Shipping and shipbuilding scenario evaluations
through integration of maritime and macroeconomic models.

Proefschrift

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Dit proefschrift is goedgekeurd door de promotoren:

Prof.Dr.ir. U. Nienhuis MBA
Prof.Dr. H. Meersman
Prof. Dr. E. Van de Voorde

Samenstelling promotiecommissie:

Rector Magnificus,	voorzitter
Prof. Dr.ir. U. Nienhuis MBA ,	Technische Universiteit Delft, promotor
Prof. Dr. H. Meersman,	Universiteit Antwerpen, promotor
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Prof. Dr. H. McLaughlin,	Canterbury Christ Church University

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To my father:
As sometimes it is
the mind that is weak
and the flesh that is strong

Propositions

1. An integrated model of the macro- and shipping economy allows us to answer the questions from industry and government with a much better founded 'It depends'.

2. Any (Ceteris Paribus) prediction of the future is false, as the given insight will influence our behaviour.

3. The insight gained from creating a model from scratch is of more value than the actual outcome.

4. South America will be the dry bulk shipbuilding area of the future, but only if politics and work ethic are irrelevant for the success of shipyards.

5. Opening up the Northern Sea Route for the dry bulk trade between Europe and Asia will only be beneficial if either the rates in shipping far exceed the cost price or the fee for passage drops at least below 15 USD per Gross Tonnage.

6. Studying economics is like studying religion, both have several mutually exclusive theories, both have followers that will fight (scientific) battles to prove their theory is the only right one and lastly both offer salvation only to their true followers.

7. The division of the amount of data needed by the amount of data available always exceeds one because reality does never follow theory

8. More than a handful simple relations put together make a very complex model.

9. A quick fix in a programme is the best way to introduce an unusual and hard to solve bug.

10. The 'C' and 'V' are the keystrokes most often used in a PhD research, usually accompanied by the 'Ctrl'-key and to be applied on data rather than text.

These propositions are regarded as opposable and defendable, and have been approved as such by the supervisors Prof. Dr. Ir. Ubald Nienhuis MBA, Prof. Dr. Hilde Meersman & Prof. Dr. Eddy Van de Voorde.

Stellingen

1. Een integraal model van de macro- en maritieme economie stelt ons in staat om vragen van de industrie en de overheid te beantwoorden met een veel beter onderbouwde 'Het ligt eraan'.

2. Elke (Ceteris Paribus) voorspelling van de toekomst is fout, aangezien het verkregen inzicht ons gedrag zal beïnvloeden.

3. Het inzicht verkregen door een model van de grond af op te bouwen is van meer waarde dan de resultaten die het model genereerd.

4. Zuid Amerika is het droge lading scheepsbouw gebied van de toekomst, maar alleen indien politiek en werkhouding geen rol spelen in het succes van werven.

5. Het gebruik van de Noordelijke Passage voor het vervoer van droge lading tussen Europa en Azië zal alleen succesvol zijn als of de vrachttarieven ver boven de kostprijs liggen of de kosten van een passage ten minste lager zijn dan 15 USD per Gross Tonnage.

6. De bestudering van de economie lijkt op de bestudering van religies, beiden hebben elkaar uitsluitende theorieën, beiden hebben volgelingen die met elkaar op de (wetenschappelijke) vuist gaan om hun gelijk te behalen en tenslotte beloven beide alleen verlossing voor trouwste volgelingen.

7. De breuk van de hoeveelheid benodigde data gedeeld door de hoeveelheid beschikbare data is altijd groter dan één omdat de realiteit nooit de theorie volgt.

8. Meer dan een handvol eenvoudige vergelijkingen samengevoegd maken een zeer complex model.

9. Een snelle reparatie van de programmacode is de beste manier om een ongebruikelijke en moeilijk te vinden fout te introduceren.

10. De 'C' en 'V' zijn de meest gebruikte toetsen in een PhD onderzoek, meestal vergezeld van de 'Ctrl'-toets en toegepast op data in plaats van tekst.

Deze stellingen worden opponeerbaar en verdedigbaar geacht en zijn als zodanig goedgekeurd door de promotoren Prof. Dr. Ir. Ubald Nienhuis MBA, Prof. Dr. Hilde Meersman & Prof. Dr. Eddy Van de Voorde.

Contents

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Summary

This research focusses on the use of consistent scenarios to help ship owners, banks and other parties with an interest the maritime business get a better grip on the future. Many data sources such as Clarcksons are available to the industry, however the models used here are often not known and fed by brokers estimates. Also many sources are required to get data on the entire span of the industry. This in turn results in inconsistencies within the data. Hence the current situation is far from optimal. This research is investigating a consistent approach to this problem. Though due to the time and data limitations, the focus is not on predicting the near future, but on what will happen in the medium and long term, given a certain scenario. The difference compared with a base scenario is investigated, rather than the absolute values.

The model created for this purpose has three distinct elements. First there is the macroeconomic module that represents the economies of major maritime areas. This model allows to follow wage development, exchange rates, imports, exports and many more similar variables. It also sets the demand for transport on each of the routes for dry bulk, wet bulk and general cargo/containers.

The second part of the model reflects the maritime markets. It contains sub models of the secondhand and newbuilding pricing of vessels, as well as models for scrapping and ordering vessels. All these models are estimated using General Additive Models (GAM), a technique that can work very well with real contracts, rather than with time series. Lastly all the costs of each vessel can be determined within this part as well.

The final element assigns the available fleet to the available cargo, it combines demand and supply. This is done on a weekly basis and on the basis of minimal total costs. The costs of a trade changes weekly, not only through the fact that prices and time charter rates change, but also due to the fact that the positioning of vessels is important and taken into account in this model.

A stable and verified model has been created and a number of scenarios are have been tested. While each scenario is interesting as an object of learning about the complex relations within the maritime industry, the fact that scenarios can be combined to help select good and best investments is of practical use to the industry. Unfortunately this part has not been fully developed yet, the NPV calculations can be done, but no method has been selected to help in the weighing of the scenarios.

The investigation has shown that both the amount of data available and the periods for which data was available, pose some problems. Especially the amount of vessels ordered is on the low side, resulting in lowered scrapping and difficulties when a large increase of the fleet is required. These elements should be further investigated and improved in the future.

1. Introduction

This chapter will introduce the subject of long term predictions in the maritime industry. It begins by giving a brief maritime history of the Phoenicians, one of the oldest trader societies, in Section 1.1. Section 1.2 relates the questions of the past to the maritime markets of today and extends upon these questions. This chapter concludes with 5 research questions.

1.1 The history of maritime commerce

Two quotes from “Commerce and Finance” by O.M. Powers [1903] on the history of commerce are presented here to start this chapter.

“The history of commerce is the history of civilization. In his barbarous state man's wants are few and simple, limited to his physical existence, such as food, clothing and shelter, but as he advances in the scale of intelligence his wants increase and he requires not only the comforts and conveniences of life but even the luxuries. […] No civilized community produces all the things which it consumes. A portion of its needs must be supplied by an interchange of products with other communities or nations and this is the beginning of commerce, either domestic or foreign. Moreover, it may be impossible for a nation to produce all that it needs to consume, owing to physical peculiarities of the country, its lack of coal, wood, or ore, its climate, etc.”

“The first navigators and carriers of goods by water, of which we read, were the Phoenicians who inhabited the narrow strip of coast land along the east of the Mediterranean Sea. Having a large sea frontage with little interior distance, these people were naturally attracted to seafaring occupations. Their coast abounded in good harbours, and their abundant forests supplied the materials for ship building, while agriculture was difficult on account of the hilly and rocky nature of the land. […]The Phoenicians imported largely raw materials, which they made up in Tyre and Sidon, and then exported the finished product either by their own ships seaward or by caravans to the east. Thus they were a manufacturing as well as a maritime nation.”

Powers states at the start of his book that commerce has been intertwined with our existence. The basis for commerce is and has always been that even in the pre-history nobody was perfect and able to provide all he needed by himself. As we evolved, so did our products and the skills required to create these products, giving further rise to more specialisation and therefore trade. The first recorded trading nation, to his knowledge, is Phoenicia. This empire is depicted in Figure 1.1. The Phoenicians are blessed with wood and natural harbours, but lack the resources for manufacturing requiring trade for their survival. Although trading raw materials from a place of abundance to a place of high demand might already yield profits, the Phoenicians introduced the modern concept of adding value 3000 years ago. Adding value to a product involves transforming a raw material into something of a higher value, such as cloths, jewels, etc. and only selling those products to other regions.

One cannot help wondering if and how their business men looked at the future. New ships were a huge investment and even wooden ships in these days had a life expectancy of more than 10 years and just like today it took at least a year, but more likely two, to build one. This could be a clear indication of them feeling the need to investigate their future, before ordering a new vessel. To make an informed decision, the Phoenician business men would certainly be asking questions such as: Will there be a war, which trades will be booming, will there be enough trade, does one optimise the vessel for payload or speed and perhaps even, will there be enough capable crew available (and against what price)?

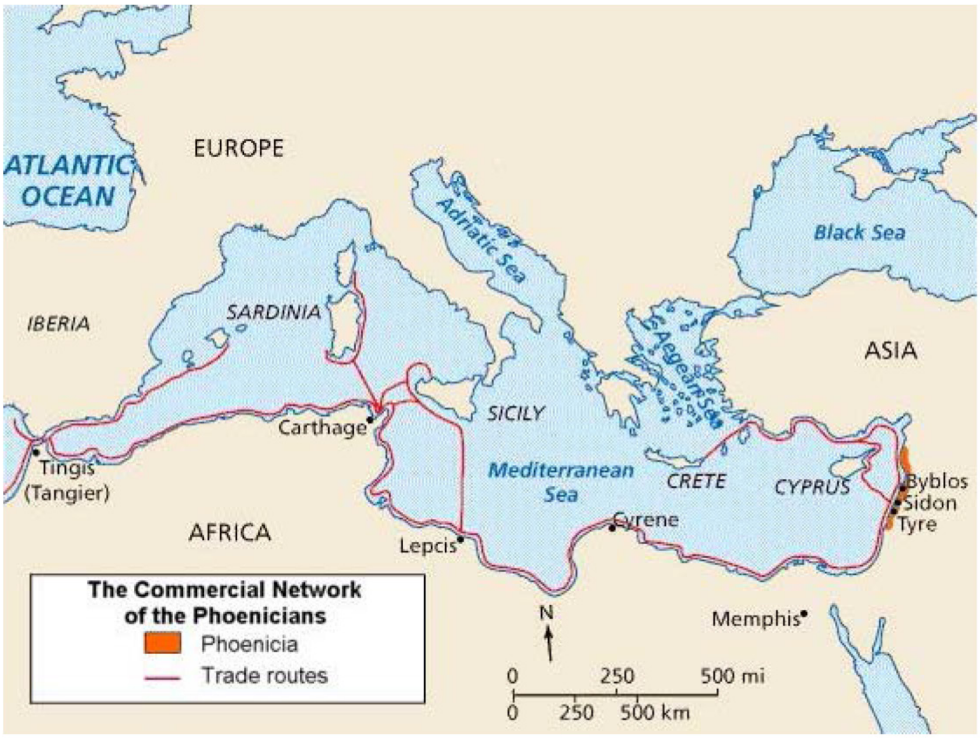


Figure 1.1: Trade routes, colonies and cities founded by Phoenician traders all around the Mediterranean (Source: Wikipedia.org [2011])

Because vessels were such a large investment, it seems likely that a single merchant would not pay for it all by himself. At least in ancient Greece there were people taking part in an investment for a cut of the profit, and such a system would most likely also be in place in Phoenicia. Another good reason to assume that investors existed is the reduced risk for an individual; not all of an investor's money is put in a single vessel, but instead he can spread his money over many ships and thus be sure that although, several may sink and lose him money, there will be enough ships left to yield an okay profit. Still, an investor would like to estimate the risks of losing his money before committing to a contract. An upcoming war could mean vessels are more likely to be pirated or sunk, including this newly build one. Furthermore, not all shipbuilders construct vessels of the same quality, and if a vessel is built at a shipyard the investor does not know, it may be at greater peril in a storm, due to bad construction.

Almost the same questions are still asked today by shipping companies, investors and banks. Currently we have information technology at our disposal, which grants present day investors access to far more information than their Phoenician counterparts. However, are we therefore better able to predict the future of a market? Before answering that, a closer look is taken at today's questions and the differences with the ones the Phoenicians traders asked themselves.

1.2 The need for information on the future

Nowadays we do not see many merchant captains anymore, buying goods at the market and selling it on the market in another town, but instead the trading and transportation function are separated. Both type of companies try to maximise profit. The companies sailing a vessel do this by trying to find the best voyage or time charter for a vessel. This is easier said than done. Because it is often difficult to determine what the best voyage is. Is it the one with the highest current profit or the one putting the vessel in a position where it could obtain a larger profit in the future? The first question is solvable with the information on current trips, but for the second one an investor requires information about the future. From where does he expect large quantities of cargo to be transported from, where will this cargo be transported to and where are suited vessels going to be?

The questions only get more complex when an investor is considering an extension of his fleet. Though here increasing is discussed the same discussion can be held for decreasing the fleet. To increase a fleet's capacity, an investor can charter a vessel or buy a secondhand or new vessel. The risks and profits involved with each option differ greatly, but all depend on the future market for that particular vessel's type and size. Where in the time of the Phoenicians a vessel lasted 10-15 years, nowadays the life expectancy of a vessel is at least 25 years, although vessels of over 75 years still sail the world. A company buying one, or a bank financing such a vessel, would like to make sure it is a good investment, even if it is not likely that a vessel will remain with a single company during its life, thus a period (much) shorter than 25 years can be considered. At least we now have classification societies, so that the investor and owner are sure a vessel is built according to a minimum standard, leaving them with one risk element less than the Phoenicians. The other questions, however, remain to this day. Mainly, will there be enough trade to pay back the costs of the vessel?

A group not yet mentioned explicitly in the introduction are the shipbuilders. The current required investments in infrastructure make shipbuilding a much riskier occupation than in the days of the Phoenicians, where little equipment was needed. Nowadays there are many yard-groups operating globally, constructing the steel hull where labour is cheap and doing the outfitting of the vessel where technical skills are available. In the current climate with significant overcapacity and low prices for orders, a wrong investment in a location, or even being late with investing in a 'good' location for ship production, might cause shipbuilders to lose orders to competitors. Political factors also have a significant influence of these investment decisions, but the economic conditions of labour, productivity and stability are the main factors of influence.

Until this point the future has been treated as a single option. To be right about the future one can choose to remain vague. A classical example of this was when the oracle of Delphi made her prediction to Croesus in 537 B.C. saying, "If you cross the (Halys) river, a great empire will be destroyed". Two large empires would go to war due to that crossing, but it was Croesus' empire that would be destroyed. Another approach would be to not limit the future to one option, but investigate a number of options for the future and be prepared for all of them. This idea also has classical roots: as Bradfield et al. [2005] mention Plato and his ideal 'Republic' as one of the first known scenario of the future written down. Admittedly Plato's ideal 'Republic' is not very helpful when deciding on a business strategy because it does not represent different futures. The origins of scenarios as a strategic planning tool are traced back by Bradfield et al. [2005] to Khan and his book from 1960: On Thermonuclear War. In this book Khan thought the unthinkable, considering the use of nuclear weapons in the cold war and its effects on mankind. Bradfield et al. also mention Shell in the 1970s as the first company to apply the ideas of scenario planning to the business environment, and they are still using it today. What is business scenario planning exactly? Many different ideas exist about this. Chermack et al. [2001] provide various examples and distil these into 3 rules on scenario planning. The first one is that scenarios are not predictions or forecasts. The second one is that they are challenging the current ideas of the future. The last one is that scenarios are internally consistent, meaning they are real options for the future. They also mention that scenario planning still is something for big companies as smaller companies lack the knowledge and resources to use this option for tuning their business strategy.

This uncertainty combined with the earlier described questions demonstrates the need for information on scenarios for the future. The main research question of this thesis is:

What are good investments in shipping given a consistent set of scenarios?

To answer this, the following 4 sub-questions have to be answered for each scenario:

1. What will the demand for maritime transport be on the most important routes?
2. What fleet development will be required to support this demand?
3. Which type of vessels will be built and which will be phased out?
4. How will the newbuilding sector react to these changes?

It might seem odd that 'freight rates' are not part of these questions, but the focus of these questions is on the medium to long term future, while the freight rates are the result of the current situation. In the short run demand for transport is almost fixed [Stopford, 2009]. If there is an (unexpected) change in demand, the current fleet will have to cope with this change. If the limits of the current fleet are reached, meaning almost all vessels are sailing filled to capacity and near their maximum speed, rates will explode. This happened in 2008. Although other factors and emotions were influencing that boom as well, the basis was a perceived shortage of capacity. Now imagine we have perfect knowledge of the future demand and fleet development. If there are not enough ships, there is room for a company to gain extra profits by building an extra ship. This ship is delivered on time for the increase in demand. However, there will be more companies doing this. With instant knowledge of the effects of building another vessel, this would go on until there would be no extra profits to be gained by building an extra vessel. The freight rates would therefore be around marginal costs plus a small profit margin. The freight rate is therefore not predicted exactly in long term predictions, but rather a rate is indicated that is 'healthy' for the given situation. A healthy rate is one where no companies are gaining extreme profits, but also everybody is getting paid their costs, so no bankruptcies occur.

For the above described situation the assumption is that owners act rationally and have instant access to all information. Under these assumptions it is not the goal to predict the future, but rather see the differences in future scenarios under certain conditions. In reality there will not be a shock to just a single variable, therefore the future will never occur as described. However a lot can be learned about the effects and importance of variables of the economy from studying the differences between two outcomes. A change in an economic variable might simultaneously lead to an increase in demand for vessels and a lowering of the average newbuilding price, creating an extra increase in demand. The comparisons are the subject of this thesis.

Who will benefit most from the answers to these questions? Currently large models require large companies, who guard their advance gained by these models closely. In the maritime industry many yards, investors and shipping companies are actually small, still all these small players would benefit from better understanding the markets in which they operate. Also being able to test their investments against a variety of scenarios will help them ahead in this immensely competitive environment. While perhaps owning and maintaining such a model is beyond the reach these small players, the discussion of its results can still benefit them, as will future research using such a model. For the larger companies already owning one or more models, this research will still offer an overview and application of the latest ideas and practices of scientists in the field of maritime economics and shows what strength and weaknesses the combination of all these ideas can bring.

Before researching an answer to the research questions in Chapter 3, 4 and 5, the options currently available to answer these questions are presented in Chapter 2. This chapter also explains what the currently available models are lacking. In Chapter 6 the research questions are tested, and the last chapter will present the conclusions and suggestions for further research.

2. Review of existing models

This chapter gives an overview of the available models that help to make decisions about the future and their availability to companies in the maritime sector. Companies can use these models to determine their strategy for the long run (the research question). In the first section the options available from academia are presented: Macro Economic Models, Shipping Models and Fleet models. The benefits and drawbacks of each are also described. In the second section the information available from consulting firms is investigated and remarks on the applicability of this information are made. In the last section a new instrument is proposed to close the gap between the different models and allow analyses of all of the research questions. The details of this approach will be further described in the Chapter 3 to 5 of this thesis.

2.1 Models in academia

Shipping has long interested academics for several reasons. The most important one is that shipping and especially tramp shipping is viewed as a perfect market [Stopford 2009]. There are almost no barriers to entry, a ship is a registered good that can be transported over the world (and therefore registered where it will be most profitable), and it is a global market, both in customers and providers of shipping services. Another reason is that there is, relatively speaking, a lot of information available on the market, thanks to Lloyd's, Clarksons, the Baltic and many others.

In view of the research questions for this thesis the models that consider all four shipping markets (shipping, secondhand, newbuilding and demolition) are very relevant for the development of the fleet, fleet construction and the identification of profitable ship types. For this last part, more information could be obtained from models/programs that deal with routing vessels optimally for maximal profit or minimal costs. However, the question on transport demand remains.

Transportation is a derived demand since there is no primary need for transport. It exists because materials are required for the production of goods, but these resources cannot be found (in sufficient quantities) at the location the goods are made [Blauwens, 2008]. The demand for the produced goods also determines the demand for transport, therefore this study on shipping starts with an overview of Multi Country (MC)-Models. Using such a model will allow the development of scenarios on a macroeconomic level (rising inflation, fall in consumption, exchange rate imbalance, etc.). This in turn allows the study of the effects of such an event on trade in general, before assessing what this will do to the freight rates, fleet size and shipping itself.

2.1.1 Macro models - Multi Country

Multi Country (MC)-Models are not uncommon and they are usually developed by large institutions or banks. Their main goal is to help the user in evaluating the effects of a certain monetary policy, like an interest increase of a central bank. Most models were developed in the 1980's and 1990's, though many are still in use and were updated over time with new insights and requirements. Table 2.1 on the next page shows an overview of 14 MC-Models on which publications are available. The publications refer to the best found model description, not to the latest status or update. The table states the name and owner of the model, a reference to a publication of the model and shortly summarises the particulars of the model, based on this publication.

Table 2.1: Overview of MC-models and their publications

Name	Owner	Publication	Particulars
Interlink	OECD	Richardson [1988]	Focussed on the short and medium term, it started with individual country models and predicted trade and the trade balance for OECD and 6 non-OECD regions.
Multimod	IMF	Masson et al. [1990], Laxton et al. [1998]	Focusses primarily on the influence of shock from the industrialised countries on the developing countries.
MCM / FRB Global	Federal Reserve	Edison et al [1989], Levin [1996]	Contains 5 countries, but does split trade in goods, services and investments.
MSG2	Brookings Institute	McKibbin and Sachs [1991]	Large focus on money flows and stocks/accumulation.
Fair's model		Fair [1994]	US focused, with 43 other trading partners present. Non-linear equations are used.
NiGEM	NIESR	NIESR [1997]	Differentiates between the development of countries in their models. Each country modelled individually.
Quest (III)	European Commission	Ratto, et al. (2009)	Dynamic Stochastic General Equilibrium Model of the Euro Area. Used for testing the effects of fiscal policy.
Liverpool Model		Minford et al. [1986]	Links 9 OECD countries, with one element for the rest of the world. It assumes rational expectation and can be seen as a new-classical model.
OEF Model		Burridge et al. [1991]	This model is UK focussed and models the world in 3 steps: World Economy with 19 countries/regions, UK country model and 91 industry sectors modelled.
HERMES	European Commission	Italianer [1986]	Another sectorial model that allows countries to build their own model, than link it to the rest by bilateral trade flows (on sector level).
MIMOSA	French	CEPII and OCFE [1996]	18 Countries/areas of which 6 are modelled with detailed sectors, the less economic power, the less equations (Developing countries only to keep linkage consistent).
EPA	Japan	Economic Planning Agency [1995]	Focus on monetary and exchange rate policies. Uses quarterly data and has 15 countries/regions.
MEMMOD	CB Germany	Deutsche Bank [2000]	Focused on Germany and its trading partners, import and export play an important role.
EUROMON	CB Netherlands	Bondt, et al. [1997]	Focused on the financial sectors and pre-euro EU, testing the influence of new parties entering the EU.

When reviewing the models several axes of difference become clear. The first one is the goal of the model. Is it for general predictions and therefore prolonged use, or was it created to investigate a single question? EUROMON is an example of the second group, created solely to determine the influence of new entries into the EU.

The presence of a focus country is another element in which the models differ. To have a focus country is the common approach of (national) models, like MCM (Federal Reserve Board – Multi Country Model), Fair's model, OEF (Oxford Economic Forecasting), EPA (Economic Planning Agency) and MEMMOD (Macro-Econometric Multi-country MODel). These extensively model the "home" country and sometimes several trading partners while only using a very simple representation for the rest of the world or other country groups. This representation of the group of "others" is often linked to the oil price.

Only NiGEM (National Institute's Global Econometric Model) and to some extent HERMES (Harmonised European Research for Macrosectoral and Energy Systems) attempt to model all countries individually, though not necessarily identically. HERMES lets each country model its own economy as long as certain variables on trade are present and determined in the same way. Most modellers do not follow this approach due to the lack of sufficiently reliable data.

Next to these two axes of focus there is an axis of fiscal vs. physical between the models. The first group looks only at the flow of money, its accumulation and exchange rates (EPA and MSG2 (McKibbin Software Group version 2)). The second group looks at physical trade and often models industrial sectors individually (OEF, Interlink and HERMES). Most models are somewhere in between, modelling a home industry, but not a specific sector.

A last axis of difference is the amount of countries or areas represented in the model. The average would be between 10 and 20 economic areas/countries, but the MCM has only 5 and Fair's model 43. If the sectors are considered as individual (macro) economic areas, OEF, HERMES and MIMOSA all exceed the 100 areas.

Based on the review of models it seems that all models have their own purpose and focus area. They also require significant amounts of data to work properly. It is difficult for a company in the maritime sector to select a good option. A model with a focus on trade requires too much data and a more general model mostly focuses on fiscal policy, rather than trade. It is clear from this review that (sea) transport has not been a focus of these models and neither has the goal been to provide a model usable by private companies.

It is possible to sketch an outline of a model with a focus on trade and transport based on the average of the above mentioned MC-Models. This model would contain between 10 and 20 countries or regions, a representation of industry, though not split in sectors, be used for policy investigations, rather than a single event and have at most 2 levels of model complexity for the countries or regions in the model.

2.1.2 Shipping models - World shipping

Although most Multi Country Models have been created fairly recently, in the last two decades of the 20th century, researchers have been investigating and modelling the shipping industry for a much longer time. One of the firsts to look into shipping were Tinbergen [1936] and Koopmans [1939]. Most of these models are aimed at predicting the future time charter or freight rate, in order to allow owners to assess the earning potential of a vessel. An overview of these models is presented in Table 2.2.

A split in models could be made based on how the transport capacity is treated. In many models the capacity is only a function of the average sailing speed and the number of new builds and demolitions. Others model individual vessels, their number, size and costs. This latter option is primarily used for the wet bulk models. This occurred because in the 80s many oil companies still owned and operated their own fleet of vessels. These companies were very much interested in optimizing for cost reduction.

Table 2.2: Overview of shipping models and their publications

Name/Author	Market	Year	Particulars
Tinbergen [1936] en Koopmans [1939]	Dry Bulk	1936	Demand is known, freight rate is determined.
Norship/ Strandenes [1986]	Wet and Dry Bulk	1977-1981	Demand is a function of world trade and rates; world trade has a fixed growth rate.
Hawdon [1978]	Wet Bulk	1978	Demand is known, freight rate is determined.
Charemza & Chronicki [1981]	Wet and Dry Bulk	1981	Demand is known, freight rate is determined.
Dynamo / Rander [1984]	Wet Bulk	1984	Demand is known, freight rate is determined.
Martinet /Devanney & Kennedy [1980]	Wet Bulk	1980	Demand for oil to be specified by the user.
Beenstock & Vergottis [1993]	Wet and Dry Bulk	1993	Demand is inelastic and fixed.
Zannetos [1966]	Shipping	1966	Random walk.
Tsolakis [2005]	Wet and Dry Bulk	2005	Demand is known, freight rate is determined.

No structural model exists for liner shipping. Even Beenstock and Vergottis [1993], seen by many as the largest and latest of the structural models, did not incorporate liner shipping in their model. This is most likely caused by the fact that liner shipping only existed since the 80s and much of the information on liner shipping is closely guarded by the companies themselves since they see it as important to remain competitive.

Since 1993 only one model was developed. This limited amount of development coincides with the introduction of Vector Autoregressive (VAR) models into the field of maritime economics and the increased availability of data from sources such as Clarksons. These new VAR models require large data series to work properly as well as stationarity testing and examining data for co-integration (common integration). These approaches eliminate trends from the data before creating a (reduced form) VAR model. Another set of models related to the increase of data availability are the ARMA, ARIMA, ARCH and GARCH[1] models, which relax the assumption of constant volatility and replace it by a time varying volatility. Kavussanos [1996] and Veenstra [1999] performed significant amounts of work on these kinds of models, though a more complete overview is contained in Glen [2006].

The end of these free form models was brought on by the realization that some of the data used in the models was fabricated (created by broker estimates, rather than real sales, see section 2.2). Time independent and non-linear models are currently the new techniques used for the investigation of the shipping market. Adland [Adland and Cullinane, 2006] is and has been especially active in this field.

2.1.3 Fleet scheduling models

This last section on academic models focuses on models that do not look at the total shipping fleet, but focus on optimally scheduling a given fleet. Several tanker models already look at the fleet distribution when transporting a given demand, though the interest of the developers of these models is the freight rate rather than the optimal deployment schedule of the fleet. All models can be seen as a special class of the vehicle routing problem (VRP) for which a significant amount of literature exists. In the last 40 years a lot of research has been done on this special maritime case and contrary to the other fields, liner shipping is a dominant element in this type of research. For an overview of research on the maritime applications until 2003 see Ronen [1983], Ronen [1993] and Christiansen et al [2004]. Each of these papers reviews a decade of scheduling models.

The biggest difference is the large variation between transporting units. Where trucks are largely considered identical, the size and cost structure variation for vessels is large and different categories must be created. Also, because the sailing time is relatively long compared to the loading and unloading time, it is interesting to optimize the vessel's speeds. For trucks a fixed speed is usually used, due to the shorter transportation distances (several pick-ups/drops in 1 day are possible). Also vessels will usually not return to their origin, there is no central depot for vessels. Trucks, on the other hand, often have a central starting and finishing point. Many other aspects are the same however, such as partial loading, multiple origins and destinations, and a time window in which to load and unload. The class of the VRP that comes closest to these boundary conditions is the Pick-up and Delivery Problem with Time Windows (PDPTW).

The first paper by Ronen [1983] also proposes a classification system of the models using 20 categories each of which have between 2 and 8 different options to choose from. To give an idea of the broad area covered by this field, this classification results in over 20

[1] ARMA: Autoregressive Moving Average Model (Future values of a time serie are the results of external shocks and internal trends)
ARIMA: Autoregressive Integrated Moving Average Model (When time series are not stationary, differencing is applied to make them stationary, after which an ARMA model is estimated for the stationary series)
ARCH: Autoregressive Conditional Heteroskedasticity (Variance is time (and history) dependant)
GARCH: Generalized Autoregressive Conditional Heteroskedasticity (Error variance is represented by an ARMA model)

million different model classes. New techniques, which are inspired by nature and called swarm intelligence, have been introduced in the late 1980's into the VRP solutions, to supplement the Node-Arc, Path and Tree problem definitions for Operation Research Models (OR-Models). The most commonly known ones are Particle Swarm Optimisation (PSO), Ant Colony Optimisation (ACO), Bee Colony Optimisation (BCO), Genetic Algorithms and Tabu Search. Good overviews of the techniques and their differences are given by Teodorovic [2008] and Kumar & Kumar [2011].

A last area to mention is that of the Decision Support Systems (DSS), which support a user when making decisions. These programs optimise e.g. the fleet deployment for the parameters chosen by the user. The user is also able to overwrite or limit the system's solution, by setting e.g. certain cargos for a vessel. An example of such a system is Turborouter [Fagerholt and Lindstad, 2007].

The field of fleet scheduling is enormous and many options and choices must be made by a company when selecting a solution. Also, the focus of all of the currently available models is the short to medium term. The power of many of these models lies in the real time optimization of schedules of vehicles or ships. Furthermore, the outcomes of the medium term models are very sensitive to the data input and changes in e.g. costs of vessels can result in completely different solutions [Lachner and Boskamp, 2011].

2.2 Information from consulting firms

The main source of information on the market status and behaviour comes from consultancy firms and registers such as Clarksons, Drewry and Lloyd's. They either provide their own actual data, or outlooks on the future, based on their own internal models and the knowledge of their brokers. The problem with this data is that much of it is based on the opinion of experts and therefore market sentiment plays an important role. As an example consider the price of a 5 year old 170,000 DWT bulkers. In the market such a vessel is sold on average 3-4 times a year, though a monthly update of the price is provided by Clarksons [2010]. Table 2.3 below presents the information provided by Clarksons for a 5 year old 170,000 DWT bulkers on a quarterly basis. The column "Price" contains the average selling price for such vessels based on reported contract prices. Vessels sold within the range of 165,000- 185,000 DWT and between 2 and 8 years of age were used to determine these figures. The column "Amount" indicates the amount of contracts concluded. The column "Index" is the value taken from the time series of 5 year old 170k DWT Bulkers.

While in 2010 and 2011 the prices are not off by much, the difference is enormous for the year 2008. High prices are reported, while actually the only contracts concluded that year were far below the values reported and for over a year not a single vessel within this range was sold.

Table 2.3: Comparison between contract prices and index for 5 year old vessels (Source: Author based on data from Clarksons)

Quarter	Amount	Price (mln USD)	Index (mln USD)
2008 Q1	2	36.8	135.7
2008 Q2	0	-	142.4
2008 Q3	0	-	150.0
2008 Q4	0	-	107.1
2009 Q1	0	-	45.2
2009 Q2	3	50.7	46.2
2009 Q3	4	56.8	53.8
2009 Q4	1	52.0	50.9
2010 Q1	2	57.3	50.9
2010 Q2	0	-	58.6
2010 Q3	0	-	55.7
2010 Q4	1	59.0	56.6

This problem is not new, but it is important to realise when one makes interpretations and decisions based on this data. Ship buyers and sellers would be supported better with models that provide information on what a vessel is reasonably worth based on the current market conditions and a wide range of expectations about the future market conditions. This allows a potential buyer to assess the risks involved in buying a vessel for a different price. Such models are not available to companies at this moment, with the exception of the common business economic assessments such as Net Present Value, Internal Rate of Return, etc.

2.3 Bridging the gap

The overview in this chapter shows that significant amounts of research have been done for each area of relevance to this research. Not mentioned in this chapter is the research done on individual aspects, like secondhand or newbuilding vessel price determination (for an overview see Pruyn [2010] and Mulligan [2008]).

In Table 2.4 a summary is provided of the applicability of the model types described in this chapter. The research questions have been summarised here as well. The table clearly shows that all level of models academic models allow scenarios to be run. Only consultant information covers the entire range of the sub questions, but does not allow scenarios, which is the most important aspect.

Table 2.4: Summary of applicability of available models

Research question	Macro model	Shipping model	Fleet scheduling	Consultant firms
Sub 1 Transport demand	x			x
Sub 2 Fleet assignment			x	x
Sub 3 Fleet composition		x	x	x
Sub 4 Newbuilding sector		x		x
Main Scenarios for shipping	x	x	x	

Beenstock and Vergottis [1993] have the largest and best known model of the maritime sector that is documented. Still they did not cross the gap to a macroeconomic country level or to the assignment of an actual fleet to trade cargo. Currently, no research exists trying to cross the gap between two levels, let alone combining all three levels (macroeconomic, shipping and fleet optimization) in a linked model. However, exactly this type of instrument would provide answers to the main research question and the four sub questions.

Such an instrument would select the best vessels and fleet size to fulfil the transport demand derived directly from a Macro-economic Multi Country Model. Because the data on wages, inflation, production costs, etc. is also available from this model and can be combined with the requested newbuildings, it will also be possible to see where shipbuilding would take place, only considering the economic side. Scenarios for the future could also be created instead of accepting one outcome of the program as the truth. By running a number of different scenarios, the risks of a certain strategy or planned investment can be assessed, answering the main research question (on the choice of a good strategy).

The benefits of such a large combined model would be that from the macro level down to the micro level consistent scenarios can be developed. The effect of changes on all levels can be checked for their implications towards shipping, newbuilding and scrapping. Strategies of companies in the maritime market cannot only be tested against a set of scenarios for future global development, but also for various other cases, such as the introduction of the new larger Panama Canal locks. This canal option can also be tested further against different future transport demand scenarios. Moreover this same analysis will also provide information to ship owners and shipbuilders on what size vessels will be most profitable for this new market situation.

Exactly such an instrument is researched, developed and evaluated in this research. Although the purpose is not to be able to predict the long term future, the complex model developed for this project should be able to investigate plausible scenarios on the different levels described here and report back information on transport cost movements as well as which vessel size and type will be in demand. A modular build up is proposed that contains all levels as described in this chapter; Country behaviour, Ship Market behaviour and Fleet behaviour. Figure 2.1 shows these levels and their expected interaction.

The user should be able to set scenarios for the parameters influencing the country behaviour and the fleet behaviour. This is represented by the red arrows. The output of the Country behaviour directly influences the shipping market behaviour and the fleet behaviour. For example, consider the influence of wages and exchange rates on the ship building market or trade demand on the fleet behaviour. This influence is represented by the blue arrows. The shipping markets influence the fleet behaviour, as the capital costs of a vessel is strongly related with the newbuilding and/or secondhand price of that vessel. The purple arrow represents this behaviour. The fleet assignment will result in a certain income level. Newbuilding and secondhand prices are influenced by the potential income of the vessel, which is shown by the orange arrow. One type of interaction, the influence of the cost of transport on the demand for transport, could be considered missing in the model. However, the demand for transport, especially for shipping (of low value goods), can be seen as almost fixed (see e.g. [Stopford 2009]). This means that in the short run the demand for transport is not influenced by the price. In the long run it has been noticed that if prices are high transport tends to get optimised for distance, rather than convenience. Therefore in theory the price of shipping would not influence trade significantly and therefore this influence is not included in the model.

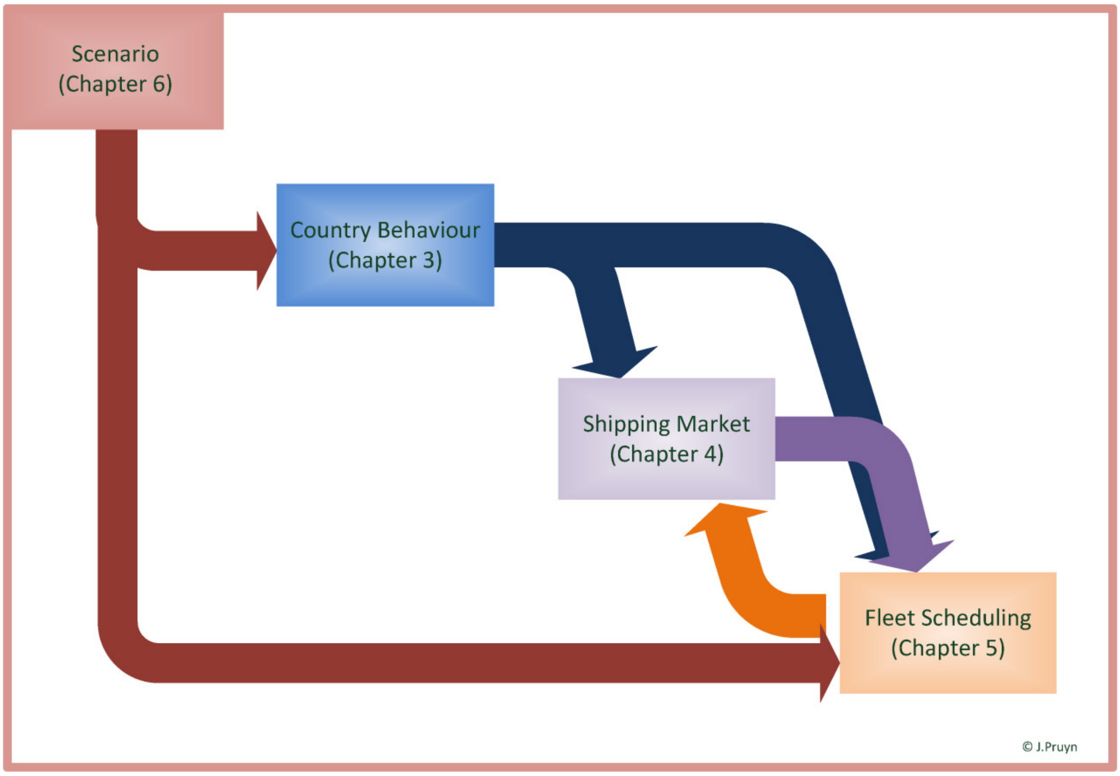


Figure 2.1: Conceptual model for a consistent maritime economic evaluation

The results from the scenario runs will be discussed in Chapter 6. The modelling of Country behaviour is discussed in the next chapter. The demand for new vessels as well as pricing of the secondhand and new vessels is examined in Chapter 4. The fleet behaviour will be dealt with in Chapter 5. These links are also visually represented in Figure 2.1.

3. Establishing the Multi Country Model

In this chapter a multi country model will be defined, created and tested. Before examining the creation of the model, Section 3.1 and 3.2 will discuss the requirements posed by the scenario analysis and the other modules on such a model. The setup of a model satisfying these requirements is discussed in section 3.3 and tested in section 3.4. The last paragraph is a short conclusion on the status of this module.

3.1 Determining the output required

Before solving the generation of the demand for maritime freight transport, it is important to first have a clear idea of what is required as output. Output in this setup is not only determined by what the user might like or require, but also by the data required by other modules to function properly. Figure 2.1 shows that there are two modules that require output from the macro-economic multi country module: the shipping market module and the fleet behaviour module. For the shipping market the newbuilding costs will be the most dependent on the country variables. A yard is located in a country and is influenced by the economy of that country, which in turn influences the costs and minimum price of a vessel. The secondhand market is a global market and the scrapping market will have at most the same dependencies as the newbuilding market. Therefore in subsection 3.1.1 the variables important for the newbuilding market will be determined. For the fleet behaviour module the input to be considered is transport demand, and this relation will be discussed in subsection 3.1.2.

3.1.1 Selecting the variables important for a newbuilding market

One of the first to look extensively into newbuilding prices was Benford [1968]. He estimated the costs of building a vessel by regressing 25 newbuildings of 9 different yards. He split the costs up in direct or material costs and indirect or labour costs. The ship itself was split up in hull, outfitting, machinery and engineering. All his man-hour estimates were in form of equation 3.1.

$$MH = a * X^{b} \tag{3.1}$$

MH are the man-hours and X is the total weight of an element. Not much has changed in the past 43 years as estimators at shipyards still use similar equations at almost the same detail level to calculate (minimal) cost prices. The parameter X may represent other characteristics, or MH may refer to smaller parts of the vessel, but the essence remains the same. Also CGT (Compensated Gross Tonnage), a unit developed by the OECD to make different vesseltypes and sizes comparable in the effort needed to construct it, comes in this form [OECD, 2007].

This cost price usually forms a base for the selling price of the vessel. In times of crises yards might be willing to sell at a loss. Economically, the minimal price for a vessel is the price at which the loss incurred due to a vessel is equal to the loss incurred without having that vessel in the order book. The cost price has a direct influence on that price. The maximum price however is not related to the cost price. Under the conditions of a perfect market, vessels will be sold for the cost price plus a small profit mark up to ensure growth.

In the same decade as Benford Zannetos [1964] presented his model of the tank ship industry, although he does not model newbuilding prices. Instead, he links them, or rather the presented index, to spot prices. He uses newbuilding costs and spot rates to estimate the amount of orders and signifies that prices of vessels are not moving in line to prevent over investments into the market.

Hawdon [1978] follows Zannetos [1964] as he also links the price per DWT to the current spot rate. He also establishes that the current size of the fleet has a negative impact on price and the steel price level has a positive impact on price. He introduces this last variable to capture the building costs of a vessel, while spot rates and fleet size are used to capture the market status.

Beenstock and Vergottis [1993], take an entirely different approach to newbuilding prices. They do not relate them to costs, but attribute their slow movements to the fact that they perform as a future market for secondhand prices. They see secondhand prices as the real asset price and because newbuildings will not become available instantly, these assets function as futures of the secondhand price. Their model includes the future price corrected for two premiums; an upward one for technological improvements and a downward one for the risks involved.

In the same year Jin [1993] proposes a completely different approach, for starters the current output is set by capacity and the price moves to match it with demand. As capacity is determined, the capital costs and man-hours involved in production are also set. The remaining costs of production are solely determined by the production processes.

Strandenes [1986] uses an equilibrium model for newbuilding. The shipbuilding market is represented by a supply-cost curve, though no details are revealed. Capacity is calculated using CGT, rather than DWT or GT, since by definition it better represents the work involved in a vessel.

Dikos [2004] continues on the observations of both Zannatos [1964] and Strandenes [1986] that the price in newbuilding is only weakly dependant on the demand for vessels. He uses a model with TC-Rate, DWT ordered, oil prices and an index for air transport costs. He states that under uncertainty and perfect competition there should be an existing upper threshold level that, once reached by the prices for new vessels, would immediately trigger production by many yards. As soon as supply increases, the price of new vessels will decrease along the demand curve of investors. Thus, if ever the price climbs to this ceiling, it is immediately brought back to a slightly lower level, due to the offers by other shipyards with slightly higher marginal costs. Yards rationally anticipate this and an upper reflecting barrier is imposed on the process. This barrier, which arises due to perfect competition and rational expectations, accounts for the significant lack of volatility observed in newbuilding prices according to Dikos. However, looking back on the boom around 2008 and the hike in newbuilding prices that was seen at that time, this theory seems to have lost its value. Dikos also differs with his predecessors in that he views shipbuilding as not being capital intensive and compares the modelling of it with that of process and assembly industries. In these industries he has found that prices have continuously dropped, due to reductions in quality, rather than due to improvements in efficiency; he assumes this also goes for shipbuilding, although no further proof is provided.

In his research Tsolakis [2005] reviews a number of earlier attempts and from this deducts a number of variable types to include in the modelling of newbuilding prices. These are cost based variables, asset pricing variables and supply/demand variables. His choices for these variables are steel price and exchange rate (Yen/Won) for costs. TC-rate and secondhand value are used for asset pricing and Orderbook/fleet for supply/demand.

The last investigation into newbuilding prices found in literature was performed by Mulligan [2008]. He reflects on the non-linearity found by Adland and Koekebakker [2007] for the secondhand value of vessels. His proposal is a simple model that uses demand and its second and third power, and a variable for heavy industry production costs (Producer Price Index (PPI)). Though he gets good results for his entire data set, with dummies for the vessel type using Clarksons time series for specific vessels types and sizes, the results for the individual types deteriorate quickly. This should not be surprising with only 3-4 data points for size within each series. With his approach he disregards the asset pricing in his model, taking a step back from the ideas of Tsolakis [2005].

When considering the different approaches and the fact that more or less local data will be available for the region of the yards, it seems only logical to follow the approach of Tsolakis [2005] considering the 3 types of variables. The cost variables are interesting as shipbuilding has the following characteristics: it requires capital to start and run a shipyard, including pre-financing of vessels if the payments are not in line with production and it still involves a lot of people and steel, though together they form about half the price of the vessel nowadays, while the other half is subcontracted work, making it an assembly process as Dikos [2004] described. This would require that elements for all costs should be available for modelling. These include wage rate data for the labour factor, interest, exchange rates and inflation (PPP) for the capital element and PPI for an indication of the costs of sub-contracted work. Also, building time might have an influence as the expectations of the future will play a role in whether a price is accepted or not. The longer the building time is, the more uncertain the future and the greater the risk and the risk premium. The other elements, demand/supply and asset pricing, are not linked to the macro-economy. So far demand, orderbook, fleet size, TC-rate and secondhand value are the elements mentioned in the literature. Their place and determination within this model will be discussed later.

