 5 largest gainers alone are set to gain an additional 132,244,000 tons traded.

When considering the loss of bulk trade flow between the two scenarios, the country estimated to see the largest loss is China, losing – 119,380,000 tons in exports and -34,480,000 tons in imports. Furthermore, the country with the second largest loss in total tons traded is the Laggers, seeing a loss of -13,260,000 tons in exports and -126,100,000 tons in imports. The bilateral trade flows that were impacted the most are China-Laggers -91,980,000 tons, China-US -31,280,000 tons, Laggers-US -19,690,000 tons, US-Laggers -18,480,000 tons and China-Japan -9,470,000 tons. These losses showcase the widespread adverse effects of the proposed NTM on all the countries within the trade matrix, both directly and indirectly.

S \ D	China	India	Indonesia	Malaysia	Brazil	Spain	United States	Japan	Italy	Egypt	Singapore	Netherlands	Laggers	ROW	Total Exports
China	0	1212	735	833	806	440	6457	2059	524	159	800	1152	-5685	-2435	7058
India	186	0	86	53	110	41	765	60	75	33	90	150	-847	-348	456
Indonesia	247	101	0	53	10	12	148	135	14	8	82	23	-16	-679	137
Malaysia	421	82	57	0	9	9	208	147	10	4	202	50	-19	-742	439
Brazil	805	58	25	27	0	82	320	64	41	24	65	94	-53	-1090	463
Spain	97	20	4	5	47	0	205	40	281	15	10	116	-172	-433	235
United States	1865	510	95	156	618	261	0	916	274	65	432	676	-1220	-2547	2100
Japan	1565	135	120	117	48	24	1298	0	48	7	175	103	-97	-1955	1589
Italy	233	55	11	15	71	294	744	103	0	40	26	151	-274	-910	559
Egypt	16	16	4	1	3	29	21	3	30	0	3	14	-13	-102	24
Singapore	1054	125	294	319	23	4	437	210	10	3	0	97	-29	-1034	1514
Netherlands	179	37	10	10	52	183	383	66	257	19	36	0	-240	-475	517
Laggers	-284	-45	-12	-18	-21	-110	-307	-22	-148	-16	-68	-172	-134	1019	-339
ROW	-579	-60	-56	-102	-11	-110	1049	-190	-140	-32	-140	-252	463	586	425
Total Imports	5805	2245	1376	1469	1763	1161	11728	3589	1277	327	1713	2203	-8335	-11144	

Figure v: Showcases the transportation effects of digitalization in Tens Thousands of tonnes for scenario 2.

Annex XII, Figures w and Figure x showcase the difference in both TUES and tons transported between scenario 1 and scenario 2. The next section aims to test the robustness of the model and the data alike to ensure that the results presented thus forth in this chapter are accurate and reliable.

4.3 Sensitivity Analysis

Although the various elasticities were gathered through various pieces of peer-reviewed literature, I conducted a sensitivity analysis to ensure the robustness of the econometric model and the results obtained. To conduct this analysis, I changed the composite demand, substitution, and supply elasticity. By independently changing these variables, I can note any changes to the model results as a result of the respective change. With minor changes in the results, the model is not sensitive to change, equating to a robust model and significant changes to the result, meaning it is sensitive to changes.

The composite demand elasticity was the first elasticity I performed a sensitivity analysis. The composite demand elasticity simulates price changes and demand for items at the new price. Within this paper, I utilize various elasticizes gathered for each county as per Kee et al. (2008); where no elasticity is listed for a specific country, I use -1.21. As seen in *Table 16* below, to conduct this analysis, I alter the elasticity by +/- 0.5 and compare the output of the two points, *Percentage Change in Output* and *Change in Net Welfare,* to the baseline results of the model. Regardless of this change to this elasticity, the results see a nonsignificant change to its output. This signifies that the composite demand elasticities are accurate and the results robust.

		Percentage Change in output			Change in Net Welfare	
Countries	**-0.5**	**Baseline**	**0.5**	**-0.5**	**Baseline**	**+0.5**
China	0.52	0.49	0.46	17348	16935	16453
India	0.40	0.38	0.35	4233	4142	4045
Indonesia	0.15	0.14	0.13	2725	2677	2624
Malaysia	0.33	0.31	0.29	3169	3123	3071
Brazil	0.24	0.23	0.22	3322	3257	3182
Spain	0.12	0.13	0.12	2387	2419	2443
United States	0.23	0.22	0.21	17167	17215	17237
Japan	0.38	0.36	0.34	6680	6574	6450
Italy	0.17	0.16	0.16	3385	3405	3410
Egypt	0.09	0.09	0.09	561	564	566
Singapore	0.54	0.50	0.47	3901	3830	3750
Netherlands	0.15	0.15	0.15	4054	4135	4205
Laggers	0.07	0.06	0.05	5212	5252	5293
ROW	0.02	0.01	0	-20568	-19905	-19058

Table 16: Showcases the results of sensitive analysis conducted on the composite demand elasticities.

The next elasticity I perform a sensitivity analysis is the substitution elasticity. This elasticity showcases the willingness of consumers to substitute domestically produced goods for imported goods. Within this research, I use 2.9 as the baseline elasticity for countries where no elasticity was given, and the exact elasticity listed for countries listed explicitly in the paper by Bajzik et al. (2019). As seen in *Table 17* below, the results of this sensitivity analysis showcase non-significant changes to both the percentage change in output and the change in net welfare. Due to these minuscule changes, the substitution elasticities are also accurate, and the results of this econometric model continue to be proven robust.

		Percentage Change in output			Change in Net Welfare	
Countries	**-0.5**	**Baseline**	**0.5**	**-0.5**	**Baseline**	**+0.5**
China	0.46	0.49	0.51	16318	169351	17462
India	0.38	0.38	0.38	4141	4142	4142
Indonesia	0.14	0.14	0.13	2724	2677	2641
Malaysia	0.31	0.31	0.31	3129	3123	3116
Brazil	0.23	0.23	0.23	3258	3257	3255
Spain	0.12	0.13	0.13	2348	2419	2474
United States	0.21	0.22	0.23	16929	17215	17438
Japan	0.35	0.36	0.37	6495	6574	6633
Italy	0.16	0.16	0.17	3293	3405	3491
Egypt	0.09	0.09	0.09	560	564	567
Singapore	0.49	0.50	0.52	3765	3830	3882
Netherlands	0.14	0.15	0.17	3999	4135	4244
Laggers	0.07	0.06	0.05	5630	5252	4938
ROW	0.02	0.01	0.001185	-19026	-19905	-20602

Table 17: Showcases the results of the sensitivity analysis conducted substitution elasticities.