3.1.2 Transport demand output

In maritime economics, transport demand is usually expressed in ton*miles. This can be the total demand, but it can also be expressed in tonnes cargo on a specific route (miles). With the ton*miles option there usually is no ballast voyage taken into account. Ballast voyages would then need to be taken up in the determination of the fleet capacity; e.g. a ship can only do 10 voyages a year as it has to relocate, limiting the supply of ton*miles to 10 trips of a certain distance with maximum cargo capacity. To avoid guessing what performance is used, cargo quantities and origin-destination sets will be used for transport demand. The required optimization of the ballast trips needs to be done in the supply model.

Another influence on the supply is caused by the variations of demand over time. Kavussanos and Alizadeh [2000, 2001, and 2002] and Schulze [2009] all show that there is a statistically significant seasonal trend in the dry bulk, tanker and container markets. These variations over time increase the demand of transport and vessels since the demand in certain seasons is higher than the average. This would require data on at least a quarterly basis. Although not researched yet, it would be expected that weekly variations in demand for transport also have an influence on the freight rates and the supply of transport. For this project, a weekly time period is selected for the specific reason that most ports have weekly schedules, but not daily schedules, and using a monthly time period would result in too high aggregation levels. Therefore, it is preferably to have weekly data that allows for variations in the demand of transport.

The supply side of the model will have costs associated with different sizes and types of vessels, yet the costs for all these types are influenced by the current bunker rates, the wage costs, the interest costs, port and canal fees, etc. These factors influence the cost side and hence the profitability of vessel types, which in turn and in time could influence the investment strategies of companies. While certainly interesting, these costs are not very common in Multi Country Models with the exception of interest rates, oil prices and wages. Unfortunately, it is not directly clear which wage rates will influence the crew rates in this case. Creating scenarios where the movement of these costs are set (except for interest) is still a viable approach for the current model. This does not exclude these variables from future research. It just means that this would be done in a separate module, taking data from the current module and overwriting cost scenarios with the results.

The last element on which to decide is the detail level of the demand. In general 5 types of trade can be recognized in the export of countries: dry bulk, wet bulk, general cargo, money and others. This is of course viewed from a maritime perspective. Money and others will not be transported by ships and are irrelevant for our purpose. The other three types could be further split up into smaller types of cargo. This would better represent reality, as certain cargos cannot be transported on the same vessel, either at the same time, or even at all. For example a grain carrier is usually not suited to also carry iron ore, although both are bulk cargos. Grain is a voluminous cargo, while iron ore is a very high density cargo. This requires different design approaches to the cargo hold and therefore different vessels. However, a downside also exists for splitting the trade up further. Detailed vessel data will be required to determine which cargos vessels can carry. Unfortunately this data is not available at an aggregated level, making the detail of the supply side limit the required subdivision of trade to dry bulk, wet bulk and general cargo. This will result in an underestimation of the amount of vessels required as vessels can now pick a return cargo that might in reality not be available to them.

Summarizing the needs of the assignment module on the output, the following is required: weekly data on cargo quantities to be transported from origins to destinations, divided over the three trades of dry bulk, wet bulk and general cargo. This data should reflect the seasonality found in the demand for transport. For the future the possibility should be left open to also output oil and bunker prices and crew wages.

3.2 Determining the input scenarios

After determining the output required by other modules in the previous section, it is important to examine the input requirements of the Multi Country Model. Inputs are defined as variables which can be altered by the user to investigate the effect of those variables on a given scenario, thus influencing his strategies. The input or data required is also a result of the equations selected. These equations are outlined in section 3.3.

The variables that are subject to a variation can have a direct or indirect influence on trade between two countries, which is important for the scenarios. On the other hand, changing these variables should not destroy the behaviour of the module completely by fixing too much output. Three groups of variables come to mind that a user should be able to change. The first group of variables is those influenced or determined by the government of a country. The second group alters the (spending) behaviour of consumers, and a third group considers extremes, such as wars or a great depression. This last one is perhaps a step too far for this thesis, as the effects of such events are very uncertain. Literature on the subject like Imei and Weinstein [2000] and Baker [2007] suggests that increased military spending shortly boosts an economy, but in the end reduces consumption and investments, increases inflation and interest rates, and results in higher unemployment.

The following variables are part of the group that the government influences:

- Interest policy of the central bank
- Inflation target of the government/central bank
- Tax levied, both direct and indirect

Changing these settings will influence the development of a country and thus also that country's trade with others. These variables can be used to change the way a government is trying to lead a country, and the effects of this on trade should be measurable.

A second group of variables reflect the behaviour of the consumers in a country. These variables include:

- Total consumption
- Investments
- GDP

These two settings allow the model to differentiate between the choices consumers have in spending or saving money. This also applies to companies (though they will require the savings to do the investments).

3.3 The development of the Multi-Country Module

In Table 2.1 in section 2.1 an overview of literature on Multi-Country models (MC-models) is presented. All these models express the trade between two countries in a monetary value. A conversion from this monetary value to a value expressing the amount of goods must be applied in order to fulfil the output requirements. On the other hand, the goal of this research is for the final product to be usable by companies and not only by experts. Having business users set the exact changes to the macro-economic variables might not be very feasible. Instead, it would be a better solution to have them select the time and place of a scenario. E.g. they could change the settings for a country's government stance on inflation and set the importance of this variable. The Multi-Country Module of Figure 2.1 can be detailed as shown in Figure 3.1. Selections for scenarios are adapted to the correct settings by a block of programming. The MC-model is run and the output is made available to the next modules, either directly or in the case of transport demand after conversion of trade in USD to trade in tonnes. The build-up of the MC-model, the scenario adapter and the trade to transport converter are the subjects of this section.

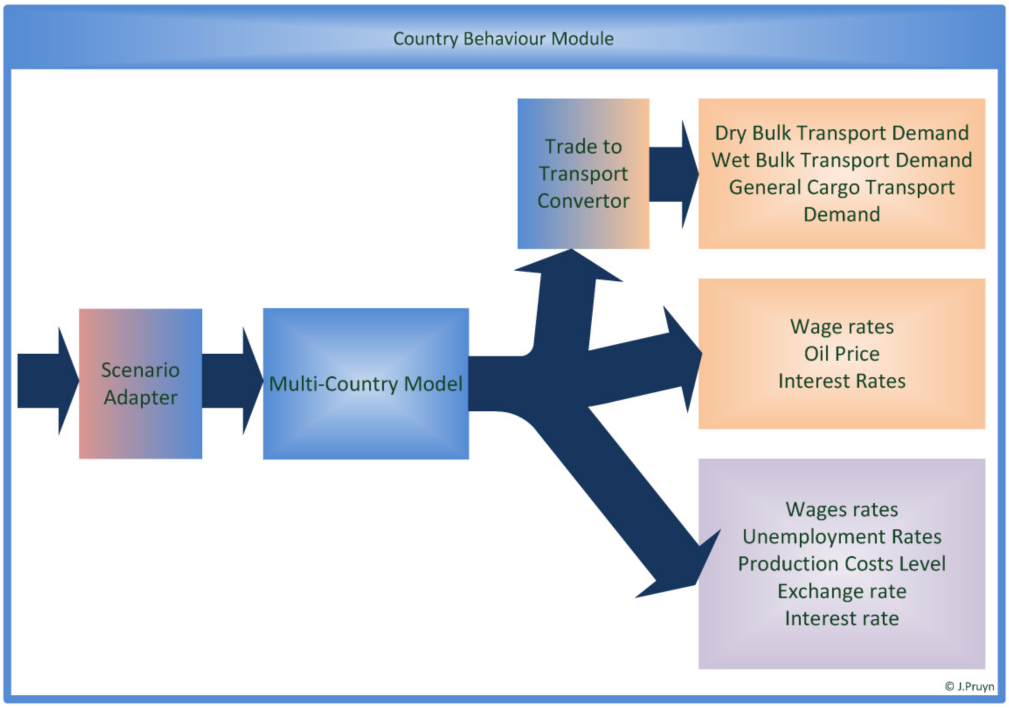


Figure 3.1: Blocks within the country behaviour module

3.3.1 The choice of a multi-country model

Ideally, a model could be selected from the list of Table 2.1 which fulfils three main requirements. The first requirement relates to the function of the model. It is a transport model, so the representation of the countries should be complete and contain all of the output elements of Figure 3.1 without getting overly complicated. Another requirement is that the model needs to contain the maritime nations and their bilateral trade. The third requirement is that although the model itself may assume continuous growth, it must be possible to apply shocks to the variables so that their effects can be investigated. Unfortunately, no such model exists already. The models that come closest do not focus on a specific country or specific sector, but instead are focussed on trade and long term predictions. The MCM, Liverpool model and MEMMOD seem to be the most closely related to these targets (see Table 2.1 for details).

Would the relaxation of one or more model requirements help in the selection of a model? 193 countries exist in the world according to the UN [2009] count. About a quarter of these countries are completely landlocked (44 in total, including 5 city-states, such as the Vatican and Andorra). To model the remaining 149 countries and their trade, while including the influence of the land-locked countries would result in a very large and complex model. The model requirements were relaxed by grouping countries into region. Each region was selected so that a strong economical link exists within the region, meaning that the region provides similar products to be exported or imported. Of course the countries should also be geographically related, meaning they neighbour each other.

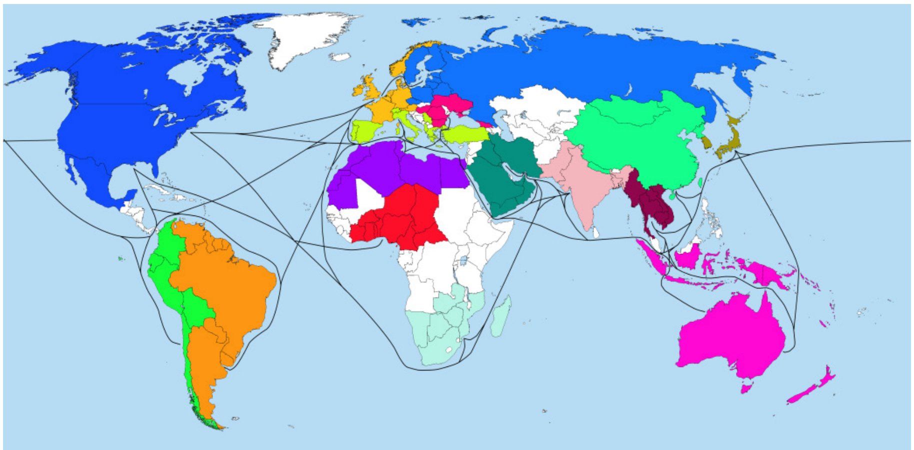


Figure 3.2: Assignment overview of countries to maritime trade regions

Using these criteria 16 regions were created based on their relevance to maritime trade. This leaves a number of countries in a seventeenth group, representing the remaining countries. Figure 3.2 presents these regions and their countries in colour codes. An important element for the results of this model is that the USA is one region and not split into the east and west coast. The decision causes the distance between the USA and other regions to be underestimated and, more importantly, underestimates the use of the Panama Canal. This is compensated by routing all internal transport of this region through the Panama Canal.

Each region is given a name, an abbreviation, a main country and a main port (or two in the case of the USA). An overview of these selections is given in Table 3.1. The economy of the main country is extended to incorporate the economies of the other countries in its region. The selected main country was usually the most important economy of that region. An exception was made in the case of Russia, which was not chosen to represent any region, since Russia's economy spans over several regions. It therefore does not accurately represent any of the regions it is located in. In this case, the choice was made to let the second largest economy, Romania, be the main country because it better represented the state and development of that area. A similar argument goes for the selection of Saudi Arabia as the main country of the Middle East region. In the area Saudi Arabia is the largest country of this region, but in population and economy it is not. However, given its position as mediator for that region, Saudi Arabia better represents the "average" of that region than for example Iran or Iraq. Also data availability played a role in this decision. Selection of the main port only influences the distance between two regions and is therefore not only based on the size of the port within the region, but also on the average distance for that region.

Table 3.1: Overview of regions with their main attributes

Region	Abbreviation	Main Economy	Main Port
Hamburg – le Havre Range	HAM	Germany	Rotterdam
Baltic Area	BAL	Poland	Gdansk
Black Sea Area	BLA	Romania	Odessa
Mediterranean	MED	Italy	Genoa
North Africa	NAF	Morocco	Algiers
West Africa	WAF	Nigeria	Lagos
Southern Africa	SAF	South Africa	Durban
Middle East	MEI	Saudi-Arabia	Dubai
Greater India	IND	India	Bombay
Southeast Asia	SEA	Thailand	Johor
Greater China	CHI	China	Shanghai
Far East Asia	FEA	Japan	Bussan
Oceania	OCE	Australia	Dampier
North America	NAM	USA	Houston / Los Angeles
West Coast South America	WSA	Chile	Valparaiso
East Coast South America	ESA	Brazil	Santos

None of the models under consideration will have these selected maritime regions at the basis of their model. As a result, it is necessary to re-estimate the model equations with the data for these regions. Therefore, an additional requirement exists for the selected MC-model: it must have extensive documentation on the equations used within the model. This last requirement led to selecting the MEMMOD model of the Deutsche Bank [2000] as it has an extensive documentation and fulfils the other requirements too. The MEMMOD model is focused on Germany and the effects of growing international economic integration. Due to this integration, policies not only affect the country itself but also the trading partners. The approach of the Deutsche Bank was to create a structural model based on neo-classical theory. Special care was taken to ensure the reflection of homeland policy on trade partners and vice versa. The trade partners are represented "by compact models of their economy" as was stated in the model's description. These compact models will be used for all regions. The model allows representing both short term and long term behaviour by using parallel equations for the elements where a difference between long and short term can be expected. This focus on trade and the selected variables together with extensive documentation of the model were the most important reasons to adopt it as the basis of our model.

3.3.2 The estimation of the multi-country model coefficients

A search for appropriate input data was performed after selecting a model and determining that a re-estimation was required. A priori the preference is to use as few data sources as possible to minimize the effect of different definitions on the final model. The following three sources were chosen as the main sources for the data: IMF [2008], World bank [2008] and OECD [2008a]. In order to extend the economy of the main country to represent all of the countries in that region, various variables needed to be scaled. There are two types of (data) variables present within the model: levels, which represent a state of the economy and can be summed (e.g. GDP) and rates (e.g. inflation), which indicate the change of a level. Rates cannot be summed, but require weighting. The goal was to get a good scaling while keeping the amount of variables needed from all countries to a minimum.

This approach was tested using the North America region. The choice to use this region was based on the fact that there are only 3 countries in it: USA, Canada and Mexico. These countries actually have quite different types of economies. The findings were than further tested on the Hamburg-Le Havre region. Good results were found for this region too. The variables selected for this scaling of the main economy are: GDP, Population, Inflation, Import and Export. The last two variables, import and export, perform a key function in our model. Although it is economically correct to eliminate the internal trade, as trade within the region would no longer be an import or export, but a domestic trade. It is however essential to our model to represent this internal trade too, as the regions are large and sea transport is often used within the regions. The choice was therefore made to include these imports and exports within a region in the model.

The data provided by the 3 sources (IMF, World bank and OECD) provide all the data required for the developed countries, in quarterly and yearly time intervals. The data for countries in Africa, South America and parts of Asia is not readily available from these sources, other than at a higher aggregation level. In these cases the national banks and statistical agencies were consulted first, before moving to more dubious sources such as publications in papers and estimation based on other available variables e.g. estimating capital by using depreciation and investments time series. As a final resort data from another country was sometimes substituted for the data of the main country. This was done if no data was available. This was also done when an anomaly took place in the history of the main country and data was thus unusable as average data for the region. For example, this was the case with Germany, where the reunification of the former East and West resulted in a break in data series for several variables of that country. Due to the limited availability of data for several regions, yearly time series are the only option for data input. In Table 3.2 the regions and data sources consulted (besides the 3 main sources) are presented together with the time period for which continuous data was available for all of the variables. In case a dataset was not (completely) available for the main country, (scaled) data from other dominant or similar economies was substituted for this. The countries used for this are mentioned in the column called secondary countries.

Table 3.2: Overview of data sources per region

Region	**Main economy**	**Suplementary economies**	**Suplementary data sources**	**Data availability**
Hamburg – le Havre Range	Germany	Netherlands, France	-	1980 – 2005
Baltic Area	Poland	Sweden	-	1990 – 2005
Black Sea Area	Romania	Hungary	NSA[1,2], NB[3]	1995 – 2005
Mediterranean	Italy	-	-	1981 – 2005
North Africa	Morocco	Algeria	NSA[4,5], Est	1987 – 2005
West Africa	Nigeria	Niger, Ghana, Cameroon	NSA[4]	1995 – 2005
Southern Africa	South Africa	-	P[6] (1983-1993)	1995 – 2005
Middle East	Saudi-Arabia	-	NB[4,7], Est	1996 – 2004
Greater India	India	Pakistan	NB[8], NSA[9], Est	1996 – 2005
Southeast Asia	Thailand	-	NSA[10,11]	1995 – 2005
Greater China	China	-	NSA[12], NB[13], P[14]	1993 – 2005
North East Asia	Japan	-	-	1980 – 2005
Oceania	Australia	-	-	1980 – 2005
North America	USA	-	-	1980 – 2005
West Coast South America	Chile	-	NB[15]	1993 – 2005
East Coast South America	Brazil	Argentina	NB[16], NSA[17], Est	1995 – 2005

NB = National Bank, NSA = National Statistical Agency, P = Papers, Est = Deduction of results from other data.

[1] NIS [2008], [2] KSH [2008], [3] BNR [2008], [4] UNSTAT [2008], [5] CAPMAS [2008], [6] Wakeford [2003],
[7] SAMA [2008], [8] RBI [2008], [9] COI [2001], [10] NESDB [2008], [11] BTEI [2008], [12] NBSC [2008],
[13] PBC [2008], [14] Holz [2005], [15] BCC [2008], [16] BCB [2008], [17] INDEC [2008]

The data provided for Southern Africa might seem peculiar. Why use a paper providing some data for the period of 1983 to 1993, when most variables are not covered for that time span? The goal has always been to create as complete a time series as possible from 1980 until 2005. The equations are regressed with as much of the available data as possible and several equations might therefore take the benefit of the extra data available.

For the long term MEMMOD model 19 equations per country must be estimated. Next to these there are another 16 identity equations, establishing relations between internal variables of the model. In total there are 39 variables per country, of which 4 are exogenous. These four are the target inflation, the depreciation of capital, the direct and the indirect tax rate. These rates are fixed for the long term, but can be changed when the government decides on a different direction for the economy. They will remain fixed in the model unless a variation is specified by the user in a scenario.

All of the equations used by the MEMMOD model are presented below. In total 44 coefficients have to be estimated per country, expressed as c(x). In Table 3.3 a summary of the estimation results are presented: the number of data points used and the R^2 of that estimation. For three equations alternatives have been occasionally used in the original model. When these alternatives have been used in for a region in this model, an "A" is put in the cell. A list of variables and details of the not estimated equations that are not estimated can be found in Appendix A.

$$\Delta \log(Priv\_C) = c(1) + c(2) * \Delta \log(YV / (p * Wo)) + c(3) * r + c(4) * \Delta \log(Priv\_C_{-1}) + c(5) * \log(Cons_{-1} / GDP_{-1}) \quad (3.2)$$

In the long run the equilibrium level the ratio between private consumption (Priv_C) and savings does not change (is equal to $Priv\_C_{-1}$). However, generally private agents try to maximise their profits or their utility, this equilibrium ratio can therefore be offset by changes in the income generated with savings, the interest rate (r). Also the if the disposable income (YV) changes real consumption will change as well. The final part of the equation is to ensure that in the long run real private consumption is proportional to real GDP, by introducing the ratio of total concumption (Cons) divided by GDP [Memmod, 2000].

$$\log(E\_frac) = c(6) + c(7) * \log(E\_frac_{-1}) \quad (3.3)$$

The labour supply is proportional to the total population. This fraction does however display a slow change due to immigration and emigration, hence a trend coefficient is added to the equation [Memmod, 2000].

$$\log(I) = c(8) + c(9) * \log(Y) + c(10) * r \quad (3.4)$$

If the production function is assumed to be the Cobb-Douglas function and firms are assumed to be profit-maximising. Investments are there adjust the capital stock to its long term optimum. For this framework to work the user cost of capital should influence the optimal cost of capital. However this was not found. Hence the Investments are solely dependent on final demand (Y) and the costs of financing (r) [Memmod, 2000].

$$\begin{aligned} \log(A) &= c(11) + c(12) * \log(Y) + c(13) * \log(p * (1 - ti\_frac) / w) \\ \log(A) &= c(11) + c(12) * t + c(13) * \log(E_{-1}) + (1 - c(13)) * \log(Y * p * (1 - ti\_frac) / w) \end{aligned} \quad (3.5)$$

It has been seen that the ratio between wages (w) and sales/final demand (Y) are quite stable. Also the indirect taxation (ti-Frac) plays an important role as it increases the paid wages. The adaption of employment to production is sometimes sluggish, as elements such as overtime help in the first adjustments. Still for the long run it will hold. The second option is allowing for this stickiness if necessary) [Memmod, 2000].

$$\log(IM_{2000}) = c(14) + c(15) * \log(Y) + c(16) * \log(p * (1 - ti\_frac) / IM\_p) \quad (3.6)$$

The import equation resembles the ideas of the investment and employment equations. It results from optimisation behaviour of firms. This implies that the marginal product of imported units has to be equal to its marginal costs. The long run optimal value of import can thus be described by a relation between the final demand (Y), its price deflator (p) corrected for indirect taxes (ti_frac) and the import price deflator(IM_P)) [Memmod, 2000].

$$\Delta \log(w) = c(17) + c(18) * \Delta \log(w_{-1}) + (1 - c(18)) * \Delta \log(p) +$$
$$(1 - c(18)) * c(19) * \Delta \log(Y) + c(20) * \Delta(A\_frac) + c(21) * A\_frac_{-1} \quad (3.7)$$
$$\Delta \log(w) = c(17) * \Delta \log(w_{-1}) + c(18) * \Delta \log(LAS) + c(19) * \log(LAS_{-1} / w_{-1})$$

Over the long run, the wage development takes into account the price inflation (p) and the productivity gains (ΔY), attributable to labour. In classical theory the wage rate clears the labour market and results only in natural unemployment. The natural unemployment is a disputable factor and not used here. Unemployment (A_Frac) is however still a key factor of influence on the change of wages (w_{-1}). Wages are slow to adept, especially in a recession, therefore for several countries the first equation was not able to provide a good estimation of wages. In these cases the this slowness to react was used and wages are made dependant on past wages (w_{-1}) and the long term wage level (LAS). The determination of this value is discussed under the identity equations below [Memmod, 2000].

$$pi = c(22) * \Delta_2 \log(co / (1 - ti\_frac) +$$
$$c(23) * (1 - c(24) * pi_{-1} + c(24) * ((1 - 0.4) * pi_{+1} + 0.4 * pi_{target})) \quad (3.8)$$

The price deflator of domestic demand (pi) is in the short run influenced by changes in production costs (co) and capacity utilisation. In the long run expectations (and politics) play a role as well, represented by the target inflation (pi_{target}) as well as past and future values of the price deflator (pi_{+1}/pi_{-1}) [Memmod, 2000].

$$\log(co) = c(25) * \log(w) + (1 - c(25)) * \log(IM\_p) \quad (3.9)$$

The production costs (co) are expressed as a weighted combination of wage costs (w) and import costs (IM_p). The share of each is an indication if the production is more dependent on imports or on labour) [Memmod, 2000].

$$p = c(26) * p_{-1} + c(27) * pi \quad (3.10)$$

Although price level is officially an identity equation, the mixed use of sources as well as the creation of regions has caused this relation not to hold. The suggestion to relax this equation was already made in the MEMMOD model [Memmod, 2000].

$$\Delta \log(G) = c(28) * \Delta \log(G_{-1}) + (1 - c(28)) * \Delta \log(GDP) + c(29) * \log(RSST) \quad (3.11)$$

Government demand (G) is assumed to have direct relation with GDP. Even though this relation was decreasing in the last couple of years. As governments borrow heavily a relation with the steady state interest rate (RSST) was found to be significant as well [Memmod, 2000].

$$\log(SB / (GDP * p)) = c(30) + c(31) * \log(SB_{-1} / (GDP_{-1} * p_{-1})) + c(32) * \Delta(A\_frac)$$
$$\log(SB) = c(30) + c(31) * \log(SB_{-1}) + c(32) * \Delta(A\_frac) \quad (3.12)$$

Social benefits (SB) are determined by the number of children, unemployed labour force (A_frac) and senior citizens. The height of the benefits are often linked to the wages. This has been approximated here by the use of GDP and price level (p). In some cases the link to GDP was not found and the social benefits were not divided by GDP and price level [Memmod, 2000].

$$\log(M / p) = c(33) + c(34) * \log(GDP) + c(35) * \Delta(r - pi) \quad (3.13)$$

Money (M) may be held for two reasons; transactions and speculations. Thus in the first stage real money (M/p) is regressed against GDP. Holding money requires paying the opportunity costs for not saving or investing it. These costs form the second stage of the model and are represented by the nominal interest rate (r-pi) [Memmod, 2000].

$$rs = c(36) * rs_{-1} + (1 - c(36)) * RSST + c(37) * \log(Y) \quad (3.14)$$

The short term interest (rs) is focussed returning to a steady state interest rate (RSST), while incorporating growth of final demand (Y) [Memmod, 2000].

$$\begin{aligned} \log(1 + r) = (1 - c(38)) * \log(1 + r_{-1}) + c(38) * \log(1 + r_{+1}) + \\ 1/40 * \log((1 + rs)/(1 + RSST)) \end{aligned} \quad (3.15)$$

The long term (government bond) interest contains a forward and backward looking policy element (r_{+1}/r_{-1}), as well as incorporation of the short term interest (rs) deviation from the steady state short term interest value (RSST) [Memmod, 2000].

$$\log(Wo) = c(39) * \log(Wo_{-1}) \quad (3.16)$$

The growth of the population (Wo) is assumed to be stable and a fixed percentage of the current population [Memmod, 2000].

$$\Delta \log(X) = (1 - c(40)) * \Delta(IMAK) + c(40)) * \Delta \log(X_{-1}) \quad (3.17)$$

Changes in nominal export (X) depends on a weighted average of the rate of change in the previous period and an expression for foreign activity (IMAK). The formula for foreign activity is given in the identity equations section [Memmod, 2000].

$$\begin{aligned} \Delta \log(PEx) = (1 - c(41)) * \Delta((1 - 0.143) * \log(p_{-1}) + 0.143 * LPAC_{-1}) + \\ c(41) * \Delta \log(PEx_{-1}) \end{aligned} \quad (3.18)$$

The price deflator for exports (PEx) is related to the domestic demand price deflator (p), the weighted average price development in other countries (LPAC) and its past value (PEx_{-1}) [Memmod, 2000].

$$\Delta \log(IM\_p) = (1 - c(42)) * d(PExA) + c(42) * \Delta \log(IM\_p_{-1}) \quad (3.19)$$

The price deflator for import is build up similarly, it is the weighted average of the past import price deflator and the weighted average of its trading partners' export prices [Memmod, 2000].

$$\log(Ex) = c(43) + c(44) * \log(Ex_{-1}) + (1 - c(44)) * \log(p_{+1} / NAM\_p_{+1}) - (rs - NAM\_rs) + c(44) * (rs_{-1} - NAM\_rs_{-1}) \quad (3.20)$$

Lastly for the country model the development of the exchange rate of a country with the USD is the result of the past rate (Ex_{-1}) and the difference in development in the price deflator (p), short term interest rate (rs) and the past short term interest rate (rs_{-1}) [Memmod, 2000].

$$\log(Oil) = c(45) + c(46) * \log(Oil_{-3}) + c(47) * \log(Oil_{-2}) + c(48) * \log(Oil_{-1}) \quad (3.21)$$

The final equation to estimate is the development of the oil price. This is assumed to be related to its past values only. It is an autonomous element in the model [Memmod, 2000].

Table 3.3: Summary of country equation estimation, number of data points and R^2

Equation	BAL	BLA	CHI	ESA	FEA	HAM	IND	MED
1 [3.2]	9, 73.63%	10, 81,30%	11, 60.95%	6, 97.64%	22, 81.04%	22, 79.34%	9, 25.19%	21, 67.07%
2 [3.3]	15, 91,97%	25, 19.93%	16, 96.84%	16, 92.00%	25, 97.05%	25, 90.46%	25, 98.03%	25, 85.75%
3 [3.4]	12, 80.49%	10, 95,56%	26, 99.49%	10, 21.46%	25, 75.46%	22, 94.35%	26, 99.22%	26, 96.14%
4 [3.5]	12, 73.81%, A	12, 90.30%	16, 98.03%	13, 72.73%	26, 92.07%	24, 88.42%	16, 99.62%	25, 97.08%
5 [3.6]	12, 97.92%	13, 99.62%	19, 98.70%	15, 91.75%	26, 98.83%	26, 99.75%	17, 98.34%	26, 99.23%
6 [3.7]	12, 12.37%, A	11, 92.10%	14, 69.18%	8, 99.86%, A	21, 25.20%, A	23, 35.28%	15, 17.22%	23, 73.12%
7 [3.8]	11, 98.51%	7, 88.48%	14, 92.06%	8, 70.95%	23, 86.84%	23, 92.63%	23, 80.47%	22, 94.38%
8 [3.9]	12, 51.58%	11, 02.60%	16, 67.46%	15, 98.12%	26, - 78.83%	26, 72.29%	9, 47.94%	18, 91.71%
9 [3.10]	11, 96.71%	8, 98.61%	11, 95.41%	11, 99.11%	-, -	25, 99.52%	11, 99.22%	25, 99.93%
10 [3.11]	12, 66.72%	14, 38.63%	24, 21.34%	10, 40.03%	24, -19.68%	24, 27.22%	24, 14.38%	24, 56.77%
11 [3.12]	10, 75.18%, A	7, 99.48%	14, 92.72%	8, 23.63%	23, 97.57%	21, 86.04%	15, 82.80%	22, 98.81%
12 [3.13]	12, 98.44%	11, 00.85%	19, 95.14%	11, 82.61%	26, 94.42%	15, 88.63%	17, 20.69%	19, 07.85%
13 [3.14]	12, 96.40%	10, 57.82%	12, 76.38%	10, - 03.48%	25, 90.24%	25, 26.99%	9, -10.33%	25, 86.62%
14 [3.15]	11, 96.78%	9, 79.40%	12, 92.76%	9, 08.38%	24, 96.52%	21, 82.72%	9, 65.35%	24, 91.34%
15 [3.16]	12, 98.77%	9, 99.25%	16, 99.62%	25, 99.92%	25, 99.63%	25, 99.60%	25, 99.96%	15, 99.85%
16 [3.17]	11, -22.81%	11, 0%	11, -46.62%	11, 07.17%	11, -07.56%	11, -65.54%	11, -71.45%	11, - 21.23%
17 [3.18]	9, 14.70%	9, - 54.96%	9, -3946%	8, - 35.17%	9, -27.68%	9, -53.76%	9, -09.64%	9, - 43.19%
18 [3.19]	10, 54.86%	10, - 77.79%	10, 32.80%	10, - 09.18%	10, - 61.78%	10, 64.28%	10, 33.16%	10, 38.31%
19 [3.20]	12, 91.19%	9, 96.14%	11, - 2232%	9, 85.94%	24, 85.33%	24, 67.41%	8, 75.74%	24, 56.80%

Equation	MIE	NAF	NAM	OCE	SAF	SEA	WAF	WSA
1 [3.2]	9, 77.33%	23, 22.37%	22, 76.99%	22, 39.91%	11, 97,02%	10, 93.61%	9, 26.01%	16, 47.04%
2 [3.3]	25, 98.79%	25, 98.57%	25, 93.91%	25, 94.23%	12, 42.96%	25, 98.09%	10, 00.71%	16, 66.75%
3 [3.4]	22, 85.73%	25, 87.21%	25, 96.00%	26, 96.69%	13, 02.14%	26, 50.91%	10, 26.66%	16, 93.48%
4 [3.5]	10, 98.65%	19, 98.09%	25, 99.49%	26, 98.28%	13, 97.31%	23, 89.36%	10, 95.86%	13, 92.35%
5 [3.6]	26, 93.96%	26, 49.09%	25, 99.79%	26, 98.94%	13, 98.93%	26, 92.87%	10, 93.79%	17, 95.93%
6 [3.7]	6, 30.64%, A	18, 05.35%	24, 71.31%	24, 65.23%	11, 85.68%	18, 77.66%	6, -03.41%,A	11, 95.81%
7 [3.8]	18, -25.68%	17, 64.44%	23, 92.14%	23, 37.98%	8, 82.24%	23, 80.33%	9, 81.33%	12, 84.24%
8 [3.9]	10, -236.07%	17, 33.44%	26, 98.98%	26, 98.70%	9, 69.55%	26, 98.39%	10, 34.22%	13, 88.21%
9 [3.10]	-, -	25, 99.65%	25, 99.83%	25, 98.83%	12, 98.49%	25, 99.74%	9, 95.18%	11, 99.42%
10 [3.11]	24, 20.59%	24, 03.60%	23, 43.83%	24, 25,39%	11, -54.90%	24, 03.59%	10, -13.68%	16, -13.03%
11 [3.12]	12, 81.78%	17, 99.39%	23, 99.64%	23, 99.30%	11, 52.38%	9, 63.92%	10, 66.63%	11, 77.62%
12 [3.13]	11, 86.52%	25, 97.91%	26, 85.17%	26, 99.19%	13, 78.81%	26, 94.00%	10, 72.49%	24, 98.01%
13 [3.14]	25, 06.38%	25, 18.83%	24, 88.62%	25, 52.10%	12, 69.15%	25, 20.41%	10, -49.90%	13, 82.29%
14 [3.15]	20, -38.39%	23, 53.18%	24, 93.03%	24, -13.70%	11, 80.07%	24, 44.38%	9, 05.74%	12, 82.02%
15 [3.16]	16, 99.71%	25, 99.91%	25, 99.97%	25, 99.95%	12, 99.60%	25, 99.94%	10, 99.96%	11, 99.87%
16 [3.17]	11, -13.43%	11, -41.28%	11, 35.57%	11, -39.03%	10, -50.19%	11, -31.24%	11, -01.04%	11, 26.92%
17 [3.18]	7, -22.54%	8, -09.66%	9, 49.25%	9, -26.83%	9, -48.63%	9, -31.04%	4, -16.90%	9, 30.31%
18 [3.19]	10, 10.72%	10, -74.87%	9, 53.46%	10, -74.99%	10, -12.38%	10, -22.51%	10, -80.03%	10, 02.55%
19 [3.20]	10, 35.16%	24, 82.86%	XXXX	24, 59.53%	11, 85.45%	24, 96.04%	24, 94.50%	11, 77.10%

Table 3.4: Summary of the oil price equation estimation, number of data points and R^2

Equation	Oil price
20 [3.21]	23, 47.59%

Due to the limited data available, a strong indication by the regression routine that the coefficient needed to be set to zero was ignored as long as the sign of the coefficient was right. The main reason for this is that it was deemed more important to have the proper links in place, facilitating future research, rather than estimating the best possible model.

The first striking observation is the fact that almost all estimations for equations 3.17, 3.18 and 3.19 perform worse than just using the average. In Eviews, the software used, this results in a negative R^2. What kind of equations are these and why do they perform so badly? The Equation set 3.17-3.20 is the trade block of the model. Equation 3.17 determines the export, Equation 3.18 the export deflator, Equation 3.19 the import deflator and Equation 3.20 the Exchange rate to the USD (hence no value for Northern America). These equations make use of three identity equations that determine the world export deflator for imports of this country, the world import deflator for exports of this country and the international competitors' price deflation. All three equations use a fixed fraction of the division of import and export of one region to the other region. One problem in this case is certainly the limited data available which spills over from several regions to all regions. The low number of 8-11 data points indicates this and does not help in getting good results or determining the exact source of the problem.

One potential source might be selecting the wrong year to base the fractions on. This hypothesis was tested and it was found that the results shown are already the best results of three years of fractions tested, though differences were not large. This leaves two options open, to accept the ill fit and continue with the modelling process or to use the mean in the model since it results in a better fit. However, before selecting a solution something else needs to be clarified first.

The goal of this model is to provide input to determine the demand for maritime transport. As occurs in all statistics, the sum of exports does not match the sum of imports. Part of this is normally blamed on the fact that exports are reported in free on board prices (not including transport costs) and imports include transport costs as these are also paid for by the importer. However, based on the data used for this model, exports seem to exceed imports, which is not in line with the idea of added transport costs. This requires the selection of either exports or imports as the input of the trade conversion. Because of the bad performance of the trade block (export side) of the model and the fact that another data source, which will be used to convert the money trade into volumes, is also based on imports, the decision was made to leave the equations in the model despite the fact they perform poorly. However, import (Equation 3.6), an equation with a very good fit for all regions, was used to determine trade in the other parts of the model.

One other equation requires extra attention, Equation 3.10. This is officially an identity equation in the original model. It states that the current price deflator for domestic demand is the price deflator of the last period plus the current inflation. However, consumption inflation was more readily available and used in this model. This resulted in the problem that even though both variables come from the same source, they had to be replaced by an estimated variable. Such data issues probably bugged the original model as well, because in the original model this identity equation is occasionally relaxed by allowing a coefficient. This approach has also been adopted in this thesis and only in two cases has the identity equation been maintained, resulting in the two dashes in the table.

The limited data availability was shown to have a major impact on the estimation of the model. The original MEMMOD model used quarterly data, but in this research only yearly data is available, because many more regions are covered. This results not only in less data, but also the period under consideration for the equations with lagged values is much longer. Even with this simplification, for several regions data was scarcely available, resulting in estimation of equations using less than 6 data points. This is statistically not sound. It is enough to cover the degrees of freedom in all cases, but not much more.

The goal of this model was to provide realistic behaviour and allow the application of scenarios. While the values themselves might not be accurate predictions of the future, the impact of a change can still be compared to a base case scenario without these changes. By using the relative changes, the problems with the data are expected to be reduced, while still gaining significant insight. The next subsection will therefore take a look at the output of the model and establish whether it is sufficiently realistic to continue with.

3.3.3 Conversion of the Multi Country Model output to trade volumes

The output of the above described model is the imports and exports of each of the regions to all regions expressed in USD. The amount of exports includes exports from a region to itself as each region consists of multiple countries and there can be significant volumes of international seaborne trade going on between those countries. The same holds for imports. The demand for shipping is expressed in ton*miles, or tons traded between two points, a legacy of Tinbergen [1934].

There are two issues which must be solved when converting this stream of money into volumes of trade. The first is to convert a monetary value into a weight value representing goods traded. There is no fixed ratio for this, as it depends on the value and composition of the traded goods. This issue will be handled later. The second issue is linked to the fact that ships are specialized to a certain degree. They cannot transport all types of goods. A first approach to this is to split the vessels according to their major trades: dry bulk, wet bulk and general cargo. Dry bulk is the trade of all dry materials loaded in bulk and without packaging, with the main products being iron ore, grain and coal. Wet bulk is the bulk transportation of liquid products. These can be loaded and unloaded through pumps. The main trades are crude oil, oil products, LNG/LPG and chemical products. The general cargo trade used to be ships loading a large amount of small parcels of (packed) goods on board. Nowadays the container trade is the largest of the general cargo trades, though specialised trades such as reefers (cold transportation of fruits) and car carriers still exist as well. Next to these three major cargo types there are many others, like fishing, passenger, dredging, etc. These are, however, much smaller and often local and therefore not considered for this model.

Clearly each of the sub trades mentioned here have their own specialised vessels. However, in many cases the division is not clear, or at least not stored in the popular vessel databases available. Therefore, the division of trades will not go beyond this split into the three major trade types. As a preliminary assumption this division is assumed to be constant over time. This assumption has been made for two reasons. Firstly, when the export and import of manufactured products grows, the requirement for raw materials and energy rises as well. The last two are mainly represented in the dry and wet bulk class with the first one mainly present in the general cargo trade. The second reason is that already in the macroeconomic model the choice was made to keep the division of trade fixed for each country. To do the same here will only increase the consistency of the model.

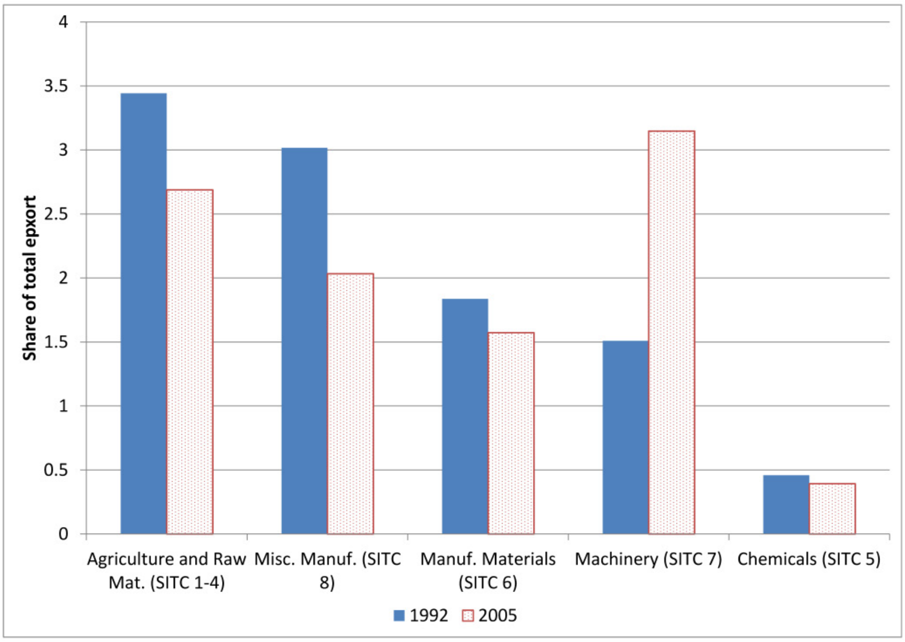


Figure 3.3: Reallocation of exports across SITC one-digit industries (Source: Author based on data from Amity and Freund [2008])

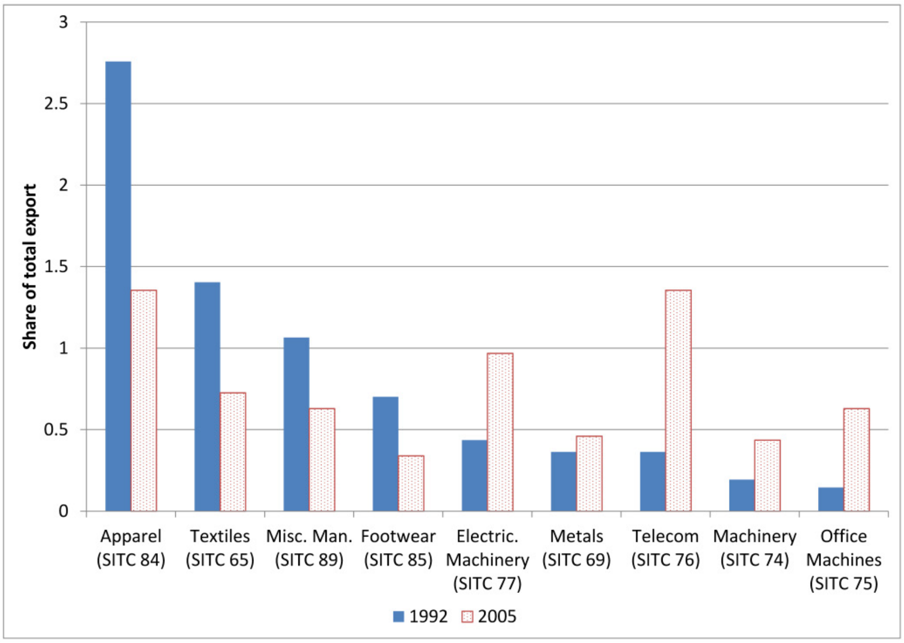


Figure 3.4: The reallocation of manufacturing exports across major two-digit sectors (Source: Author based on data from Amity and Freund [2008])

Research related to the changes of goods shares in the export of China [Amity and Freund, 2008] shows a drastic change in the goods exported and produced when looking at the years 1992 and 2005. At the 1-digit SITC [2009] level the fractions of export have moved quite drastically (Figure 3.3). Fractions are calculated on the basis of constant USD. It is impossible to assign a 1-digit SITC code completely to one of the three trades identified, luckily Amity and Freund [2008] also went a level deeper in their export classification.

Figure 3.4 shows the changes between 1992 and 2005 for the most important goods exported from China on the 2-digit SITC code level. This figure clearly illustrates a move to more knowledge intensive products. Here a decline is seen in footwear and other textiles, while an increase is seen for telecom and electrical machinery. Though the data level provided here is not definitive, it appears that the major redistribution took place within the category of general cargo, or more precisely within the container trade. A first thought could be that this is a good sign, as the sum of a certain group seems to remain equal. However, many more groups at the 2-digit SITC level exist and overall it is a very complex problem. Especially as more exports in USD does not necessarily mean more exports in tonnes. In other words no clear better system for division can be found and the assumption of static fractions over time on the highest level seems feasible.
The process outlined above allowed us to divide the money value of the bilateral exports into the 3 maritime trades and a group of others. The WITS [2008] data, a database on trade from the World Bank, used to determine these fractions per region, is on country level. For each region the exports were summed on both sides of the trade for countries within the same region.

Next to the three groups of trade, financial trade is also part of the import and export figures. Part of this trade group is the investments made abroad by companies. It is necessary to find a proper way for assigning the correct volume to a specific trade. The example above, taken from Amity and Freund, also serves another purpose. On the highest level there might seem to be a move between trades, on the second SITC level however, it appears the move of trade is within one trade group. Further details are not provided by the paper. Using the WITS [2008] database (World Integrated Trade Solution) it was clear that even the two digit SITC level can result in over-simplification. On the 3-digit SITC code level most groups were homogeneous and could be assigned solely to one of the four trade groups identified. The WITS database supplies this 3-digit bilateral import and export data for almost all countries in the world. The exact division is left out of this thesis, but is based on the author's best efforts. Discussions on its correctness are useful, but will only alter the end results by more than a fraction of a per cent.

Table 3.5: Volume weighted mean of trade value (Source: Author with data from WITS)

Equation	Wet bulk	Dry bulk	General cargo
$/ton	1.00	1.00	4.00

The issue of converting USD to tonnes still remains. The WITS database not only provides data on how much value per 3-Digit SITC group was transported between two countries, but also how many tonnes. This allows the determination of a value/ton ratio for each group per bilateral trade. Taking steps of 0.5 USD in this ratio, trades were grouped and a volume weighted average was determined. Table 3.5 presents the results for the three cargo groups. Note that results were not determined per country or per trade, but for the entire group. This implies that for certain countries trade might be over or underestimated, though this effect is expected to be small. Figure 3.5 shows the distribution of the volume over the different price categories. Only general cargo has a wider spread, which is to be expected.