Lastly, I perform a sensitivity analysis on the supply elasticities used within this research. Within this research, I utilize the respective elasticises provided in a paper by Tokarick (2010). The baseline supply elasticity used for countries not specifically listed was 1.49, whereas the countries with an explicitly mentioned elasticity used the respective elasticities mentioned within the paper. As seen in *Table 18* below, the results of the sensitivity analysis showcase mostly non-significant changes throughout the results of the model. However, the one country and output which did have a notable change was Indonesia seeing the percentage change in output flip from a positive result to a negative when changing the elasticity by -0.5. What this shows is that nearly all the results are not sensitive to changes although the elasticity for Indonesia shows slight sensitivity to the changes made. Overall, the supply elasticity used is accurate and the ensuing results are robust.

		Percentage Change in output			Change in Net Welfare	
Countries	**-0.5**	**Baseline**	**0.5**	**-0.5**	**Baseline**	**+0.5**
China	0.46	0.49	0.51	17619	16935	16344
India	0.25	0.38	0.47	4360	4142	3972
Indonesia	-0.05	0.14	0.27	2851	2677	2552
Malaysia	0.20	0.31	0.40	3261	3123	3017
Brazil	0.11	0.23	0.33	3511	3257	3067
Spain	0.08	0.13	0.16	2524	2419	2341
United States	0.17	0.22	0.26	17669	17215	16857
Japan	0.28	0.36	0.43	6922	6574	6299
Italy	0.11	0.16	0.20	3615	3405	3245
Egypt	0.00	0.09	0.16	585	564	549
Singapore	0.46	0.50	0.54	3948	3830	3730
Netherlands	0.13	0.15	0.17	4208	4135	4077
Laggers	0.04	0.06	0.08	5040	5252	5440
ROW	0.01	0.01	0.01	-22476	-19905	-17880

Table 18: Showcases the results of the sensitivity analysis conducted supply elasticities.

Based on the sensitivity analysis conducted, it can be concluded that the model and elasticities used within this research is only sensitive to change for the supply elasticity in the one instance listed above. Considering the sensitivity analysis, alongside the reputable literature used to gather the elasticities, it is realistic to consider that the modelling and subsequent results are robust.

Chapter 5: Conclusion and limitations

The final chapter aims to summarise the main takeaways from the research, with a focus on the economic, trade and transportation impacts of digitalization throughout the supply chain. Furthermore, I will also discuss the limitations of this research and areas for future research.

5.1 Key Takeaways

Main Takeaway 1: China as a big winner in terms of exports. Scenario 1

Seeing the largest growth value of exports out of all the countries simulated, China is projected to see a percentage change in output of 0.49%. Although it may seem like an insignificant percentage at first glance, one must consider the vast amount of trade China conducts in exports alone. When comparing the preliminary trade matrix to the new trade quantities, the amount exported increase is valued at USD 36,182 million. Furthermore, the simulation projects their largest value increase in exports to the United States at USD 18,257 million, *Laggers* at USD 6692 million, Japan at USD 5726 million, India at USD 3370 million, and the Netherlands at USD 3184 million. These results showcase the extensive global reach China has already had both pre and post-shock. Additionally, it shows how significant the role digitalization plays in both increased efficiency and in facilitating trade. Furthermore, this increase in trade also shows exceptional benefits for producers and consumers alike. Overall, producers can expect a percentage increase of 0.13% in their prices and a 0.62% increase in their revenues. Consumers can expect a percentage decrease in prices of -0.51%, thus increasing their total consumption by 1.27%. Overall, the positive effects of digitization China would see must be considered.

Main Takeaway 2: United States winning big in terms of imports. Scenario 1

In contrast to China, the United States sees the largest growth in imports in terms of values out of all the countries listed. Projected to see a growth of 1.58% in imports, coming out to a total value of USD 37,866 million. Comparing the Preliminary trade matrix to the final trade values, the largest areas of bilateral trade growth are imports from China-US totaling USD 18,257 million, Japan-US USD 3809 million, Laggers-US USD 3167 million, Italy-US USD 2152 million, and India-US USD 2041 million. These results show the increase in economic growth the United States would see utilizing these digital technologies and trading with countries that also utilize them. The most shocking increase is the significant growth in trade value with China compared to the other countries simulated. However, it is worth noting that pre-shock, the US already traded a considerable amount with China, hence the significant increase in value. Similarly, both producers and consumers are predicted to see positive benefits from digitalization. Producers are estimated to see a percentage price increase of 0.14%, thus increasing their revenues by 0.36%. Whereas consumers would see a percentage decrease of consumer prices by -0.50%, increasing their consumption by 1.57%. In total, the positive effects of digitalization on the already sizable economy of the United States should not be understated.

Main Takeaway 3: Digitalization Impact on Net Welfare Scenario 1

Finally, it is important to consider the overall positive impact of digitalization on net welfare. When assessing the economic effects of these technologies, we must consider both producer and consumer surplus to get a comprehensive view. Notably, every country is expected to experience significantly positive economic benefits through digitalization. The United States is projected to see the largest growth in net welfare effects, with a total increase of USD 17,201 million. This is primarily due to the substantial growth in imports, which will result in a significant increase in consumer surplus (USD 12,004 million) and a positive gain for producers (USD 5,196 million). China is projected to follow closely behind, with a total welfare increase of USD 16,927 million, comprising a consumer surplus increase of USD 7,089 million and a producer surplus increase of USD 9,838 million. The total welfare of all countries simulated is projected to be USD 73,821 million, highlighting the substantial benefits countries can expect from utilizing these technologies. It is also essential to consider the positive impact that digitalization will have on countries that still need to implement these technologies. Overall, Laggers are projected to see a net welfare increase of USD 5,573 million, with consumers projected to gain the largest portion of surplus at USD 3,675 and producers gaining USD 1,899 million. This is because the increased efficiency and productivity seen in countries that have adopted digitalization will likely trickle down to other countries, contributing to their economic growth.

Main Takeaway 4: Digitalization Impact on Maritime Trade Scenario 1.

Another essential aspect that should be considered is digitalization's overall impact on the container and bulk trade. Firstly, it is seen that bilateral trade interaction is positively impacted, with some seeing a more significant increase in thousands of TEUS and tens of thousands of tonnes transported. It must be considered that container trade has more value than volume. Therefore, although the total impact may seem insignificant due to the 15.15% degree of containerization used when calculating the conversion method, one must consider the value of goods being transported. Additionally, the increase seen by those lagging behind in implementing these technologies must also be noted. It shows that their own throughput increases due to this increase in efficiency elsewhere by default. Lastly, we see the largest increase in imports of containerized goods in the United States. This signifies a boost to an already robust economy in terms of increased consumer demand and consumption.