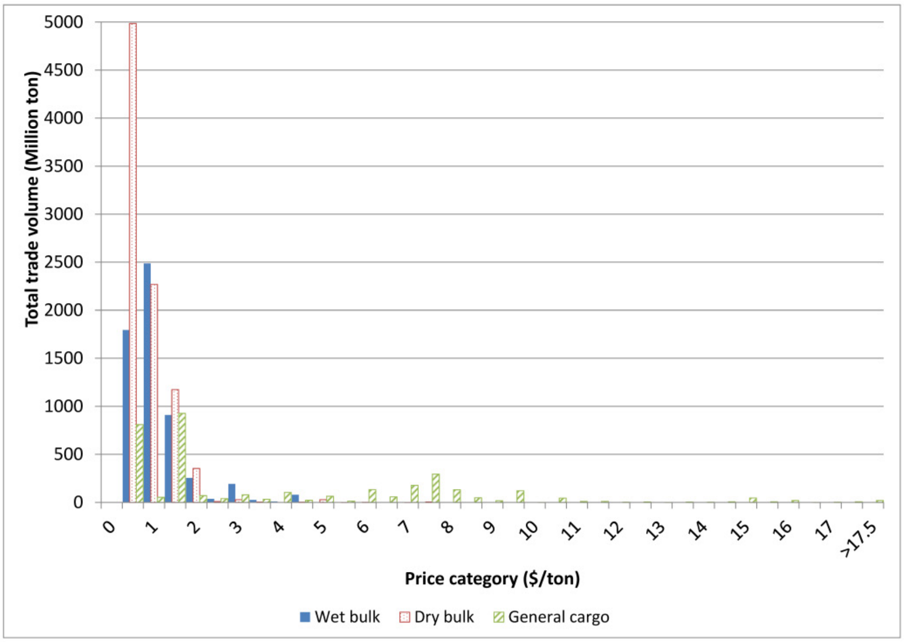


Figure 3.5: Goods volume classed per price (Source: Author with data from WITS)

3.3.4 Conversion of yearly trade into weekly trade

In the discussion of desired output in section 3.1.2 it was stated that weekly data capturing the variations in demand was preferable. The data available now is yearly tonnes for 3 different trades. How to convert this into weekly demand is the subject of this section. As a first suggestion the yearly value could be divided by 52 (weeks) and this average could be used. However, this will not result in a smooth transition between one year and the next. This would lead to some unrealistic behaviour. Four aspects play a role in this realistic conversion:

- smooth transition between years,
- seasonality of trade,
- a selectable level of randomness and
- the total demand for a year should remain the same.

The first aspect is therefore a smooth transition between years. How smooth will this transition need to be, considering the fact that ultimately randomness will be added to the curve, breaking up this smoothness? The choice for the creation of a continuous line must be made between a simple linear trend or a more complex smooth trend. The linear trend can be calculated in such a way that it runs from year mid to year mid using the average weekly trade. For a smooth line, the Bezier curve can be used. The Bezier (cubic) curve allows a smooth line to be drawn through a number of points, ensuring that the second derivatives at the points are equal for both sides. To do this four points are needed to draw each line piece between two points: P-1, P0, P1 and P2 are needed to draw the line segment P0-P1. Bezier curves are widely published and used in many applications. We refer to e.g. Farin [1983] for a more detailed explanation and an algorithm for application (in a graphic environment).

The smooth line ensures that no rapid increase in demand comes after a period of depression but postpones this rise until later in the year. Although randomness will partly destroy this smoothness, the trend will still be seen. Therefore, the choice was made to calculate a smooth line between the two consecutive mid-year points, a slightly larger effort.

The second aspect was seasonality. All trade is influenced by seasonality. On the one hand this could be due to harvesting seasons, in the case of grain, or due to human culture, in the case of Christmas. However trade in this model is investigated at quite a high level, which could result in seasons cancelling each other out. In three papers Kavussanos and Alizadeh [2000, 2001, and 2002] investigate the presence of seasonality in dry and wet bulk freight rates, while Schulze [2009] investigates this for the port of Hamburg and container trade. All find significant changes for certain months, though not necessarily the same month for all three trades. In order to compensate for the seasonality, the weekly values are increased or decreased by the relative influence found for seasonality on trade in these three papers.

The third aspect is a selectable level of randomness. Most literature found in this area focused on port arrival distributions. These papers all focus on the queue types and distributions to use for a port as well as how to predict the operability and effects of investments in extra equipment or berths. It is clear that vessels do not arrive with fixed intervals or in a fixed size. In this case it does not really matter if a vessel loads or unloads cargo. To mimic this, the demand for transport on a certain route should vary over time. The randomness should be selectable by the user due to the simplifications applied to the model. So far all simplifications have reduced the demand for vessels. The fact that all cargo is available in one port has an especially large impact on this. By varying the demand for transport, a larger fleet needs to be maintained to cope with these variations in demand. The variations could thus be tuned to get a more realistic demand for transport.

The fourth aspect requires the total annual trade demand for a year to not change as a result of the previous three considerations. This seems logical, but when using a smoothing function combined with seasonality and random distortions, it is not straightforward. In order to achieve this, the final results are scaled (up or down) to match the original year value. This scale factor is "original year value" / "Sum of new weekly values".

An example with four steps is given below in Table 3.6. The top row shows the original smoothed data and year total. The second row contains the random deviations, which are applied by multiplying by (1+x). They are almost all positive for this example. The correction calculates the new yearly total, seen in row three. In this case the new total is larger than the original value. To get back to the original value, the ratio between the new and desired total is calculated and applied to all values of that year (rows four and five). Using this methodology, the randomness is still included in the annual demand, without changing the average annual total. Correction in this way does lead to some loss of smoothness between consecutive years, but this effect is in the same range as the magnitude of the randomness itself.

Table 3.6: Demonstration of the randomness correction procedure

Equation	Q1	Q2	Q3	Q4	Total
Smooth Result	20.00	23.00	27.00	30.00	100.00
Random (-0.10 - 0.10)	0.07	-0.07	0.10	0.07	-
Results without correction	21.40	21.39	29.70	32.10	104.59
Correction	0.96	0.96	0.96	0.96	
Results with correction	20.46	20.45	28.40	30.69	100.00

3.4 The evaluation of the module

This section will be the first part of the validation of the model. It will verify if the developed model provides the output and flexibility described in the first two paragraphs. This process is called verification, and it tests if the model acts as intended.

3.4.1 Multi Country model verification

At the end of Section 1.2 five research questions were defined. In the first two sections of this chapter (3.1 and 3.2), the output which forms a link between this MCM module and other modules was determined. If both of these are combined, it is possible to see for each of the research goals which elements are of interest, see also Table 3.7. These elements are the ones whose behaviour should be investigated in this verification section. The two elements described in section 3.2 will be discussed in the next section 3.4.2: the conversion to weekly trade data and the presence of implemented seasonality.

Table 3.7: Variables important for the research questions

Research (sub) questions	Important variables
What are the risks and benefits of a certain strategy given a set of scenarios?	Not directly related to the MC-module
1. What will the demand for transport do on the most important routes?	Not directly related to the MC-module
2. What fleet development will be required to support this demand?	PPP, PPI, exchange rate, wages, interest
3. Which type of vessels will be built and which will be phased out?	GDP, consumption, savings, investments
4. Which countries will be best suited for building these vessels?	Import, export

Next to the identification of important output variables, section 3.2 also identified a number of variables which were used to create scenarios. These are:

- Interest
- Inflation
- Tax regime
- Consumption
- Investments

The remaining subsections will provide summaries of the scenarios and verification which can be used to judge the quality of the chosen model implementation. However, a selection of scenarios to test must be made before continuing.

3.4.1.1 Scenario Selection

There are a total of six variables that can be tested in any combination on any combination of the 16 regions, each with a positive and negative change option and that can be applied in ten different years/moments of time. As a result countless possible options exist, which means that a pre-selection of scenarios is required to keep it manageable.

To reduce the number of scenarios, which must be examined, logical combinations of changed variables and regions must be selected. When strong trade links between two regions exist, one expects a change in one region to affect the other region over time. A priori we would expect a strong link between North America, Western Europe and China, though perhaps the dependency of China on the other two is larger than vice versa. On the other hand Africa does not have a big influence on the global economy. To test if this behaviour is exhibited by the model, at least Western Africa, China and either North America or Western Europe should undergo the scenario changes. Besides these three regions, Korea and Japan are important shipbuilding countries, and their output (they are from one region) should also be considered due to their importance in the final model.

The variables to be tested are separated in two groups. The first three are more politically oriented and combining these elements does not easily fit in an overall scenario. Therefore, these variables will be tested individually. The second set of variables represents consumer behaviour. Here each variable can be tested individually and in a combination where consumers can either save/invest or consume, requiring that an increase in one element means a similar decrease in the other.

Because the model is a long term equilibrium model, the values will move back to their original prediction over time. This also means that it is not particularly relevant if a shock is negative or positive. Therefore, positive shocks will be tested in all individual cases with the exception of the combined scenario, where this is not possible. Because the model will move back to its base scenario, timing of the event in the scenario becomes interesting. Therefore, every scenario will be done at two points in time: 2005 and 2010. It is expected that the latter will not have enough time to return to its equilibrium state, given a big enough shock. In case of the 2005 timing, some data is still fixed. This fact might influence the behaviour of the model.

The set of scenarios tested on the model will be six types of positive shock at two points in time in three different regions, resulting in 36 scenarios to be tested in the output of five different regions. Though not discussed yet, the output variables are not all equally important in each of the scenarios. The discussion of this selection will be done within each of the scenario sections below.

Each scenario tests the influence of a positive shock of 1% and the effect of this shock on the monitored variables, both within the region and the other regions. In this chapter only a a selection of the results will be presented and discussed. As there are 90 figures in total, of which most do not show a reaction at all. The sections below will present only the region's behaviour to which the shock was applied and an example of the reaction to the shock in the other region (only if needed).

3.4.1.2 Verification 1; the influence of a different interest policy

The first shock to be tested is an increase in the long term interest rate by 1%. In general, money will be more expensive which will limit the spending power of the population and companies. This means that the consumption and investments will probably be reduced as well as potentially limiting the import of goods. Other regions that are dependent on this region for their exports will need to cope with this change.

The legend of all the graphs is the same and presented at the beginning of this overview in Table 3.8. Also, the scales are uniform to allow for an easier comparison.

Table 3.8: Colour legend for the graphs of section 3.4.1

GDP
Consumption
Investments
Import
Export
Inflation
Production Costs
Wage rate
Interest (Long term)
Exchange rate

North America is such a region and this propagation is shown in Figure 3.6a-b. As described above, the effect of the unexpected shock in 2005 results in a somewhat delayed reaction. The shock in 2010, however, builds and reduces over time and the reaction to it does the same. The factors for wage and production cost see a delayed reaction, quite similar to what one would expect in reality; we are slow to adapt our wages and cost structures as they are usually fixed for at least a year at the time.

In all scenarios, the biggest reaction on changes in North America is seen in the region of Greater China, Figure 3.7a-b. A large part of the export of China is consumed by North America. Any drop or increase in the consumption will therefore affect the production in China. One reaction is the same for all nations though: in a reaction to the change in imports from North America, the exchange rate is adjusted, rather than the physical imports and exports.

Figure 3.6a-b: Effects of a 1% interest shock in 2005(left) and 2010(right) in North America on North America

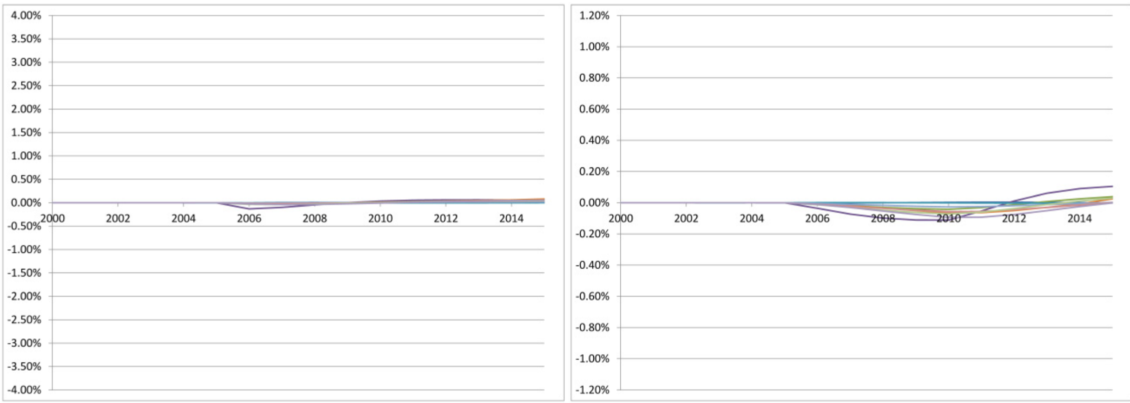


Figure 3.7a-b: Effects of a 1% interest shock in 2005(left) and 2010(right) in North America on the Greater China region

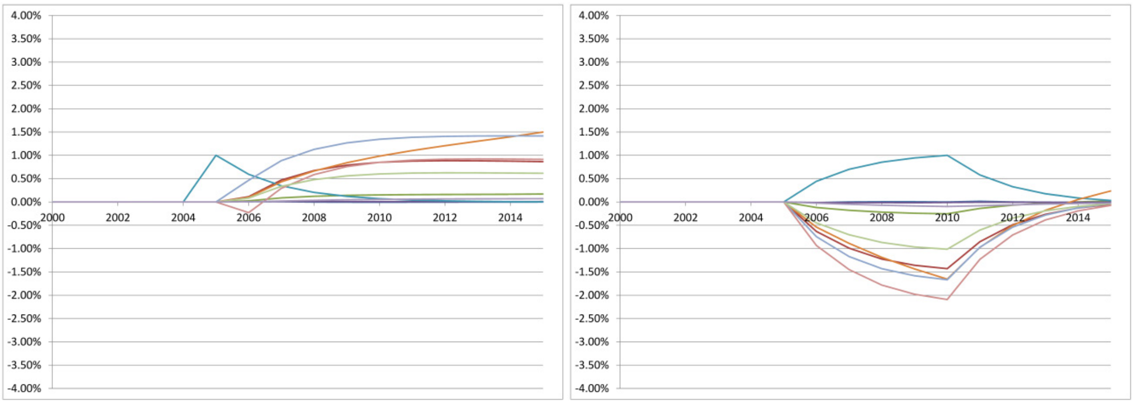


Figure 3.8a-b: Effects of a 1% interest shock in 2005(left) and 2010(right) in Greater China region on the Greater China region

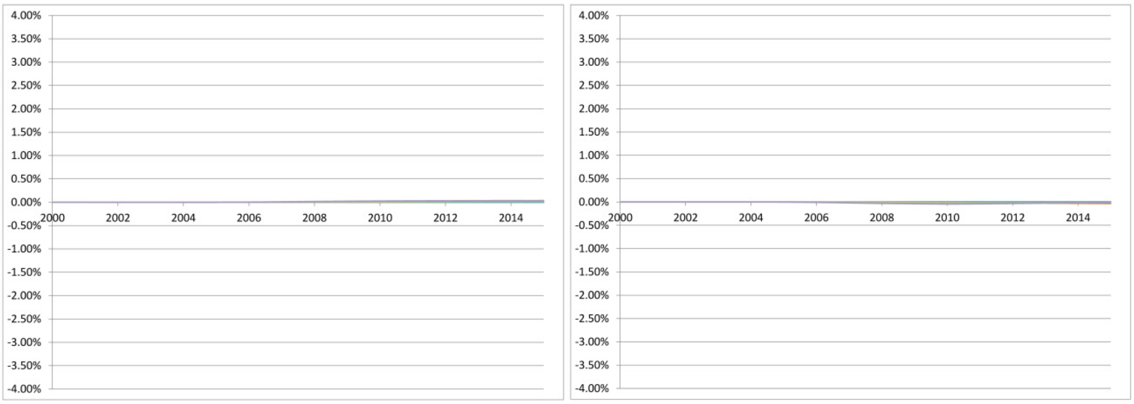


Figure 3.9a-b: Effects of a 1% interest shock in 2005(left) and 2010(right) in the Greater China region on North America

In the case of the interest change applied to the Greater China region, the effect of fixed values for 2005 can be clearly seen. The reaction to the change in 2005 shown in Figure 3.8a-b, is opposite to what would be expected. This can be explained by the fact that for 2005 many variables are still fixed. The reaction seen is actually based on the reduction of the interest rate, back to normal in 2006. This explains the largely positive reaction to this in the increase in costs. In the 2010 case, a similar reaction as in the North America case is seen. On the other hand, as the regions selected here are not heavily exporting to China, no reaction can be seen in Figure 3.9a-b. This is seen not only for North America, but also for Hamburg-Le Havre, Fareast Asia and West Africa.

Lastly the interest increase is applied to West Africa. No reaction is expected to this in other regions and no reaction is seen. However, the small shock has a large impact on the investments made in this region are for both the 2005 and 2010 case, see Figure 3.10a-b.

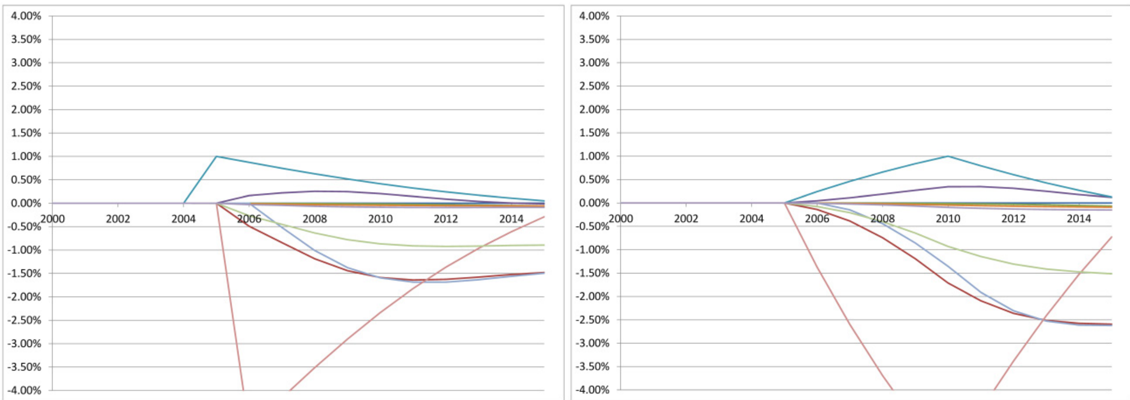


Figure 3.10a-b: Effects of a 1% interest shock in 2005(left) and 2010(right) in West Africa on West Africa

3.4.1.3 Verification 2; the influence of a sudden 1% inflation increase

The second test looks into the effect of increased inflation. When inflation occurs money will be worth (slightly) less and products will become more expensive. Over time wages will have a tendency to rise to compensate for this drop in material income. Figure 3.11a-b, Figure 3.12a-b, Figure 3.13a-b and Figure 3.14a-b show this effect for North America, Greater China and West Africa, though in different settings. In North America the wage increase is delayed, but is almost equal to the inflation. In Greater China, the wage increase is far more than the inflation, especially in the 2010 case, a dangerously unstable situation (most likely rooted in the strong growth in the last decade of the twentieth century). The most peculiar one is West Africa. Here instead of rising wages, the production actually drops and imports rise.

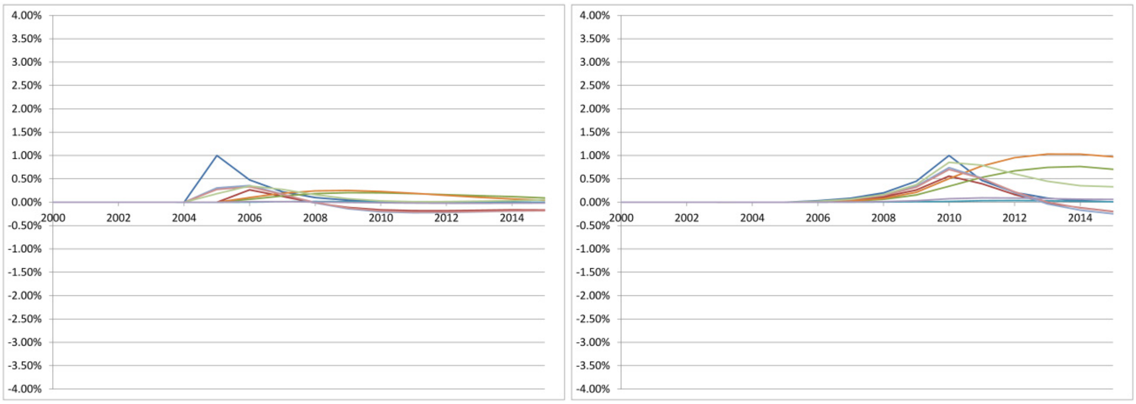


Figure 3.11a-b: Effects of a 1% inflation shock in 2005(left) and 2010(right) in North America on North America

Figure 3.12a-b: Effects of a 1% inflation shock in 2005(left) and 2010(right) in North America on the Greater China region

There is no reaction in the other regions for all values except for the exchange rate in the case of North America's inflation increase and for Greater China, which is depicted in Figure 3.12a-b. The figure shows a smaller increase in Greater China and its consequences on the other variables.

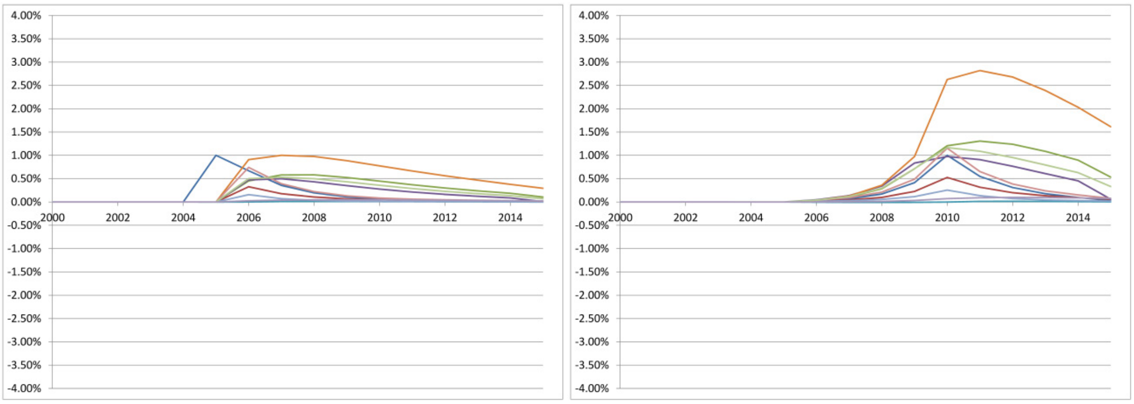


Figure 3.13a-b: Effects of a 1% inflation shock in 2005(left) and 2010(right) in Greater China region on the Greater China region

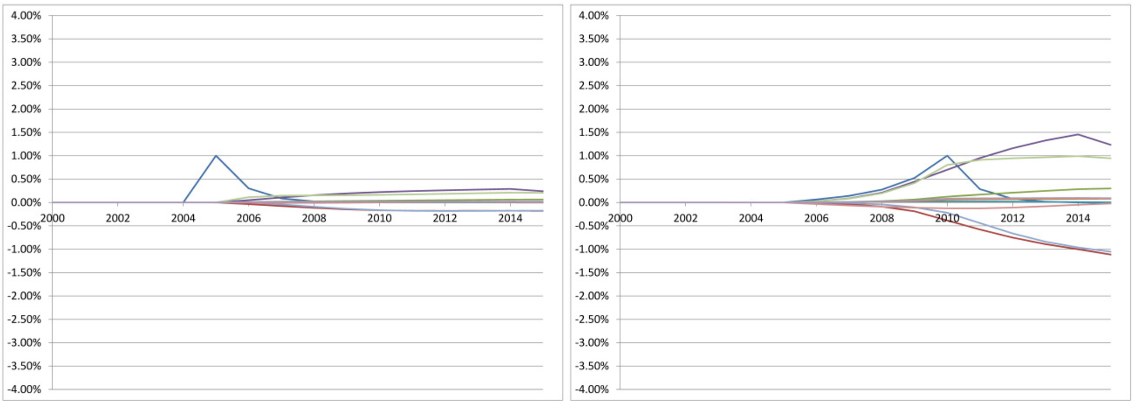


Figure 3.14a-b: Effects of a 1% inflation shock in 2005(left) and 2010(right) in West Africa on West Africa

3.4.1.4 Verification 3; the influence of an increase in VAT

The third test is an increase in VAT. In the 2005 case this is done instantly over the period of 1 year. In the 2010 case, the increase and consequent decrease is spread out over 9 years, with a difference of 0.2 % per year. The increase in VAT should cause a reduction in consumption as well as potentially reduce imports. The results are presented below in the Figure 3.15a-b, Figure 3.16a-b, Figure 3.17a-b and Figure 3.18a-b. Firstly, the model seems to react randomly in all the 2005 cases. The partially fixed data on 2005 might be a cause for this. On the other hand, in the 2010 cases it is striking that the impact of a reduction of VAT is larger than the impact of an increase. In many cases the positive effect does not create a return to the earlier steady state, but shows an increase in Consumption, investments and GDP. Only the 2010 case for Greater China lacks this behaviour. This might also aid in the positive outcomes for the 2005 cases.

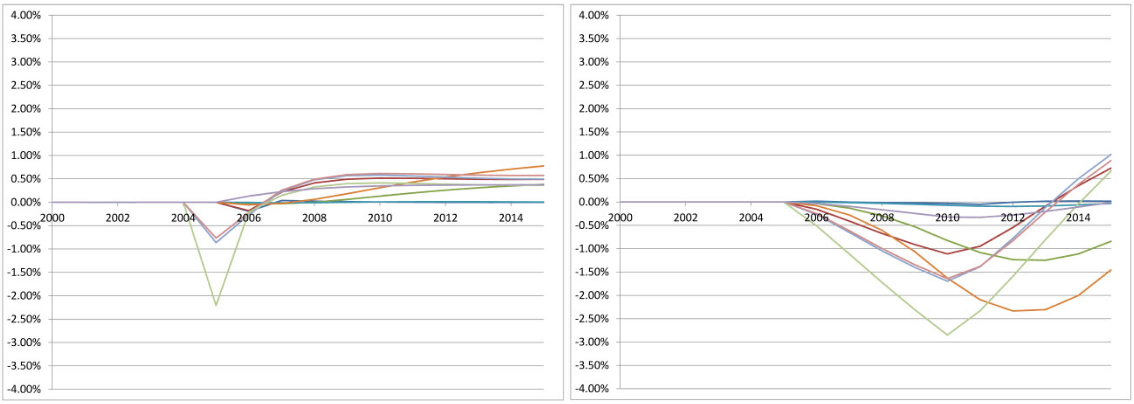


Figure 3.15a-b: Effects of a 1% VAT shock in 2005(left) and 2010(right) in North America on North America

Figure 3.16a-b: Effects of a 1% VAT shock in 2005(left) and 2010(right) in North America on the Greater China region

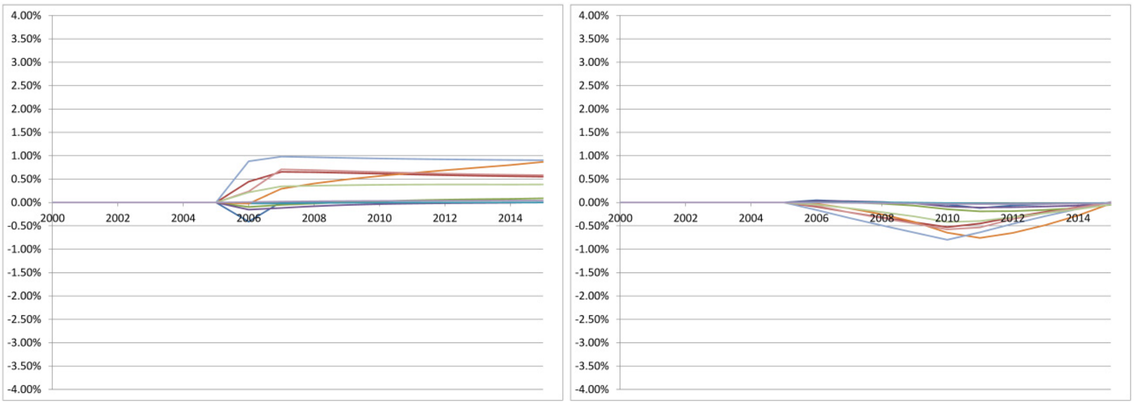


Figure 3.17a-b: Effects of a 1% VAT shock in 2005(left) and 2010(right) in Greater China region on the Greater China region

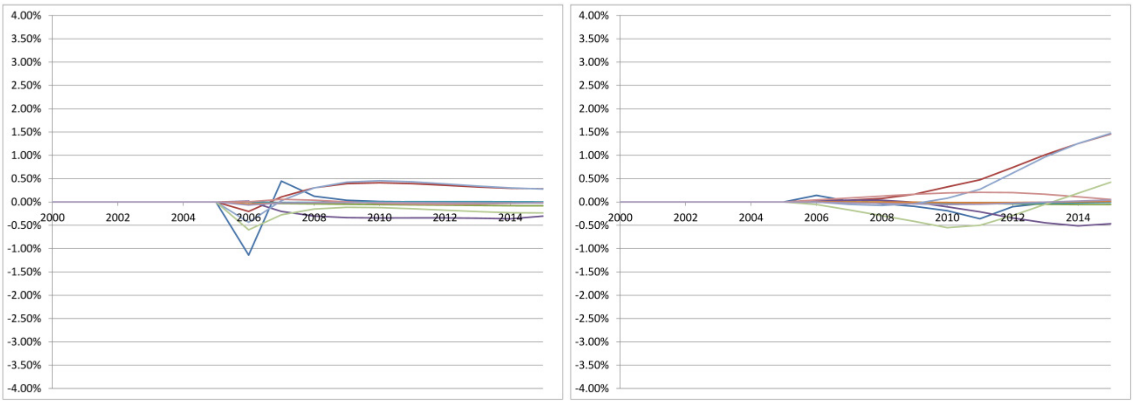


Figure 3.18a-b: Effects of a 1% VAT shock in 2005(left) and 2010(right) in West Africa on West Africa

3.4.1.5 Verification 4; the influence of an increase in Consumption and GDP

The fourth test is an 'unexpected' increase in Consumption by 1%, which in turn will increase GDP if no other changes are made. The 2005 case for North America shows some very strange behaviour, which can be explained by the fact that for 2005 not all GDP elements are available, but instead only the GDP itself. In the base run this causes a discrepancy, in the sense that GDP is not the same as when it would be calculated from the other model variables. However to test a 1% increase in Consumption, the GDP will also need to be corrected for this. This causes the huge spike in Figure 3.19a. As in all other cases, the changes in North America are absorbed largely by the Exchange rate (see Figure 3.20a-b). In all three 2010 cases (see also Figure 3.21a-b and Figure 3.22), the return to normal is almost instant in the year after the increase. In the 2005 case for North America, there is a large instability in the market, resulting in a lower, but stable, average for the remaining model time. For Greater China (Figure 3.21a) the increase remains stable for the rest of the simulation, while in the case of West Africa, the return actually overshoots in the negative direction.

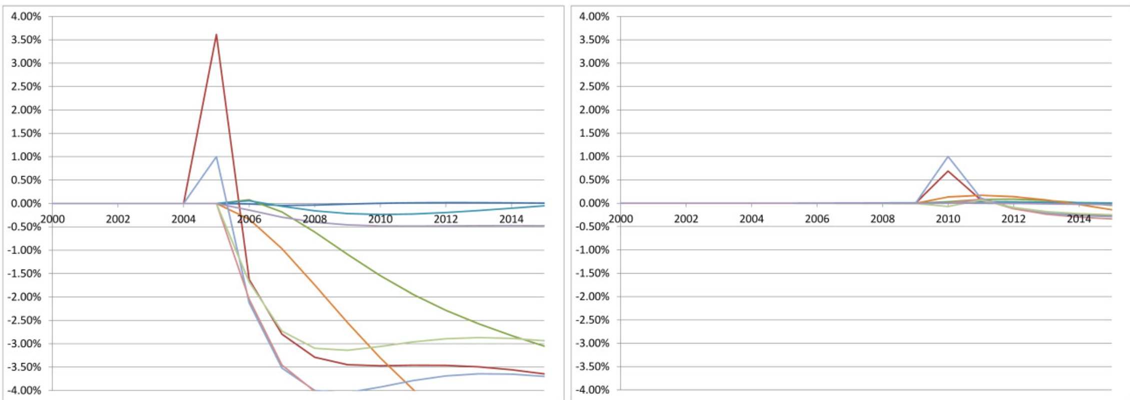


Figure 3.19a-b: Effects of a 1% consumption shock in 2005(left) and 2010(right) in North America on North America

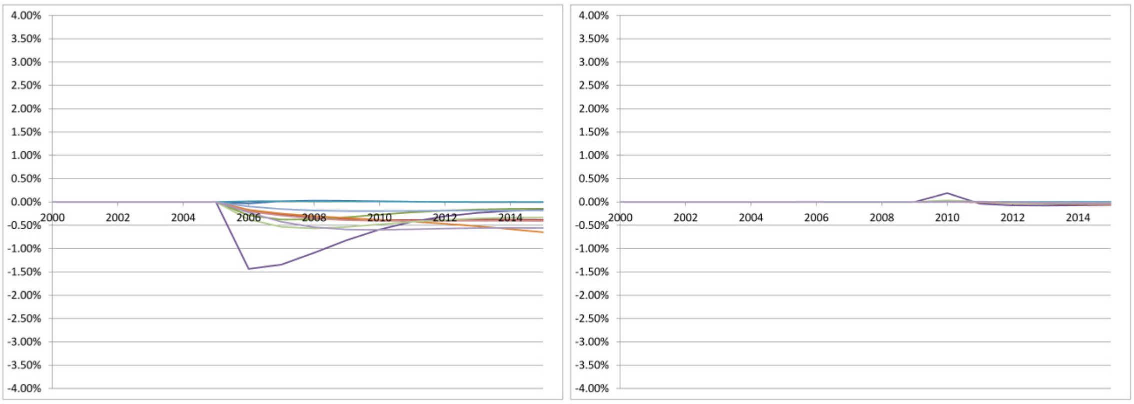


Figure 3.20a-b: Effects of a 1% consumption shock in 2005(left) and 2010(right) in North America on the Greater China region

Figure 3.21a-b: Effects of a 1% consumption shock in 2005(left) and 2010(right) in Greater China region on the Greater China region

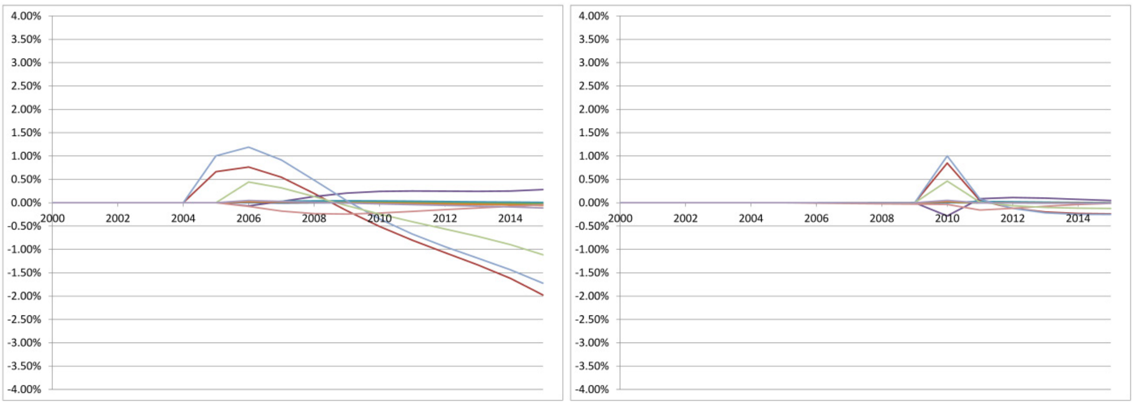


Figure 3.22a-b: Effects of a 1% consumption shock in 2005(left) and 2010(right) in West Africa on West Africa

3.4.1.6 Verification 5; the influence of an increase in Investments and GDP

In the fifth test the Investment is increased for one year by 1% and the GDP is also increased. Within the model investments are more the result of other elements than an important variable in its own right that has a major impact on other elements.

Except for the North America 2005 case, Figure 3.23a-b, Figure 3.24a-b, Figure 3.25a-b and Figure 3.26a-b clearly show an instant return to the original status the year after. The reaction of the other regions is zero except for the North America case, where the impact is absorbed once more through the exchange rate (Figure 3.23). The exception of the North America 2005 case is explained in the same way as for the consumption. The total GDP in 2005 is not a model variable, but a given value which is not equal to the model value. The effects shown are to be attributed to the increase in GDP and not to the increase in Investments.

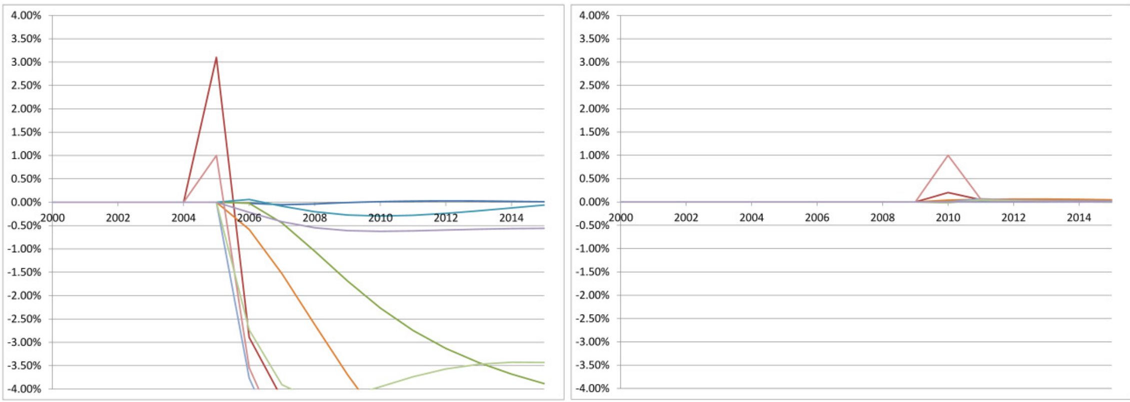


Figure 3.23a-b: Effects of a 1% investments shock in 2005(left) and 2010(right) in North America on North America

Figure 3.24a-b: Effects of a 1% investments shock in 2005(left) and 2010(right) in North America on the Greater China region

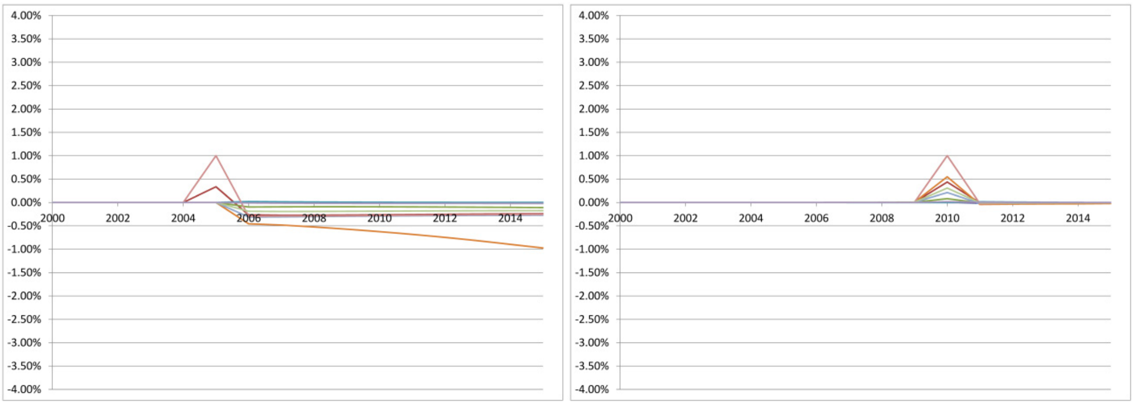


Figure 3.25a-b: Effects of a 1% investments shock in 2005(left) and 2010(right) in Greater China region on the Greater China region

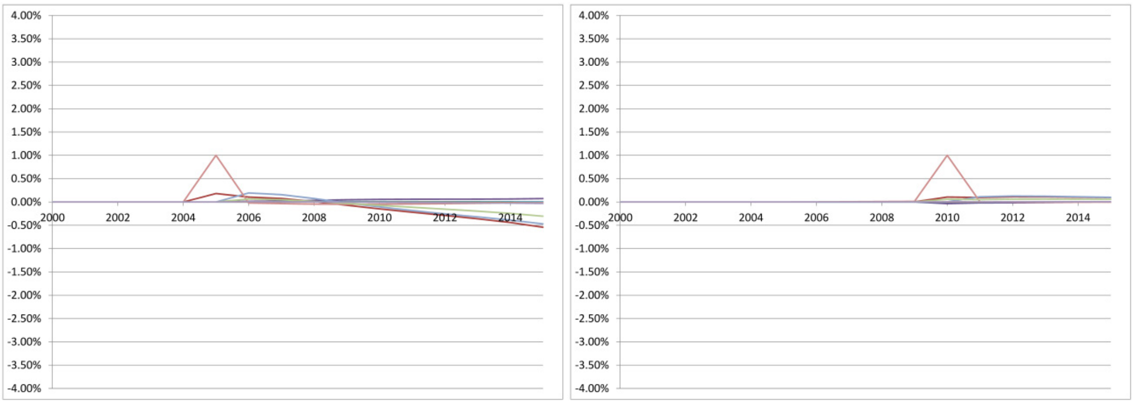


Figure 3.26a-b: Effects of a 1% investments shock in 2005(left) and 2010(right) in West Africa on West Africa

3.4.1.7 Verification 6; the influence of an increase in Consumption compensated by a decline in Investments

The final model test is an increase in consumption by 1%, compensated by a decrease in investments for the same (absolute) amount. In this way GDP will remain the same. The expectation is that without even changing GDP the effects will be small. This is true for all three 2010 cases (Figure 3.27a-b, Figure 3.29a-b and Figure 3.30a-b). In the 2005 case for Greater China some given value prevented a return to the original values, but other than that the difference remains stable. In West Africa (Figure 3.30a-b) the investments are much smaller than the consumption, meaning the needed change in investments is much larger and the instant return to the original values is not possible in one year. As a result it takes more than one year. Finally the North America case does not show an extra increase in GDP in this scenario as a result of investments being determined by an identity equation in the data provision part of the model. It does still show the same consequences. It also shows that the model moves back to the base scenario, though not immediately in the 2005 case. In the 2010 case this happens immediately and as GDP remains equal exchange rates do not change either, see Figure 3.28a-b.

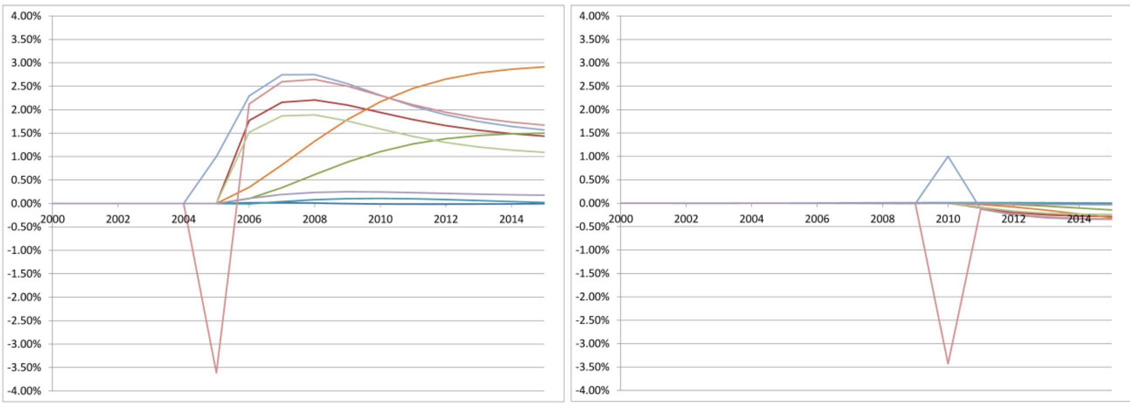


Figure 3.27a-b: Effects of a 1% consumption shock compensated by investment decline in 2005(left) and 2010(right) in North America on North America

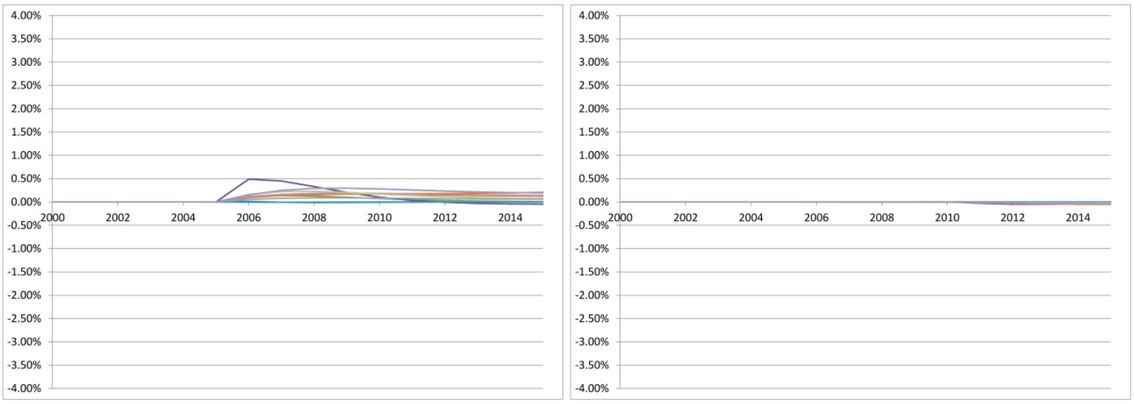


Figure 3.28a-b: Effects of a 1% consumption shock compensated by investment decline in 2005(left) and 2010(right) in North America on the Greater China region

Figure 3.29a-b: Effects of a 1% consumption shock compensated by investment decline in 2005(left) and 2010(right) in Greater China region on the Greater China region

Figure 3.30a-b: Effects of a 1% consumption shock compensated by investment decline in 2005(left) and 2010(right) in West Africa on West Africa

3.4.1.8 Conclusions

Several conclusions can be drawn from the above described verification. The model is stable and shows realistic behaviour for most cases. Values can be altered and different regions clearly react in a different manner. However, especially those regions with significant data issues (as described earlier) or small economies show unexpected behaviour, such as large overshoots for small changes. These changes seem large for the particular economy, but on the global scale they are usually small. This scale effect should allow for rational results to be obtained from the model as long as the focus of the research is on the larger economies, rather than the smaller ones. Their effect on the large economies is virtually zero as shown in this section.

The timing of events should be constrained to the fully modelled period. This fully modelled period is between 2006 and 2015. For the period 2000-2005 data points are available for most of the model variables. Changes to variables, or fixing the output, could result in only part of the model taking up these changes. In 2006 all data is determined by the model and changes will affect all countries. The limitation is perhaps somewhat artificial, but necessary in view of the data quality.

3.4.2 Trade verification

In this subsection the approach chosen to convert import and export values in USD to dry bulk, wet bulk and general cargo quantities is verified. The approach has three steps, first splitting up the USD value over the three trades, next converting it to tonnes of cargo and lastly converting the yearly values into weekly values. This final step once more has three steps. First a smooth curve between mid-year values is established. Next the seasonal effects are added to this and lastly randomness is added on top of this.

The results of this conversion from yearly values to weekly values are presented in Table 3.9. For each trade route the difference between the sum of the weekly values and the yearly value is calculated. The table presents the data collected this way: Min is the largest negative difference for a route and a year between the sum and the original yearly value. Max is the largest positive difference. Average represents the average of all differences, while average distance is the average of the differences taken as an absolute (positive) value. While the smoothening introduces some differences, these are increased by the seasonal effect. This is indicated by the increase in average distance and the lower minimum value. The chosen approach for the random function works in such a way that the random total is exactly equal to the original year value.