Main Takeaway 5: Scenario 2 Impact on exports and imports.

Scenario 2 paints a different picture of the impact on exports and imports due to digitalization, being slightly offset by the negative NTM simulated for every bilateral trade interaction with the country group *Laggers*. However, similarly to scenario 1, the projected biggest winner in terms of value exported is China again, albeit at a significantly lower value. With China estimated to see a percentage change in output of 0.28% compared to a previously projected change in output of 0.49% in scenario one, the negative shock of the NTM has undeniably had a widespread impact on all countries within the matrix. Nonetheless, the significant growth China is expected to see must be recognized, valued at USD 20,610 million in exports alone. Another notable change is that Singapore is now projected to see the largest projected growth in output at 0.49%. In contrast, China was projected to see the largest growth in the previous scenario. Within scenario 2, Singapore is projected to see a growth in exports valued at USD 4,420 million. A decrease in value from scenario 1 of USD 113 million.

When looking at the value of imports gained due to the positive and negative shock, the biggest winner by a landslide is the United States, projected to see a total of USD 34,247 million in imports. Furthermore, the US is projected to see a percentage growth of 1.42%, whereas they were projected to see a 1.58% growth in imports in scenario 1. Although this decrease of 0.16% in imports may seem insignificant, it translates to a loss of USD 3,619 million. Another notable remark is that Brazil is projected to see an additional percentage growth in imports compared to scenario 1, estimated to see a growth of 2.49% in scenario 2 compared to a growth of 2.44% in scenario 1. This translates to a total growth of USD 5,149 million imported in scenario 2, compared to USD 5,052 million in scenario 1, representing a growth of USD 97 million between the two scenarios. This increase can be attributed to the large amounts of imports Brazil does with China and the US, respectively—China-Brazil post-shock valued at USD 2,352 million and US-Brazil at USD 1,803 million.

Main Takeaway 6: Scenario 2 Impact on Net welfare.

Another essential aspect to consider is the implications of the NTMs simulated in scenario 2 on the net welfare of the countries within the trade matrix. When considering the net welfare of a country, I consider both producer and consumer surplus. In contrast, tax effects are not considered due to the nature of the research within this paper. The top 3 countries which are predicted are the United States, China, and Japan. Predicted to see the most significant positive effects of the NTMS proposed within scenario 2, the United States is expected to see a net welfare of USD 14,798 million. Consumers are expected to see the largest gain in surplus, gaining USD 10,865 million, whereas producers are still expected to see a significant increase, projected to gain USD 3,933 million. Furthermore, it is worth noting that the net welfare effects are projected to decrease by USD 2,403 million from scenario 1 to scenario 2 as a direct result of the decrease in trade with the *Laggers* and the negative NTM that has been simulated. Consumers are projected to lose USD 1,139 million and producers USD 1,263 million in surplus, respectively.

Following closely behind China, the second-largest increase in net welfare effects is expected to be valued at USD 12,420 million. Of this amount, consumers are projected to see the largest increase in surplus at USD 6,818 million, where producers still gain a considerable amount of USD 5,602 million. However, this is a considerable decrease from the positive effects in scenario 1, with producers losing significantly more at USD 4,236 million and consumers losing USD 1,487 million, respectively. Afterward, Japan is projected to see the third-largest growth in net welfare effects, valued at USD 6,561 million. Consumers will see a bigger portion of the increase in surplus valued at USD 3,603 million and producers at USD 2,958 million, respectively. In scenario 2, Japan is anticipated to see a net welfare loss of USD 11.1 million compared to scenario 1. As a result of this projected loss, consumers are expected to gain USD 101 million of surplus. However, this gain is offset by the anticipated loss of USD 113 million by producers due to the adverse effects of the NTMS.

The most notable change is the negative impact seen on the conglomerate *Laggers.* Due to the negative effects of the proposed NTM on the *Laggers*, the projected loss in net welfare is calculated to be a staggering USD – 12,103 million. It is worth noting that this is the only negative effect seen on total welfare throughout both scenario 1 and scenario 2. Of this substantial loss to the *Laggers* welfare, consumers are anticipated to see the most significant portion of their welfare lost, losing a total of USD – 11,103 million. In contrast, producers see a less significant loss than consumers losing USD -1,000 million. More notably, this is a significant change compared to scenario 1, where *Laggers* were anticipated to gain a net welfare of USD 5,573 million due to the positive dominion effects of digitalization. The change from scenario 1 to scenario 2 is as follows: a change of USD -22,613 million in net welfare, consumers losing USD -14,777 million, and producers losing USD -4,674 million. These changes in welfare between the two scenarios highlight the actual adverse effects of not implementing digitalization while also highlighting the benefits digitalization brings when adequately implemented.

Main Takeaway 7: Scenario 2 Impact on Maritime Trade.

As seen in *Annex XII Figure T* and *Figure U* the negative impact of the proposed NTM for Laggers must be considered. The most staggering result is the overall loss of both TEUS, and tons transported between each country. Between the two scenarios, China is projected to see the largest loss in exports of both TEUS and tons due to the large amount of trade conducted with the *Laggers*, which heavily impacts the bilateral trade flow. On the other hand, The United States is projected to see the largest loss between the two scenarios, with the largest portion of TEUS and tons lost coming from trade with China and *Laggers*, respectively. Overall, it is essential to note that regardless of the 20% loss projected with the negative NTM, the positive effects of digitalization can still be seen through the net gain in imports and exports.

5.2 "What is the economic and logistic impact of countries investing in digitalization throughout the supply chain?"

The conducted literature review and the GSIM models ran within this research were meant to aid in answering the main research question and the sub-questions. Below, I will present the answers to the aforementioned questions.

To answer sub-question 1, after conducting a rigorous review of the available econometric models and comparing the advantages and disadvantages of each type of model, I have concluded that the best model to use is a partial equilibrium model. More specifically, I utilize the GSIM trade model, which allows me to showcase the actual economic effects of digitalization through the changes in a country's net welfare. Furthermore, a PE model is more suitable for this research as it requires less time to calibrate, allowing me to more closely adhere to the time restraints faced with data collection and completion of this research.

To answer sub-question 2, I look at the foundation on which the country selection was made when creating the trade matrix within the GSIM. After conducting literature and reviewing various case studies showcasing the increase in efficiency seen in ports through the utilization of digital technologies, maritime operators are vital in digitalization. Furthermore, throughout this research, the safe assumption is made that the facilities that maritime operators own are the hubs of digitalization for many companies that operate within ports.

To answer sub-question 3, we look at the NTM used to simulate the impact of countries delaying the implementation of these digital technologies. What was found through running the GSIM was the negative implications of not implementing these digital technologies were not only seen directly by the conglomerate of countries named Laggers but also by every other country represented within the trade matrix. These negative effects include the loss of both significant values of exports and imports but are also seen in the loss of overall net welfare compared to the holistically optimistic scenario 1.

To answer sub-question 4, I utilize the conversion method to quantify digitalization's transportation and logistics impact. What was seen through the simulation of both scenarios 1 and 2 is that overall, every country is projected to gain cargo throughput in both TEUS and tons. Furthermore, in scenario 1, we also see a trickle-down effect in the positive benefits of digitization, impacting the Laggers. Which in turn also increases their cargo throughput. However, when looking at scenario 2, we see a steep decline in cargo throughput in all the countries within the matrix. This can be attributed to the decreased efficiency vessels see when calling ports in the Lagger countries. Furthermore, the group Laggers is projected to lose cargo throughput due to the negative impact. The resulting loss in throughput can be attributed to ships having to stay in ports longer and vessels calling ports in nearby countries, which have decided to invest in these digital technologies to ensure a more efficient and quicker port call.

To answer sub-question 5, I look toward the results of the impact of digitalization on TEU and bulk trade, respectively. Through the analysis of this converted data, it is apparent that the countries that invest in digitalization indeed see more cargo throughput. Furthermore, it is worth noting that the countries with the larger trade flows before implementing these technologies by default see a more considerable increase in trade flow due to the multiplier effect of the NTM. However, even countries with smaller economies see significant positive impacts on their economies and their cargo throughput.

Therefore, through the conducted literature review, the scenarios ran within this research, and the answers to the sub-questions posed, it can be deduced that digitalization has a positive economic, trade, and transport impact.

5.3 Research Limitations

The first limitation faced within this research was using a PE model compared to a CGE model or a gravity model. However, the PE model used within the research allowed for a quicker, more in-depth analysis of the economic impact of digitalization. The use of a CGE model or gravity model would have allowed for further inputs to be used and the analysis of interlinked sectors. However, for the purpose of this research and the time limit imposed, I could not consider using either of those models. Furthermore, the missing 2022 trade data for specific countries limited the research. Due to this missing data, an assumption had to be made, allowing for the use of 2019 data instead of the data.

5.4 Areas for future research

When considering areas for future research, one may consider further breaking down maritime trade and utilizing specific HS codes to analyze the impact of digitalization on a more segmented market. Another aspect that may be considered for future research is the analysis of tariffs on digitalization. Furthermore, future research may also utilize a different econometric model and analyze the different sectors at play, allowing for a more in-depth analysis of the various economic forces at play.

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Appendix I

Based on existing fleet and orderbook
TEU capacity available on board operated ships.
All figures are consolidated.

Consolidated subsidiaries

Maersk includes Maersk A/S, Hamburg Sud, Alianca, Sealand Asia, Sealand Americas and Sealand Europe & Med
MSC includes WEC Lines and Log-In Logistica
CMA CGM Group includes CMA CGM, APL, ANL, CNC, CoMaNav, Containerships, Feeder Associate System, MacAndrews, Mercosul Line and SoFrana
COSCO Group includes COSCO Shipping, OOCL, Shanghai Pan Asia Shipping, New Golden Sea Shipping, Coheung and Diamond Line
Hapag-Lloyd includes NileDutch and DAL, and integrates the former UASC fleet
Evergreen Group includes Evergreen Line and Italia Marittima
Zim (ZISS) includes Gold Star Line
PIL (Pacific International Lines) includes Advance Container Line and Mariana Express Lines
IRISL Group includes IRISL, HDS Lines, Valfajre Eight Shipping and Khazar Shipping
Sinokor Merchant Marine includes Heung-A Line
Transworld Group includes Straits Orient Lines
Shanghai Jin Jiang Shipping includes Shanghai Hai Hua (HASCO)
Grimaldi (Napoli) includes Atlantic Container Line and Finnlines
Swire Shipping includes Westwood Shipping and Pacifica Shipping
FESCO includes FESCO ESF
Unifeeder includes Unimed Feeder Services (UFS), Feedertech, Shreyas Shipping and Transworld Feeders
Rifline inclldes Kalypso
Samskip includes Nor Lines A/S and Seaconnect
Peel Ports includes BG Freight
GS Lines includes Portusline Containers International (PCI)

Figure a: Retrieved from Alphaliner top 100 list. Showcases the consolidation of various subsidiaries. Retrieved from: https://alphaliner.axsmarine.com/publictop100/ on: 14/08//2023

Appendix II

Rank	Operator	Teu	Share
1	Mediterranean Shg Co	5,209,989	19.0%
2	Maersk	4,149,918	15.2%
3	CMA CGM Group	3,511,846	12.8%
4	COSCO Group	2,955,867	10.8%
5	Hapag-Lloyd	1,884,159	6.9%
6	ONE (Ocean Network Express)	1,681,897	6.1%
7	Evergreen Line	1,673,600	6.1%
8	HMM Co Ltd	792,074	2.9%
9	Yang Ming Marine Transport Corp.	705,614	2.6%
10	Zim	578,663	2.1%
11	Wan Hai Lines	453,324	1.7%
12	PIL (Pacific Int. Line)	295,331	1.1%
13	SITC	156,231	0.6%
14	KMTC	153,261	0.6%
15	IRISL Group	137,604	0.5%
16	X-Press Feeders Group	135,517	0.5%
17	Zhonggu Logistics Corp.	121,430	0.4%
18	UniFeeder	117,420	0.4%
19	Sea Lead Shipping	110,993	0.4%
20	Sinokor Merchant Marine	109,739	0.4%
21	Antong Holdings (QASC)	86,593	0.3%
22	TS Lines	79,623	0.3%
23	Global Feeder Shipping LLC	76,985	0.3%
24	Swire Shipping	73,580	0.3%
25	RCL (Regional Container L.)	72,807	0.3%
26	Emirates Shipping Line	69,119	0.3%
27	SM Line Corp.	68,489	0.3%
28	Matson	63,776	0.2%
29	Ningbo Ocean Shg Co	62,251	0.2%
30	Arkas Line / EMES	54,357	0.2%