Table 3.9: Effects of conversion on year totals

Step of the conversion	Min	Max	Average	Average distance
Bezier smoothening only	-4.55%	17.58%	0.30%	0.66%
+ Seasonal effect	-5.23%	17.58%	0.07%	0.70%
+ Random effect	0.00%	0.00%	0.00%	0.00%

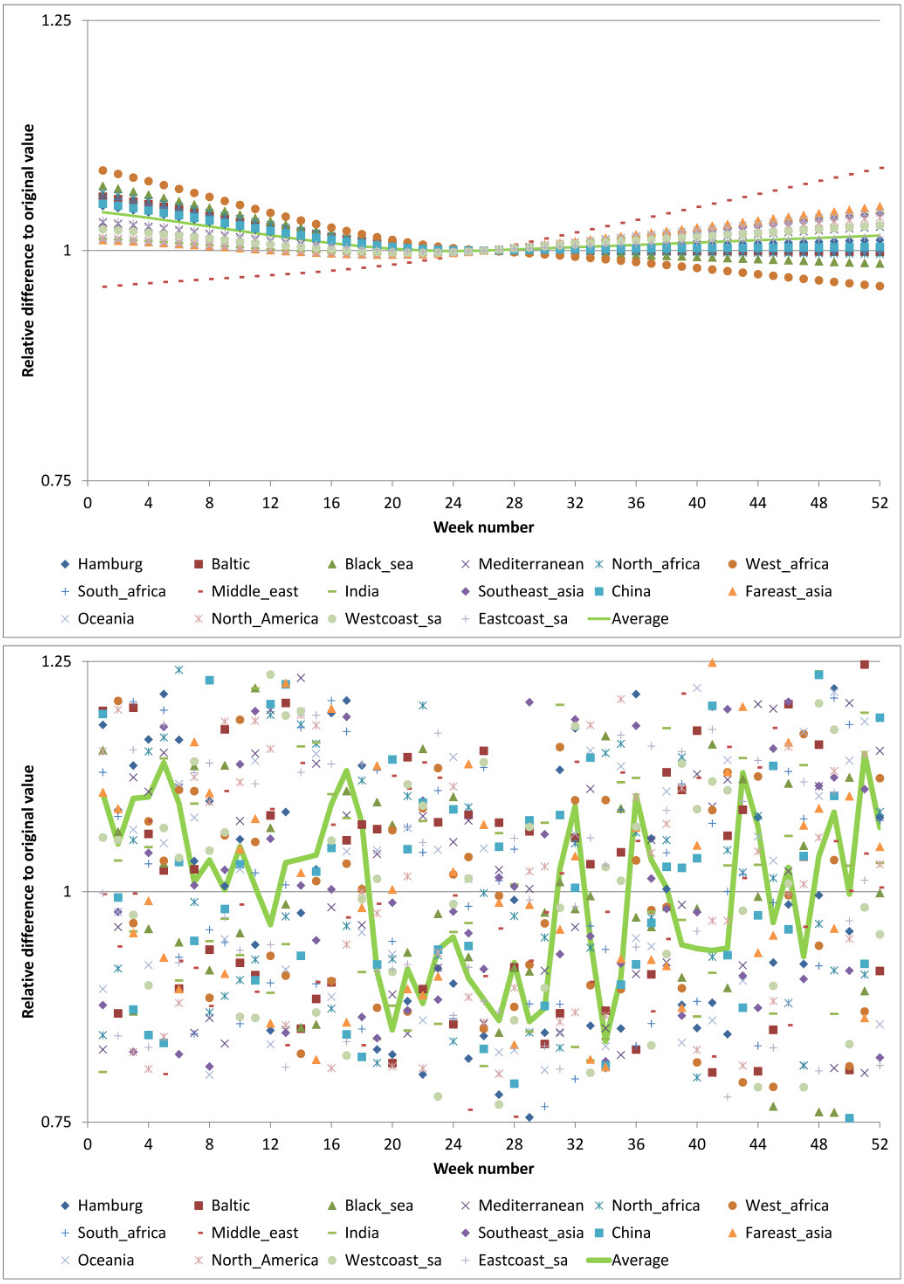


Figure 3.31a-b: Dry-Bulk 1995 relative values per week to year average for the Bezier curve (top) and random application (bottom)

Although not directly apparent, a seasonal pattern exists in the average line of Figure 3.31b. To check this for the route to Southeast Asia and the route to North America the averages of all 26 simulated years were taken per week and divided by the average of 1/52nd of the original year values. These two routes were picked as Southeast Asia does not have a seasonal influence and North America does have a seasonal trend. To clearly show the results in one graph, the results of Southeast Asia have been moved up by 0.25, see Figure 3.32. The line for North America follows the seasonality closely. The straight line is a trend line, showing that on average there has been growth in this period. This shows that even though randomness of a much larger range is added to the results, the seasonality is still found to have an important influence on the trade in a particular week (when averaged over a number of years).

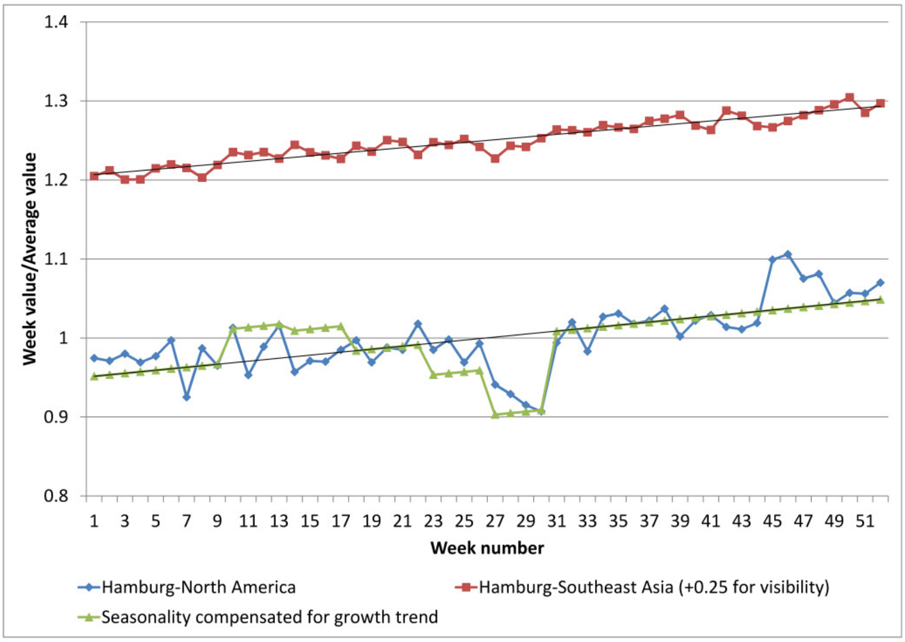


Figure 3.32: Average of random effects per week over 26 years

3.5 Conclusions

The conceptual model has been extended (shown in Figure 3.33) to summarize chapter 3. It has been shown that results are realistic, even though the model data is problematic for the proper estimation of the MC-model. This is partially the result of the fact that for several regions data is scarce. However, for these same regions trade is also relatively small. A change of model was considered, but due to the use of the same variables in other models it was concluded that this would not improve the estimation results. Better data might be purchased from specialist sources, though for a large number of African countries this data is simply not available. Ultimately this has limited the validity of the model. The conversion of trade to transport was fully verified and functions properly within the assumptions and boundaries set.

The goal of this research is to develop and prove the usefulness of an integral approach to solve the research questions. While the multi country module provides transport amounts for all three major bulk trades, the effort to be put into developing a single shipping market and corresponding fleet is large. Developing all three markets is beyond the scope of this research. Therefore it was decided to pick one of the three trades.

Although general cargo or container trade is much more popular these days for investigations, data on this sector is hard to come by. Also due to the limited number of providers and even fewer numbers of alliances in container trade, the market behaviour is obscured. Ever since Tinbergen the market for bulkers (both dry and wet) has been considered as an example of near perfect competition, making it a good starting point for the investigation of supply behaviour in chapter 6.

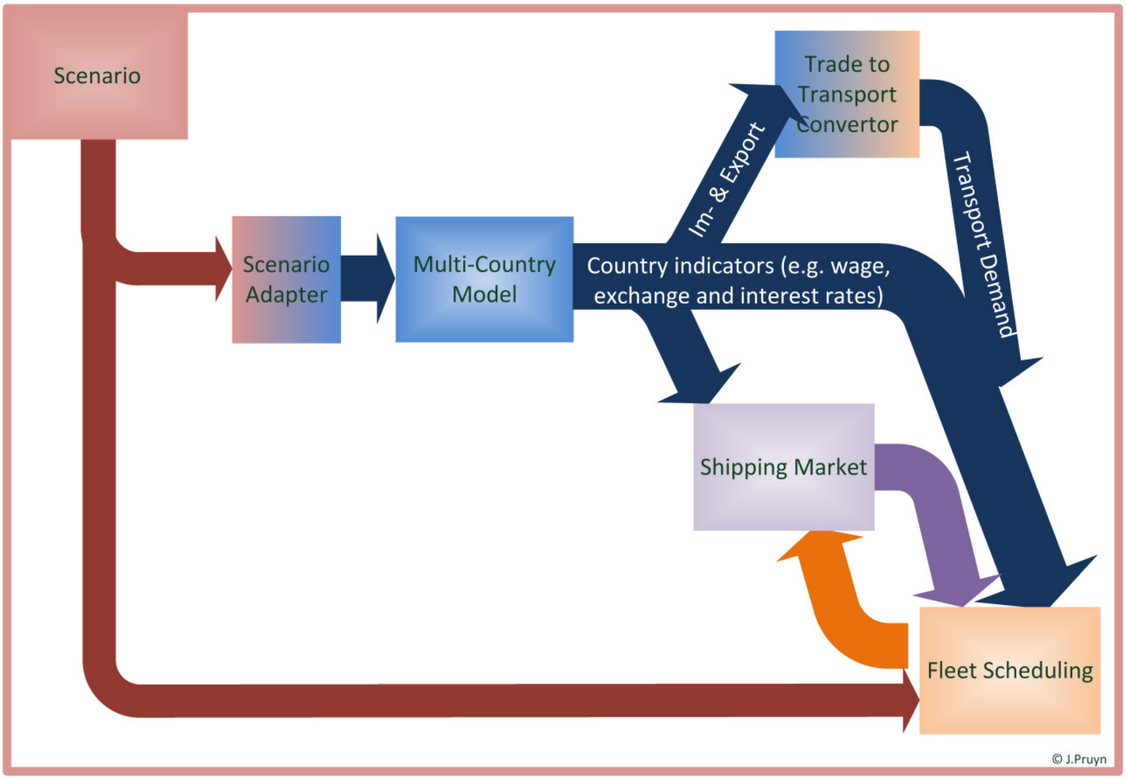


Figure 3.33: Conceptual model including the details for the multi country module

One of the regions showing doubtful results is the Middle East. This region is very important when considering the transport of oil. This weakness in the MC-model makes Dry bulk the most suited trade to the concepts of this research.

4. Developing the shipping market model

This chapter is aimed at estimating three of the four shipping markets as described by Stopford [2009]. The four markets are the Freight market, secondhand market, newbuilding market and Scrap market. The first one, the Freight market, is where transport demand and transport supply meet. This market is modelled explicitly in this thesis in the Fleet behaviour module, which is described in the next chapter. The other three markets are modelled as part of the shipping market.

Not all the markets require a model for both the price and quantity traded. For instance the number of secondhand vessels traded does not change the size of the fleet. The price, however, is important in relation to the capital costs of the vessel. In case of the newbuilding market, the price is important for the same reason. The amount of new vessels ordered increases the fleet (over time) and is therefore also important. The last market, the scrap market, removes vessels from the fleet, which is an important element of the model. The scrap price is less important, although it does compete with the secondhand price and will therefore be treated together with the secondhand price. For an overview of the relationship between the newbuild, secondhand, and scrapping markets, see Figure 4.1.

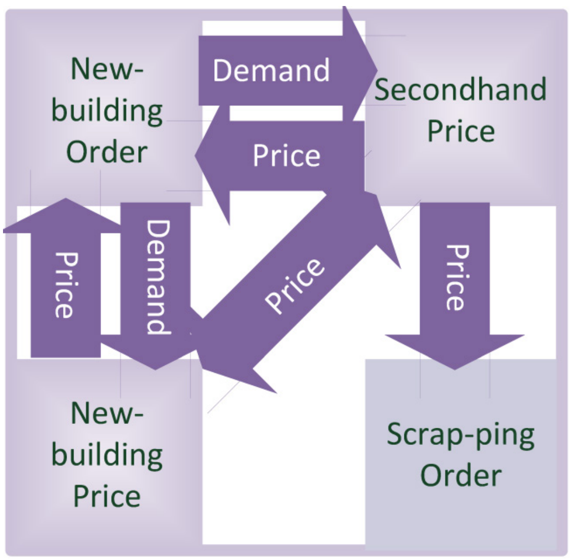


Figure 4.1: Setup of the shipping market block

The first section of this chapter will look into the secondhand pricing. Section 4.2 develops the price side of the newbuilding market, followed by the ordering side presented in section 4.3. The scrapping and pricing of scrap vessels is examined in section 4.4. The final sections will present the conclusions of this chapter.

4.1 Capturing the value of the vessel

As mentioned in the introduction of this chapter, the price of the vessel is important for the model, but the quantity sold is not. Furthermore, to know the current value of a vessel one also needs to consider the scrap price, especially for old vessels, since the scrap price will often be higher than the (estimated) sale price for such vessels. This section will first outline the model used for the secondhand price of the vessel, followed by a mathematical description of the non-linear parts of this model. The last part of this section will briefly look into scrap prices as an alternative price value, especially for old vessels.

4.1.1 Estimating the secondhand price of a vessel

In Pruyn [2010] an investigation was made into the current status of vessel pricing estimations. The conclusions of this study were that non-linear estimates together with individual information on the vessel were the latest and best techniques. The availability of individual sales data stimulated this advance, as well as the discovery of the fact that time series on secondhand values were usually based on broker estimations rather than actual sales. The final suggestion of this paper was to use a General Additive Model (GAM) for the estimation of a secondhand pricing model. The decision to include a variable in the estimation of the secondhand price is based on both the consideration of the sign as well as the strength of the relation itself.

The above approach is tested here. The 12.5 years from June 1998 – December 2010 were examined, and the data used was on actual vessel sales obtained from Clarksons and Tradewinds. After cleaning up the database 4926 individual contracts remained. This dataset contained 3228 Handysize vessels, 1254 Panamax vessels, and 444 Capesize vessels. While initially individual models were created for each size category the results quickly showed that the break between Handysize and Panamax is somewhat arbitrary and does not improve the quality of the estimations. All equations were thus estimated using all data available.

The explanatory variables under consideration were the size, age and income of a vessel. Next to these the cost of financing and the status/price of the newbuilding market are also seen as important for the determination of the secondhand price. The owner always has the choice between purchasing a currently available secondhand vessel and ordering a new vessel, which would be available in some time.

Elements can be expressed in several ways. Size could be expressed in DWT, GT, L*B*D, or a number of other measures. As the main interest of the buyer is the cargo carrying capacity, DWT was selected as the sole element characterizing a vessel's Size. For age only one measure exists though the detail of this element can be varied. For many (older) vessels only the age in years is known and this is therefore used in the model, though a choice for fewer groups could also be made; e.g. young, moderate and old. The representation of income has several options, as Clarksons provides TC-rate time series for various vessel sizes and earning indicators for several vessel classes. While a buyer will logically examine both, when considering the price, a smart buyer would also consider his profits, rather than just the income. This is especially true with rising fuel prices, since the portion of costs taken up by fuel in such a period is close to 40-50% of the total yearly costs [Pocuca 2006, Stopford 2009]. One would expect this to influence the price negatively (a high fuel price will result in a lower price). For the cost of finance LIBOR is considered as an indicator, indicating a very good investment climate for almost the entire period. Lastly, the influence of the newbuilding market should also be considered. While price differences are important in the consideration between an existing and a new ship, the time it takes to deliver the vessel should also be part of the consideration. Clarksons provides a newbuilding price index, but does not disclose how this is calculated. This creates a problem for the model. While the index could be used to (better) estimate secondhand values in a standalone model, it is not an option in an integrated model, since one cannot reproduce the value correctly. This leaves only the orderbook to represent both the delivery time and price in one estimation since a large orderbook indicates that both delivery times will be longer as more vessels will need to be finished before the new one and prices will be higher as yards are more secure about their future and can afford to miss an order. Tsolakis [2005] argues that with an increasing fleet an increase of the amount of replacements and orderbook is required. Therefore, the size of the orderbook should be taken relatively, as a percentage of the fleet size. This seems logical, although it leaves open the choice between a representation of the different size classes or one value over all sizes.

Table 4.1: Overview of considered variables and their extreme values and expected extreme values for the period June 1998 – December 2010. (Source: Author with data from Clarksons)

	Min	**Max**	**Expected min**	**Expected Max**
DWT (ton)	10027	259587	25000	175000
Age (year)	1	37	1	30
TC-rate (USD/day)	2606	209287	3000	15000
Earnings (USD/day)	5229	68074	2500	12000
Bunkers (USD/ton)	55.5	702.5	50	1000
LIBOR (%)	0.387	6.9562	1	5
Orderbook / Fleet size group (%)	4.03	120.66	5	20
Orderbook / Fleet totals (%)	1.87	79.83	5	20
Price (mln USD)	0.5	158	1	50
Price / DWT (USD/ton)	18	4625	50	650

The boom and bust of the world economy in the period 2007-2009 was a large one, in the same order of magnitude as the one from the 1970s. The data available for model estimation is 2000-2010, which contains this boom. The larger model considered here is a rational model, with prices only exceeding cost prices by a small margin. In the boom period prices were much higher than the modelled cost levels. In Table 4.1 an overview is given of the recorded minimum and maximum values of the variables of this period and an expectation of the modelled minimum and maximum for the market.

The determination of the expected min and max as presented in the table above, are detailed below. For DWT, the found min and max are not extreme, however the expectation is that almost all of the vessels (in the model) will be between about 25000 DWT and 175000 DWT (blue dotted box). Looking at Figure 4.2, it is clear that this expectation is true (blue line), although on the lower side of the vessel size range about 312 vessels lie outside of the expected values, and by the upper limit 69 vessels are excluded out of 4929 in total. The other two lines represent the data points left when only the expected range is used and when this range is extended by 10%.

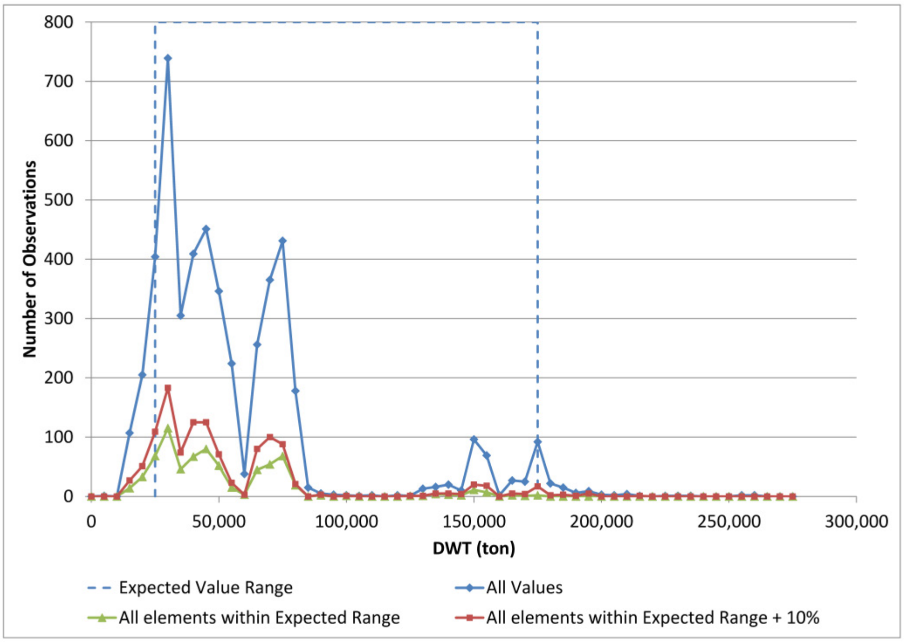


Figure 4.2: Division of data points over the various DWT classes (Source: Author with data from Clarkson)

Age has no lower limit, but the upper limit is set to 30, since many publications use a 30+ category for the remaining vessels. In total 74 vessels (out of 4929) are excluded by this limit, which indicates that very few vessels make up this 30+ category.

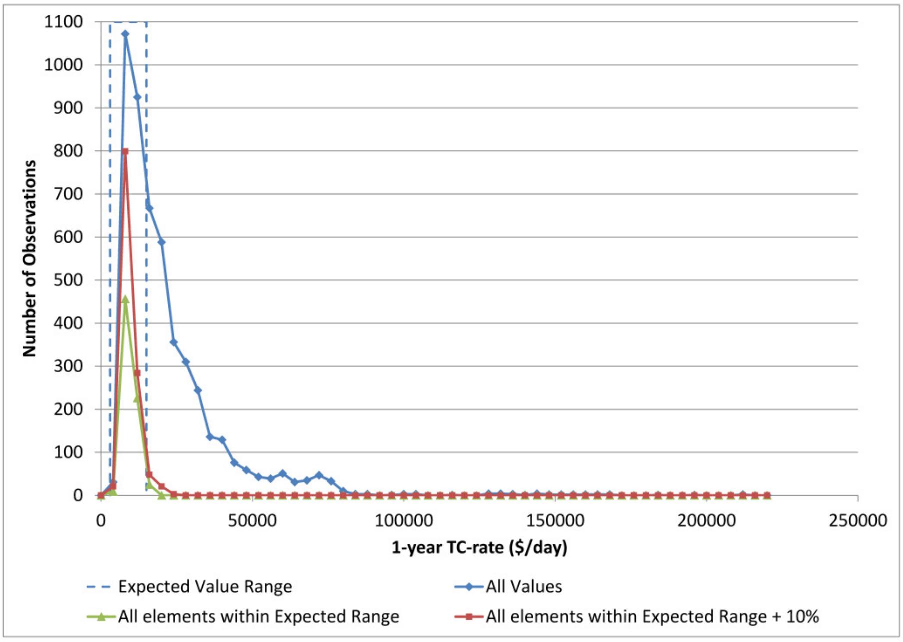


Figure 4.3: Division of data points over the various 1-year TC-rate classes (Source: Author with data from Clarkson)

The biggest problems arise with the variables representing income; the boom in shipping has caused astronomically high day rates for ships, up to 200k+ USD! While in the model costs are considered as the basis for the price, a value much higher than 15000 USD a day is not to be expected. Something similar but less extreme exists for Earnings. In Figure 4.3 this is demonstrated for the TC 1-year day rates. Almost half (2233) of the data points would be excluded based on this rate. Actually all contracts after April 2003 do not fall in the expected range + 10%.

Bunkers are an exception in Table 4.1, where the expected range is larger than the values found in the investigated period. The reason for this is that bunkers have remained expensive even after the bust and due to the scarcity of oil the price of bunkers is expected to rise even further in the future. LIBOR is taken to be between 1% and 5%. This range was used in the MC-Model and obtained using the data from 1990-2000. The range found in the 10 years thereafter does not differ much, though prior to 1990 much higher LIBOR values have been the norm. Both orderbook level and price suffer from the boom in the period under investigation and contain many values outside what would be expected based on a cost based approach.

The price range is based on the time series data provided by Clarksons for the 1990s, while the ranges for the orderbook are deduced using the following logic: an average ship will become about 25 years old which requires on average that 4% of the fleet needs to be replaced every year. Furthermore, in the period 1992-2006 the world economy grew with about 2-3% and it has been shown that the shipping industry grows about 4 times as fast, between 8-15% [OECD 2008b]. Therefore, the maximum required annual fleet replacement is 19% (4% replacement + 15% growth). As a minimum, only 4% of the current fleet would need to be placed on order each year. The extra 1%, in the chosen minimum, functions as margin for extra orders obtained for the year after the current one. The size of this margin is debatable, but historic data indicates that the only time so many ships were on order was during the Oil Crisis in the 1970s. Although no records of the fleet on order were kept during the height of this boom, about 100+ mln GT was delivered in 3 years' time. The fleet at the start of this period was not even 250 mln GT (Lloyd's fleet statistics). In other words the average increase was about 12% year on year and does not exceed the 19% maximum set. Other 3 year ratios do not exceed this and are generally in the range of 10%.

Even when using the "Expected range + 10%" (purple line), only 1176 out of 4929 data points remain for calculation of the model and as stated earlier only the period until April 2003 will be relevant. It was decided that too much is missed if only this limited amount of data is used. To compensate for the fact that the R^2 given by any statistical program is for the entire set, this value will be also calculated for the described ranges. The variable that shows the best fit for the above described ranges will be selected to represent an indicator.

Table 4.2 presents the first step of the investigation to determine the selected variables. For each of the price variables, price and price per DWT, each of the explaining variables is tested in turn. As stated above the R^2 of the "Expected Model Region" is calculated next to the R^2 of the entire data set. Both are based on the same equation, but the first one limits the data range to base this value on. The last element representing the model is the significance of the variable.

Table 4.2: Single variable GAM-model, test on explanatory power of each variable

Y	Element	DWT	Age	TC-rate	Earnings
Price	Minimum R-Squared Region	0.2653	0.2812	0.1712	0.0235
Price	R-squared All	0.2641	0.2829	0.5401	0.2690
Price	Significance	***	***	***	***
Price/DWT	Minimum R-Squared Region	0.0288	0.2285	0.0701	0.0221
Price/DWT	R-squared All	0.0316	0.2292	0.1779	0.3066
Price/DWT	Significance	***	***	***	***

Y	Element	Bunkers	LIBOR	Orderbook/ fleet	Orderbook/ fleet (totals)
Price	Minimum R-Squared Region	0.1992	0.1764	0.1005	0.1739
Price	R-squared All	0.1992	0.1554	0.1959	0.2526
Price	Significance	***	***	***	***
Price/DWT	Minimum R-Squared Region	0.2080	0.1823	0.1709	0.1477
Price/DWT	R-squared All	0.2080	0.1556	0.2182	0.1631
Price/DWT	Significance	***	***	***	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

All results are significant (for the entire dataset) and no single variable is able to score higher than 30% for the R^2 for the expected model region. This means that no variables can be discarded at this point. The next step is to test all variable combinations (8 in total). For each combination insignificant variables were removed along with the ones that violate intuitive behaviour, e.g. increased bunker costs should reduce the price of vessels as the profits the vessel may earn are lower. The results in Table 4.3 show that this was not the case in any of the equations and bunkers have been eliminated in all equations.

Table 4.3: Multi-variable GAM-model, with removal of insignificant and counter intuitive variables.

Y	Result elements	DWT, age, TC-rate, bunkers, LIBOR, Orders per type	DWT, age, TC-rate, bunkers, LIBOR, Orders totals	DWT, age, earnings, bunkers, LIBOR, Orders per type	DWT, age, earnings, bunkers, LIBOR, Orders totals
Price	Minimum R^2 Region	0.4853	0.4571	0.4038	0.4576
	R^2 All	0.7634	0.7645	0.7058	0.6964
	Deleted Variables	LIBOR, Bunk	Bunk	LIBOR, Bunk	LIBOR, Bunk
	Significance	***	***	***	***
Price/ DWT	Minimum R^2 Region	0.5280	0.5317	0.5018	0.4639
	R^2 All	0.6306	0.6223	0.6372	0.6212
	Deleted Variables	Bunk	Bunk	LIBOR, Bunk	LIBOR, Bunk
	Significance	***	***	***	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

As should be expected the R^2 of the expected region is always smaller than the R^2 entire range. It was not possible to optimise for this region using the entire data range. However, in almost all cases the model with a slightly worse fit overall performs better in the region important for the model. The best performance was the combination of the 1-year TC-rate, without the bunker costs, with the Orderbook ratio for the entire fleet and estimating the Price per DWT. In this case LIBOR was also still significant. The final equation is provided below in Equation [4.1]. The use of s(..) indicates a variable that is estimated in a non-linear fashion, while the other variables are estimated as linear variables. The main reason for this mix is the unrealistic or unexplainable fluctuations some variables showed. This behaviour was attributed to the fact that in that particular range of data values, no or very few data points were available, causing this instability. This was solved by estimating this variable linearly, forcing the potential non-linear behaviour onto the other variables. Figure 4.4a-c shows the output of the remaining three non-linear variables.

$$\text{Secondhand Price/DWT} = c_1 + \text{s}\left(\text{DWT}\right) + \text{s(Age)} + c_2 \text{*TC\_Rate} + c_3 \text{*LIBOR} + \text{s(\% fleet on Order)} \quad (4.1)$$

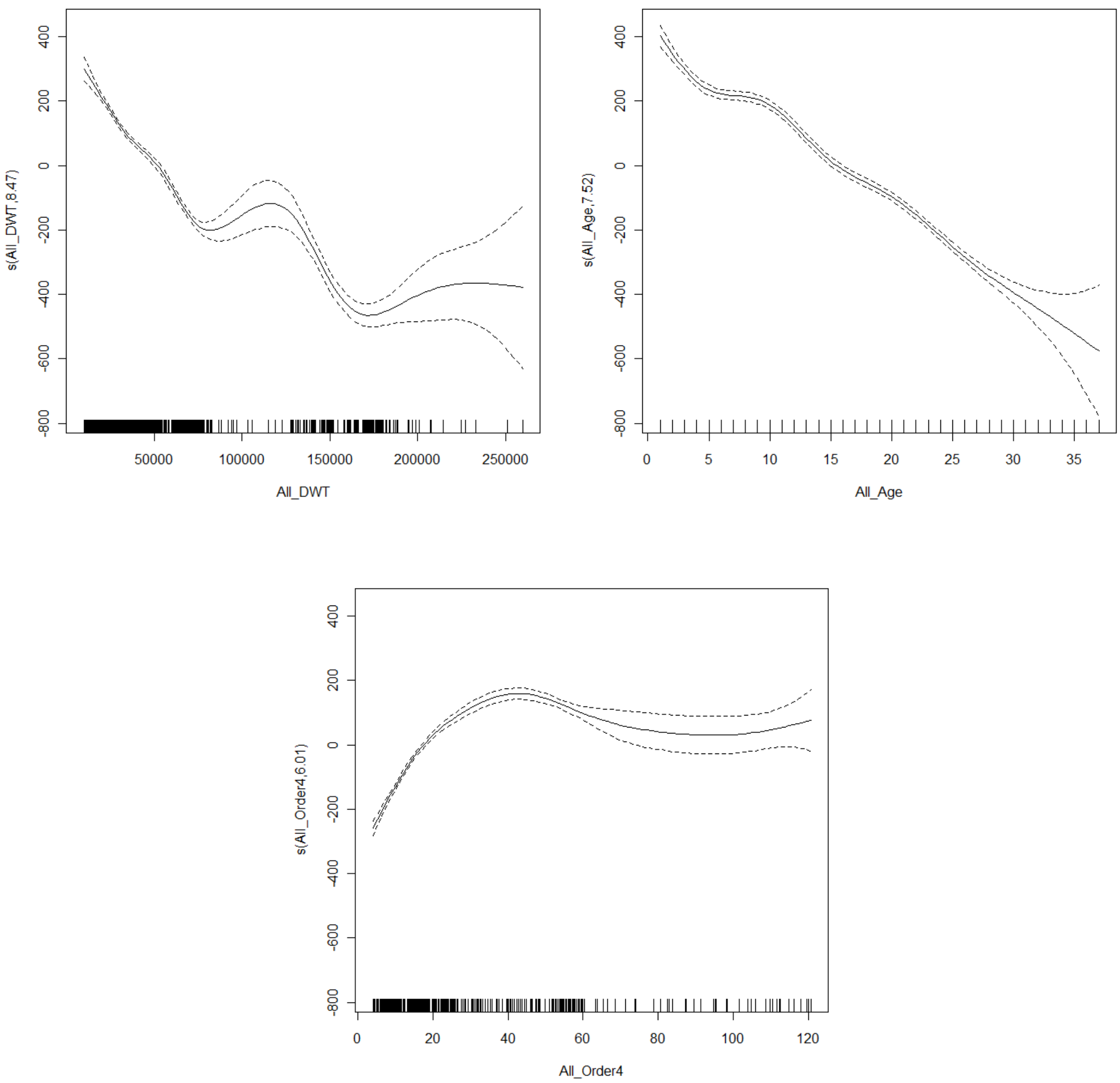


Figure 4.4a-c: s(DWT) (a), s(Age) (b) and s(% fleet on order) (c) for Equation 4.1

Each of the graphs above has a clear nonlinear behaviour. The relation between DWT and Price per DWT shows that in general the price per DWT is declining with size. This is certainly what would be expected as the economy of scale would make larger vessels not only cheaper to operate, but also cheaper to build. However, certain size ranges are priced higher than others, and these ranges are not traded as much as the other ranges. The first range is between approximately 85.000 DWT and 120.000 DWT, the second is above approximately 160.000 DWT. The vessels of the first range are just outside the range that fits through the Panama Canal, yet they do not offer the same cost reduction as larger vessels. The vessels of the second range are too big for most ports and the costs of not having a cargo are very high. Therefore, these vessels are not as popular as other size ranges. As a result, these are mostly traded in the rising markets and are barely traded in the bad markets. This theory is supported by Figure 4.5, which shows the division of sales of different vessel size groups over time. While all vessel sizes show clear peaks around 2003, 2007 and 2009, the above mentioned ranges are barely sold. These low sales values are not strange and as can be seen in Figure 4.6, there are barely any vessels of that size in the 1998 fleet.

The almost linear shape of Figure 4.4b for age versus Price per DWT is also as expected. Older vessels have a shorter remaining life and therefore less time to earn back the invested money. Each additional year reduces this capacity by the same amount. However, the graph shows that between 5 and 10 years of age the price is almost stable. This could be caused by the fact that this is the range in which many companies sell their new vessels out of principle, rather than out of need or opportunity It could also be that many operators see these vessels as having at least 20 years of trading life remaining, since most vessels are demolished between 25-30 years of age. Next to uncertainty of the length of the life of a vessel, the income in these years is 20 years away. When making a net present value calculation for such a vessel the impact of these final years is limited. In any case, vessels in this age group are clearly more desirable, reducing the effect of age on the price.

Lastly, Figure 4.4c shows the demand graph. At first this graph is almost linear, and it levels off when the orderbook reaches a size of about 30% of the current fleet. Although it was mentioned in section 3.1.1 that the 2008 peak proved Dikos' [2004] theory of a ceiling on newbuilding prices wrong, it seems that at least the effect of the newbuilding market on the secondhand prices reaches a ceiling. Apparently the two get disconnected during very large booms, which could be caused by speculation. Speculation results in the attraction of asset players who are looking for short term (speculative) profits, rather than owners who are trying to understand the market and buy vessels to operate the vessel for at least several years.

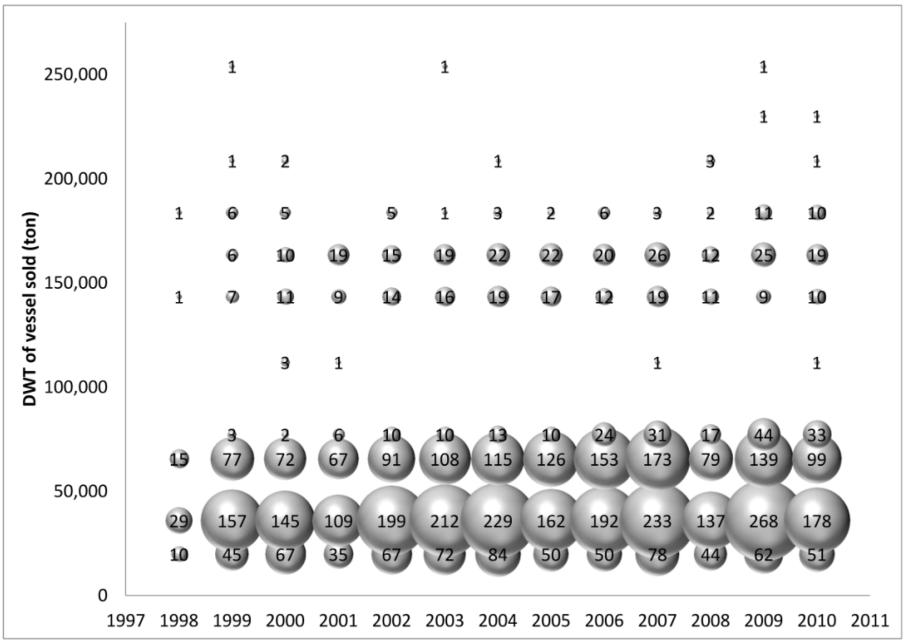


Figure 4.5: Amount of vessels sold per size group and year (Source: Author with data from Clarksons)

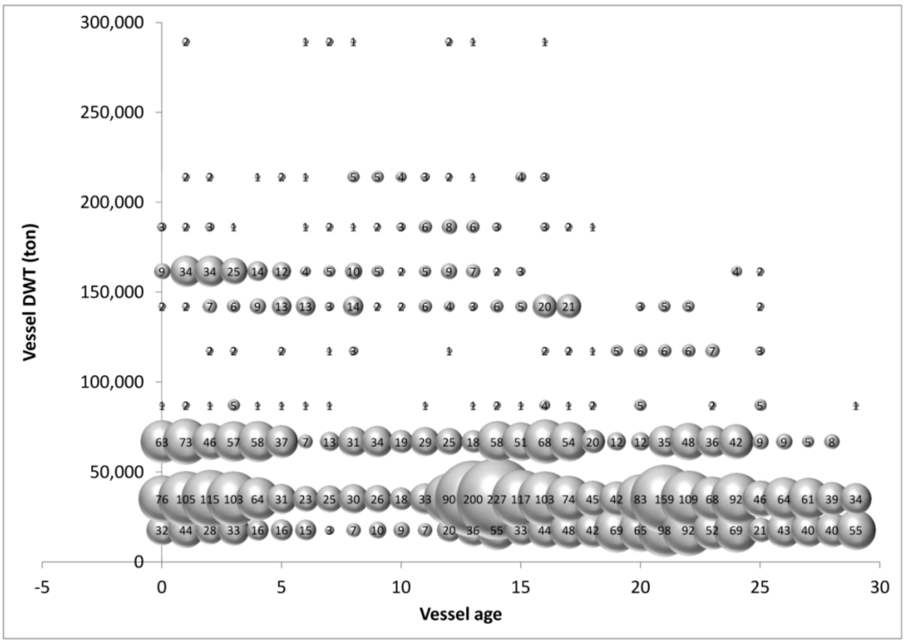


Figure 4.6: Amount of vessels per size group and age in the 1998 fleet. (Source: Author with data from Lloyd's)

4.1.2 Gam formula fitting for secondhand price estimation

The next part of the model incorporates the price estimator in the fleet assignment model. To do this the non-linear links have been captured in formulas. This section outlines this process. The results of the GAM estimation are presented in a graphical form. The fitting of formulas to these graphs for application in the calculation module has been done by sight. Each coloured part of the graph has its own trend line estimation and formula. In general, formulas were kept as simple as possible without going outside of the dotted confidence zones. Keeping a formula simple means achieving a good fit, with the

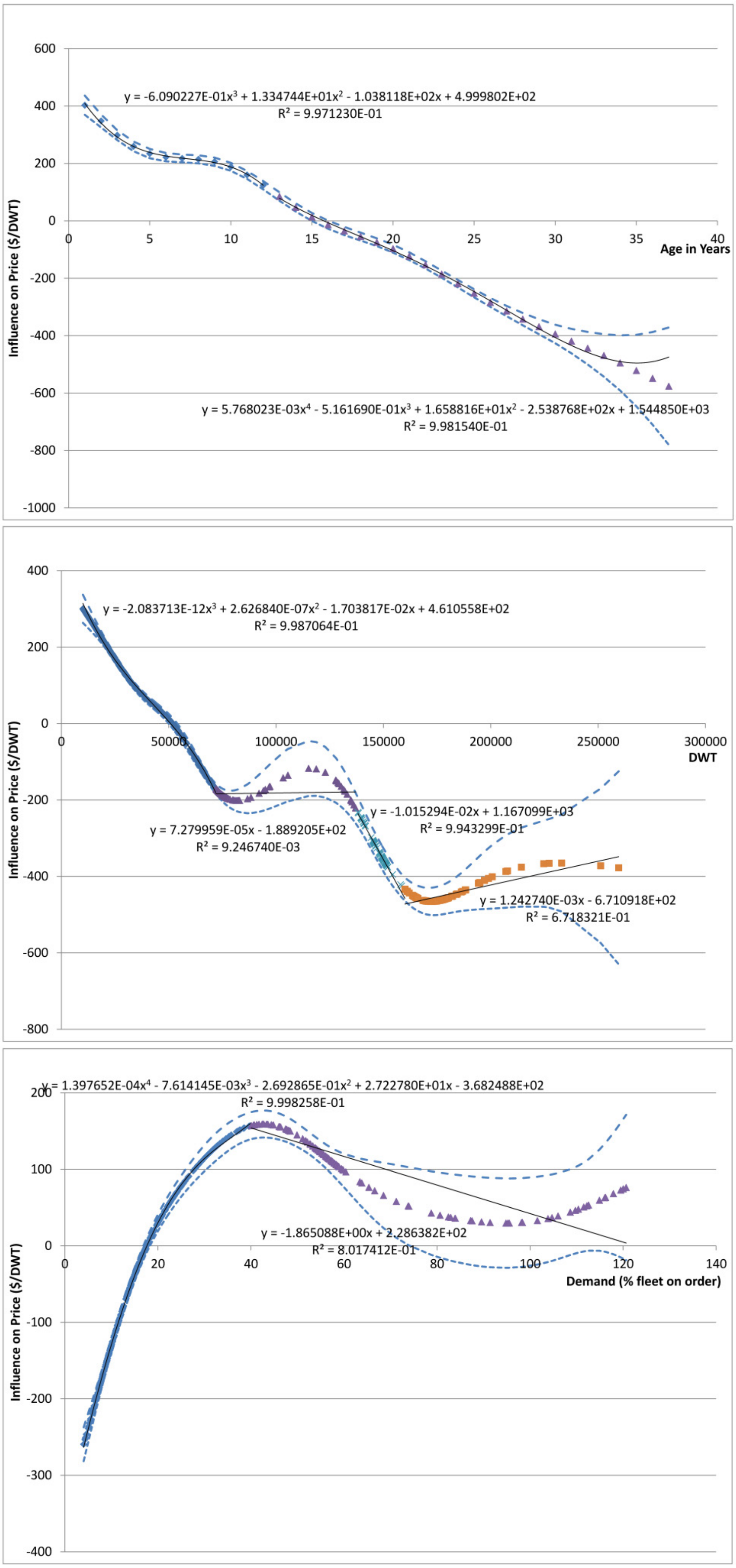


Figure 4.7: a-c: Estimation of formulas to represent the secondhand price GAM results

lowest possible power of x. Figure 4.7a-c shows the results for the estimation of the secondhand value. The vertical axis always represents the effect on price in USD per DWT. The horizontal axis represents the variable mentioned in the graph title. Although the trend line estimation data is presented in the graphs, it is also summarised in Table 4.4 together with the coefficients of the linear estimated variables. These are the formulas used in the model.

Table 4.4: Overview of the estimated formulas for the secondhand price GAM results

Element	Validity	Estimated equation	R^2
Intercept	-	263.1989	-
Age	>0	-6.090227E-01*Age^3 + 1.334744E+01*Age^2 - 1.038118E+02*Age + 4.999802E+02	0.9971
Age	>12	5.768023E-03*Age^4 - 5.161690E-01*Age^3 + 1.658816E+01*Age^2 - 2.538768E+02*Age + 1.544850E+03	0.9982
DWT	>0	-2.083713E-12*DWT^3 + 2.626840E-07*DWT^2 - 1.703817E-02*DWT + 4.610558E+02	0.9987
DWT	>72000	7.279959E-05*DWT - 1.889205E+02	0.0092
DWT	>138000	-1.015294E-02*DWT + 1.167099E+03	0.9943
DWT	>160000	1.242740E-03*DWT - 6.710918E+02	0.6718
TC-Rate	>0	6.747669E-03*TC	1.0000
LIBOR	>0	1.863405E+01*LIBOR	1.0000
Demand	>0	1.397652E-04*Demand^4 - 7.614145E-03*Demand^3 - 2.692865E-01*Demand^2 + 2.722780E+01*Demand - 3.682488E+02	0.9998
Demand	>40	-1.865088E+00*Demand + 2.286382E+02	0.8017

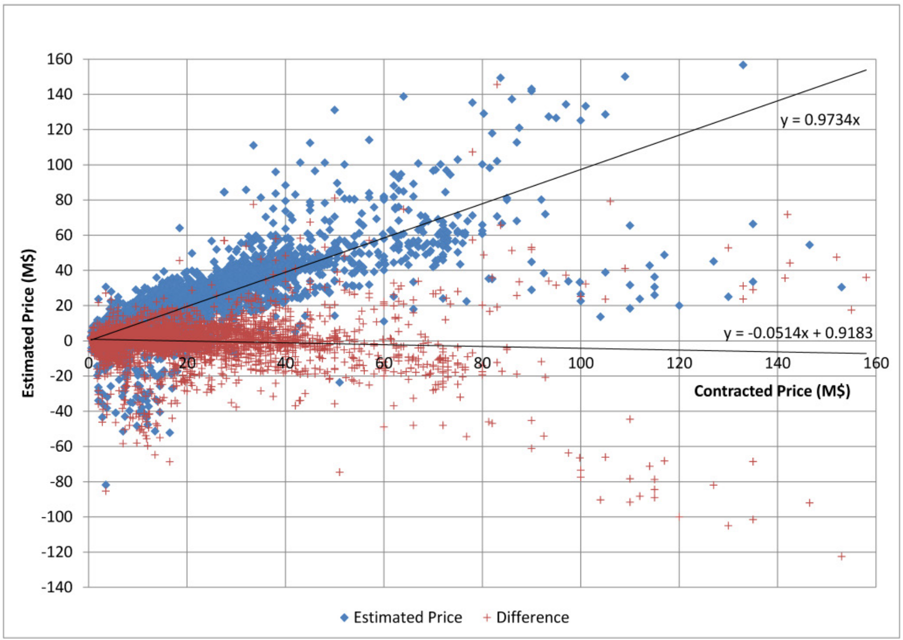


Figure 4.8: Comparison of estimated price and contract price, together with an error plot.

A final check of the results is provided in Figure 4.8. In this graph the estimated value is plotted on the vertical axis against the real contract price on the horizontal axis (blue dots). Ideally the relation between them should be one-to-one, but in the case of the secondhand estimates the ratio is 0.97. The red crosses represent the difference between the estimated and real price, which should on average be zero. For the case when all values are taken together this is true, but when the values are plotted against size a negative trend can be seen. This means that the prices of small vessels are underestimated and prices of large vessels are overestimated, even though size has been included in the model in a non-linear fashion.

The graph in Figure 4.8 on secondhand prices indicates that the large spread in the lowest price ranges and the suggestion of two paths at higher ranges contribute to the non-linearity. While it cannot be traced, the very low prices (less than 5 mln USD) are most likely either recording errors or distress sales. This was, however, not confirmed and the data has therefore been kept in the model as the results were already showing a very good fit. The graph clearly shows negative price estimations for the cheap vessels, which is not a common occurrence in the shipping industry. In these cases the scrap price of the vessel should be considered as a lower threshold. The scrap price is the subject of the next section.