Figure b: Showcases the top 30 maritime operators by capactiy calculated in TEUS and their respective global market share in percentage. Retrieved from: https://alphaliner.axsmarine.com/Publictop100/ on: 14/08/2023

Appendix III

Country	Company				
	Maersk		MSC		CMA
China	9.88%	Japan	7.39%	China	6.70%
India	4.10%	China	6.01%	Italy	3.74%
Brazil	3.98%	Italy	5.60%	Namibia	3.74%
Spain	3.73%	United States	4.06%	India	3.45%
United States	3.13%	India	3.57%	United States	3.16%
Norway	2.65%	Turkey	3.08%	Indonesia	2.97%
Italy	2.53%	Brazil	2.76%	Turkey	2.87%
Malaysia	1.93%	Spain	2.68%	Brazil	2.68%
Sweden	1.93%	Indonesia	2.35%	Spain	2.49%
Turkey	1.93%	Vietnam	2.03%	Algeria	2.11%
Egypt	1.69%	Mexico	1.87%	Mexico	2.11%
France	1.57%	Norway	1.79%	South africa	2.01%

Figure d: Created by author: Depicts percentage of total facilities located in respective country. All data is based on the respective companies' global website.

Country	Company				
	EverGreen		Zim		HMM Co
China	7.37%	China	11.05%	China	11.54%
India	7.37%	India	5.79%	South Korea	9.13%
United States	4.21%	Spain	5.79%	United States	8.65%
Malaysia	3.86%	United States	4.74%	India	7.69%
Indonesia	3.51%	Brazil	4.21%	Indonesia	3.85%
Italy	3.51%	Italy	3.16%	Brazil	3.37%
Spain	3.51%	Portugal	3.16%	Spain	2.88%
Brazil	2.81%	Colombia	2.63%	Egypt	2.40%
Japan	2.46%	Japan	2.63%	Japan	2.40%
Mexico	2.46%	Turkey	2.63%	Russia	2.40%
Egypt	2.11%	Venezuela	2.63%	Germany	1.92%
France	1.75%	Canada	2.11%	Thailand	1.92%

Figure e: Created by author: Depicts percentage of total facilities located in respective country. All data is based on the respective companies' global website.

Appendix IV

Country	Company				
	ONE		CoscoShipping		Hapag-Lloyd
India	10.00%	China	45.13%	India	7.08%
China	7.60%	Egypt	1.67%	China	5.54%
Malaysia	4.80%	India	1.67%	Brazil	5.23%
United States	3.20%	Germany	1.39%	Indonesia	4.31%
Indonesia	2.80%	Spain	1.39%	United States	4.00%
Brazil	2.40%	Turkey	1.39%	Mexico	3.69%
Philippines	2.40%	Vietnam	1.39%	Germany	2.77%
Australia	2.00%	Algeria	1.11%	Colombia	2.15%
Egypt	2.00%	Australia	1.11%	Italy	2.15%
Russia	2.00%	Malaysia	1.11%	Malaysia	2.15%
South africa	2.00%	Mexico	1.11%	Egypt	1.85%
Spain	2.00%	South africa	1.11%	Russia	1.85%

Figure f: Created by author: Depicts percentage of total facilities located in respective country. All data is based on the respective companies' global website.

Country	Company				
	Wai Hai Lines		KMTC		X-Press
China	16.46%	Japan	39.32%	Spain	9.15%
India	11.39%	China	14.53%	India	8.45%
Japan	10.13%	Indonesia	12.82%	China	4.93%
Indonesia	8.23%	India	11.97%	Italy	4.23%
Iraq	8.23%	South Korea	4.27%	United kingdom	3.52%
Malaysia	6.96%	Malaysia	2.56%	Finland	2.82%
United arab emirates	4.43%	Vietnam	2.56%	Sweden	2.82%
Philippines	3.80%	Saudi arabia	1.71%	Colombia	2.11%
Taiwan	3.80%	Bangladesh	0.85%	Croatia	2.11%
Vietnam	3.80%	Cambodia	0.85%	Indonesia	2.11%
South Korea	3.16%	Kenya	0.85%	South Korea	2.11%
Pakistan	1.90%	Myanmar	0.85%	Malaysia	2.11%

Figure g:Created by author: Depicts percentage of total facilities located in respective country. All data is based on the respective companies' global website.

Appendix V

Country	Company				
	SITC		YangMing		PIL
China	63.33%	China	7.79%	China	15.05%
Cambodia	3.33%	India	6.93%	India	10.22%
Indonesia	3.33%	Japan	5.19%	Malaysia	6.45%
Japan	3.33%	Malaysia	4.76%	Japan	5.38%
Malaysia	3.33%	Brazil	4.33%	Brazil	3.76%
Myanmar	3.33%	Indonesia	3.90%	Indonesia	3.76%
Philippines	3.33%	Turkey	3.03%	Australia	3.23%
Singapore	3.33%	Colombia	2.60%	New zealand	2.69%
South africa	3.33%	Italy	2.60%	United arab emirates	2.69%
Taiwan	3.33%	Spain	2.60%	Vietnam	2.69%
Thailand	3.33%	Australia	2.16%	South Korea	2.15%
Vietnam	3.33%	United States	2.16%	Pakistan	2.15%

Figure h: Created by author: Depicts percentage of total facilities located in respective country. All data is based on the respective companies' global website.

Appendix VI

Trade	d: destination												
s: source	China	India	Indonesia	Malaysia	Brazil	Spain	United States	Japan	Italy	Egypt	Singapore	Netherlands	Laggers	ROW
China														
India														
Indonesia														
Malaysia														
Brazil														
Spain														
United States														
Japan														
Italy														
Egypt														
Singapore														
Netherlands														
Laggers														
ROW														

Figure i: Preliminary trade matrix, countries selected by author.