4.1.3 Introducing Scrap prices as competition for secondhand prices.

Once vessel values become very low, scrapping the vessel becomes an alternative to selling the vessel secondhand. This mainly affects older vessels, especially in a bad market. Once a vessel is worth only its scrap price something peculiar happens, the depreciation of the vessel becomes 0. Such vessels can be sold in the following year for the price those vessels were bought for in the current year, excluding variations in the scrap value. This cancellation of depreciation means that only a profit on sailing the vessel needs to be obtained, and the investment itself is secured by the fact that the vessel can be sold for the same price again. Older vessels can therefore be put in lay-up cheaply and wait there for better times because their fixed costs are reduced due to these lower capital costs.

Commonly the scrap price of a vessel is expressed as the lightweight (LDT) times the price per lightweight. Both LDT and scrap price are not yet part of the model. Based on the statistics provided by Mikelis [2008], the ratio between DWT and total displacement (DWT plus LDT), can be estimated for all three vessel types. For Handy the ratio is 0.80, for Panamax 0.83 and for Capesize 0.87.

The scrap price is determined by the supply and demand for scrap. However, many unknown factors influence the demand while supply is fixed within the model (see section 4.4). To forgo a large model on scrap pricing, which is outside of the focus of this research, it is argued that the demand for scrap and therefore scrap prices is linked with industrial activity. Therefore, if the production cost indicator rises, so will scrap prices. This way scrap prices can be set by an average of the prices in 2000 and the multiplication with the industrial cost index, available from the MC-model.

4.2 Estimating the newbuilding price

Both price and order quantity are important for the newbuilding market. This section will focus on determining the price relation while the next section will consider the order quantity. The first subsection looks at a GAM approach for the price estimation. The second sub-section will convert the non-linear elements to formulas.

4.2.1 Application of the GAM approach to newbuilding prices

The approach for creating a model that estimates the newbuilding price is very similar to the approach used for the secondhand price. As already mentioned in Section 3.1, there is very little literature on the pricing of newbuilding vessels. The choice was made to set up a GAM model for newbuilding as well, as it is the newest approach for secondhand price models and allows the estimation to use individual vessel parameters.

The three variable types mentioned in Section 3.1 are cost based variables, asset pricing variables and supply/demand variables. The following variables are considered for inclusion in the model; size, income, production costs, wages, exchange rate, secondhand value, interest, inflation, building time and demand. The first five are cost related, the last one is demand/supply related and the rest are related to asset play. Lastly, the price of the vessel can be expressed in two ways: in a sales price or in a Price/DWT. Due to the non-linearity and the inclusion of size in both equations, they might yield different results and are both investigated.

For size only one option, DWT, is considered. The other two size measures, gross tonnage or compensated gross tonnage, could also be considered. However, these values would need to be estimated on the basis of DWT, as details were not provided in the available data for all vessels. Income can be estimated by using the 1-year time charter at the time of the contract signing. However because the operating expenses (OPEX) are also known in the model, it could be a better option to look at the difference between the TC-rate and the OPEX, since this represents the money available to the owner. The production costs are difficult to incorporate. The data in the model relates the costs to the production costs in 2000. However, as all countries have a relative production price index (PPI) of 100 in the year 2000, these costs do not differ in this year. Steel price is not an element of the model and would need to be linked to an index, such as the mentioned industry index (PPI). While wages suffer the same problem as PPI, in this case the average wage for 2000 is known and the data can be converted to absolute wages. This creates differences in the wages between countries also in 2000. Wages could also be used as a proxy for the production costs, since most production for shipbuilding is still labour intensive and driven by these costs, including the costs related to sub-contractors. The exchange rate is the last of the cost variables. In this case a higher exchange rate would mean less USD for the same local currency and should indicate a lowering of the price. To make the rates comparable they were indexed at 2000 to equal 1.

Because an owner has the choice between investing in a new vessel or in a secondhand vessel, the secondhand value should have a large impact on the price of new vessels, though this price should be compensated for the risk of market changes after the building of the vessel has been completed. In this case the secondhand value is estimated for a 5 year old vessel of the same size with the model derived in the previous section. In the case of interest two options need to be considered: interest as it is received or interest corrected for the inflation, so called real interest. Due to the fact that interest is taken yearly, very little variation is available for estimation. For inflation two options are available: either using the inflation of the country of construction or using the inflation of the USD only, because the other inflation should find its way into the exchange rate. The final element of the asset play variables is building time. The expected influence is a rise in uncertainty with longer building times and therefore, a lower price is demanded by the buyer.

Supply and demand are expressed in the same way as in the secondhand value estimation model: by dividing the current orderbook through the existing fleet. Three options are tested at this stage: the fraction itself, the difference between the fraction now and six months earlier, and the fraction now divided by the fraction six months earlier.

The same approach for defining the model was chosen as for the secondhand value model. First, for each variable an individual non-linear estimation is done to see if the relation is in line with the expectations and if the relation is significant. The results are presented in Table 4.5. Ideally, several options for variables, or even the variables themselves, can be removed as candidates. The entire model is estimated several times using the different options for a variable in order to find the best solution.

Table 4.5: Single variable tests with non-linear estimation.

Y	Element	DWT	TC-rate	Profit	Prod. Costs	Wage	Exchange rate	Secondhand value
Price	R^2	0.758	0.696	0.679	0.178	<u>0.126</u>	<u>0.126</u>	0.734
Price	Signif-icance	***	***	***	***	<u>***</u>	<u>***</u>	***
Price /DWT	R^2	0.559	0.217	0.273	0.198	<u>0.196</u>	<u>0.158</u>	0.577
Price /DWT	Signifi-cance	***	***	***	***	<u>***</u>	<u>***</u>	***

Y	Element	Interest	Interest (real)	Inflation	Inflation (US)	Contract duration	Orders	Diff. in orders	Div. of orders
Price	R^2	0.136	0.0665	0.075	<u>0.174</u>	0.0478	0.594	0.191	0.081
Price	Signif-icance	***	***	***	<u>***</u>	***	***	***	***
Price /DWT	R^2	0.185	0.12	0.0458	<u>0.188</u>	0.0509	0.186	0.167	0.0662
Price /DWT	Signifi-cance	***	***	***	<u>***</u>	***	***	***	***

Signif. codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1**

The dark grey shaded cells indicate variables whose behaviour does not fit the a priori expected behaviour. These variables are consequently left out of the options available for the model. The underlined outcomes for variables signify that these variables show a relationship as expected, but either due to missing data ranges or other effects show areas of very instable behaviour. They should therefore be considered for implementation, most likely in a linear form. A detailed description of the variables and their results is given in Appendix B.

This overview also shows that for all variables that are still considered for non-linear inclusion, the Price relation achieves much higher R^2 ratings than the price/DWT. For this reason this last option for the newbuilding price is dropped. Although newbuilding has also gone through a large boom, only the Orderbook value has reached values that are uncommon e.g. over 20% of the fleet on order. One could expect secondhand values to also be outside of this range, but these have been based on the model described in 4.1 and this has tempered the extremes quite successfully. Based on this first investigation, only income is left with two options to represent it, TC-rate (1-year day rate) and Profit (TC-rate – OPEX estimation). The final model to start estimations has thus become either of the two options presented in Equation 4.2 and 4.3.

$$\begin{aligned}PRICE = c_1 + s(DWT) + s(TC\_Rate) + c_2 * Wage + c_3 * Exchange\_rate + \\ s(Secondhand\_value) + c_4 * US\_inflation + s(Building\_time) + \\ s(\% fleet\_on\_order)\end{aligned} \tag{4.2}$$

$$\begin{aligned}PRICE = c_1 + s(DWT) + s(Profit) + c_2 * Wage + c_3 * Exchange\_rate + \\ s(Secondhand\_value) + c_4 * US\_inflation + s(Building\_time) + \\ s(\% fleet\_on\_order)\end{aligned} \tag{4.3}$$

Both equations yield the highest significance scores for their variables and an R^2 of over 0.90. When investigating the graphs it becomes clear that TC-rate/profit and secondhand value are very much correlated resulting in a negative trend for the first one and large values for the second one. This is logical as the secondhand value is for a large part determined by the TC-rate. To solve this only one can remain in the final equation. Based on the values of R^2 and the fact that all other graphs and significance were roughly the same, TC-rate was chosen to be present in the final model. Another benefit is that almost no derived values remain in the model, only variables directly calculated by another module.

The last variables to pose problems are also related. Although not related in the estimation of the model, building time cannot be calculated directly in the developed model as it requires detailed yard data. Therefore, an estimator will have to be chosen, which will most likely contain a version of demand. Contract duration was found to have a destabilizing rather than stabilizing influence on demand. This is also illustrated in Figure 4.9. With an increasing orderbook size (shown by the red dots) the contract duration (grey dots) is expected to increase as well. However, for many vessel sizes this is not the case. Only at the start of the rise in 2006 an increase in building time is seen. Afterwards this duration actually reduces. Also for small vessels 2001 shows a very long average building time, with no clear indication as to why this happens. An explanation for this could be the expectations of the ship owners. They might actually ask for longer delivery times as they are expecting a boom to happen in a couple of years, rather than in the short term.

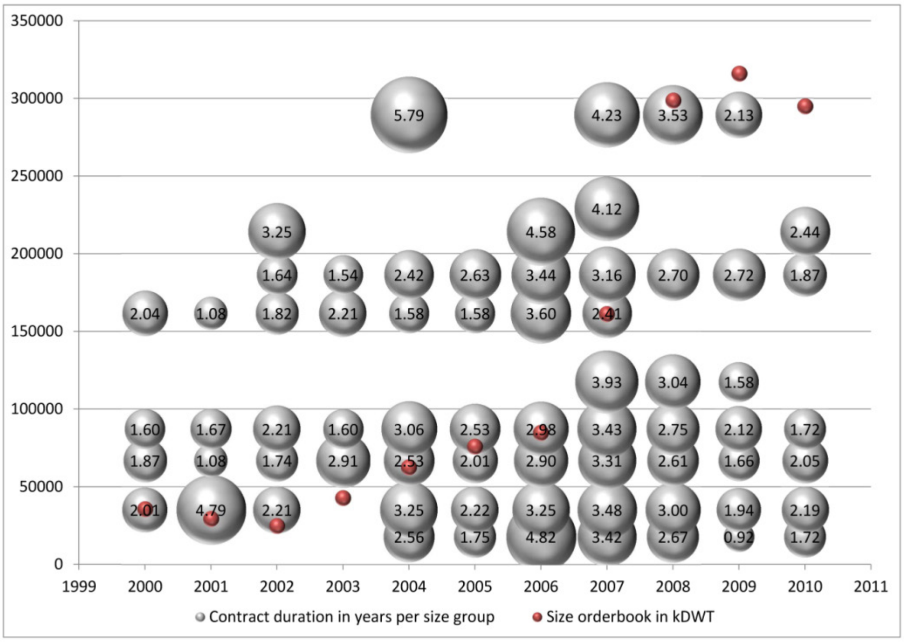


Figure 4.9: Building time per size group and year shown together with the absolute orderbook (Source: Author based on data from Lloyd's and Clarksons)

The chosen solution was to drop contract duration from the model and re-evaluate several different options for demand. Another reason to do this was that demand is the only variable which has for a large period of time with values outside the normal range of business. The main reason for this is that the peak in activity, between 2007 and 2009, is part of the available data. For demand the six months difference is re-introduced, as well as the smaller differences in steps of one month. The results are summarised in Table 4.6, where the shaded cells represent solutions of which the resulting graph was not accepted as a proper solution. Of the five remaining solutions two have lower than desired significance scores for the demand variable and are therefore disregarded. Δ-x stands for the difference between demand in the current month and demand x months ago. Demand-x stands for the demand of x months ago.

Table 4.6: Summary of tested demand (% fleet on order) options

Demand	R^2	Significance
Demand	0.928	***
Δ-1 Demand	0.924	**
Demand/ Demand-1	0.924	**
Δ-2 Demand	0.925	***
Demand/ Demand-2	0.924	*
Δ-3 Demand	0.93	***
Demand/ Demand-3	0.924	.
Δ-4 Demand	0.93	***
Demand/ Demand-4	0.925	***
Δ-5 Demand	0.93	***
Demand/ Demand-5	0.924	**
Δ-6 Demand	0.931	***
Demand/ Demand-6	0.926	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The demand graphs for the three remaining options are presented below in Figure 4.10a-c. Based on these graphs and the fact that the R^2 of the two month difference in demand is marginally lower than the other two (3-months and 5-months), the choice was made to implement the three month difference in the final model. The sudden increase in price seen in all three graphs is possibly the result of a threshold for opening new yards. If the amount of orders a month reaches this threshold, new yards will be set up just to take part in the boom. However, the setting up of these yards will come at an extra price, and all other yards will move their price up to this new level.

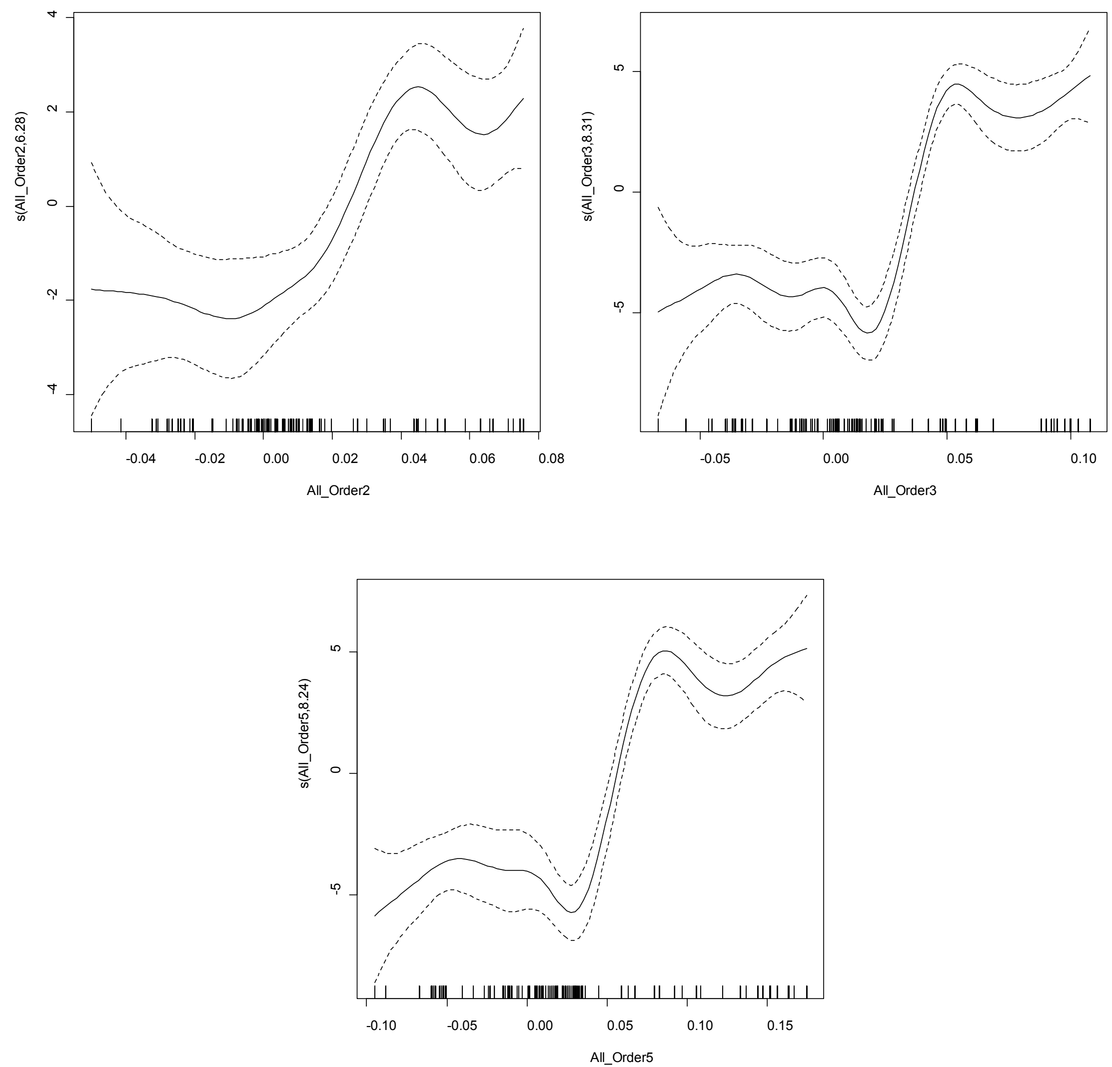


Figure 4.10: a-c: Results for demand (% of fleet on order) options (Δ-2 (a), Δ-3 (b), Δ-5 (c)) for the Equation 4.2

With this last choice the model for estimating newbuilding prices has been finalised and is presented in equation 4.4.

$$\begin{aligned} PRICE = c_1 + s(DWT) + s(TC\_Rate) + c_2 * Wage + c_3 * Exchange\_rate \\ + c_4 * US\_inflation + s(\Delta_{-3}\% fleet\_on\_order) \end{aligned} \quad (4.4)$$

4.2.2 GAM formula fitting for newbuilding price estimation

Just as with the secondhand price modelling, the results of the GAM model cannot be directly implemented in a larger model, because the results cannot be used by regular programs. Again the non-linear behaviour will be represented (in parts) by a formula.

Table 4.7: Overview of the estimated formulas for the newbuilding price GAM results

Element	Validity	Estimated equation	R^2
Intercept	-	49.46481	-
Wage	-	4.94E-05	-
Exchange Rate (2000=1)	-	-3.21E+01	-
Inflation (US)	-	1.10E+03	-
DWT	>0	-0.000000001290826*DWT^2 + 0.0003738869*DWT - 24.2693	0.9959
DWT	>114861	2.598941E-04*DWT - 2.803858E+01	0.9861
DWT	>203000	3.557066E-10*DWT^2 - 3.675044E-06*DWT + 1.152301E+01	0.9960
TC-Rate	>0	-2.788885E-17*TC-Rate^4 + 0.000000000003956987*TC-Rate^3 - 0.0000001905046*TC-Rate^2 + 0.003827022*TC-Rate - 31.64518	0.9933
TC-Rate	>49250	1.862251E-13*TC-Rate^3 - 3.493136E-08*TC-Rate^2 + 2.326968E-03*TC-Rate - 4.882439E+01	0.9916
TC-Rate	>102500	9.280414E-05*TC-Rate + 1.475534E+01	0.8454
Δ-3 Demand	>0%	-1.875040E-01*Demand - 4.650507E+00	0.4779
Δ-3 Demand	>2.4%	3.980628E+00*Demand - 1.466641E+01	0.9968
Δ-3 Demand	>4.73%	-3.465077E-03*Demand + 4.098996E+00	0.0005

The coefficients are presented in Table 4.7. Figure 4.11a-c shows the results for the estimation of the newbuilding price. The vertical axis represents the effect on price in mln USD. Again, the relations have been estimated using linear lines as much as possible, in order to eliminate some of the smaller fluctuations of the graph in low density areas. Even then the R2 scores of those segments do not fall much below 0.5. Care is taken, with each estimation, that the dotted lines of the confidence intervals are not crossed by the estimator lines, ensuring a solution that could hold based on the data available.

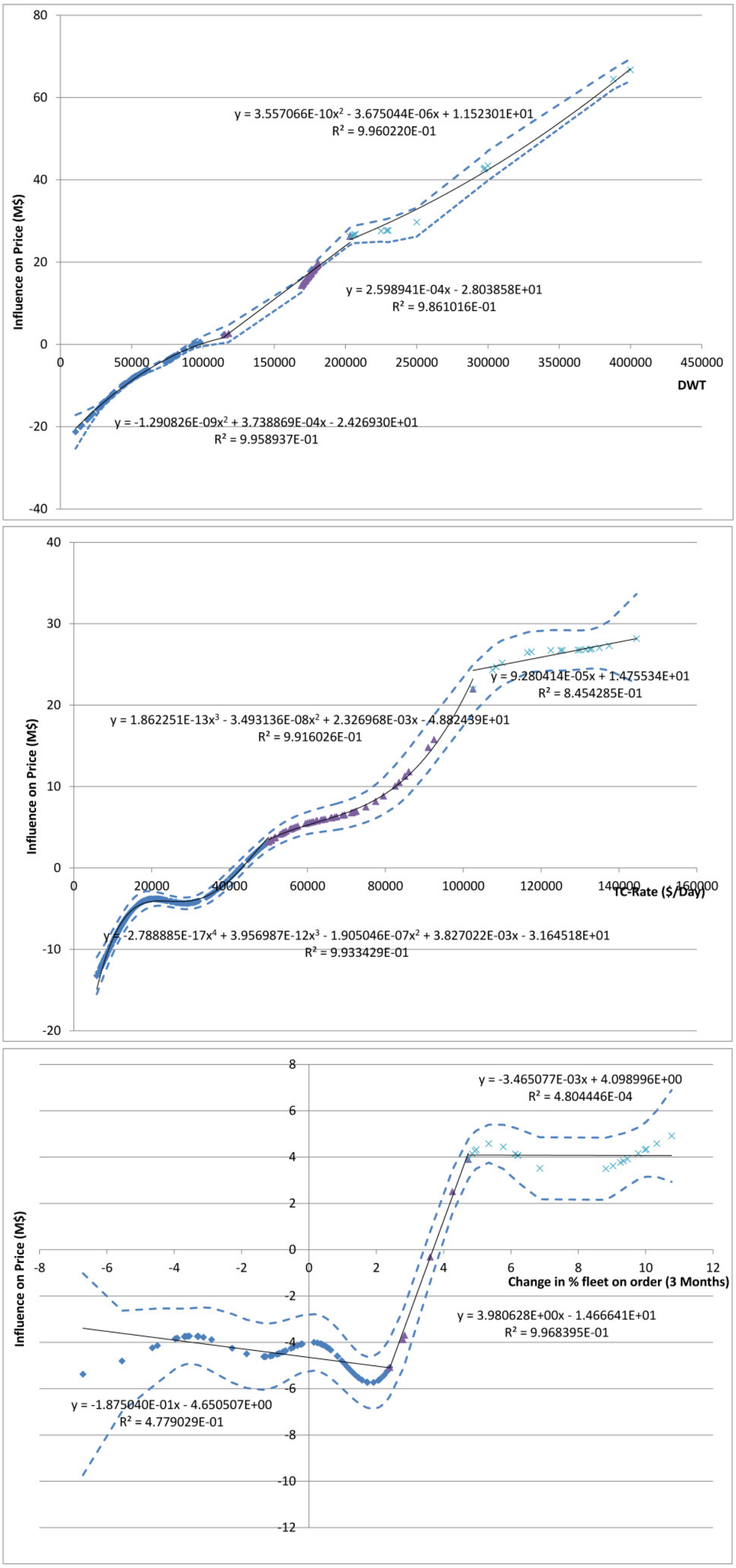


Figure 4.11a-c: Estimation of formulas to represent the newbuilding price GAM results

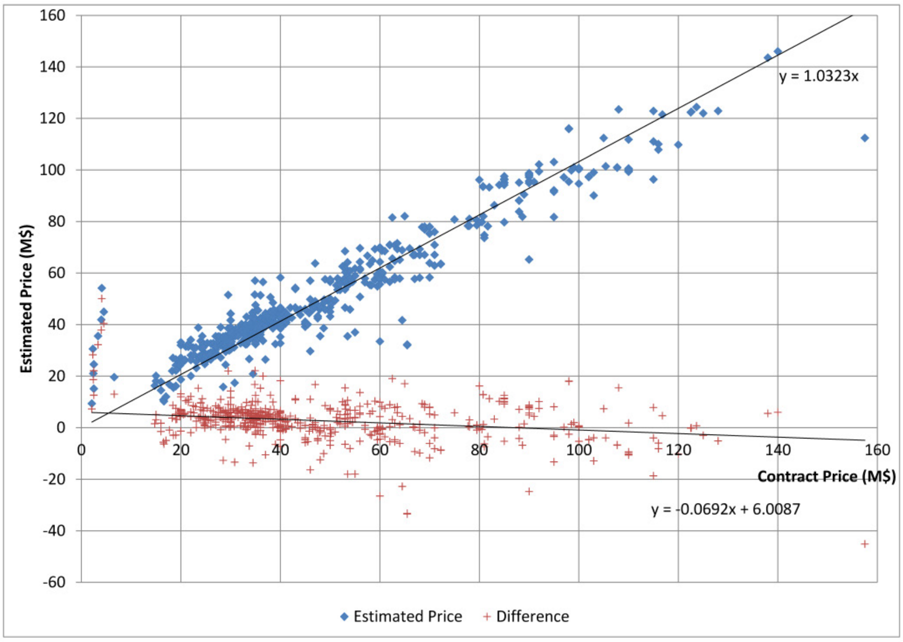


Figure 4.12: Comparison of estimated price and contract price, together with an error plot

The results for real and estimated price are provided in Figure 4.12 as a final check. In each graph the estimated value is plotted on the vertical axis against the real contract price on the horizontal axis (blue dots). Ideally, the relation between them should be one-to-one, but in this case it is 1.03. This means that a deviation of about 3% exists again. The red crosses represent the difference between the estimated and real price, which should on average be zero. Again, just like with secondhand pricing, a trend can be seen. This trend has the same meaning, prices of small vessels are underestimated and prices of large vessels are over estimated, even when size is included in the model in a non-linear manner. A problem could be the distress sales or recording errors on the left of the graph. The real prices of these vessels were in the 1-5 mln USD range, while the model estimated much higher prices. It could be the result of a human recording error (factor 10 or similar), or it could indicate some distress sales. As this could not be verified the data was left in the estimation, although without it the model would most likely score slightly better.

4.3 Newbuilding decision

In the last section, the price for a new vessel has been established, and in this section a model for the amount of ships ordered will be determined. The first subsection will look at the input parameters for the model. The second subsection will determine the optimal model, and the final subsection will convert the GAM formulation into programmable equations.

4.3.1 Selecting the Vessel ordering parameters

The newbuilding price contains several country specific elements such as the exchange rate and wage. A country specific orderbook would be the ideal outcome of this section.

Unfortunately, this is not a very likely possibility given the following circumstances. The same data on newbuilding contracts that was used for the determination of the newbuilding price estimator is used here. In the period 2000-2010, not all 16 regions have built bulkers. Actually, the majority of the bulkers were built in China (65%), followed by Fareast Asia (28%) and then India and Southeast Asia (both 3.5%). All other regions together only compose a fraction of a per cent. With only three data inputs, the ordering model cannot differentiate between the different regions. Therefore, the orderbook will be modelled on a global level. However, keeping track of the price development of the different countries can be an interesting output of the model.

Secondly, the orderbook should capture the differences in popularity and risks of the size groups at least on a yearly level. Arguably, the best option is to estimate separate equations for each size group. However, the size group 125,000-150,000 DWT has had no ordering in the years 2000-2010, which makes it impossible to estimate separate equations. Another option would be to include at least size as a factor in the ordering equation. This will most likely overestimate the need of vessels of the size group 125,000-150,000 DWT, but at the same time all 1452 (=11 years * 12 months * 11 size classes) data points can be used. A more important problem with this approach is that in the model the preference during the period 2000-2010 has been taken as fixed. This would make using the monthly ordered DWT instead of the number of ordered vessels also a good option. However, this splits the problem in two. This way a solution based on the model results is needed that divides this DWT over the 11 size classes, related to their popularity in the modelled year. Both options have been investigated and the results for the second option were far superior. R^2 was between 0.49 – 0.62 for the option based on numbers on orders and between 0.79 – 0.83 for the DWT estimation.

The timing of the orders is the last element which must be taken into account. The ordering model should be able to capture the speeding up and slowing down of ordering vessels. Figure 4.13 shows the timing per month and size group with the amount of orders represented by the size of the bubble. Often, a single bubble, of around four orders, exists in one month and no other orders for several months before or after. It does not seem very likely that in that exact month the circumstances were perfect for ordering four vessels, while the months before and after the circumstances changed enough to prevent any orders. More likely, four identical vessels were ordered in one contract. A simple solution for this is to average the orders over a longer time period. This will still capture the increasing or decreasing order rate, but it would eliminate the arbitrary nature of the exact timing of the order. Summing up values to year totals is another option. However, this would reduce the data points available to only 11 values. This is a very small number on which to base a regression with several explanatory variables. Therefore, the choice was made to stay with monthly values. A 7 month period is chosen to be compared with the results of the real value to see which option results in the best fit. Without going into the exact details, the choice could easily be based on the R^2 range of the potential models. While it was between 0.79 – 0.83 for the DWT estimation with exact order values, it improved to 0.92 – 0.96 for the order data averaged over 7 months.

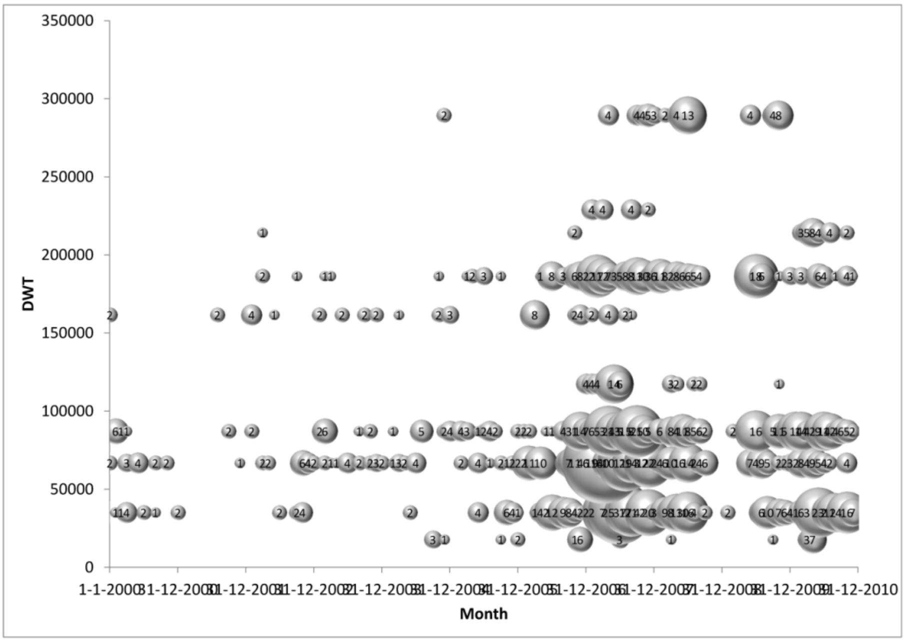


Figure 4.13: Overview of the number of vessels ordered per month in each age group (Source: Author with data from Clarksons)

In the previous paragraphs the outcome of the ordering model has been established as a monthly ordering value expressed as DWT based on a 7 month average. Before going into the modelling itself, it is good to consider which elements are expected to influence the ordering of vessels. Both the newbuilding price and the secondhand price play a role in the ordering of vessels. One would expect a rational owner to consider newbuilding if the secondhand price of young (below 5 years) vessels of the same size and capabilities is higher than the newbuilding price. As the actual lifetime of a vessel is uncertain, both can be assumed to have an expected service life left of about 25 years. The higher price is paid for the secondhand since one does not have to wait for this vessel to be delivered. If the secondhand prices are lower, purchasing secondhand vessels would always be the better option from an economical point of view, and no newbuildings would be ordered. Also the state of the market reflected by an income potential could have an influence on the ordering of vessels. Even if a large enough difference exists between the secondhand and newbuilding price, if there is no expectation of income to be made with the vessel there is no need to build one. Lastly the time an owner needs to wait for his vessel could influence his ordering. If he has to wait longer, the risk is bigger and the gap between newbuilding and secondhand price would need to be larger.

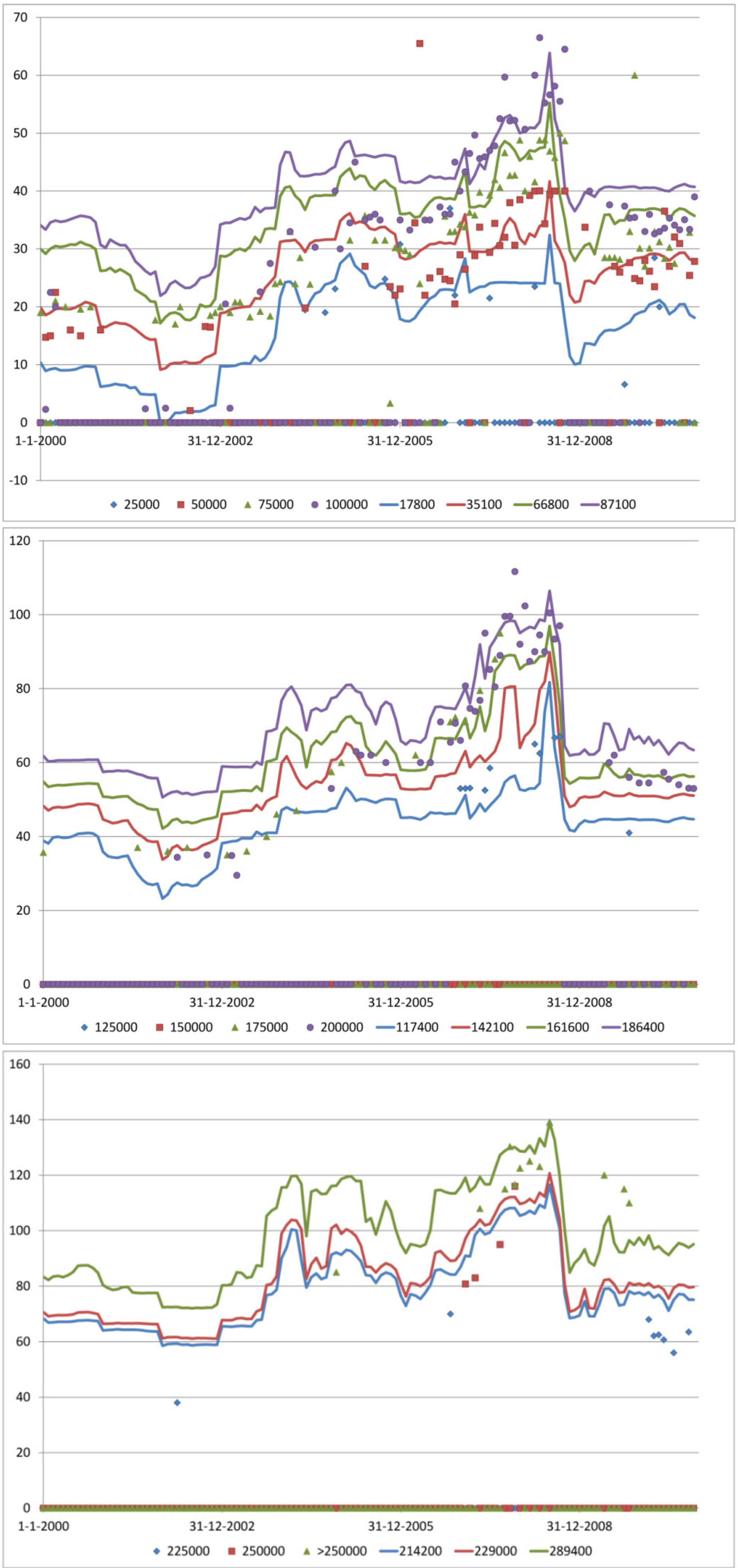


Figure 4.14a-c: Representation of newbuilding prices in time series approximation and real contract data points. (Source: Author with data from Clarksons)

In the case of secondhand and newbuilding prices there is a choice to be made. The first one is which prices will be used. If the newbuilding contracts are used, prices of the vessels contracted are also known, so they could also be used. However, no secondhand prices are known for these vessels. More importantly, zero orders is also a data point and no prices are available for contracts for these points. This means that for both a young (1-2 years old) secondhand price and a newbuilding price monthly data series are needed for each size group. Clarkson provides these data series, but with several issues as demonstrated in section 2.2. The main objection is that these series are mostly based on the estimations of ship brokers. Also the sizes provided do not match the representative sizes for the size groups, and the age of a new secondhand is 5 years old. All these aspects indicate that monthly estimates would be used regardless, even if the data from Clarkson is used. The latter only comes in monthly series. It might therefore be better, also from the point of view of integration, to use the estimation models already developed for secondhand and newbuilding prices. In Figure 4.14a-c the resulting monthly data series and original contract newbuilding price averages for that month within a size group are presented. Several observations can be made from this figure. First, the amount of contracts diminishes quickly with increasing size. The second is that in general the lines and dots are quite close to another, with perhaps an exception for the first 3 years. Here prices are slightly overestimated most likely an effect of the lower amount of data points in that area for the estimation of newbuilding price model. Still the newbuilding price model is considered a decent estimator.

4.3.2 Estimation of the optimal Vessel ordering model

A possible downside of using these estimators is that they both already make use of the income and orderbook for the determination of the newbuilding and secondhand value. If income or orderbook shows a counter intuitive relation with the amount of orders, this could be compensation for their role in the price estimations. This would mean that, even if the relation is not as expected, if the significance is high, the variables should not be discarded. The options for the variables in this case are similar to the ones already described in the previous sections on secondhand (4.1) and newbuilding (4.2) prices. In both cases the TC-rate came out as the best representation of income and for the reasons mentioned above it might be best to use it here as well. The choice for orderbook is different in the two options; therefore both estimators will be tested: the orderbook and the change in the orderbook over a 3 month period.

The choice for DWT ordered, instead of size group specific orders, also becomes an important decision. What is the best way to average the different values of the input over the different size classes? The easiest one will be discussed first. Orderbook and its 3-month change are already based on the entire fleet. For the vessel prices (new and secondhand) two options were tested. The first one is setting the January 2000 value to 1 for each size group and then averaging these fractions per month. This will allow the individual use of these estimators. The second option is dividing the newbuilding price by the secondhand price of that month and averaging this over the size classes. This captures the above assumed relation between ordering and these two prices, but the assumption might be wrong. Finally, for the TC-rate two options are tested: setting January 2000 as 1, the same as with the vessel prices and calculating the TC-rate/Cargo ton and averaging this, since it does not differ a lot over the different classes.

Table 4.8: Summary of the tested ordering models

Elements		**NB-price, SH-price**	**NB-price**	**SH-price**	**NB-price/ SH-price**
TC/ton, demand	R^2	0.953	0.953	0.953	0.953
	Significance	***	***	***	***
	Deleted	NB, SH	NB	SH	NB/SH
TC, demand	R^2	0.953	0.953	0.953	0.953
	Significance	***	***	***	***
	Deleted	TC, NB	NB	SH	NB/SH
TC/ton, Δ3-demand	R^2	0.917	0.751	0.91	0.825
	Significance	***	***	***	***
	Deleted	Orderbook	NB	-	-
TC, Δ3-demand	R^2	0.918	0.748	0.91	0.824
	Significance	***	***	***	***
	Deleted	Orderbook	NB	-	-

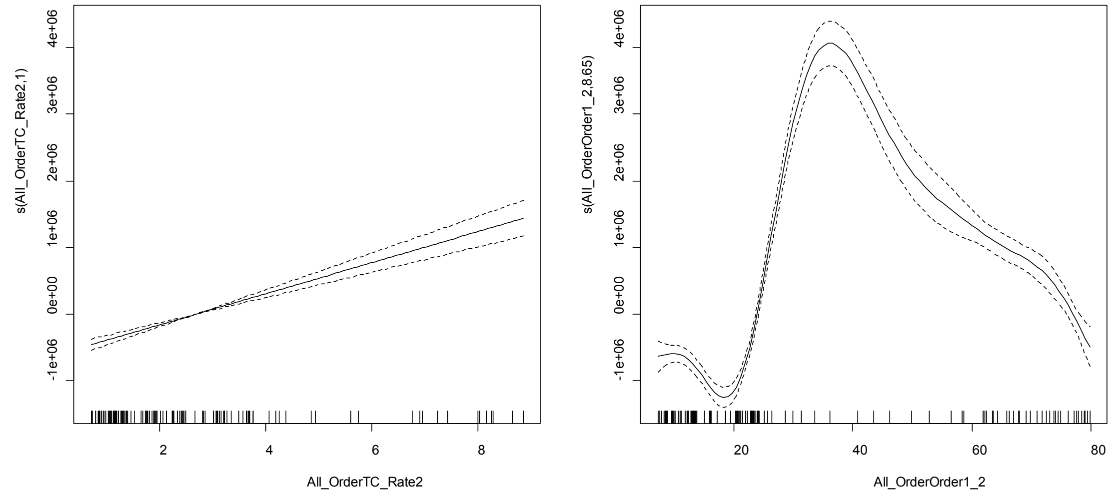


Figure 4.15a-b: Non-linear relations for Equation 4.5

When reviewing the model results in Table 4.8, it is clear that in the first two columns all models are basically the same. The one exception is where the TC-rate is replacing the SH value of the vessel. The final two rows clearly indicate that the 3-month difference in orderbook is a worse predictor than the current orderbook, with all R^2 lower than compared the first 2 rows. Here also a small difference occurs between the two approaches of the vessel income. This makes sense in hindsight as both approaches make the TC-rate dimensionless by dividing through a class specific constant. The combination of TC-rate with the percentage of fleet on order is selected to form the model. When inspecting the graphs of the two variables (Figure 4.15a-b) the fact that the relation between the TC-rate and the ordered DWT seems linear stands out. When tested by estimating the model with a true linear representation of TC-rate, this linear relationship is confirmed. The final model therefore becomes:

$$DWT\_Ordered = c_1 + c_2 * TC\_Rate + s(\% fleet\_on\_order) \quad (4.5)$$

4.3.3 GAM formula fitting for the Vessel ordering model

The final step was to capture the non-linear part of the model in a set of equations. The same approach as in Section 4.1 and 4.2 was used to perform this task. Trend lines with the lowest possible power that stay within the 90% bands of the equation were targeted, while keeping the amount of different equations as low as possible. Due to the large fluctuations in the effect of the orderbook on orders, 3 sections were defined (see also Figure 4.16). The first section seems to represent the normal range of orders, with a declining tendency to order once orderbooks are getting filled up (see also the comments made on this subject in section 4.1 with the reference to the work of Dikos [2004]). However, in this case this ceiling would be estimated at about 20% of the ships on order, rather than the 30% estimated in that section. There is a clear second ordering burst after the 'normal' max has been exceeded, when the percentage of the fleet on order reaches 40%, the willingness to order seems to decline. Each step has their own estimation, see also Table 4.9.

Table 4.9: Overview of the estimated formulas for the vessel ordering GAM results

Element	Validity	Estimated equation	R^2
Intercept	-	602926.9	-
TC-rate (USD/Day)	-	2.324630E+05	-
% fleet on order	>0	-1.066587E+04*Orderbook^2 + 1.991691E+05*Orderbook - 1.520207E+06	0.9926
% fleet on order	>18	-2.759564E+03*Orderbook^3 + 2.203582E+05*Orderbook^2 - 5.367980E+06*Orderbook + 4.012682E+07	0.9999
% fleet on order	>35	-8.933553E+01*Orderbook^3 + 1.645836E+04*Orderbook^2 - 1.073101E+06*Orderbook + 2.582915E+07	0.9921

The final part of this section looks at how well the results fit. The R2 was already given and is very high, but a plot as in the previous cases in section 4.4 was also done for this case, see Figure 4.17. Immediately one problem is apparent from the plot; the ordered DWT may become negative in the estimation. Using a trend line to estimate the co-integration of the two series, the remaining value for R2 is 0.8728 (with the trend line going through the origin). This makes the model still a good estimator for the ordered DWT, especially considering it requires only the TC-rate and the current orderbook as input.

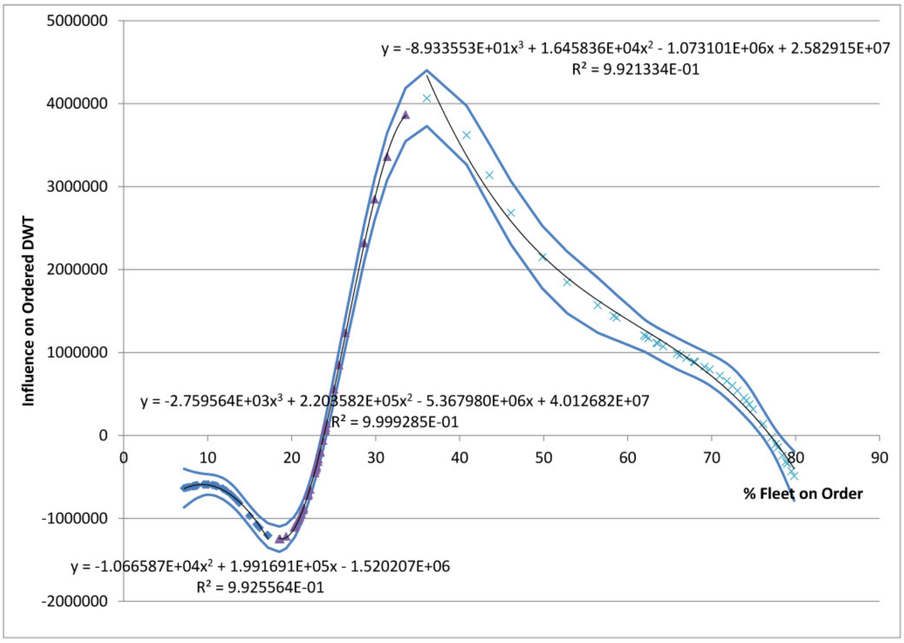


Figure 4.16: Estimation of formulas to represent the vessel ordering GAM results

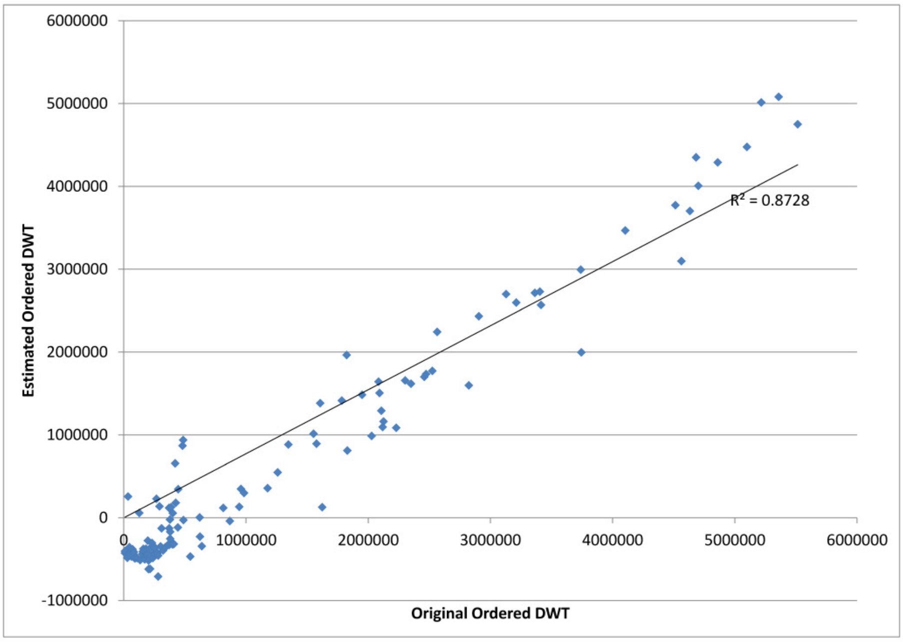


Figure 4.17: Comparison of estimated and original values for the vessel ordering model

4.3.4 Converting ordered DWT to specific vessel numbers

Which vessel sizes are ship owners most likely to order? In all the papers reviewed on shipping models, this question was never answered. Because the main focus of this research is to see if an integral approach is feasible and useful, it was decided to create a simple model for the selection of vessels. This choice will forego the forward looking potential of ship owners and assume their ordering is based on the vessel types which are currently (at the time of ordering) performing the best.