In millions USD	d: destination												
s: source	China	India	Indonesia	Malaysia	Brazil	Spain	United States	Japan	Italy	Egypt	Singapore	Netherlands	Laggers	ROW
China	0	141011	74897	99376	64322	43507	620774	186015	54146	17649	93328	127879	2483979	4400596
India	24882	0	9867	7191	9724	4796	80230	5700	8509	4093	11831	18500	261588	222015
Indonesia	30464	11823	0	8802	1003	1599	17874	16003	1749	1013	12917	3205	3261	225654
Malaysia	50104	9315	7563	0	884	1090	23342	15932	1220	444	33091	6348	4573	326518
Brazil	91058	6340	3108	3842	0	9761	38147	6603	4823	2844	8345	11911	12627	469516
Spain	9192	1921	462	551	3753	0	19861	3401	33142	1649	1088	15767	87719	670067
United States	179653	47332	9986	18103	53578	26480	0	80305	27411	6553	46163	72877	479077	3076664
Japan	177676	13928	15051	16458	4318	2703	139768	0	5307	771	22342	12374	26048	1056599
Italy	23737	5411	1200	1708	5789	35775	73121	9048	0	4233	2749	20884	107712	1109264
Egypt	1777	1761	450	94	280	3531	2146	238	3333	0	303	1673	4094	76617
Singapore	121749	13899	37230	51586	2012	426	45306	20791	1082	373	0	11118	8824	715536
Netherlands	17453	3444	1035	1131	4059	22866	36262	5509	31707	1901	3642	0	113440	1298165
Laggers	109944	20030	3231	4076	9068	59843	449371	7215	70383	4979	18362	73961	98417	2361775
ROW	744620	147421	34568	40863	74227	207739	1154926	205381	349489	25685	79225	355447	882547	12179792

Figure j: Trade matrix with raw trade data. All data gathered from: https://comtradeplus.un.org/

Appendix VII

In millions USD	d: destination													
s: source	China	India	Indonesia	Malaysia	Brazil	Spain	United States	Japan	Italy	Egypt	Singapore	Netherlands	Laggers	ROW
China	0.00	0.70	0.90	0.85	0.90	0.90	0.90	0.85	0.85	0.80	0.80	0.85	0.85	0.90
India	0.70	0.00	0.90	0.85	0.90	0.85	0.90	0.90	0.85	0.80	0.80	0.85	0.85	0.90
Indonesia	0.90	0.90	0.00	0.85	0.90	0.90	0.90	0.85	0.90	0.90	0.80	0.90	0.90	0.90
Malaysia	0.85	0.85	0.85	0.00	0.90	0.90	0.90	0.85	0.90	0.85	0.70	0.90	0.90	0.90
Brazil	0.90	0.90	0.90	0.90	0.00	0.90	0.85	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Spain	0.90	0.85	0.90	0.90	0.90	0.00	0.90	0.90	0.75	0.80	0.90	0.70	0.70	0.90
United States	0.90	0.90	0.90	0.90	0.85	0.90	0.00	0.90	0.90	0.90	0.90	0.90	0.85	0.90
Japan	0.85	0.90	0.85	0.85	0.90	0.90	0.90	0.00	0.90	0.90	0.85	0.90	0.90	0.90
Italy	0.85	0.85	0.90	0.90	0.90	0.75	0.90	0.90	0.00	0.85	0.90	0.70	0.85	0.90
Egypt	0.80	0.80	0.90	0.85	0.90	0.80	0.90	0.90	0.85	0.00	0.90	0.85	0.90	0.90
Singapore	0.80	0.80	0.80	0.70	0.90	0.90	0.90	0.85	0.90	0.90	0.00	0.90	0.90	0.90
Netherlands	0.85	0.85	0.90	0.90	0.90	0.70	0.90	0.90	0.70	0.85	0.90	0.00	0.85	0.90
Laggers	0.85	0.85	0.90	0.90	0.90	0.70	0.85	0.90	0.85	0.90	0.90	0.85	0.00	0.90
ROW	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

Figure k: Created by author. Shows percentage of trade flow only accounting for seaborne trade between countries.

In millions USD	d: destination													
s: source	China	India	Indonesia	Malaysia	Brazil	Spain	United States	Japan	Italy	Egypt	Singapore	Netherlands	Laggers	ROW
China	0	98708	67407	84470	57890	39157	558696	158113	46024	14119	74663	108697	2111382	3960536
India	17418	0	8880	6112	8752	4077	72207	5130	7232	3274	9465	15725	222350	199814
Indonesia	27417	10641	0	7482	902	1439	16086	13603	1574	912	10333	2884	2935	203089
Malaysia	42589	7918	6428	0	795	981	21008	13542	1098	377	23164	5714	4115	293866
Brazil	81952	5706	2798	3458	0	8785	32425	5943	4341	2559	7511	10719	11364	422565
Spain	8273	1633	416	496	3378	0	17875	3061	24856	1320	979	11037	61403	603060
United States	161688	42599	8987	16293	45541	23832	0	72274	24670	5898	41547	65589	407215	2768997
Japan	151024	12535	12794	13989	3886	2433	125791	0	4776	694	18991	11137	23443	950939
Italy	20176	4599	1080	1537	5210	26831	65809	8143	0	3598	2474	14619	91555	998338
Egypt	1421	1409	405	80	252	2824	1931	214	2833	0	273	1422	3685	68955
Singapore	97399	11119	29784	36110	1811	383	40776	17673	974	336	0	10006	7942	643983
Netherlands	14835	2927	931	1018	3653	16006	32636	4958	22195	1616	3278	0	96424	1168349
Laggers	93452	17026	2908	3668	8161	41890	381965	6494	59826	4481	16526	62867	83654	2125597
ROW	670158	132679	31111	36777	66804	186965	1039434	184843	314540	23116	71302	319902	794292	10961812

Figure l: Created by Author: Finalized trade matrix accounting for only seaborne trade between countries.

Appendix VIII

Vessel type	Median time in port (days)	Median time in port, annual change (%)	Average age of vessels	Average size (GT) of vessels	Maximum size (GT) of vessels	Average cargo carrying capacity (dwt) per vessel	Maximum cargo carrying capacity (dwt) of vessels	Average container carrying capacity (TEU) per container ship
Container ships	0.80	13.7	14	37 223	237 200			3 431
Dry breakbulk carriers	1.17	2.1	21	5 463	91 784	7 427	116 173	
Dry bulk carriers	2.11	2.3	14	32 011	204 014	57 268	404 389	
LNG carriers	1.13	0.9	11	95 356	168 189	74 522	155 159	
LPG carriers	1.03	-1.5	15	10 541	61 000	11 799	64 220	
Liquid bulk carriers	0.98	1.3	14	15 739	170 618	27 275	323 183	
All ships	**1.05**	**4.8**	**16**	**21 732**	**237 200**	**26 997**	**404 389**	**3 431**

Source: UNCTAD, based on data provided by MarineTraffic (https://www.marinetraffic.com).
Note: Ships of 1,000GT and above. Not including passenger ships and Ro/Ro vessels.

Figure n: Showcases the median time in ports for all ships. Taken from UNCTAD Review of Maritime Transport 2022, page 82.