What is the best way to select which vessels are performing well? TC-rates are linked to costs, and thus on average a vessel will not make a profit. However, a successful vessel type can be expected to be operating more than its competition. The percentage of time a vessel type is active is used as representation of this. The fraction of DWT ordered for a certain vessel type is therefore set equal to the division of the activity fraction of that vessel type by the sum of the activity fractions of all vessel types. In this way, changes in fleet activity are directly reflected in the ordered fleet and also in the deliveries some years later. On the other hand, a change in average activity does not influence the relative ordering of vessel types.

This approach still leaves one question unanswered: after how many years will the ordered vessels become active? The average duration between signing and delivery was 2.83 years according to the available data. From Table 4.10 it is clear that this duration is not dependant on the size of the vessel. It is possibly influenced by the number of orders. However, the second part of the table shows that for the 11 data points available this relation is not obvious. On estimation correlation of 0.375 is obtained, which indicates a relation, albeit not a strong one. It therefore makes sense to assume a fixed period for the model and this period was rounded to an average of 3 years.

Table 4.10: Overview of average duration between signing and (planned) delivery. (Source: Author with data from Clarksons)

Size group	**17,800**	**35,100**	**66,800**	**87,100**	**117,400**	**142,100**	**161,600**	**186,400**	**214,200**	**229,000**	**289,400**
Duration	2.98	2.88	2.78	2.63	3.68	-	2.49	2.86	2.62	4.12	3.42
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Duration	1.85	2.31	1.93	2.31	2.83	2.29	3.26	3.41	2.85	2.08	2.00
Orders	32	7	33	38	32	57	171	628	258	142	273

For the years between the start of ordering and the model delivering those orders, the average orders placed in the period 2000-2010 are used. Naturally one third of the starting orderbook will be delivered each year since no further data is available.

4.4 Scrapping decision

While ordering increases the size of the fleet, the scrapping market reduces the fleet size. The pricing of scrap vessels was already treated in section 4.1 as part of the secondhand valuation of the vessel. This section will discuss the amount of vessels scrapped. Newbuilding is a decision that only affects the fleet in three years' time. Scrapping, on the other hand, has an almost instant effect on the shipping fleet and is irreversible. All of the before mentioned maritime models (see section 2.1) are only interested in the size of the fleet instead of the actual numbers scrapped. Some go beyond this, but focus on the newbuilding orders as an abstract measure, not requiring the orderbook to enter into the existing fleet. For scrapping, the price or price per lightweight (LDT) can be of interest for these models, but without investigating the scrapped volume as an internal model factor.

Very little literature exists on the topics of scrapping and determining if a vessel should be scrapped. Cockburn and Frank [1992] were the first to investigate the scrapping of tankers. Their observations are that scrapping is delayed if oil prices are high. Their model for estimating the scrapping probability includes secondhand value, age and DWT.

In their set up of a fleet utilization model for managers, Jin and Kite-Powell [2000], explicitly model the scrapping of vessels. However, for analytical purposes they assume all vessels are the same and do not consider ports of call and distances. Based on their analysis, they prove that in their model the rate of scrapping is influenced by the operating cost of the oldest (most expensive) vessel and that the scrapping probability will also increase when the average costs of this vessel are much smaller than its marginal cost.

The last econometric paper on scrapping is from Knapp et al. [2008]. They investigate the probability of scrapping based on data from 29 years on over 50,000 vessels. Their tests are an investigation of ideas brought forward by Mikelis [2008]. The latter uses data on the current fleet to get an idea of the impact of the International Convention for the Safe and Environmentally Sound Recycling of Ships of the IMO. Next to the before mentioned size, age and current income, they also investigate scrap steel price, class, flag, changes in flag, detention and many other particulars. Only the first 4 proved to yield smooth curves, and the others are represented by dummy variables of which many are found insignificant. They also split up the scrapping likeliness according to country of scrapping (India, Bangladesh, China, Turkey and Pakistan).

Of the three papers found on modelling scrapping or scrapping decisions, only the last one provides a workable framework for application in this research. The first one delivers some useful results, but its data is almost 20 years old and includes a significant amount of steam driven tankers. The second one, although very interesting, does not provide a readily adaptable model and the paper suggests a simulation approach.

Out of the four variables crucial for determining the probability of scrapping, only scrap metal price is not already available in this model. Age and Size (GT or DWT) are available as vessel data and current TC-rate for the vessel size is also already calculated.

Within this setup other data is also available that was not available to Knapp et al. [2008], such as the location of the vessel. If a ship owner had to decide if a vessel needed scrapping, it would not make much sense to instantly scrap a vessel currently involved in a profitable trip. It would make more sense to demolish a vessel that is not on a trip but in lay-up, or losing money if it would be sailing against the current TC-rate. Such a vessel would be worth getting rid of for a ship owner (if he does not lose too much on the sale as well).

Still there is an issue overlooked in Knapp’s paper, but mentioned by Cockburn and Frank [1992]. It does not make sense to scrap a vessel if the secondhand value of that vessel is higher. This means that even if a vessel is currently making a loss when sailing, it would still not be scrapped if the secondhand value is higher than the scrap price.

This exact situation was tested in the model. If the vessel is in lay-up, each week the model tests if the vessel would be making a loss and if it would be worth more on the scrap market. If both are the case, the vessel is assigned a scrapping probability based on its age. The values are based on the work of Knapp et al. [2008], although corrected for the fact that quarterly data is used in their work and in this model weekly data is used. The probability of scrapping is thus expressed by Equation 4.6.

$$\begin{aligned} &p_{scrapping} = 0.02 + 0.01 * Age \\ &Price_{Scrap} > (TC\_Rate - Costs_{fixed} - Costs_{variable}) * (30 - Age) - (Price_{current} - Price_{Scrap}) \\ &Price_{Scrap} \geq Price_{current} \end{aligned} \tag{4.6}$$

In the model the scrap price is found on both sides of the equation. However, before eliminating it, the following should be considered; the scrap price is the minimal price of the vessel, hence its secondhand price and the scrap price can only be identical. Using this new second condition, the last part of the first condition is reduced to zero. The implemented conditions are presented in Equation 4.7.

$$\begin{aligned} &p_{scrapping} = 0.02 + 0.01 * Age \\ &Price_{Scrap} > (TC\_Rate - Costs_{fixed} - Costs_{variable}) * (30 - Age) \\ &Price_{Scrap} = Price_{current} \end{aligned} \tag{4.7}$$

The scrapping decision is thus based on the fact that a vessel would lose money when sailing and the income from scrapping is at least equal to selling the vessel to another owner. The scrapping income is determined by an estimation of the lightweight of the vessel and a scrap steel price, which changes with average production costs.

4.5 Conclusions

In this chapter three of the four shipping markets have been investigated. First the pricing of new vessels and of secondhand vessels have been discussed. In both models 3 elements play a very important nonlinear role; the size of the vessel, the TC-Rate and the demand expressed in % of the fleet on order. In case of the secondhand vessels, age is another important element. For newbuildings the linear relations with wage, exchange rate and USD inflation are also of influence when considering the price.

The ordering and scrapping volumes are also estimated, although the latter is a direct result of the assignments a vessel gets in the next part of the model. The fact that in all cases, where the GAM approach was applied, at least one variable showed highly non-linear behaviour is proof of the need for such an approach. Normal linear estimation might not have captured this behaviour, because quite high powers of x would have been required.

With these sub-models it is now possible to update the conceptual model and fill in the approach for the shipping market. This is done in Figure 4.18. The shipping market block is replaced by four blocks representing three submarkets: newbuilding, secondhand and scrapping. While originally both newbuilding and secondhand prices were expected to have an influence on each other and on ordering, the modelling process has eliminated this, leaving only demand for vessels to influence the price. Also the exports required from the MC model have been further specified, both the direct variables and the fact that only the dry bulk market is modelled. The last block remaining to be investigated is the Fleet behaviour, which is the subject of the next chapter.

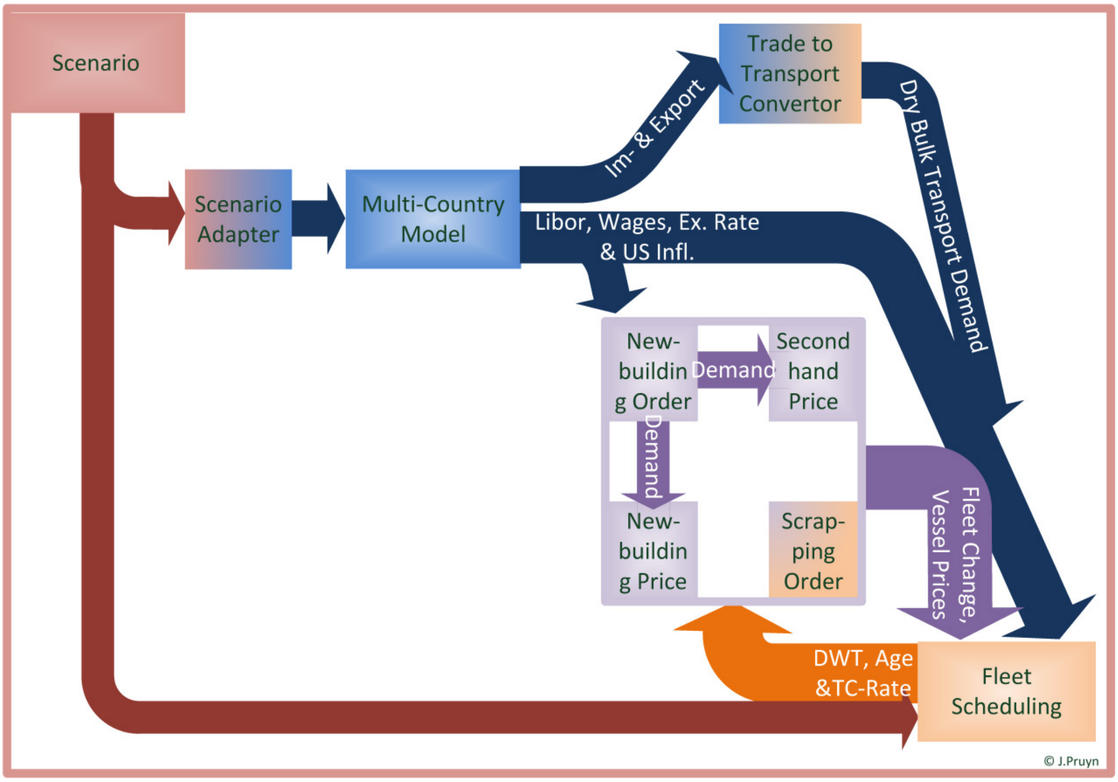


Figure 4.18: The model including implemented Country behaviour and shipping market

5. Allocating the world fleet to trades

Many of the maritime models described in Chapter2 express the size of the fleet either in total DWT or total ton*miles. These are very abstract forms of the fleet and they results in the freight rates being indicative rather than route specific. The idea behind this model is to present the rational freight rates and TC-rates. The approach chosen is to allocate the entire world bulker fleet. The disposals and purchases are done in such a way that the vessels that are not able to earn money are scrapped and new vessels are bought based on profitability and regular order patterns. The fleet is committed to transport all available cargo and assigns vessels in such a way that the total costs are minimized. Before going into detail about how the model does this, the construction and division of the starting fleet is discussed as well as their properties.

5.1 Describing the bulker fleet

The fleet as it existed in 1998 was chosen as the starting fleet. The data comes from Lloyd's World fleet stats [1993-1998]. Ships are grouped in age and size groups. Age group span is five years and size groups increase with 5,000 DWT. As the model has some simplifications, the existing fleet will need time to adjust to the model parameters. As the Multi Country Module only allows changes to be made after 2005, there are 7 years, or 364 weeks, to move from the real fleet to the rational fleet required for the model. This will leave the period of 2005-2015 available for experiments with scenarios. Which coincides with the period available from the MC-Model (2006-2015).

The large age groups available from Lloyd's pose some difficulty in following individual vessels. On the other hand, the detailed size distribution would require a much more detailed transport allocation model. Grouping vessels into larger size groups can be easily done as it only requires summing the available data. Determining the exact size and number in each 1-year age group, on the other hand, would require some manipulation. The availability of 6 years of data is sufficient to convert the 5-year groups in 1-year groups by looking at the inflow and outflow of each group in consecutive years. The sinking of vessels could be an issue in this approach, but the number of vessels sinking is small and it is assumed to be part of scrapping as the data was mostly consistent.

After this conversion, the new fleet description consisted of 30 one-year age groups and eleven sizes of vessels: ten in steps of 25,000 DWT and one for vessels over 250,000 DWT. The vessels within each group are assumed to be the average size of that particular group, creating a diverse fleet not only differing in age, but also in size. An overview graph of the groups is presented in Figure 5.1, a copy of Figure 4.5, but for clarity and ease of reading repeated here. The height (or DWT) of each group is not the middle of the group range. Instead, the weighted average was taken of each group. The values and group sizes are given in Table 5.1. The average size for the group 200,000 till 225,000 DWT is based on the average size of newbuildings as no data was available for the current fleet.

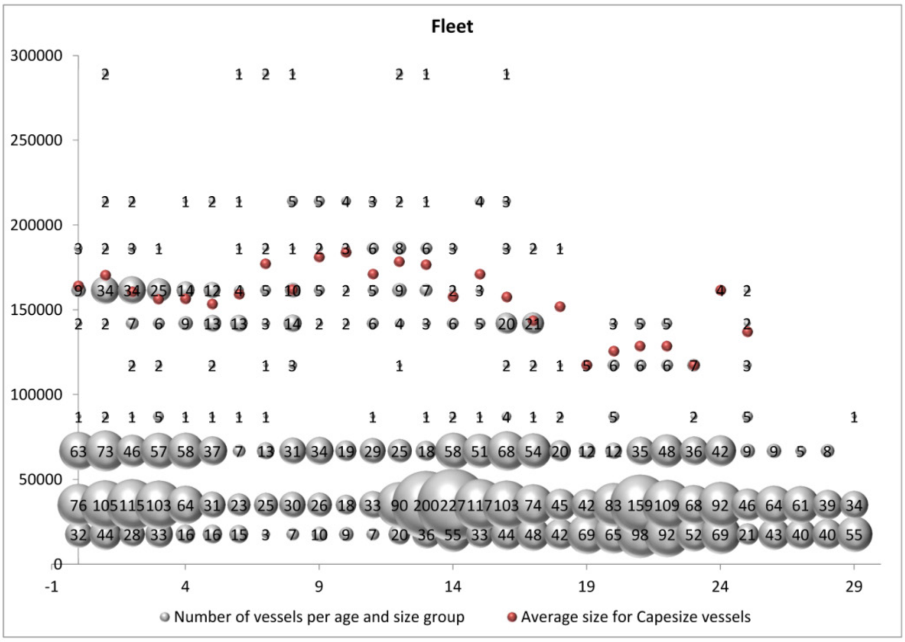


Figure 5.1: Overview of particular size and number of vessels in each age group. (Source: Author based on data from Lloyd's)

It seems that all vessel deliveries (and orders) have followed a similar pattern over the last 30 years, as represented by the size of the age group. The bubbles in the graphs are larger at roughly the same ages. Also there is a small trend of increasing (average) size of the vessels, mostly caused by the Capesize group (>100,000 DWT). The red dots in Figure 5.1 represent the average size for Capesize vessels of that particular age. The younger vessels are larger on average than the older vessels (15+). Although it is not shown here, in recent years a number of 400,000 DWT bulk carriers have been ordered for the transport of coal and iron ore to China, fitting this trend of increasing size.

In order to be able to minimise the total costs of transport, the costs of each of the vessels must be known. The cost of a vessel is not fixed. Instead, it depends on the bunker costs, on the crewing and financing costs, and many more factors. Also there is a difference in the monthly costs for vessels that are trading actively and those that are laid up.

Table 5.1: Overview of particular size and number of vessels in each size group in 1998. (Source: Author based on data from Lloyd's)

Size group	Average size	Number of vessels
<25000	17800	1142
<50000	35100	2302
<75000	66800	977
<100000	87100	38
<125000	117400	49
<150000	142100	153
<175000	161600	186
<200000	186400	47
<225000	214200	35
<250000	229000	0
>250000	289400	10

There are fixed costs and voyage costs. The fixed costs can be split between costs always incurred (here called lay-up costs) and costs only incurred when the vessel is active/not in lay-up (here called active costs). The Time Charter Costs of the vessel are equal to the fixed costs in this model, as no extra profit is obtainable. In
Table 5.2 these costs can be recognized by the fact that they are expressed in USD/year. Maintenance and part of the crew costs make up the active costs, while the rest of the costs are the lay-up costs. The voyage costs can also be split into two elements: the sailing costs and the fees. The sailing costs are independent of the route the vessel is sailing and only incurred if the vessel is sailing. In this model, they consist only of bunker costs and are expressed in USD/mile. The fees are dependent on the port and canals of the route of the vessel and are only paid once per trip, which means that these costs are determined in USD in the table. Both canal dues and port fees are taken as a fixed value that is a rough estimate of the average costs incurred. In Appendix C the determination of the costs and coefficients is further detailed.

Table 5.2: Summary of the cost determination per vessel

Cost group	Formula	Source
Depreciation Costs ($/Year)	(Secondhand Value - Scrap Value) / (31-Age)	-
Interest Costs ($/Year)	Interest rate * Secondhand Value	-
General Costs ($/Year)	a * DWT	Stopford [2009]
Insurance Costs ($/Year)	10.28 * (b * Age^2 + c) * (0.5409 * DWT)	Standards [2010], North P&I [2010], UK P&I [2010], Stopford [2009], Wang et al. [2007]
Maintenance Costs ($/Year)	d * ((365 - port days) * average speed * 24)^e * Age^i * DWT^j	Bitros and Kavussanos[2010]
Crew Costs ($/Year)	f, age < 6; g, age < 16; h, age >15	ITF[2008], Stopford [2009],
Consumption Costs ($/Mile)	(i * (DWT * l)^(2/3) * Speed^2)	Schneekluth, H. and Bertram V. [1998], MAN[2008]
Port Fees ($)	j * GT	-
Canal Fees ($)	k * GT	-

All the vessels in each of the 330 groups formed by age and size will have a different value for each of the possible trips. This is due to difference in the fixed costs, active costs, sailing costs and trip costs of each vessel. This will allow an optimizer to minimize the costs. The functionality and underlying logic of the optimizer is described in the following section.

5.2 Conditions for the allocation

Any assignment algorithm will need a set of conditions in order to be able to optimise the objective function. In this section the element to optimise as well as the conditions for the optimisation are described.

First, the selection of optimization type is described. In the introduction of this chapter it is described that the assumptions were made that the world is acting rationally and that full disclosure of information exists allowing for a perfect competition with no extra profits to be gained. The transport will be done at minimum costs instead of maximum profit. Because all information on the market is available, a cargo owner in need of transport will pick the one supplier with the lowest costs. Therefore, the optimisation performed here will be that of the lowest costs. Assume V_{ijk} is a binary variable that states if vessel k is assigned on the route from i to j and C_{ijk} are the total costs for transporting the amount vessel k can carry from port i to j. The objective of the optimisation is presented in Equation 5.1. The total number of available vessels is represented by o, the total number of starting locations by m and the total number of target locations by n.

$$MIN\sum_{k=1}^{o}\sum_{j=1}^{n}\sum_{i=1}^{m}V_{ijk}*C_{ijk} \tag{5.1}$$

The first condition to consider is the fact that not the entire fleet will be assigned at once. The demand for transport is known on a weekly basis, but the actual trip (including relocation, loading and unloading) can take up anywhere between 2 and 40 weeks. This means that only a part of the fleet is available to supply transport at a given time. The other portion of the fleet is performing a transportation action or is in lay-up for a period of time. Only the available fleet and cargo are considered each week for the assignment. Here a clear break from the as optimal assumed Pick-up and Delivery Problem with Time Windows (PDPTW) of 2.1.3 is made. That model would not require optimisation over 1 time step, but over a large number of past and future time steps. This is in itself not a problem, but it will be very time consuming if each time step vessels will be scrapped and new vessels will enter the pool. This type of solution is mostly applied in cases with a relatively small number of vehicles and a short time span, e.g. one day and up to 50 vehicles. In this case there are almost 5000 units sailing on average 5-10 trips per year split over 330 different categories and on 276 different routes. The time and computer power required would simply make this solution very impractical. It could however mean that a vessel will first need to move from another location to the loading port. In other words cargo is assigned to a specific vessel each week, but not necessarily picked up in the week of assignment.

Therefore, demand assignment will be pursued rather than demand pick-up. This simplification will not alter the overall behaviour of the system as long as all demand is satisfied because weekly demand is partially determined by a random element. This is the focus of the first condition. If the cost structure of
Table 5.2 is examined, it is apparent that the lowest costs occur when all vessels are in lay-up or waiting for cargo. In that case only the lay-up costs are paid resulting in the lowest total costs for the fleet. The problem with this case is that no cargo is transported. The first condition should therefore be that all cargo must be transported. When the cargo carrying capacity supplied by vessel k is represented by S_k and the demand for transport from point i to point j is given by D_{ij}, Equation 5.2 describes this constraint.

$$\sum_{k=1}^{o} V_{ijk} * S_k \geq D_{ij}$$ (This is for every route i->j) (5.2)

This ensures that all demand is satisfied with the available supply. In this case demand for transport is fixed by the macro-economic model, and the price of transport is not part of determining the demand. This simplification is justified by the fact that the period considered is one week. However, there are several consequences of this choice. The main consequence is that in combination with Equation 5.2 there will always need to be sufficient vessels available to handle the demand; otherwise the model will not have a feasible solution. This restriction does not prevent the cheapest vessel group from being assigned to all routes, covering all cargo. This is of course physically impossible, because the amount of assignments for one vessel is limited to one. Equation 5.3 introduces this constraint.

$$\sum_{j=1}^{n} \sum_{i=1}^{m} V_{ijk} = 1$$ (This is for every vessel k) (5.3)

The dry bulk transport demand is expressed in tonnes on a certain route, instead of different types of products. Thus all types of bulk can be combined in one cargo shipment. Therefore, the amount of ships required will be underestimated and will favour the larger vessels. In order to have a realistic behaviour of the model, this must be corrected.

$$\sum_{k=1}^{o} \sum_{j=1}^{m} V_{ijk} * R_{ijk} * Pan_k \leq \frac{\sum_{j=1}^{n} D_{ij}}{\sum_{k=1}^{o} S_k} * \sum_{k=1}^{o} Pan_k$$ (For every origin i) (5.4)

$$\sum_{k=1}^{o} \sum_{j=1}^{m} V_{ijk} * R_{ijk} * Cap_k \leq \frac{\sum_{j=1}^{n} D_{ij}}{\sum_{k=1}^{o} S_k} * \sum_{k=1}^{o} Cap_k$$ (For every origin i) (5.5)

In order to compensate for this the amount of cargo allowed to be transported by a Capesize or a Panamax vessel was limited. The model is still free to assign the vessels to any of the available source and destination combinations, but it must make sure that no more than the set maximum of vessels is assigned to each source. Capesize vessels are very much linked to the transport of coal and iron ore and to a lesser extent grain. Panamax vessels are the main transporters of grain from the US. The reason these specific trade limitations are not integrated into the allowed assignment of cargo is that the model is meant to investigate differences in trading patterns for different scenarios. If the vessels were restricted per route this possibility would be limited. New patterns and assignments would simply not arise. Let Pan_k and $Cape_k$ be 1 if a vessel k is of Panamax type or Capesize type respectively and let R_{ijk} be 1 if a route is for transporting cargo and 0 if the route leads to lay-up or waiting one week for cargo. This way the assignment of Panamax and Capesize vessels to lay-up or waiting is not limited. The two resulting constraints for Panamax and Capesize vessels are then presented in Equation 5.4 and 5.5. These constraints set the maximum number of Panamax and Capesize vessels to a fraction of the total available vessels of these types. This fraction is the division of total demand available in this origin divided by the total supply available, basically dividing trade equally over the three ship types per origin. As stated before, the first restriction requires supply to be larger than demand at all time, so no further limits are needed to prevent the fraction from exceeding 1. Also it is good to realise that the number of vessels is limited here, not the DWT of the vessel, allowing an important or expensive routes to transport a larger share of the cargo with cheaper large vessels (within the Panamax and Capesize group). All constraints are now complete for the assignment of the available world fleet to the available cargo or transport demand.

5.3 Calculating freight rates

In order to have a good feeling for the performance of the maritime transport sector, freight rates can be used as an indicator. The algorithm uses the real costs of each vessel to transport the cargo to optimise the assignment. In classical economics the price of a product is set to the marginal costs of producing/transporting the last unit. In other words, all transporters are paid the rate of the most expensive active transporter. This is not part of the optimisation, as it would require an iterative approach, which would greatly increase run time. With over 500 runs required for one scenario, this is currently not feasible. However the maximum price per route is still useful as indicator for the status of the market. High prices with about the same TC-rates would indicate a need to bring in vessels from further away due to large imbalances in trade or costs of the vessels.

This freight rate can be converted into a Time Charter Equivalent (TCE) rate. However, the monthly costs can also be used to calculate a TC-rate for a vessel type. Both are calculated by the model, but which one should be used in the further calculations? At this point the model lost its forward looking capabilities. While future demand is known, future rates cannot be predicted anymore. This means that it is impossible to use the TCE rate (based on the maximum freight rate) for determining the costs of transport in the cargo assignment module described in section 5.2. This implies that optimisation can only be done while using the real TC-rate based on the vessel costs. This TC-rate is therefore used in the determination of vessel prices, newbuilding etc. of Chapter 4.

The ratio between the TCE-rate and the TC-rate could be used to detect profits within the model. The average for the base run is a TCE rate which is about 36.5% higher than the TC-rate. However, the maximum goes to 255% and the minimum is -72.3% for a single ship size in a single week. The minus can be explained by the fact that the TC-rate is the average costs of that vessel size group. If only the more efficient vessels are used and available in the area, the rate can be lower than the average TC-rate. In hindsight, these large value fluctuations might have been better solved with a genetic algorithm or Particle Swarm Optimization (PSO) approach, calculating the cost level every step. This has not been investigated, but would make an interesting study for further research.

5.4 Calibrating to deal with a lack of supply

Due to equation 5.2 the model will crash when a lack of supply exists. As already stated in the explanation of this equation, the demand is fixed and transport costs are solely based on costs, which leaves no room for increasing the tariff to reduce demand for transport. To mitigate this problem several safeguards and small adaptions to earlier parts of the model were made. The first step is to remove vessels from lay-up. From experiments with the model it was discovered that the model would often stall if the supply to demand ratio was less than 1.15. This number might seem high, but because the vessels come in fixed sizes, there is always an oversupply on every route. Also from the perspective of a ship owner this does make sense as it is in general very costly to not have a ship when required, rather than to have about 15% over capacity.

If a value of less than this threshold of 1.15 is found the remaining time of all vessels in lay-up is reduced by one week, freeing up an extra number of vessels for that week. Vessels are laid up for a period of 6 months (26 weeks). This process is repeated a maximum of 26 times, if necessary. Next, the model is run, even if the ratio is still below 1.15. There is then no real expectation of improvement anymore and the number of vessels could still be just enough to meet the required demand.

This approach is sufficient to deal with the randomness of the demand. However, if the fleet has become too small to meet demand, this will happen for two or three consecutive weeks before the model finally crashes. It was also found that scrapping vessels on a weekly basis, but only delivering newbuildings once a year, could cause an imbalance between supply and demand as well. The fleet reduces in the course of the year, but in most cases trade increases over the course of the year. At first, with a large overcapacity, this is no problem. However, when a smaller overcapacity exists, the model experienced problems.

The reasons newbuildings are only imported once a year are twofold. First, the age of the vessel is expressed in years, meaning no difference exists between the moments of delivery within a year. Secondly, although every week DWT is added to the orderbook, this is such a small fraction that delivery of vessels would either have to be random, or only come in the form of very small vessels. It is inadvisable to add newbuildings on a weekly basis to the model. Therefore, scrapping should be adopted to also only scrap vessels once a year. This relaxes the need of a vessel to actually be laid up at the moment of scrapping, but all other aspects of the scrapping model remain the same. The vessels are scrapped at the end of the year, at the same time new vessels are delivered, creating a balance.

Preventing the model from crashing due to lack of supply proved to be the most difficult part of the entire modelling process. The only two parameters available to control this are the percentage of the fleet on order at the start of the model (1998) and perhaps the scrapping probability parameters. The duration from signing until delivery has been fixed at three years. This is about 10% longer than the average over the years 2000-2010 and perhaps about twice as long as the average of one of the years before that time period, see Section 4.3 for the details.

The stable value for fleet on order was about 12%. The ordering model would order about 4% of the fleet per year with this 3 year building time. This value is relatively low compared to reality. An explanation could be that since TC-rates are cost related, they are lower than normal and sometimes much lower than the values found in the data period used for newbuilding orders. Setting lower or higher values for the newbuilding orderbook at the start of the run has two effects. First, the model will revert to equilibrium of the same number of orders in a couple of years. Secondly, this return will make the 3-month difference in orderbook negative (in case of a larger orderbook). This in turn will influence the newbuilding price. However, in the estimation process newbuilding prices do not have any further influences. On the other hand, a lower or higher demand will influence the secondhand price, increasing the capital costs and thus the TC-rate of the vessels. This could result in higher ordering, although this was found to be relatively small in the calibration process. In other words, after several years the model is again stable, with only marginal differences in orderbook size. In the final situation the percentage of fleet on order at the start of the model was set to 12 %.

While the probability of vessels being scrapped was based on a paper from Knapp et al. [2008], these values posed some issues in combination with the simplification of trade and the lower value for vessels ordered. The above mentioned 12% of the fleet on order is a very natural number, but the delivery times of such a situation were much shorter than three years, more likely 1.5-2 years maximum. This means that fewer vessels will be delivered to the model. In turn this also indicates that fewer vessels should be scrapped. Furthermore, the amount of vessel in lay-up is inconsistent with reality. This is true especially at the beginning, when the simplifications of trade have reduced the actual demand for vessels. The influence of both lower new deliveries and the imbalance at the start means the scrapping probability will need to be adjusted downward. The exact amount is not known, but at least half of the original value is expected. The model was run several times until a stable situation over a period of 13 years existed. The probability of a vessel in lay-up being demolished was increased every week of the lay-up by (0.5%*age)/52. The original values of Knapp et al. [2008] were (2% + 1%*age)/52. These settings are the result of careful calibration and consideration, but do open the model up to some speculation. This matter should be further investigated in the future.

5.5 Model verification and result evaluation

With the full model available, the output of the entire model can be discussed. Before this is done, it is important to once more remember the goal of this model: to be able to compare scenarios and learn from the effects of changes of a variable have on the complex maritime market. This is done not only to study this behaviour, but also to be able to identify strategies that will be successful in most scenarios.

The first element is the activity of the fleet and the vessel groups. For the entire period it should show a stabilisation of the model. Furthermore, the relations between scrapping and ordering can be predicted from this. To check this, the next subsection look at the ordering and delivery of vessels as well as the fraction of vessels scrapped. The subsequent two subsections focus on the TC-rate of the vessels and the relation with trip length of the vessel types. Lastly, the newbuilding prices are discussed in the final two subsections.

5.5.1 Fleet composition

The fleet division at the start of the simulation period has already been described at the beginning of this chapter in Figure 5.1. Therefore, first an overview per main vessel class (Handy, Panamax and Capesize) will be given in Figure 5.2. When looking at the number of vessels (left half) the fraction of both Panamax and Capesize vessels have increased at the cost of Handy vessels. The figure clearly shows that the model, due to the concentration of cargo flows in one port per region, favours Capesize vessels. The amount ordered of a vessel group is related to the activity level of these vessels (treated in the next subsection). The fact that the original number of Capesize vessels was very small exaggerates the increase. The fleet is not even doubled in thirteen years' time, though in the peak of 2008, almost the same amount of Capesize DWT was on order as was sailing at that time. Actually, the influx of vessels should be at least 5% per year, considering almost 3% replacements and 2% growth. In thirteen years, with 5% year on year, this would add up to (1.05^{13}-1=) 89% of the original fleet ordered. The model is clearly ordering far fewer vessels, with only the fractions of DWT delivered for Capesize vessels being about 85%. The lower (cost-price based) time charter rates have a large influence on this.

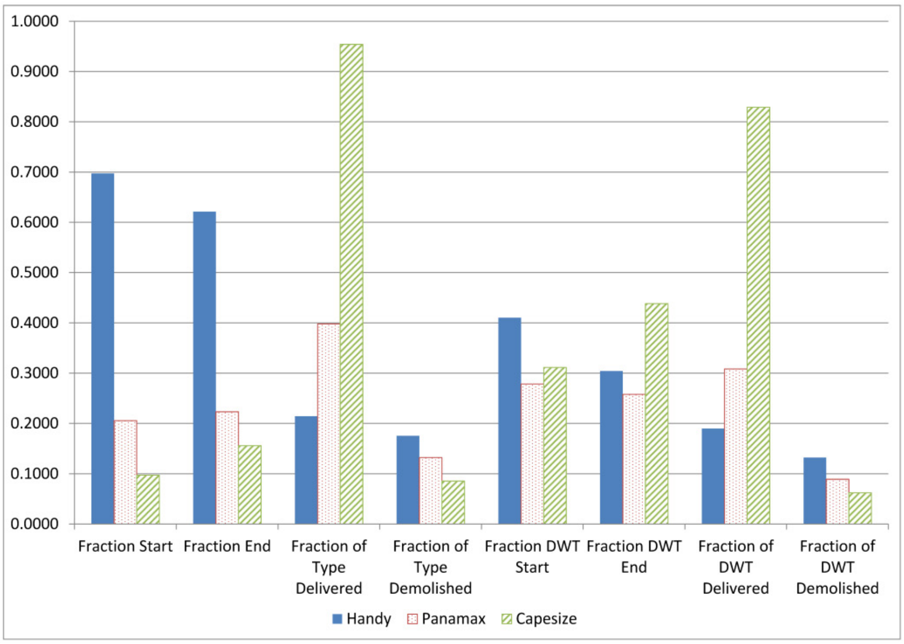


Figure 5.2: Development of fleet division and fractions delivered and demolished based on the number of vessels (Left) and DWT (Right)

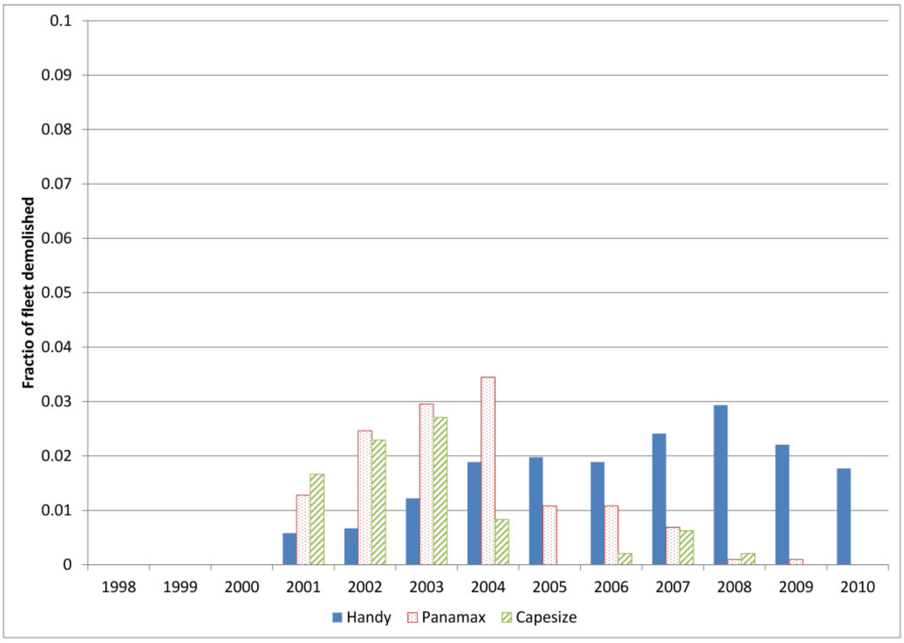


Figure 5.3: Development of the fraction demolished based on the number of vessels per class

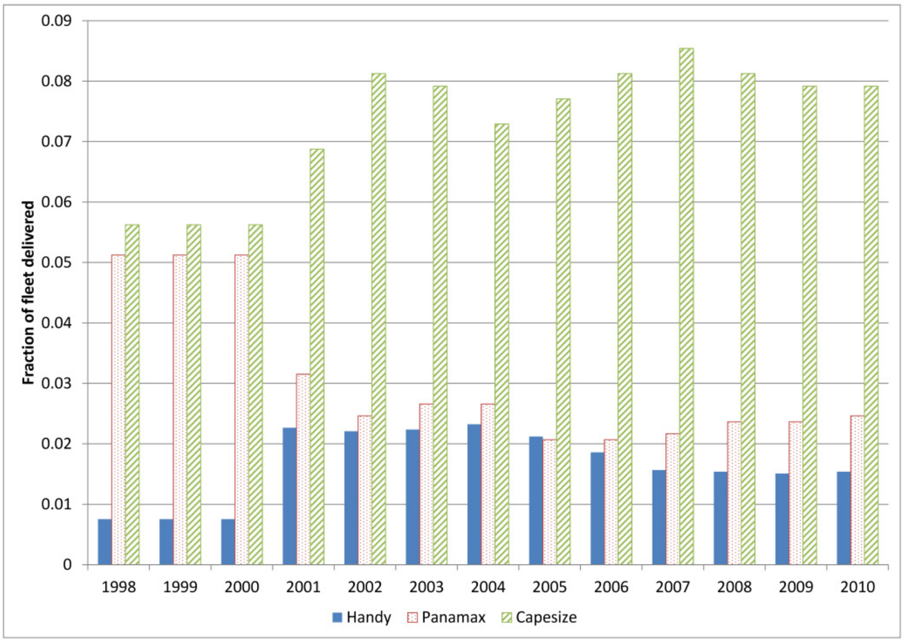


Figure 5.4: Fraction delivered based on the number of vessels per class

The fraction demolished is even lower than the fraction delivered. This is partially a model setting, but mostly caused by the fact that most vessels are active, due to the lack of new vessels input. In 13 years' time one would expect about 40% of the vessels to be scrapped and replaced, as a result of a 30 year life span. Also, in the early years over capacity is expected as a result of the simplification of one port per region. All tonnage of a region is available in one location, allowing much more efficient transport of cargo. The fact that only one type of cargo is considered amplifies this effect further. Figure 5.3 shows that at least for Panamax and Capesize vessels the demolition is almost halted in the second half of the period. Handy vessels demolition continues during the entire period. The figure also clearly shows no demolitions for the first three years. This setting was necessary to allow the model to finish the runs, without running out of transport supply, due to the much lower ordering.

The delivery of vessels offsets the demolitions. Since no exact ordering data exists for the first three years (the original orderbook), it was assumed that in years 1, 2 and 3 the same fraction as the average division of 2000-2010 is delivered. This is clearly visible in Figure 5.4. In the following years Panamax vessel deliveries are reduced to a much smaller fraction while both Handy and Capesize vessels increase significantly in deliveries. With both the first three years fixed ordering and no demolition, the model starts to adjust only from 2001 to the desired situation.

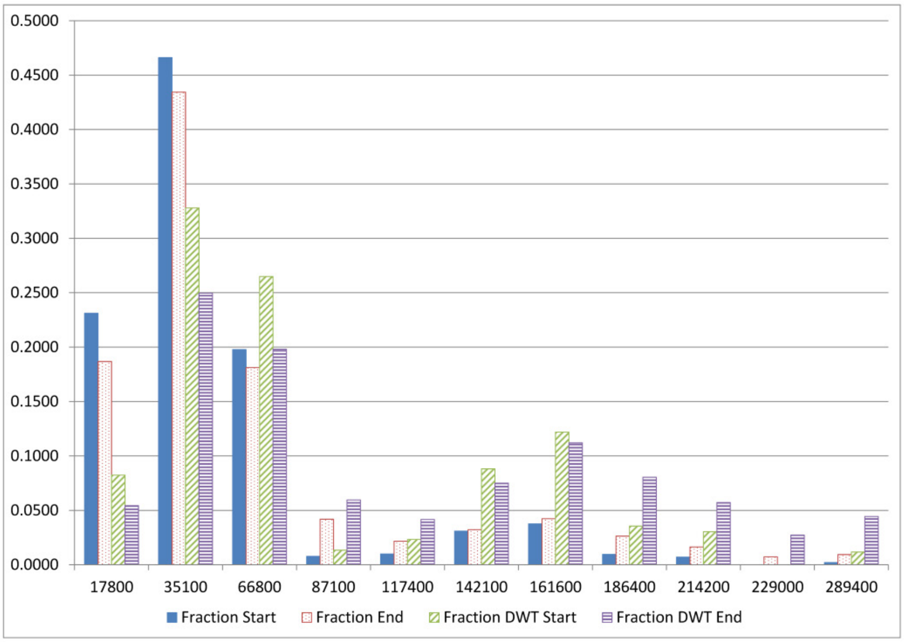


Figure 5.5: Development of fleet division and fraction demolished based on the number of vessels and DWT per size group

The fact that larger vessels are preferred is also observed in the last figure (Figure 5.5) of this subsection. It shows the changes in fraction of vessels at the start and end of the period run. This figure indicates that in most cases a move within each size group to the larger version and also overall the trend is towards larger vessels. The main exception is the increase in vessels of 117,400 DWT. Though this effect most likely is caused by the lower vessel prices seen in the non-linear relation between DWT and secondhand or newbuilding prices earlier. The difference between this trend and the trend of a scenario is the most interesting, rather than the absolute values. This part of the model is deemed verified and functioning.

5.5.2 Fleet activity

With the fleet size changes discussed here, the next step is to investigate the behaviour of the fleet. This subsection will investigate the activity level of the fleet and its division over time, size and age. The first figure (Figure 5.6) shows the activity of the fleet averaged per year as well as the fraction the fleet spent in waiting and in lay-up. Around

2001 the situation destabilises somewhat. This is the same year that the demolition and ordering of vessels presented in the previous subsection are solely based on model behaviour. After 3 weeks of waiting vessels will have to either sail or move into lay-up. Especially in the last 6 years lay-up is low, about 10%, while waiting also remains quite stable around 10% of the fleet. This can be explained by the fact that waiting is the cheapest option for all vessels. Therefore, it is the preferred assignment. When after three weeks the vessel has to move to lay-up, it can very well be that it is cheaper to assign this vessel and have another vessel wait for cargo.

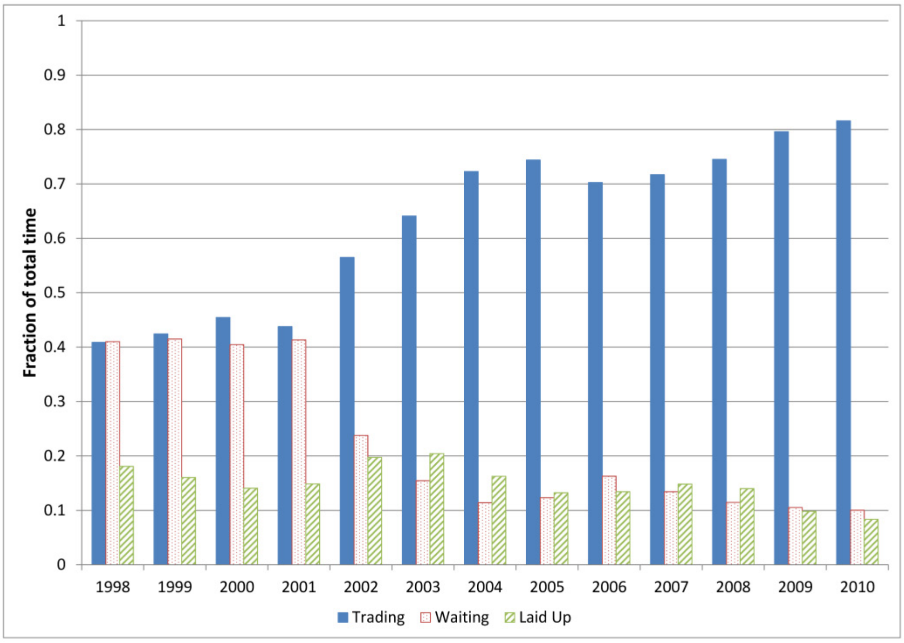


Figure 5.6: Yearly average fraction of the fleet (in numbers) active, waiting for cargo and in lay-up

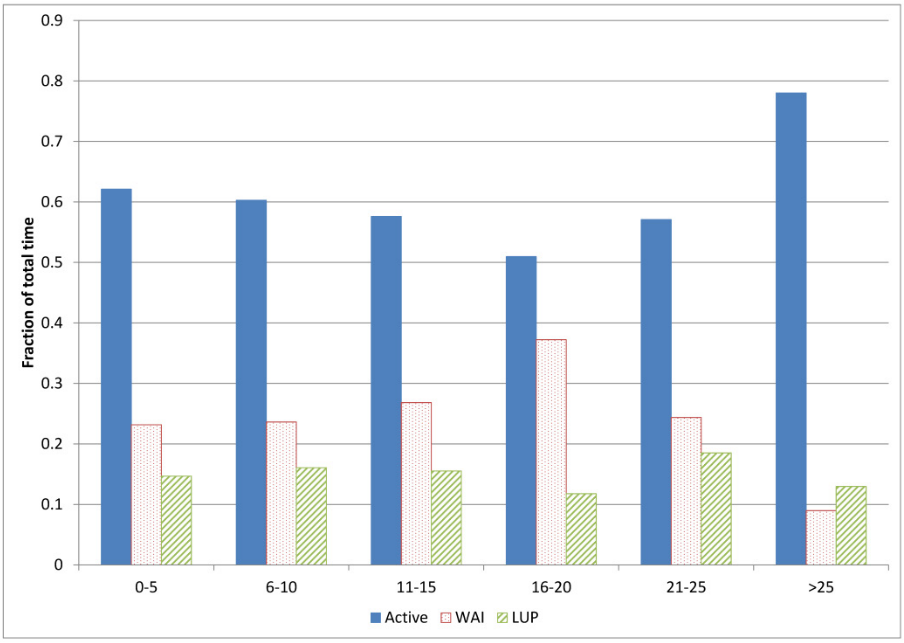


Figure 5.7: Average fraction (over 13 years) of the fleet active, waiting for cargo and in lay-up split by age group

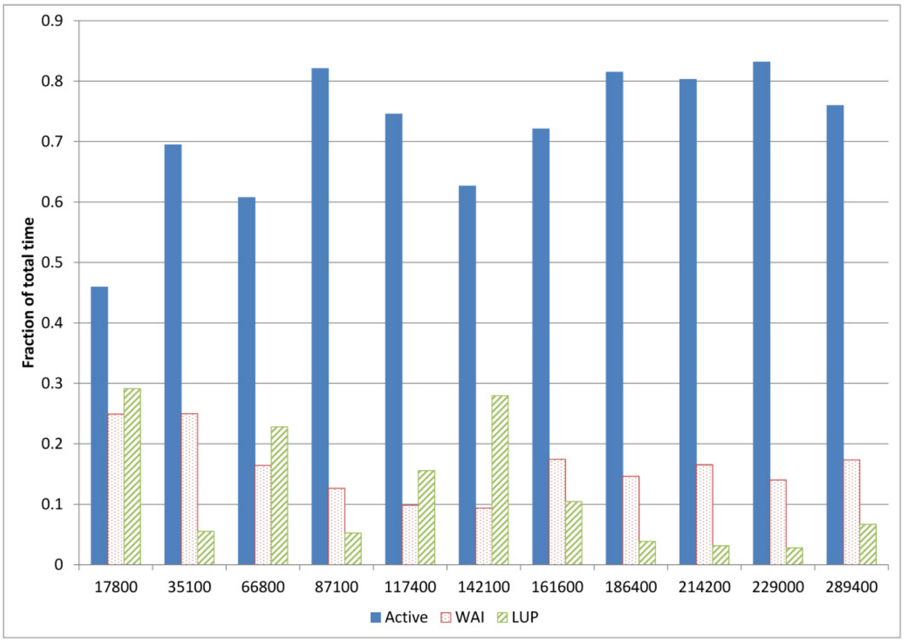


Figure 5.8: Average fraction (over 13 years) of the fleet active, waiting for cargo and in lay-up split by size group

While the figure above gives a good insight into activity over time, it does not show the performance of each vessel group. The two figures, Figure 5.7 and Figure 5.8, show the same fractions applied as averages over the 13 years run, divided by age (Figure 5.7) and Size (Figure 5.8). These figures show the costs of vessels in the 25+ years age group are higher than all other vessels. Although lay-up is lower than average, activity is lower and waiting is much higher than with the other size groups. This could be caused by just one or two vessel types, which will be discussed hereafter. The division over the size groups is in line with the earlier treated distribution of orders for new vessels. The preference for the larger vessels is again clear from this overview.

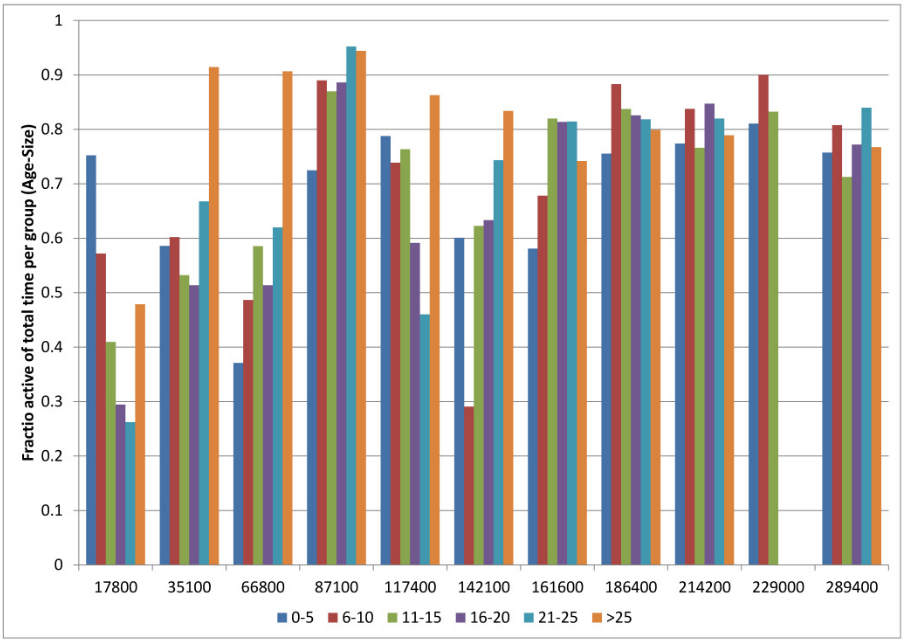


Figure 5.9: Average fraction (over 13 years) of the fleet active split by both size and age group

Figure 5.9 answers the question if the dip in activity for vessels in the 16-25 year age group is general or caused by just one or two size groups. This figure indicates that two of the size groups, 17,800 and 117,400 DWT show a large dip for this age, while others only show a slight decrease or none at all. On average the activity of this group is lower than the others. It could be related with the estimation of costs for this group of vessels. A number of simplifications were made when estimating costs and this could be the result of those assumptions. A recommendation is therefore to further investigate these costs in the future, although for now the slight difference in preference will be accepted as it is relatively small. Lastly, the fact that for 229000 DWT three columns seem to be missing is caused by the fact that in 1998 no vessels in this size group were sailing.
The above figures have clearly shown both the expected preference for larger vessels and the absence of a clear age preference. For certain size groups, age discrimination exists. The next subsection will look further into the activity of the vessels, focusing on where they were active.

5.5.3 Location of Activity

Before looking at the activity of the vessels the division of trade is first examined. Figure 5.10 shows the division of trade, expressed as Ton*miles over the various route lengths. Short sea shipping, in this case considered less than 1000 miles, is a large part of the trade, especially considering the low amount of miles involved. The next big section 2000-3000 miles represents trade within one continent e.g. Asia or Europe; this is followed by 4000-6000 Miles, the range of roughly one ocean crossing; either the Atlantic, Pacific or the Indian. Lastly, the trade between Europe and Asia can be found in the 11000 miles plus section.

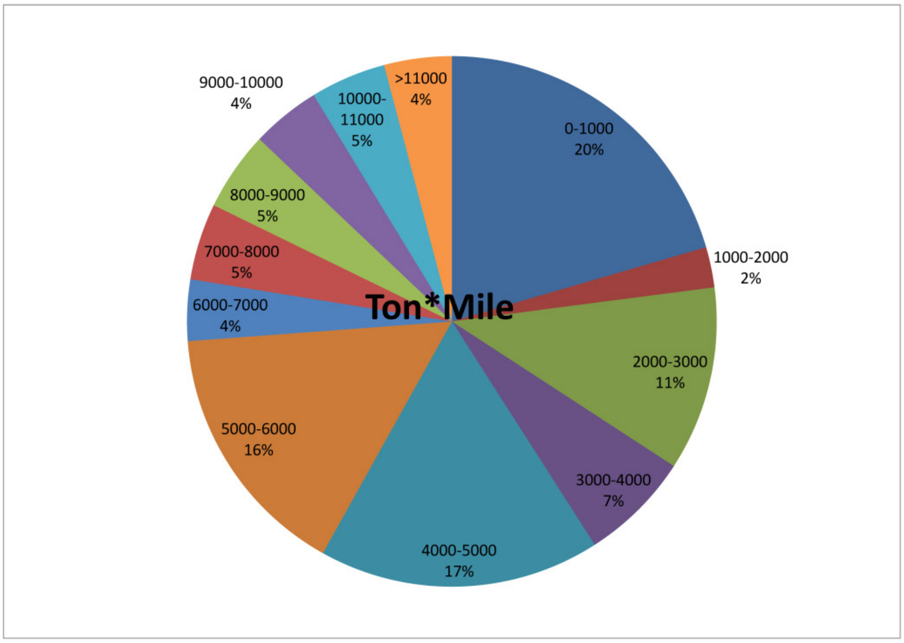


Figure 5.10: Average fraction (over 13 years) of the ton*miles transported on a certain route length

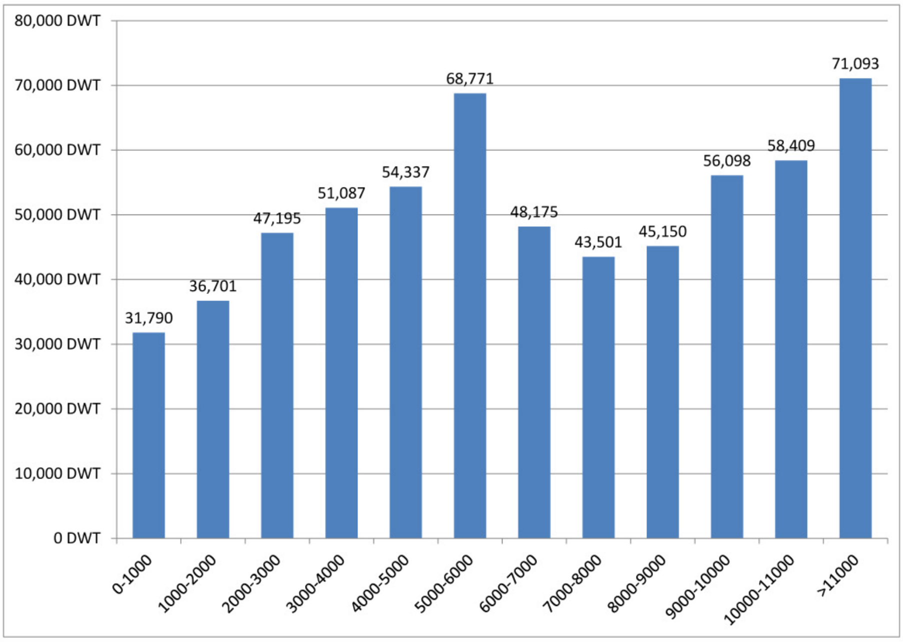


Figure 5.11: Average vessel size on each route length range

A first look into the division of vessels over the trade is obtained by dividing the transported ton*miles of a particular route length group by the total voyage distance in this group. This total voyage distance is the sum of miles travelled by all the vessels that were on this trade. The resulting tonnage is a measure for the size of the vessels sailing on the route. In general one would expect an increase in size for larger distances due to the economy of size. The benefit in travelling costs for larger vessels only pays off for longer sailing distances as the increase of port times on short routes has an adverse effect. Figure 5.11 shows the results of this calculation. The clear exception is the large vessel size for the routes between 5,000-6,000 miles. This occurs because the largest cargo volume for this route is the transport of cargo from Eastcoast North America to Westcoast North America. If a Capesize vessel tries to sail this route, it will have to go all the way around South America, while the other smaller vessels can use the Panama Canal, saving about 8,000 miles. This means the Capesize vessel will not be on this route, as the distance is different. These routes are therefore optimal only for Panamax vessels, and as a fee has to be paid for the Panama Canal, costs need to be reduced here, by using larger vessels only.

While Figure 5.11 gives a first indication of the average size of the vessel on each route length group, Figure 5.12 shows the division within a size group over the different route lengths. Note that the total per size group equals one, which is not the case per route range.

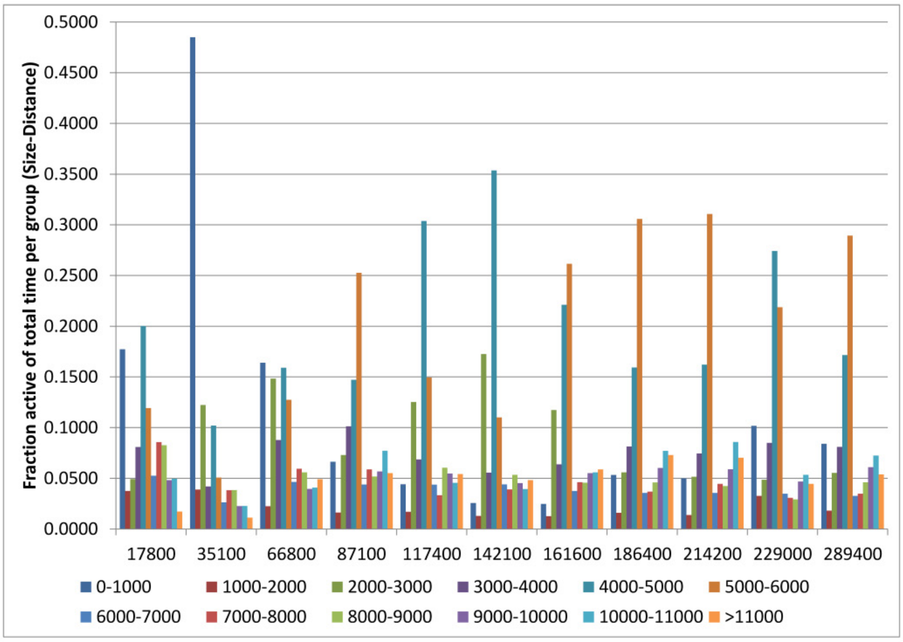


Figure 5.12: Average fraction (over 13 years) of the fleet active split by size group

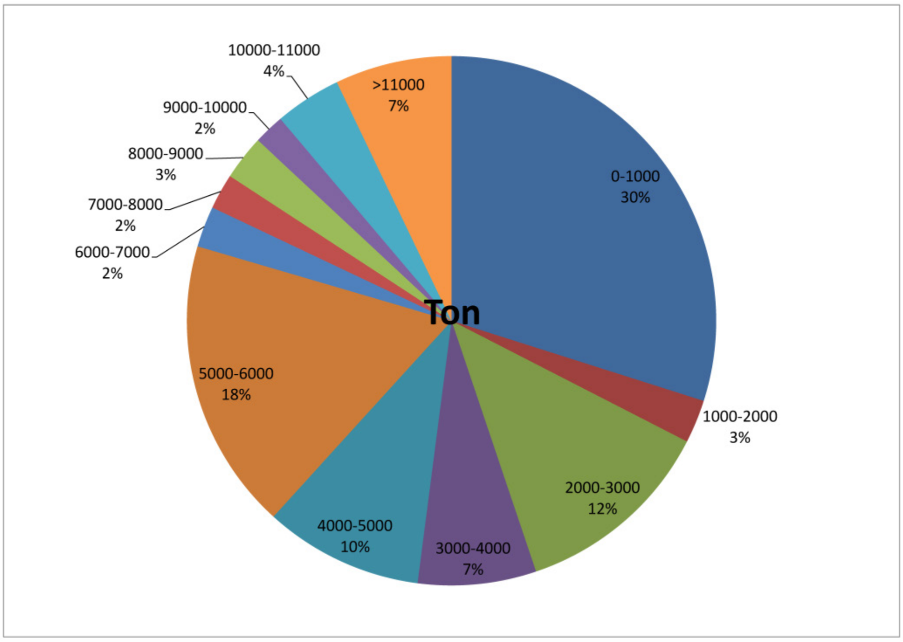


Figure 5.13: Average fraction (over 13 years) of the cargo transported on a certain route length

Examining the aspect of travelling is also interesting. The cargo traded within the simulated period is distributed as shown in Figure 5.13. Dividing the ton*miles by the cargo transported gives the miles travelled on that route. This is an overestimation, since port time has been taken as travel time and the number of voyages is not known. Figure 5.14 shows the factor of travelled miles (including port time) divided by the average route length.

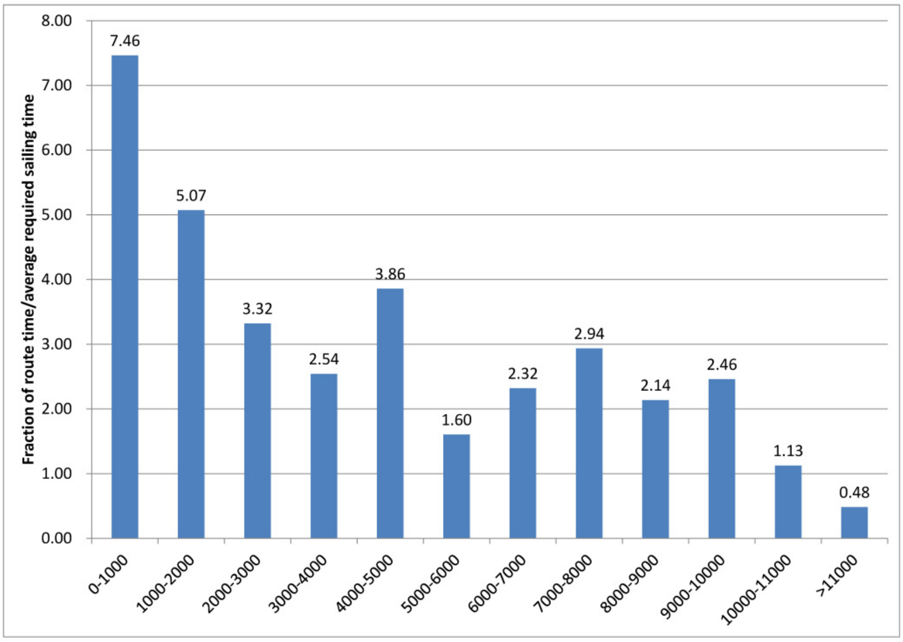


Figure 5.14: Average extra sailing/miles travelled on each route length range

The fact that the first two routes have such high values is largely caused by port time (around 1 week) that is converted to travel time in the earlier ton*miles calculation, while real minimum travel time (not coming from another port) is rounded up to one week. This means the number of miles travelled is at least quadrupled for the shorter routes. Even after taking this factor into account, the average distance travelled is still about two times the average for the shortest routes. This does not mean that many extra miles are travelled since the ton*miles are based on vessels travelling the route. Instead, extra tonnage could be increasing the ton*miles value rather than extra miles. In the calibration phase, described earlier in this chapter, it was mentioned that an oversupply in tonnage of about 15% was required for the model to run smoothly. This was also caused by the fact that vessels cannot be sailing for e.g. 60% on one route and 40% on another. The last thing to take into account is the fact this is the average of the routes, not the weighted average, which could be longer. Considering these elements and the fact that travelling time is rounded up to entire weeks, the above values seem to be realistic.

A last point to add is the value below one for the largest route. Apparently the average is a bad representation of the average travelled miles on this route. This real (weighted) average is much lower, hence the value below one. The next step to consider is the prices paid for the transport of materials on these routes. This is the subject of the next subsection.

5.5.4 Cost of Transport

A priori, one would expect the costs of transport for each route to rise with distance. As the distance is increased, the vessels have to travel longer, incurring more costs. On the other hand, a larger vessel should be able to work for a lower rate (per ton) than a smaller vessel on the same route if sufficient cargo is available. This occurs because the operating and crew costs of a vessel are not linearly dependent on the vessel's size.

Lastly, this benefit for larger vessels would be larger for longer routes since they also spend more time in port due to increased loading and unloading time. All this is present in Figure 5.15, which shows the model output for the average freight rate of the three vessel types for each route length range. From an economic point of view the service offered by a large vessel is equal to that of a small vessel, why is the price difference accepted? This has to do with the fact that storage costs increase if larger quantities are brought in at once, hence larger vessels should sail cargo at lower costs to compensate for this.

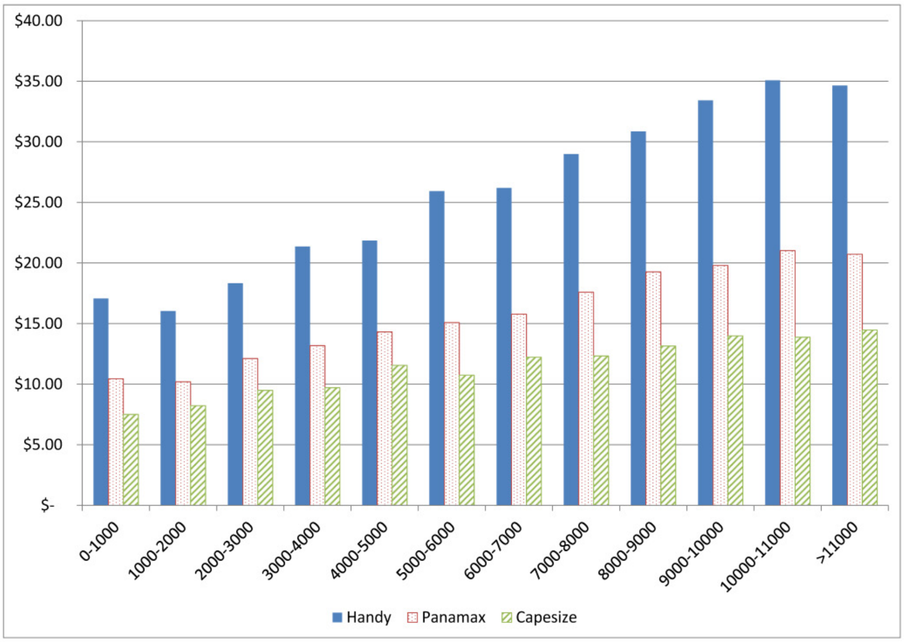


Figure 5.15: Average freight rate (USD/ton) for each route length range and vessel type

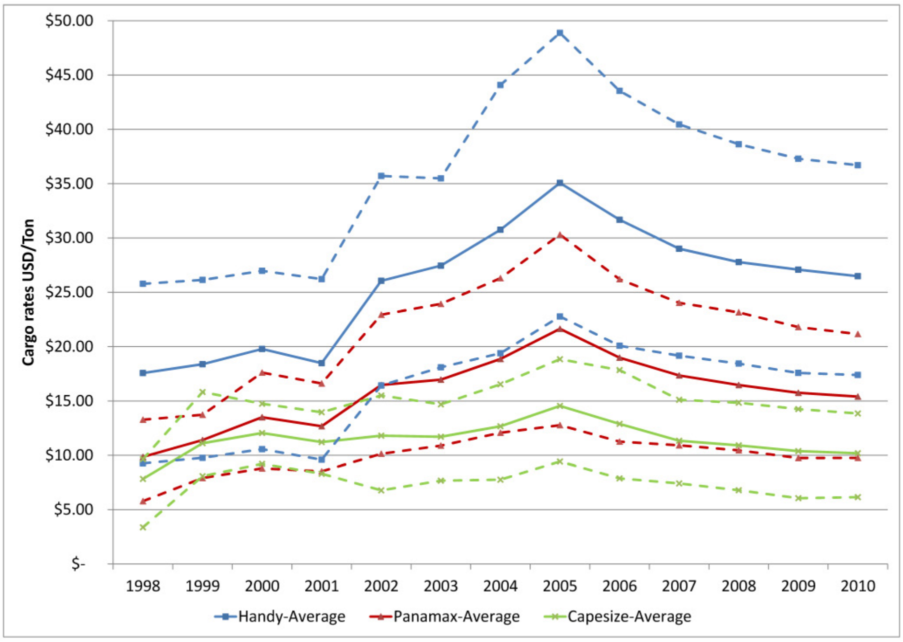


Figure 5.16: Average, maximum and minimum freight rate (USD/ton) per year for each vessel type

Another cross-section of these rates can also be studied: the development of the minimum, maximum and average rate over the period under investigation. Figure 5.16 shows that the bandwidth of each vessel type remains relatively stable and displays the same trend, a peak towards 2005 and a return to the level of 2000-2005 thereafter. This peak can also be seen in the activity level of the vessels. 2005 is also the starting year for simulated data; hence not all values will have smooth lines around this year.

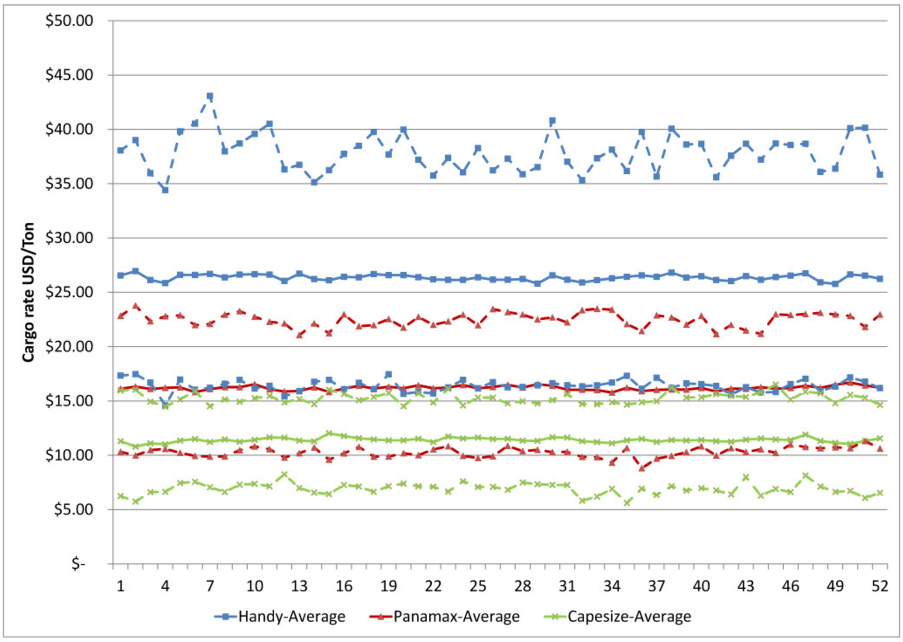


Figure 5.17: Average, maximum and minimum freight rate (USD/ton) per week for each vessel type

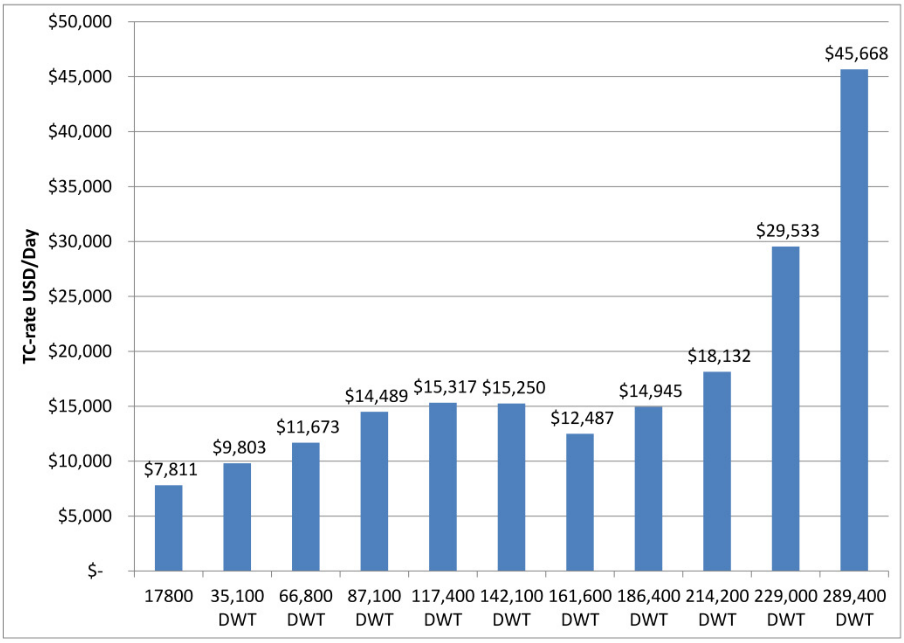


Figure 5.18: Average TC-rate (USD/day) for each vessel size group

Finally the data can also be combined into an average rate per week (Figure 5.17), to see if there is any influence of the seasonality introduced in the trade data. This figure shows the influence of seasonality can be disregarded when looking over an entire year. This seems strange at first. However, seasonal fluctuations can be dealt with quite easily since on average about 10% of the fleet is waiting for cargo and every week ships can be taken out of lay-up (without extra costs). Also not all routes displayed seasonality, which will level out part of this effect. Furthermore, the influence of the randomness of the trade can be expected to be eliminated by averaging the 13 years.

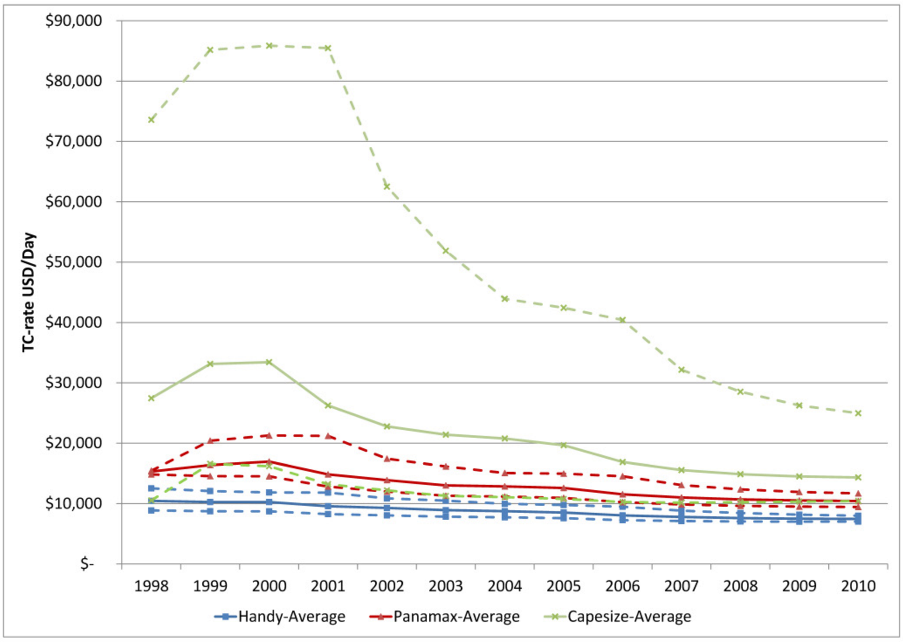


Figure 5.19: Average, maximum and minimum TC-rate (USD/day) for each vessel type

The freight rates are determined by the vessel costs. These are based on sailing costs, fees and the time charter rate (TC-rate) of the vessel. This rate is averaged over the vessel ages. Figure 5.18 gives the TC-rates of each size class. The lower values for vessels of 161,600 DWT were also seen in the estimation of secondhand values (Section 4.1.2). It is very likely that the lower secondhand value of the vessel is directly responsible for the lower TC-rate since all financial costs (interest and depreciation) are dependent on this value.

These values do not seem out of place, though the final two bars seem exceptionally high compared to the others. Comparing Figure 5.19 and Figure 5.20 explains the extreme height of these bars. Figure 5.19 shows the average, minimum and maximum TC-rate for each year for the three vessel types. Figure 5.20 shows the average yearly TC-Rate for the size groups within the Capesize categories. For the first 5 years the TC-rates of the large vessels, especially the maximum rates, are well above the other rates.

The starting values for the TC-rate are relatively close to the final values of the vessel size group. This was done through several iterations. However, the phenomenon reappeared every time. This indicates that there is an unbalance at the start between the TC-rate and secondhand price calculated from this TC-rate. Besides the TC-rate, this price is influenced by the age, DWT, demand and LIBOR. DWT is fixed, but since the other size groups do not display this behaviour, the large DWT is apparently more susceptible to this variation in input. The vessel age changes since many new (young) vessels are ordered and delivered in these size groups. This should actually increase the TC-rate because younger vessels are more expensive. In Figure 5.21 both the percentage of the fleet on order as well as the LIBOR rate are shown. Both diminish over time, but the influence of the LIBOR is linear in the newbuilding model (section 4.2), while the influence of demand has a fourth power in the equation. Hence the combination of DWT and demand seems to be the reason for the high secondhand values and financial costs of these vessels.

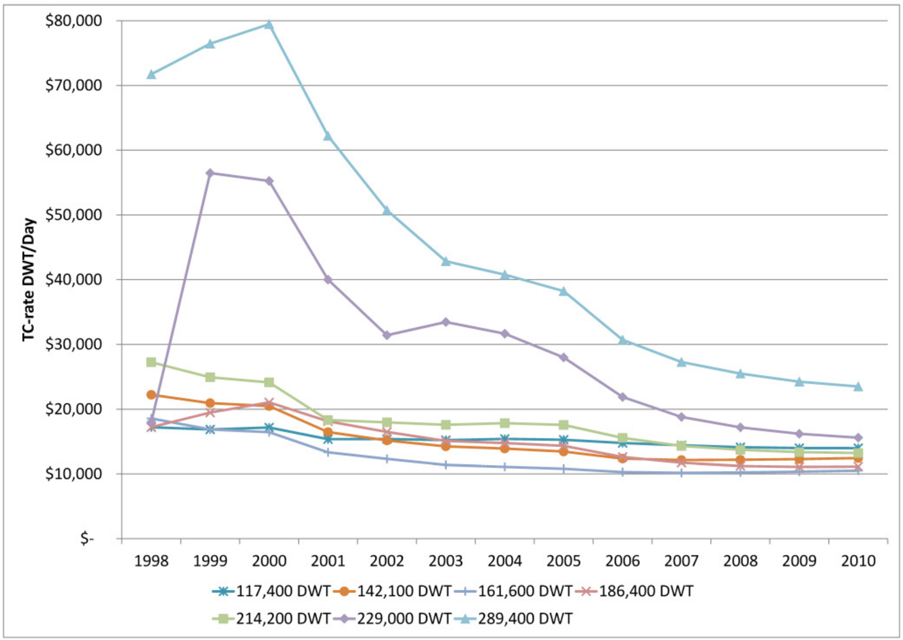


Figure 5.20: Average TC-rate (USD/day) for each vessel size group of the Capesize type

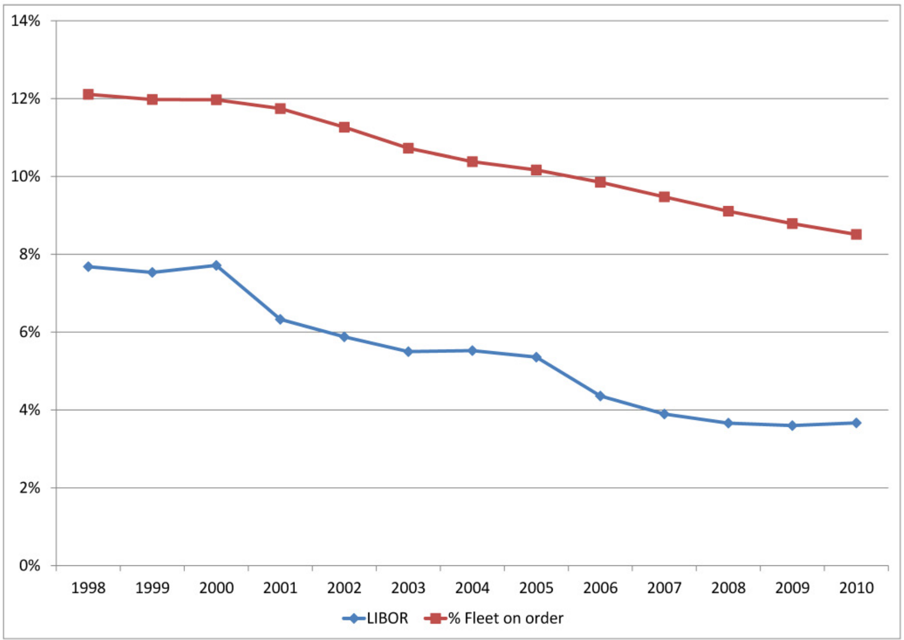


Figure 5.21: LIBOR and percentage of fleet on order over time

The influence on the freight rates is minimal, mainly because at the start no vessels exist in the 229,000 DWT group and only ten exist in the 289,400 DWT group. Moreover, during the last 5 years, which form the basis for the scenarios, the difference is much smaller. Therefore, this point will be taken up as a recommendation, but will not be further corrected within this research.

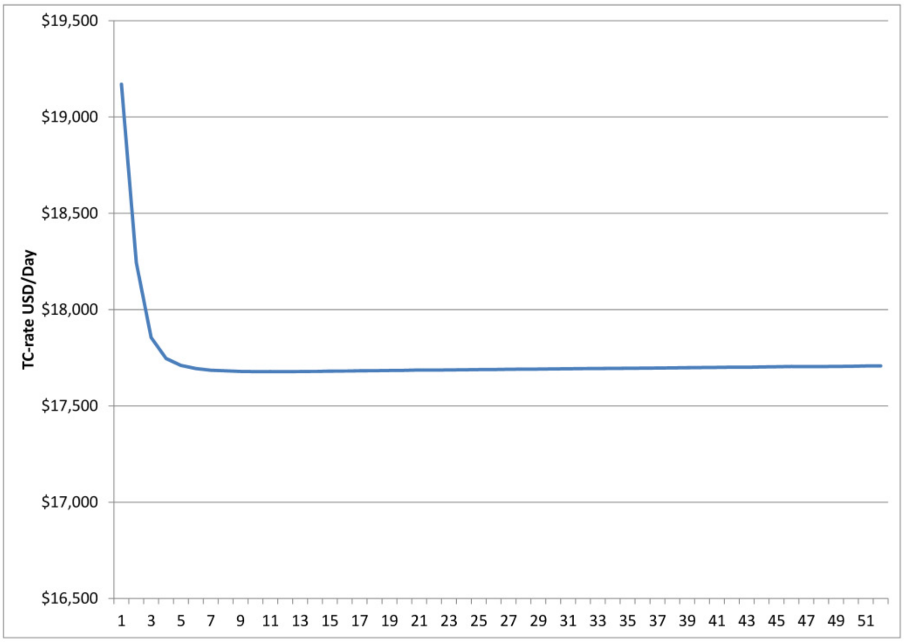


Figure 5.22: Average TC-rate (USD/day) averaged per week

The final figure of this subsection (Figure 5.22) shows the average TC-Rate per week. The peak at the start of each year can be contributed to the choices made concerning the changes in the fleet. After the last week of each year, the demolition and delivery of vessels is executed. This causes a disruption in the smooth flow of percentage of the fleet on order and the 3 month difference of this value. Also the age profile of the fleet changes, perhaps requiring a change of vessels in lay-up. It is a small, but systematic error, not hampering the comparison of scenarios.

5.5.5 Newbuilding

The previous subsection already touched upon the subject of the orderbook. This subsection will investigate the output related to the newbuilding of vessels. Figure 5.23 below shows an overview of the orderbook using both an absolute as well as a percentage axis. The amount of vessels delivered and ordered is almost equal in all years, hence the total orderbook does not change significantly over the years. However, as the fleet increases, the percentage of ships on order compared to the current fleet is reduced annually. The speed of decline is slow, as can be seen in the 3 month ratio change. This line is mainly just below zero for the entire period.

The delivery of the orderbook is shown in Figure 5.24. The orders are delivered to the market after exactly three years; hence a good indication of the composition of the orderbook is obtained from this figure as well. The large difference between the first three years and the remaining years can be explained easily by the fact that for the first three years no orders from the time before the simulation started were available. These values are based on the average ordered vessels in the period 2000-2010, for which data was available. However, the model clearly shows a different preference, especially where Panamax vessels are concerned. It also spreads the Capesize vessels over more size groups, almost all larger than obtained from the order data. The simplifications in the amount of ports and countries are presumed to be at the root of this.

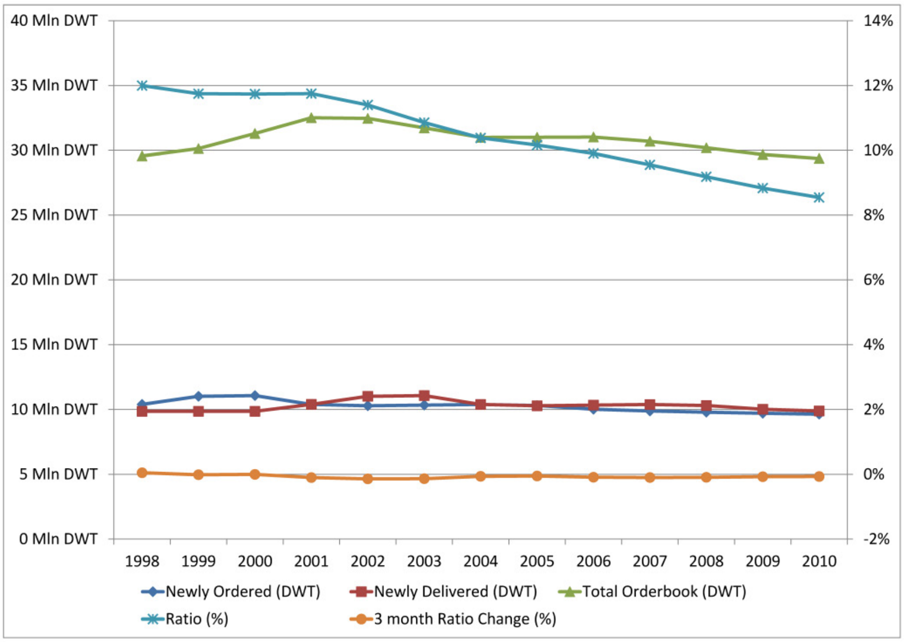


Figure 5.23: Data on the orderbook development over time

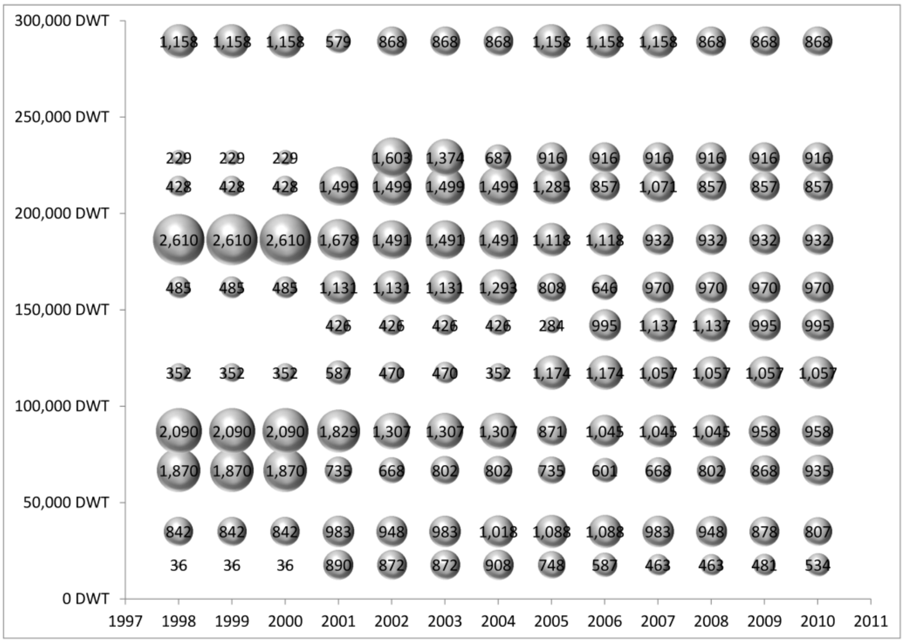


Figure 5.24: Data on the vessels delivered over time (Source: Author with data from Clarksons)

While the orderbook is an important aspect of the newbuilding market, a vessel's selling price is also very important. When modelling the ordering (4.3.3) it was found that no strong link exists between the ordering and the price of the vessel, or the price of a young secondhand vessel. The only link between them was the TC-rate. Therefore, one cannot expect to find a strong link in the results either. Figure 5.25 supports this expectation.

The secondhand value is moving in a fashion similar to the one seen for the TC-rate of large vessels. Since this is not an average weighted for the number of vessels, the influence of the high TC-rate is much larger. The average newbuilding price seems to be quite stable, fluctuating within a twenty mln USD range, with an average price of forty mln USD.

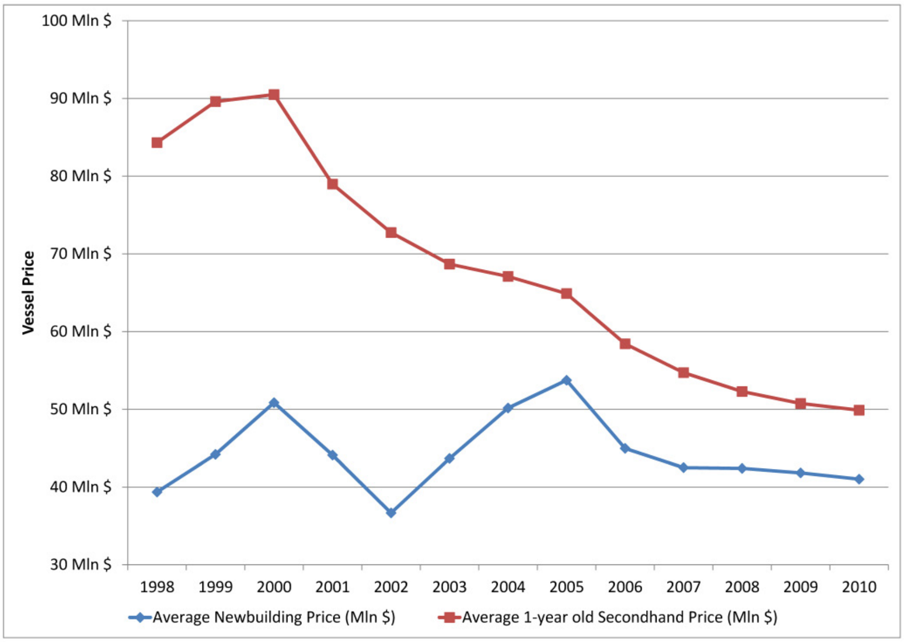


Figure 5.25: Average newbuilding and 1-year old secondhand price development over time

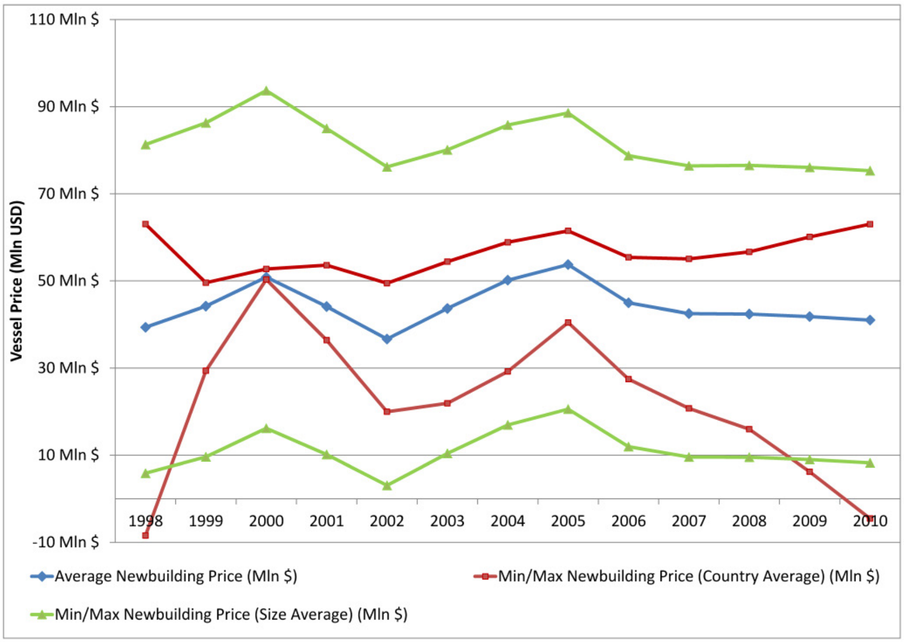


Figure 5.26: Max and min newbuilding prices over time for countries and size groups

The fluctuation in the newbuilding price is not caused by only changes in TC-rate, other influences on the price seem to play a much larger role. The average price is both the average of the regional prices as well as the average of the size group prices. In Figure 5.26 both the maximum and minimum lines of these averages are shown. While a larger vessel will be more expensive than a smaller vessel, the lines concerning the difference in size follow the same pattern as the average line. Looking into the details for each size group revealed no peculiar behaviour.

The maximum and minimum lines for country averages are not similar at all. They sometimes converge while other times they diverge. In 2000, all of the prices were the same for each region. A more detailed look is provided by Figure 5.27. Here, regions are grouped in larger regions to make the graph more readable, and the differences are much clearer. This figure shows the same variations and behaviour as before. The economic model causes South America to have the best prices after 2002, which is interesting and certainly not expected. However, this trend holds even after evaluating individual countries.