Country	Substitution Elasticity	Country	Composite Demand Elasticity	Country	Supply Elasticity
China	2.90	**China**	-1.44	**China**	3.68
India	2.90	**India**	-1.74	**India**	1.21
Indonesia	2.90	**Indonesia**	-1.38	**Indonesia**	0.38
Malaysia	2.90	**Malaysia**	-1.08	**Malaysia**	1.13
Brazil	3.20	**Brazil**	-2.17	**Brazil**	0.82
Spain	2.70	**Spain**	-1.33	**Spain**	1.08
United States	2.40	**United States**	-2.09	**United States**	1.56
Japan	3.20	**Japan**	-1.83	**Japan**	1.57
Italy	2.70	**Italy**	-1.35	**Italy**	1.24
Egypt	2.90	**Egypt**	-1.31	**Egypt**	0.50
Singapore	2.90	**Singapore**	-1.21	**Singapore**	2.79
Netherlands	2.60	**Netherlands**	-1.15	**Netherlands**	2.01
Laggers	2.90	**Laggers**	-1.21	**Laggers**	0.99
ROW	2.90	**ROW**	-1.21	**ROW**	0.99

Table 4: Showcases the various elasticities used within the GSIM the author ran. Source for Substitution Elasticity: Bajzik, J., Havranek, T., Irsova, Z., & Schwarz, J. (2019). The Elasticity of Substitution between Domestic and Foreign Goods: A Quantitative Survey. Retrieved August 17, 2023, from http://hdl.handle.net/10419/200207

Appendix IX

Country	Producer Surplus	Consumer Surplus	Net Welfare
China	9,842.8	7,092.6	16935.4
India	1,813.9	2,327.7	4141.6
Indonesia	1,080.2	1,596.6	2676.8
Malaysia	1,163.9	1,958.8	3122.7
Brazil	1,710.8	1,546.5	3257.3
Spain	860.1	1,559.2	2419.3
United States	5,196.9	12,017.7	17214.6
Japan	3,070.7	3,503.0	6573.7
Italy	1,646.3	1,759.2	3405.5
Egypt	157.3	406.7	564.0
Singapore	1,626.1	2,203.7	3829.8
Netherlands	1,044.2	3,091.1	4135.3
Laggers	1,745.1	3,506.6	5251.7
ROW	1,273.2	-21,178.2	-19905.0

Table 6: Showcases the various surplus for each country alongside the net welfare realized by the respective country. Scenario 1

Country	Percentage change in Exports	Country	Percentage change in Imports
China	0.49%	**China**	1.27%
India	0.38%	**India**	1.87%
Indonesia	0.14%	**Indonesia**	2.25%
Malaysia	0.31%	**Malaysia**	1.98%
Brazil	0.23%	**Brazil**	2.44%
Spain	0.13%	**Spain**	1.04%
United States	0.22%	**United States**	1.58%
Japan	0.36%	**Japan**	2.06%
Italy	0.16%	**Italy**	0.81%
Egypt	0.09%	**Egypt**	1.54%
Singapore	0.50%	**Singapore**	1.78%
Netherlands	0.15%	**Netherlands**	1.06%
Laggers	0.06%	**Laggers**	0.20%
ROW	0.01%	**ROW**	-0.18%

Table 7: Showcases the various percentage change in both exports and imports for each country. Scenario 1

Appendix X

Country	Percentage change in Producer Price	Country2	Percentage Change in Consumer Price
China	0.133	**China**	-0.514
India	0.312	**India**	-0.672
Indonesia	0.361	**Indonesia**	-0.928
Malaysia	0.276	**Malaysia**	-0.935
Brazil	0.285	**Brazil**	-0.756
Spain	0.117	**Spain**	-0.441
United States	0.141	**United States**	-0.503
Japan	0.230	**Japan**	-0.716
Italy	0.132	**Italy**	-0.343
Egypt	0.183	**Egypt**	-0.658
Singapore	0.181	**Singapore**	-0.793
Netherlands	0.076	**Netherlands**	-0.485
Laggers	0.062	**Laggers**	-0.091
ROW	0.009	**ROW**	0.083

Table 8: Showcases the various percentage changes in both Producer and consumer prices for all countries. Scenario 1

Country	Producer Surplus	Consumer Surplus	Net Welfare
China	5,602.6	6,818.1	12,420.7
India	1,102.0	2,333.1	3,435.1
Indonesia	1,056.5	1,639.4	2,695.9
Malaysia	1,137.0	2,007.9	3,144.9
Brazil	1,651.3	1,574.7	3,226.0
Spain	636.1	1,430.3	2,066.4
United States	3,933.1	10,865.1	14,798.3
Japan	2,958.8	3,603.0	6,561.9
Italy	1,316.7	1,563.3	2,880.0
Egypt	140.0	404.0	544.0
Singapore	1,585.7	2,208.7	3,794.4
Netherlands	750.9	2,940.1	3,691.0
Laggers	-1,000.6	-11,103.1	-12,103.7
ROW	1,253.1	-14,757.3	-13,504.3

Table 9: Showcases the various surplus for each country alongside the net welfare realized by the respective country for scenario 2.

Annex XI

Country	Percentage change in Exports	Country	Percentage change in Imports
China	0.28%	China	1.22%
India	0.23%	India	1.88%
Indonesia	0.13%	Indonesia	2.31%
Malaysia	0.30%	Malaysia	2.03%
Brazil	0.23%	Brazil	2.49%
Spain	0.09%	Spain	0.95%
United States	0.17%	United States	1.42%
Japan	0.35%	Japan	2.12%
Italy	0.13%	Italy	0.72%
Egypt	0.08%	Egypt	1.53%
Singapore	0.49%	Singapore	1.78%
Netherlands	0.11%	Netherlands	1.00%
Laggers	-0.03%	Laggers	-0.62%
ROW	0.01%	ROW	-0.13%

Table 13: Showcases the various percentage change in both exports and imports for each country scenario 2.

Country	Percentage change in Producer Price	Country	Percentage Change in Consumer Price
China	0.08	China	-0.49
India	0.19	India	-0.67
Indonesia	0.35	Indonesia	-0.95
Malaysia	0.27	Malaysia	-0.96
Brazil	0.27	Brazil	-0.77
Spain	0.09	Spain	-0.40
United States	0.11	United States	-0.45
Japan	0.22	Japan	-0.74
Italy	0.11	Italy	-0.30
Egypt	0.16	Egypt	-0.65
Singapore	0.18	Singapore	-0.79
Netherlands	0.05	Netherlands	-0.46
Laggers	-0.03	Laggers	0.28
ROW	0.01	ROW	0.06

Table 15: Showcases the various percentage changes in both Producer and consumer prices for all countries for scenario 2.

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Annex XII

S \ D	China	India	Indonesia	Malaysia	Brazil	Spain	United States	Japan	Italy	Egypt	Singapore	Netherlands	Laggers	ROW	Total Exports
China	0.00	-39.94	-24.07	-27.06	-26.65	-14.26	-224.41	-67.86	-17.03	-5.17	-25.78	-37.27	-681.28	319.07	-871.71
India	-4.63	0.00	-2.12	-1.23	-2.87	-1.03	-21.89	-1.53	-1.88	-0.81	-2.15	-3.72	-45.81	39.04	-50.62
Indonesia	-9.14	-3.76	0.00	-2.01	-0.36	-0.46	-5.78	-5.06	-0.51	-0.29	-3.04	-0.86	-0.79	26.44	-5.61
Malaysia	-15.65	-3.07	-2.19	0.00	-0.35	-0.34	-8.14	-5.56	-0.39	-0.13	-7.60	-1.87	-1.25	28.53	-18.02
Brazil	-29.61	-2.18	-0.93	-1.03	0.00	-3.01	-12.40	-2.40	-1.51	-0.88	-2.42	-3.45	-3.39	43.57	-19.64
Spain	-3.41	-0.70	-0.16	-0.17	-1.66	0.00	-7.58	-1.41	-9.82	-0.52	-0.36	-4.05	-21.41	32.90	-18.35
United States	-64.53	-17.85	-3.34	-5.45	-21.69	-9.00	0.00	-32.17	-9.46	-2.24	-14.95	-23.34	-136.99	184.50	-156.51
Japan	-57.97	-5.06	-4.56	-4.47	-1.79	-0.88	-50.44	0.00	-1.76	-0.25	-6.54	-3.81	-7.51	77.36	-67.70
Italy	-8.24	-1.97	-0.41	-0.53	-2.54	-10.36	-27.73	-3.71	0.00	-1.40	-0.91	-5.32	-31.63	57.56	-37.19
Egypt	-0.56	-0.58	-0.15	-0.03	-0.12	-1.05	-0.79	-0.09	-1.07	0.00	-0.10	-0.50	-1.22	5.00	-1.25
Singapore	-39.56	-4.74	-11.27	-12.34	-0.88	-0.15	-17.10	-8.01	-0.38	-0.13	0.00	-3.62	-2.72	38.51	-62.39
Netherlands	-6.44	-1.33	-0.38	-0.38	-1.88	-6.57	-14.45	-2.40	-9.24	-0.67	-1.29	0.00	-35.77	38.23	-42.57
Laggers	-33.44	-6.43	-0.96	-1.08	-3.51	-14.23	-145.11	-2.59	-20.67	-1.52	-5.26	-20.08	-26.59	183.67	-97.81
ROW	24.65	2.32	1.98	3.65	0.44	5.23	-53.47	6.77	7.01	1.27	5.34	11.01	61.91	-95.23	-17.13
Total Imports	-248.54	-85.29	-48.56	-52.12	-63.84	-56.12	-589.28	-126.01	-66.72	-12.74	-65.08	-96.89	-934.46	979.15	

Figure w: Show cases the change in thousands of TEUS transported between scenario 1 and scenario 2.

S \ D	China	India	Indonesia	Malaysia	Brazil	Spain	United States	Japan	Italy	Egypt	Singapore	Netherlands	Laggers	ROW	Total Exports
China	0.00	-557.44	-336.01	-377.79	-371.87	-199.15	-3128.11	-947.15	-237.83	-72.14	-360.10	-520.46	-9198.39	4368.05	-11938.38
India	-65.13	0.00	-29.81	-17.41	-40.38	-14.55	-306.68	-21.47	-26.40	-11.39	-30.25	-52.36	-613.07	535.09	-693.79
Indonesia	-127.19	-52.29	0.00	-28.01	-5.06	-6.34	-80.29	-70.46	-7.06	-3.99	-42.29	-11.92	-10.60	367.61	-77.90
Malaysia	-217.86	-42.69	-30.40	0.00	-4.88	-4.76	-113.16	-77.29	-5.41	-1.83	-105.81	-26.05	-16.81	396.72	-250.23
Brazil	-412.22	-30.28	-12.99	-14.29	0.00	-41.89	-172.36	-33.36	-21.06	-12.20	-33.67	-48.06	-45.46	605.33	-272.51
Spain	-47.45	-9.82	-2.23	-2.40	-23.07	0.00	-105.48	-19.57	-136.89	-7.22	-5.08	-56.45	-289.21	452.57	-252.29
United States	-899.58	-248.79	-46.53	-75.99	-302.28	-125.48	0.00	-448.36	-131.90	-31.26	-208.36	-325.34	-1848.68	2539.25	-2153.30
Japan	-806.88	-70.43	-63.41	-62.17	-24.84	-12.31	-701.26	0.00	-24.56	-3.53	-91.05	-53.04	-101.05	1075.10	-939.44
Italy	-114.81	-27.44	-5.73	-7.36	-35.31	-144.42	-385.83	-51.66	0.00	-19.53	-12.72	-74.17	-426.91	793.58	-512.32
Egypt	-7.78	-8.10	-2.06	-0.37	-1.65	-14.64	-10.98	-1.31	-14.91	0.00	-1.34	-6.94	-16.38	69.15	-17.32
Singapore	-550.48	-65.92	-156.80	-171.57	-12.20	-2.05	-237.75	-111.36	-5.29	-1.81	0.00	-50.42	-36.66	535.93	-866.38
Netherlands	-89.72	-18.51	-5.27	-5.24	-26.21	-91.47	-201.00	-33.42	-128.66	-9.35	-18.02	0.00	-483.71	525.55	-585.02
Laggers	-451.49	-86.92	-12.92	-14.42	-47.46	-192.25	-1969.88	-34.95	-279.43	-20.47	-70.79	-271.12	-359.98	2485.91	-1326.17
ROW	342.09	32.23	27.53	50.80	6.14	72.45	-739.60	94.35	97.01	17.67	74.26	152.68	836.49	-1302.09	-237.98
Total Imports	-3448.50	-1186.42	-676.61	-726.21	-889.06	-776.86	-8152.40	-1756.00	-922.38	-177.06	-905.22	-1343.64	-12610.42	13447.75	

Figure x: Showcases the change in tens of thousands of tons transported between scenario 1 and scenario 2.