Figure 5.27: Average newbuilding price development over time for 5 large regions

The fact that none of the vessels built were contracted to South America certainly has an influence on this. No data of South America was used in the newbuilding price estimation. Also politics play an important role in which country is successful in shipbuilding. Especially in the start-up phase government support is indispensable. In general, it is difficult to blindly trust this newbuilding price model per country. The averages are very useful as well as the differences in price development. The goal of predicting the next ship building nation cannot be accurately fulfilled using this model yet. To further evaluate these differences, the country specific input for the newbuilding price is evaluated. An overview using minimums and maximums is given in the remainder of the section.

The first two elements to be discussed are the TC-rate and the wage rate of a country. Figure 5.28 gives an overview of both elements. The TC-rate is averaged and made dimensionless since it is the same for all countries. Wage rate is expressed in USD in the calculation of price, but here it is presented dimensionless for easier comparison. The large increase of the maximum wage is the most striking part of this graph. This influences the overall average wage, which rises over time. This increase in average wages would mean an increase in newbuilding price. The actual influence on price between the highest and lowest is 2.5 mln USD. This difference is indifferent of the size of the vessel, but found considering all values, both time and country related. The effect of the average TC-rate offers an offset to this by decreasing over time. Though this offset is already 2.5 mln USD for the smallest size vessel and about double for the 35,100 DWT vessels. In either case, neither explains the jumpy nature of the average newbuilding price development very well.

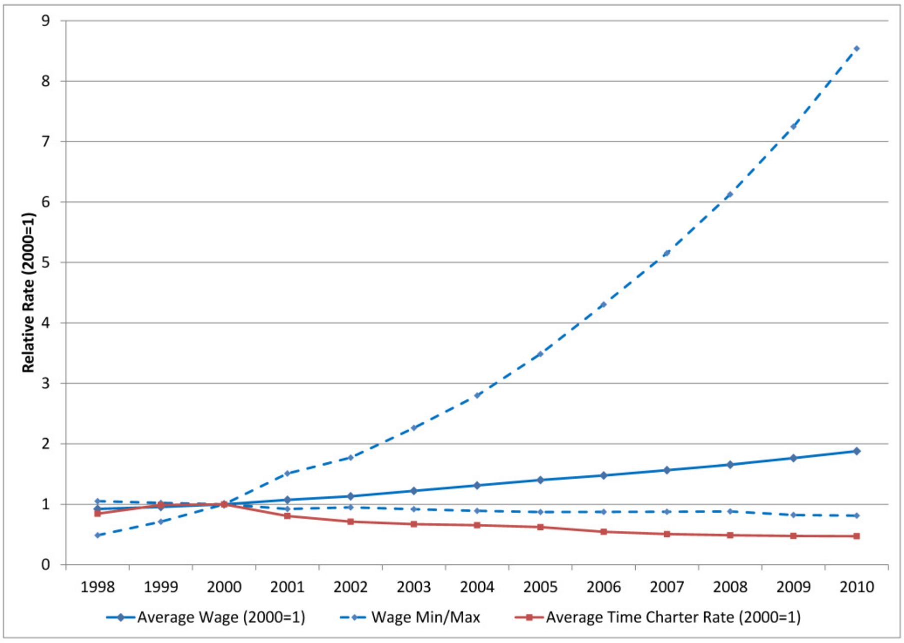


Figure 5.28: Wage and TC-rate development over time

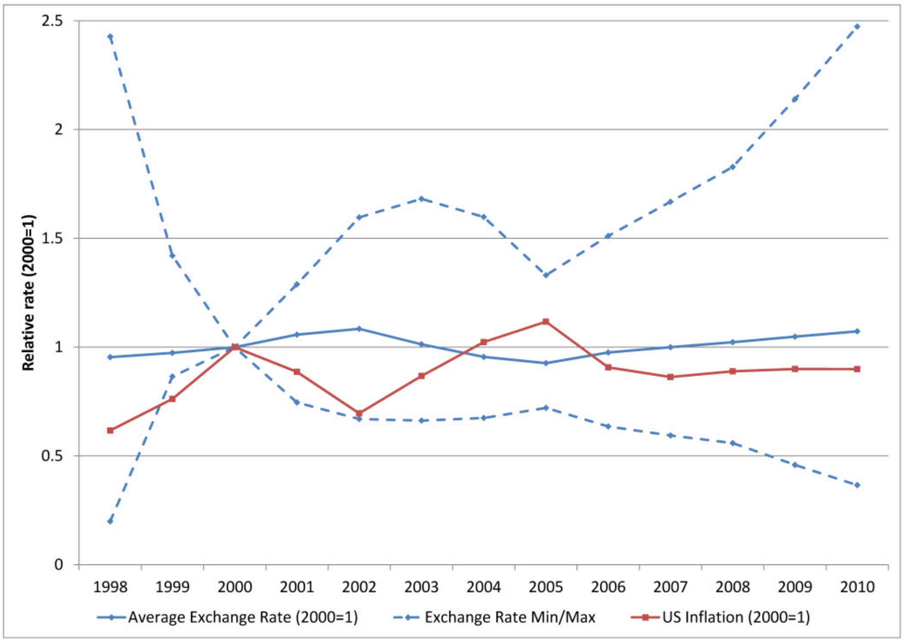


Figure 5.29: Exchange rate and North American inflation development over time

Figure 5.29 shows the two remaining variables that influence the newbuilding price. US or North American inflation was found to be a better predictor of the newbuilding price than local inflation, explained in section 4.2. This value is used in all price models and therefore no minimum or maximum is presented here. Both the US inflation and the different exchange rates show a jumpy behaviour. The US inflation can cause a difference in price of about 15 mln USD, a much larger influence than either TC-rate or wage can compensate.

The average exchange rate is rather flat, though there are large differences in the exchange rate. These are actually responsible for most of the price differences over time and per country as the maximum difference is 76 mln USD, which is independent of time and country. Within one year this is only slightly reduced to about 70 mln USD. The large influence of the exchange rate will be something to monitor and improve upon in the future as it causes large fluctuations and differences in newbuilding prices seen in Figure 5.26. Lastly, the fact that almost all these values (except the TC-rate and wage) have their 2000 value set to one explains the lack of variation in price seen in that figure as well.

The fact that the model indicated South America to be the best location for shipbuilding is interesting. The real exchange rate might not have followed the pattern of the model, resulting in a less favourable position for South American shipyards in real life. However, a far more important reason, is probably the lack of government incentives. In many other shipbuilding nations, the government has been or currently is heavily involved. Shipbuilding is both a way of obtaining foreign currency and improving the industrialisation of a country. Such aspects are not part of the model, but these results do provide material for interesting discussions on this matter.

5.6 Conclusions

This chapter has shown that the last module of the model functions properly and that the combination of all these modules is able to generate realistic results for the period of 1998-2010. The most important remarks to keep in mind are the preference for larger vessels as a result of the simplification of trade. It is also important to see that the TC-rates and secondhand prices of large vessels are out of balance in the first part of this period. Lastly, the ordering seems to remain stable and on the low side, requiring a lower demolition rate than would normally be expected. As discussed in section 5.3, an approach using PSO or a genetic algorithm might be able to solve this problem, but this has not been further investigated.

With the information from this chapter the model representation can be updated and finished. Figure 5.30 represents the final model. The assignment module is split in two important parts: the OR assigning module, which assigns vessels using the formulas of this chapter, and a status part that keeps track of the vessels. The module stores the current activity as well as the duration and costs of the trip. It also indicates which vessels are available for assignment on each route and during each week. With the model verified, the next step is to use it in a number of investigations, which is done in the next chapter.

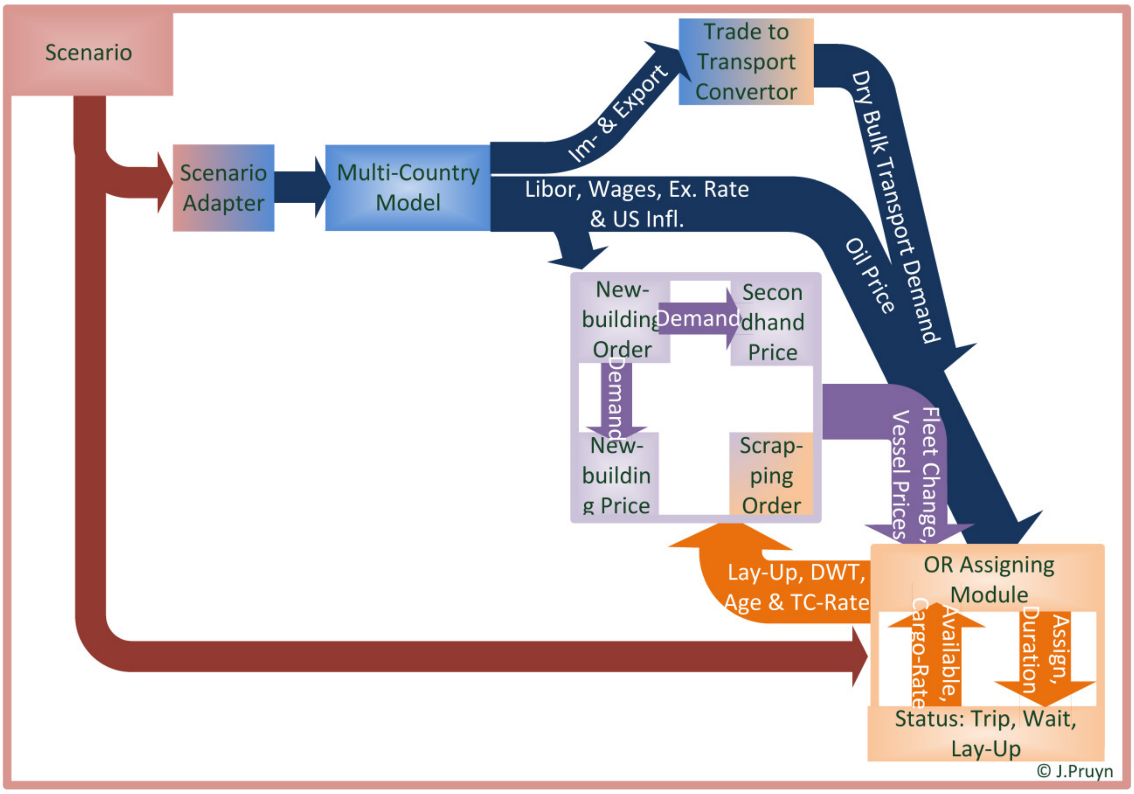


Figure 5.30: The final model representation, including the assignment module

6. Scenario Analysis

This chapter contains the answers to the research question and its sub questions asked in section 1.2:

Main. What are safe investments given a set of scenarios?

1. What will the demand for transport do on the most important routes?
2. What fleet development will be required to support this demand?
3. Which type of vessels will be built and which will be phased out?
4. How will the newbuilding sector react to these changes?

To give an answer to these questions a number of variations needs to be tested. As the goal is to both answer these questions and see the capabilities of the model, the scenarios should apply to different parts of the model and vary in complexity. Many different scenarios can be thought of and implemented in the model. Still there is a reasonable amount of effort in setting up and running a scenario. Hence their number should be limited, but cover a large part of the options available to change within the model.

Inspired by recent events and interest the first scenario considered is the opening of the Northern Sea Route, north of Russia. The impact of such a change will only be in the length of a limited number of routes. All other outcomes remain equal. This is a nice test case to see how the shipping market and assignment module deal with this. The second scenario was also inspired by recent events. The oil price has increased significantly in the recent past. As the oil price is not only connected to the fuel price, but also plays a small role in the Macro-Economic Module, the effects of this scenario are slightly larger. The third scenario envisioned will alter the outcome of one or two macroeconomic variables. To investigate how such changes propagate through all the different modules. In this case the growth of China is limited. The fourth and last scenario is the most complex one. It simulates a trade breakdown between two regions. Trade is rerouted and re-assigned, affecting all modules as a significant number of macroeconomic variables will have a different outcome compared to the base run.

The four sub questions will form the basis to study each of the scenarios by presenting the scenario results. The main question will be answered in section 6.5, considering results from all scenarios. The last section contains the conclusions drawn from this chapter.

6.1 Scenario 1: Opening up the Northern Sea Route

This section investigates the effect of opening the Northern Sea Route to regular trade. It will not take into account the extra costs of reinforced vessels, but will include the fee for the ice breakers. The first subsection introduces the concept of travelling via the north side of Russia, while the second subsection details the implementation of this scenario. Lastly the results are presented in the final subsection.

6.1.1 Introduction

Since the discovery of Asia by Marco Polo, countries and ships have tried to find a shorter route than sailing around the cape of Africa. The Suez Canal has greatly reduced the travel time, but since the Northern Sea Route (NSR), via the north of Russia, was opened in 1935, companies have looked at this route with new interest. It greatly reduces the sailing distance between Northern Europa and Asia. In recent years ice decline in the arctic is a fact (Ho [2010]) and year round shipping through the NSR is a viable option for the near future. Ho predicts coastal routes to open early 21st century, while the sea passage may not open until the end of the 21st century.

Schøyen and Bråthen [2011] calculated that currently shipping is already feasible (in the summer season) for small bulkers. Granberg [1998] made an extensive analysis of the history and the impact of opening this route. Granberg finds that especially the cargo fleet is old and will require replacement to be able to access this route. Implementing this specific renewal and the technical knowledge required to design and build such vessels is beyond the scope of this research.

Lastly the environmental aspect must be considered. Corbett et al. [2010] have performed a large study on the effect of shipping on the emissions in the arctic. They introduced both growth and engine technology/policy scenarios. While the increase of local emissions is increased significantly by the increase of transport through the arctic sea lanes, their study does not take into account the reduction elsewhere in the world. Their study does state that the effect of local emissions can affect the ice more than 'general' emissions, due to short-lived gasses that affect snow and ice. The next section discusses the set-up of the NSR-scenarios tested in this research and starts with the basic problem of establishing the distance reduction for the relevant trades within the model.

6.1.2 Implementation

The main trade affected by opening of the NSR is the trade between the two European regions, Baltic and Hamburg-Le Havre, and the two Asian regions, Greater China and Fareast Asia. The current trade goes via the Suez Canal. The size of the vessels in the current fleet is such that all of the vessels would be able to pass the Suez Canal. However, the "Vale-vessels" of 380,000 DWT or more are an exception to this. Due to the averaging of vessel sizes, the maximum size group is 298600 DWT, which would just fit in the Suez Canal (assuming the design of the vessel has taken this into account).

As there are currently no distance tables for shipping available which take into account the Northern Sea Route (NSR), the reduction in length is estimated by Liu and Kronback [2010] to be about 4300 miles for the route Rotterdam (The Netherlands) to Yokohama (Japan). Schøyen and Bråthen [2010] estimate the distance between London (U.K.) and Yokohama to be 4200 miles shorter. Lastly Xu et al. [2011] come with a more detailed stepwise approach, but leave out the Baltic region in their calculations. Their estimated reduction for Rotterdam to Yokohama is 4400 miles.

Averaging these estimates for the route Rotterdam/London-Yokohama leads to a 4300 miles voyage reduction for an 11400 miles voyage through Suez. Using this information and assuming that all other ports are located on the round trip, Rotterdam-Suez-Yokohama-NSR, the total distance of this trip will remain constant at 18500 miles. This way the length of the alternative routes for the four trips can be calculated. This is done in Table 6.1. It clearly shows that the more regular trade of Hamburg to China and the Far East does not gain as much as the more optimal trade examined in the papers described above.

Table 6.1: Overview of route lengths for routes benefitting from the NSR

Region EU	Region Asia	Suez	NSR	Total
Baltic	**China**	11342	7158	18500
Baltic	**Fareast Asia**	11608	6892	18500
Hamburg	**China**	10525	7975	18500
Hamburg	**Fareast Asia**	10797	7709	18500

The paper of Liu and Kronback [2010] also shows the historical development of ice-breaking fees. While relatively low until 2004, the rates moved from an average of 7.5 to 23.5 USD per ton as the result of the conclusion of government subsidies. These prices relate to cargo (capacity) instead of GT, the measure used for the rates at the Suez and Panama Canal. The Arctic Logistic Information Office [2013] states on their website a fee of about 750 Roubles per ton bulk cargo and a fee of 1000 Roubles per ton displacement for empty vessels. This roughly translates to about 20-25 USD per DWT, which within the model translates to a fee of 40 USD per GT. This rate is twenty times higher than the average for the Suez Canal.

As the model is not set-up to allow choices between alternative routes, the freight rates on the four routes are the only indication transport via the NSR is feasible or a waste of money with such rates. In the first setting, the current passage fee was used. In a second setting, the fee is assumed to be half of the current fee as the costs are greatly reduced due to increased traffic. The fact that small vessels (in this case Handysize and Panamax) can navigate the NSR much earlier will also be investigated.

6.1.3 The results

The first element to examine is the change in the demand for transport which will occur as a result of the opening of this shorter route. Only 8 out of the 256 available routes are affected. How big is this effect? Figure 6.1 provides the answer. This figure shows the development of ton*miles transport per year for both the base run and the NSR scenario. The ratio line expresses the relative difference, which is roughly 12%. This is a clear indication that about a third of the world's transport takes place along this route.

For this scenario three options have been tested. The first option (SC1a) is that all vessels are obliged to take the Northern Sea Route (NSR) and pay the current fee of 40 USD per GT. In the second one (SC1b), this fee is halved to 20 USD per GT, which is expected to make the transport costs about equal with the current costs through Suez. The last scenario (SC1c) only allows the small vessels to take the NSR, and the Capesize vessels have to go through the Suez Canal as the NSR is assumed not capable of handling this size yet. The fee is once more 40 USD per ton.

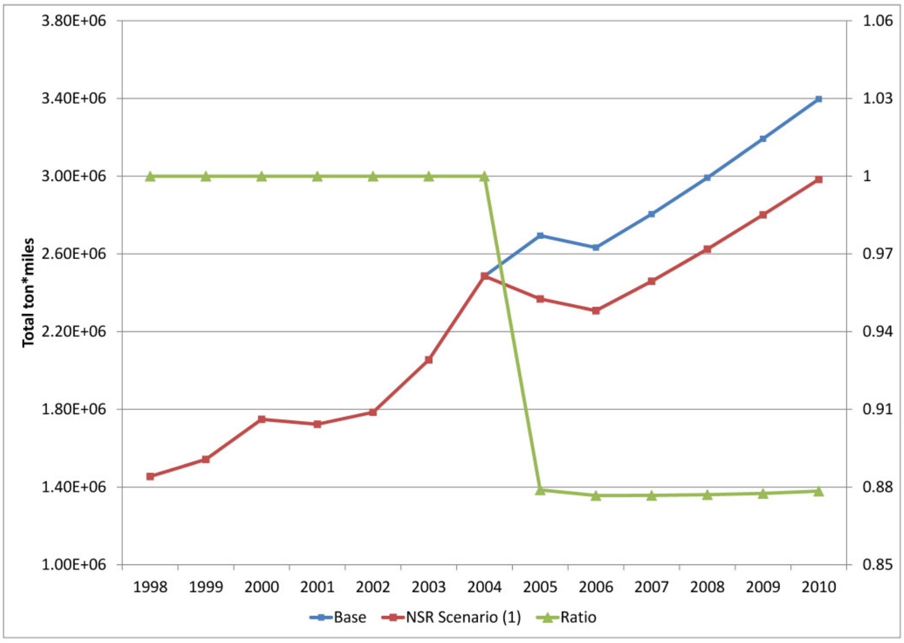


Figure 6.1: Development of transport demand due to the opening of the NSR

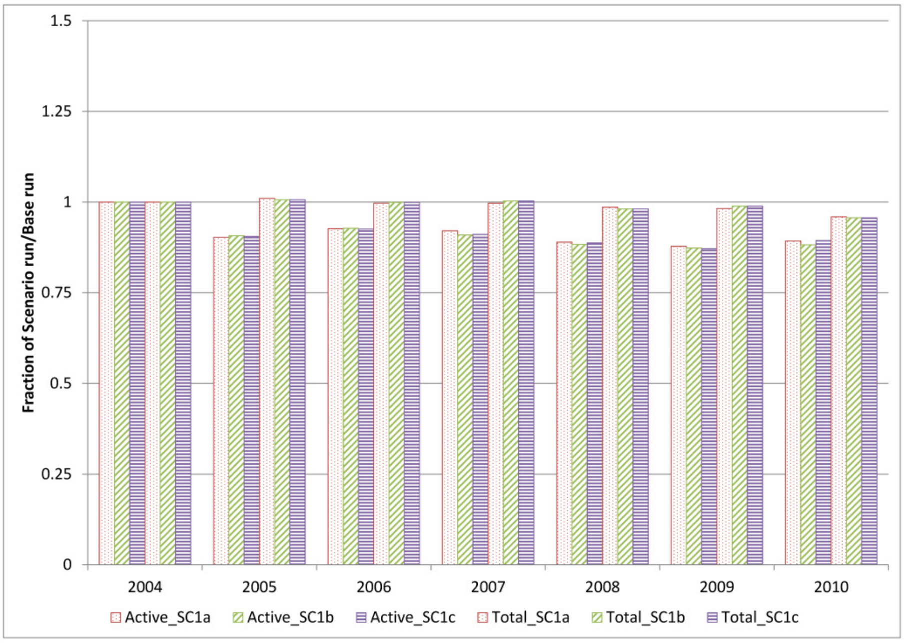


Figure 6.2: Yearly trading and total fleet activity for scenario 1

The first Figure represents the drop in Transport demand, Figure 6.2 shows the drop in activity and total fleet Size for the entire fleet (expressed as weeks in a certain activity). In all cases the total fleet size, the second set of three bars, diminishes compared to the base run. As all activities, including lay-up and waiting, are included, this indicates that the total fleet size is shrinking. On the other hand, all activity levels are lower but about the same for all runs (the first three bars). In both cases this does not necessarily mean that supply is lower. Instead it could also indicate that larger vessels are sailing instead of smaller ones.

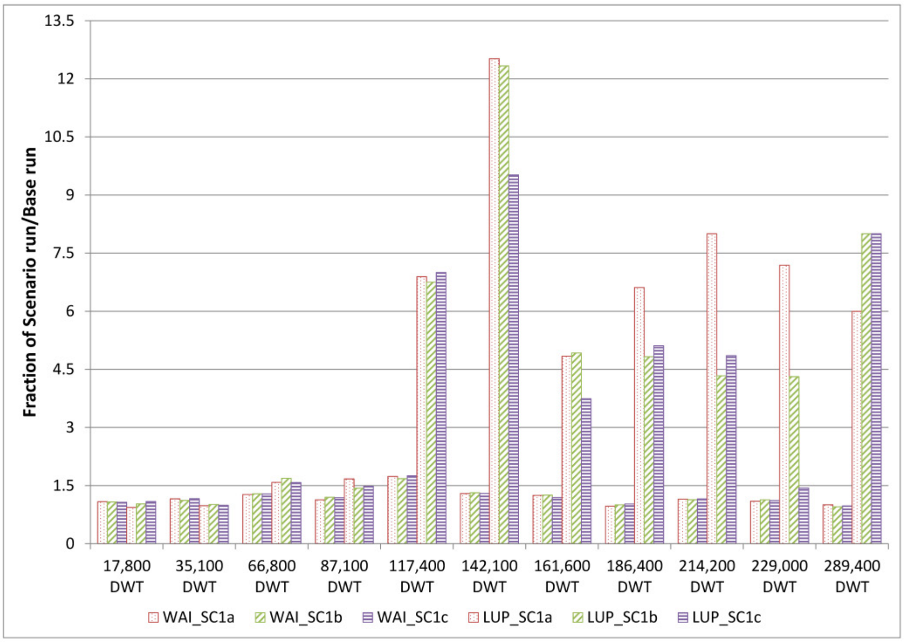


Figure 6.3: Average changes in waiting and lay-up per vessel size for scenario 1 (2004-2010)

Figure 6.3 was created to check this assumption. Here the changes in waiting (first three bars) and lay-up per vessel size group are presented. Waiting remains mostly between 1 and 1.30, with the exception of 117,400 DWT size group where waiting increases by about 70-75% in all scenarios. More striking is the increase in lay-up of the Capesize vessels. The reduction in ton*miles seems to force more of these vessels in lay-up, though closer inspection shows that for the base scenario very little time was spent in lay-up. Table 6.2 shows the absolute lay-up values. The amount of large vessels in lay-up is still negligible. Actually, the part taken up by the Panamax vessels has increased in all scenarios. To put this in perspective the total volume of lay-up (Size*time) has increased by 46% for scenario 1a and 1b and by 40% for scenario 1c.

Table 6.2: Lay-up division over vessel sizes for scenario 1

Size group	Base	SC1a	SC1b	SC1c
17800	8040/3.08%	7551/2.33%	8277/2.49%	8775/2.73%
35100	157299/60.33%	154472/47.58%	159526/47.99%	156033/48.62%
66800	75658/29.02%	119920/36.94%	127790/38.44%	119646/37.28%
87100	17692/6.79%	29612/9.12%	25360/7.63%	26244/8.18%
117400	184/0.07%	1268/0.39%	1242/0.37%	1288/0.4%
142100	138/0.05%	1728/0.53%	1702/0.51%	1314/0.41%
161600	874/0.34%	4232/1.3%	4304/1.29%	3272/1.02%
186400	644/0.25%	4258/1.31%	3108/0.93%	3292/1.03%
214200	138/0.05%	1104/0.34%	598/0.18%	670/0.21%
229000	32/0.01%	230/0.07%	138/0.04%	46/0.01%
289400	46/0.02%	276/0.09%	368/0.11%	368/0.11%

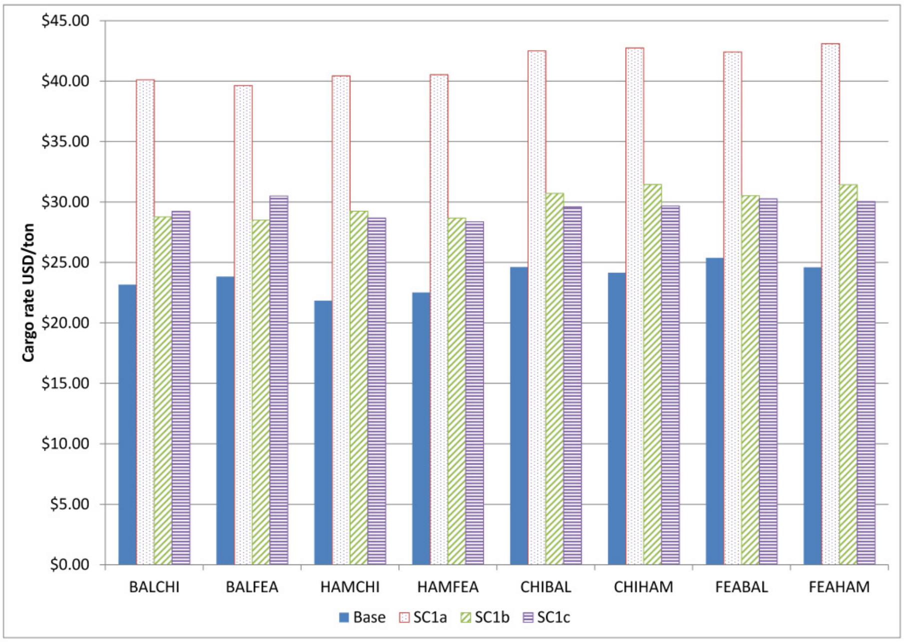


Figure 6.4: Average USD/ton freight rates for the routes affected by the NSR opening (2004-2010)

While the overall changes are interesting, the change in costs is much more relevant for a consumer of the services. These costs are presented in Figure 6.4 and Figure 6.5. The first figure shows the costs per route averaged over the scenario time. The increase with the 40 USD fee can be clearly seen. This increase is less than calculated previously, which could be achieved by using the best vessels on this route. There is an increase in price even with half the fee, as well as with only allowing small vessels (for a high fee). In the last case the route is most likely serviced by larger vessels not paying the fee for the NSR passage but taking the longer route, thus reducing the average cost increase (not weighted for traffic volume).

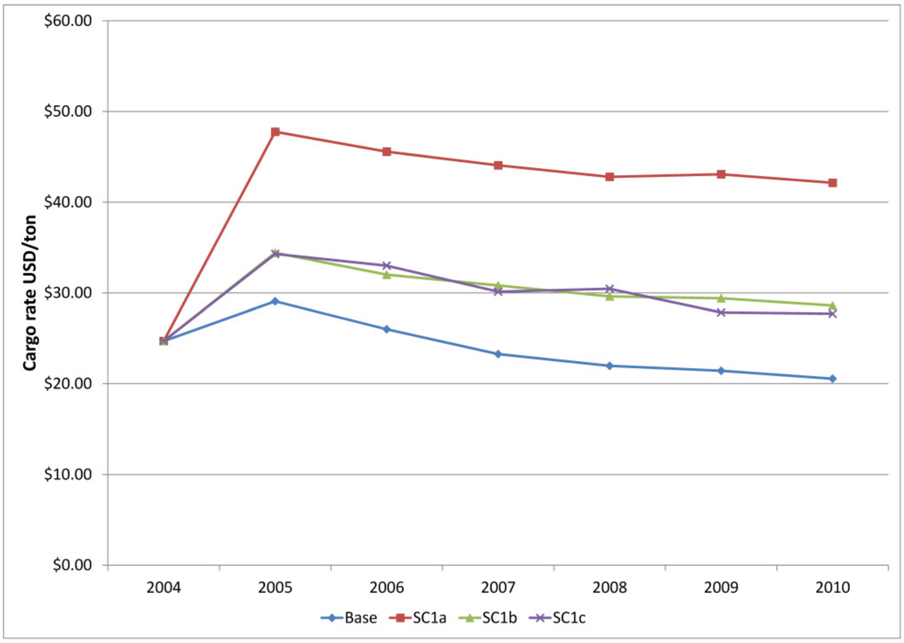


Figure 6.5: Average USD/ton freight rates for the NSR routes per year

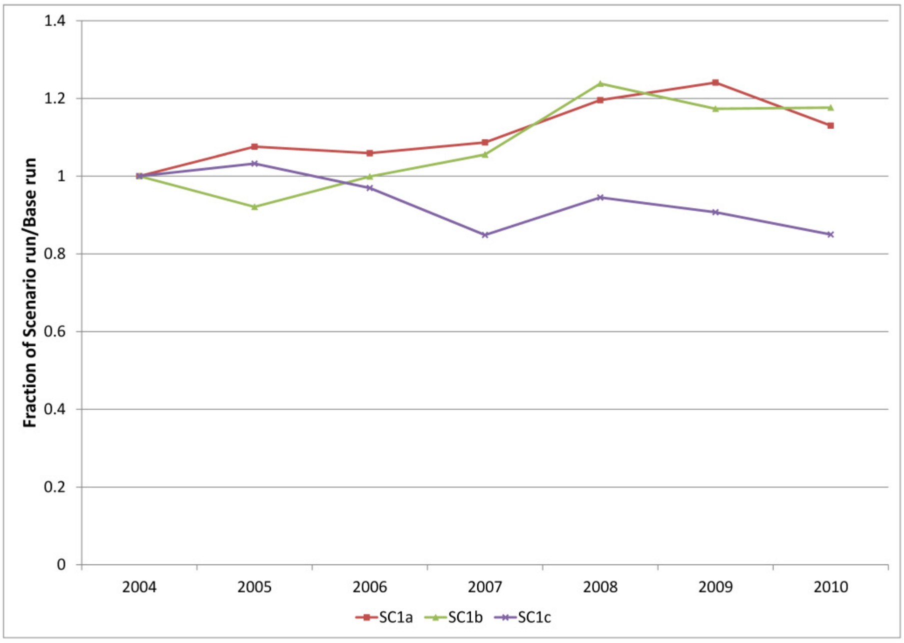


Figure 6.6: Fraction change in ton*miles for the NSR routes per year

The second figure shows the average costs of all 8 routes, but per year. In the base run 2005 has a price increase. This increase is seen in all options. It also shows the similar behaviour of the lower fee and size restriction scenario. Most likely in both cases the more cost efficient vessels sail these routes. To check this Figure 6.6 shows the change in ton*miles sailed on the NSR routes, relative to the base run. Although the demand for transport has been greatly reduced in option SC1a and SC1b, the ton*miles increase in these cases. In the third case SC1c, the ton*miles are reduced although here no large reduction was expected as the cheaper route goes through Suez, just like the base run. How is this possible?

Part of the answer can be found in Figure 6.7a-d. In this figure the divisions of the vessel sizes sailing on the 8 NSR routes are presented. It shows an increase of the usages of the 142,100 DWT and 161,600 DWT vessel sizes for the first two options, where all vessels use the NSR. The last option clearly shows an increase in the large vessels sailing on the route. The effect of option SC1c is in line with the expectations. The Suez is much cheaper per ton but allows only Capesize vessels. The biggest vessels are used here, to allow the most cargo to be transported this way. In the base case this need is less as the difference in price between Capesize and smaller vessels was much smaller.

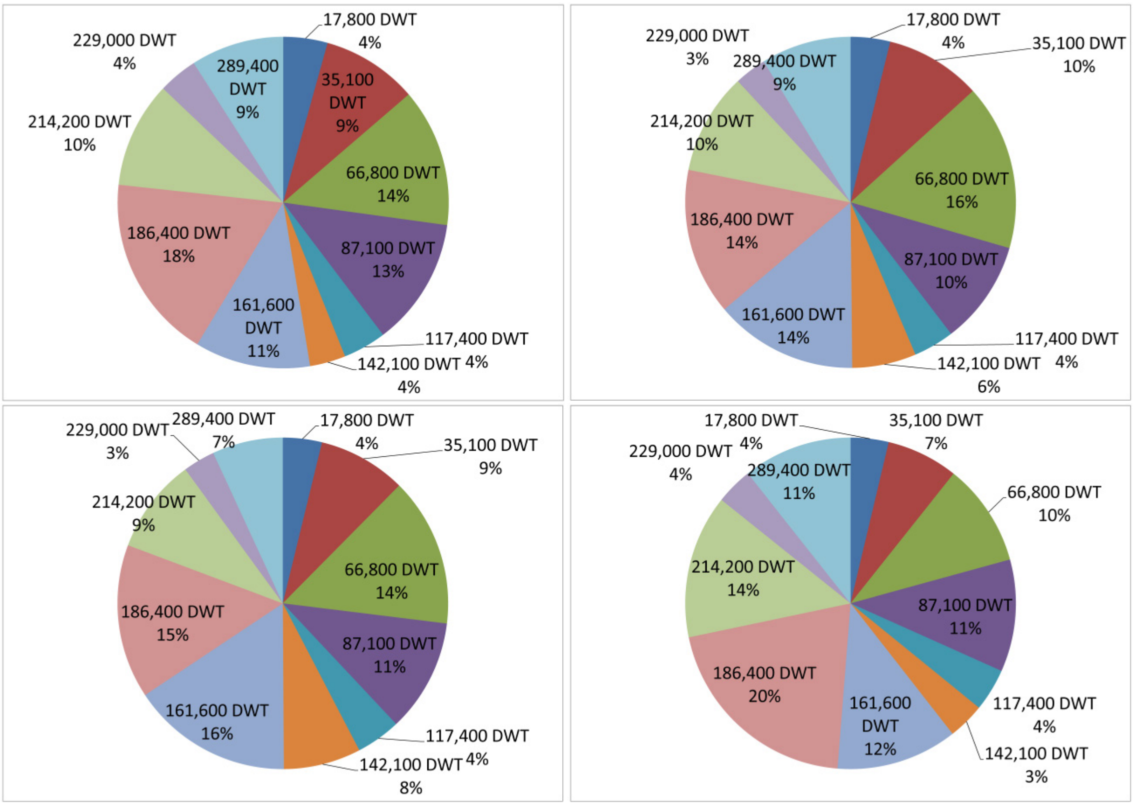


Figure 6.7a-d: Division of vessels serving the NSR Base (a), SC1a (b), SC1b (c), SC1c (d)

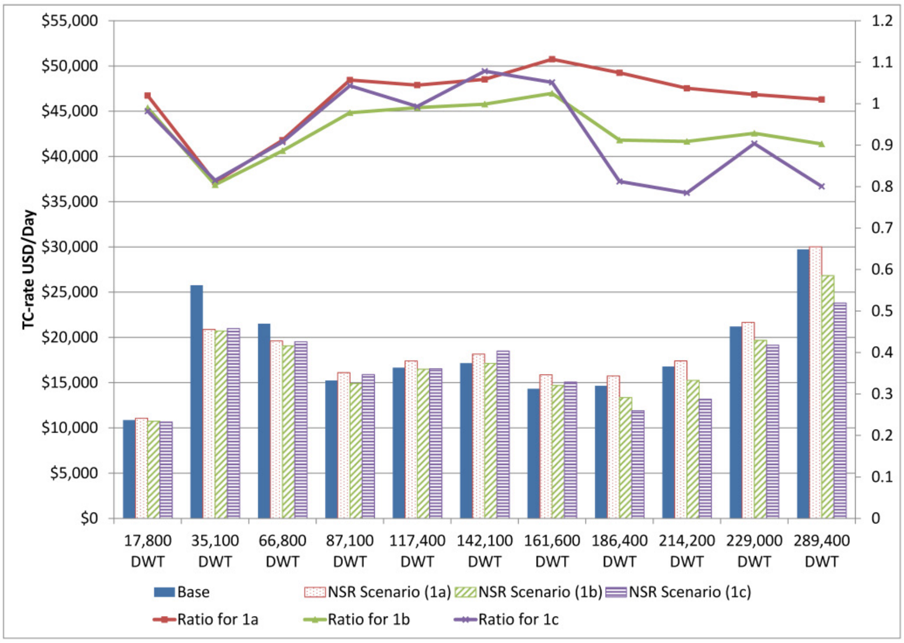


Figure 6.8: Average TC-rate and fraction of change per vessel size over the years 2004-2010

Still no clear explanation exists for the other two options (SC1a and SC1b). Figure 6.8 presents the time charter rates of the vessels. The bars represent the time charter rate while the lines represent the relative decrease in the rate compared to the base run. This TC-rate is cost based but related only to the active vessels. The popularity of the smaller Capesize vessels is still unclear. The costs per day are almost equal for the vessels between 87,100 DWT and 214,200 DWT, yet this shows a preference for the largest vessel size in this range. One explanation could be that the cargo amount is just not sufficient to warrant such a move. Also, the number of these vessels is quite limited, which could impose another restriction.

Apparently the increase of costs on the NSR routes requires an optimisation on a cost basis even if limited to 20 USD per GT. The competitive rate will be below 20 USD per GT, especially considering the fact special ice-classed vessels are required for the trip. These are generally more expensive than regular bulk carriers, adding further to the costs of the exploitation of this route.

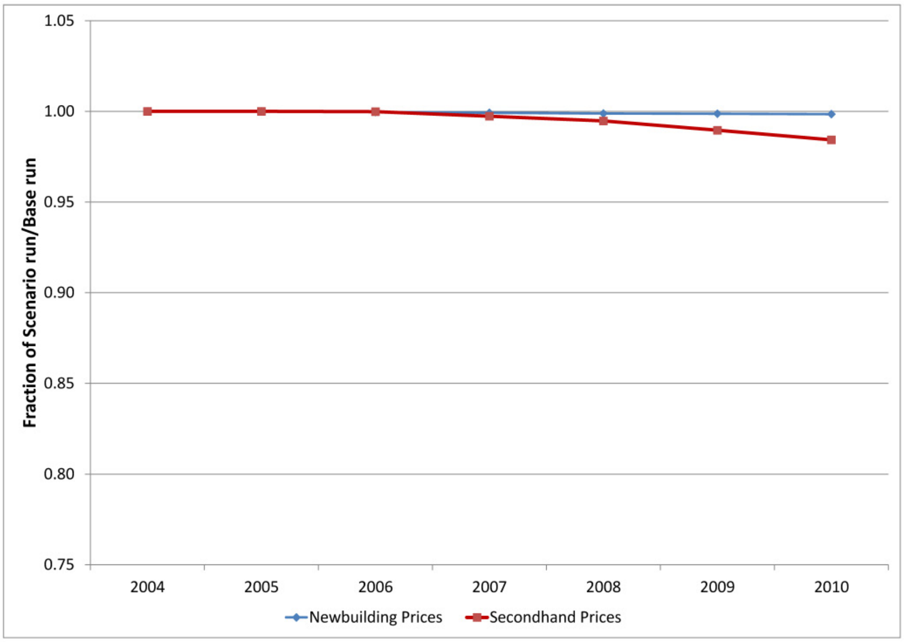


Figure 6.9: Average changes to vessel prices per year between SC1 and the base run

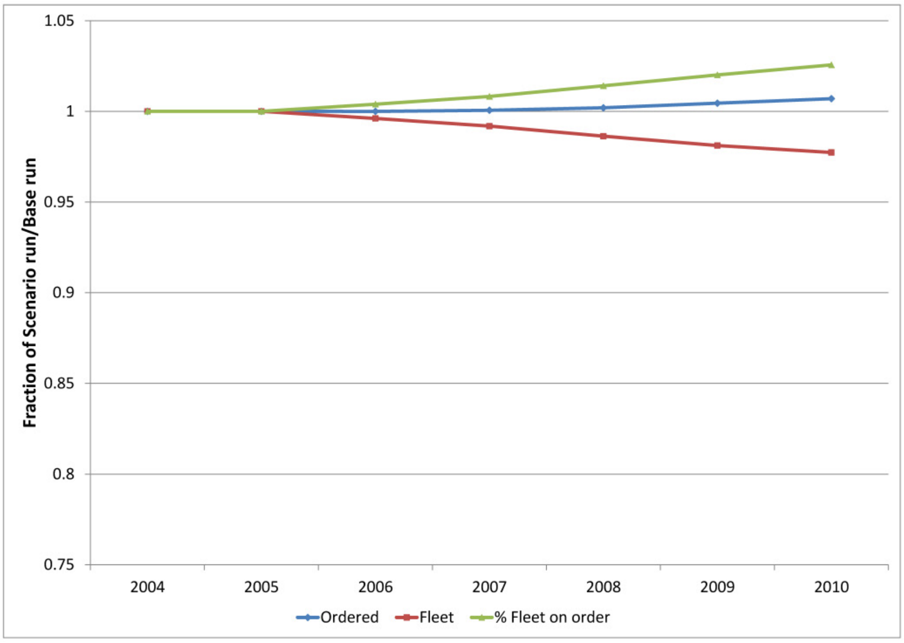


Figure 6.10: Fleet, fleet on order and % fleet on order change between SC1 and the base run

How do these changes in TC-rate affect the ship prices? Looking at Figure 6.9, the effect is very limited. Both the newbuilding price and the secondhand price barely react (less than 2% change for the secondhand price). On the other hand the drop in TC-rate for the same averaged period is quite significant. What is preventing the vessel prices from dropping with the TC-rate?

To answer this question the fleet size must be considered. The fleet sailing around in all scenarios was smaller than the original fleet. The fleet on order is measured as a percentage of the current fleet. Figure 6.10 shows that the fleet on order did not change in the first years after the opening of the NSR. This automatically means that the percentage of the fleet on order does change, not by increased orders, but by a smaller fleet. This increase, however small, could be what prevented the vessel prices from increasing.

6.1.4 Conclusion on Scenario 1

Reviewing the output described above, the NSR has potential, but not with the current high rates for the passage. It would be no alternative to the Suez Canal for dry bulk, especially not when rates are already under pressure due to a depressed market. The passage fee would need to be around or below 15 USD to compete with the Suez Canal for this scenario. If the fuel prices are higher or other voyage related costs increase, the break even rate will also increase. Considering the current real life over capacity of 400,000 DWT bulkers, this is not likely to happen in the near future.

This scenario also shows that the reaction of the world fleet on such a small change is very complex. While the total activity does decline, a large rerouting of vessels takes place and in two cases the activity on the routes actually increases rather than decreases.

6.2 Scenario 2: Oil prices explode

This section investigates the effect of the fuel price on shipping costs. This is done also for a reduction in sailing speed. The first subsection will introduce the recent history of rising fuel prices and the second discusses the implementation of this rise in the model. The final section discusses the results of this scenario and lessons learned.

6.2.1 Introduction

In the past 150 years there have been two major oil crises (Figure 6.11). During these crises, the price of oil expressed in today's money, was about the same as it is now. Although the world has been in a crisis since 2008, it is not an oil crisis. Still, the price of oil is at a very high level. Recent research of Du et al [2010], Filis [2010] and He et al [2010] shows a high level of integration between oil prices and the macro economy, inflation and stock markets. The chosen MC-Model does not link oil prices directly to the country parameters, but oil price is present in the model and does influence trade to a certain extent. This effect is studied in this scenario.

Hummels [2007] points to fuel price increases as one of the most important reasons that sea transport has not become cheaper when compared to air traffic in the past 100 years. In another paper by Notteboom and Vernimmen [2009] it is shown that the recent increase in oil prices is only partially compensated by an increase in transport prices for liner shipping. Also UNCTAD [2010] shows in an extensive study on the link between oil prices and transport costs that oil prices are of influence on the transport costs. In this study concern is also expressed for the future as higher and higher fuel prices are to be expected with oil becoming scarcer every year.

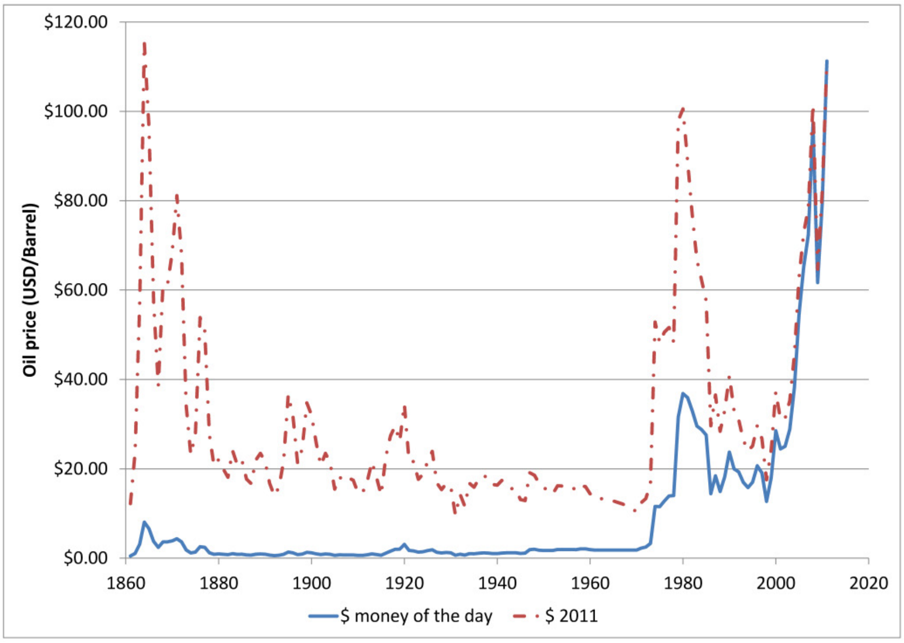


Figure 6.11: Oil price development 1861-2011. (Source: Author based on data from BP [2013])

In short higher fuel costs will result in higher prices of transport. This can be partially compensated by slow steaming, since the fuel oil consumption increases with approximately the third power of speed. Both effects, freight rate increase and speed reduction, will be studied in this scenario. The next subsection will detail how the increased oil price is implemented within the model: both in the MC-Module and the Shipping Module.

6.2.2 Implementation

In the model the oil price is determined from the past oil prices. When determining the oil prices, a first option is to use and extrapolate the real values of the past years and work along this trend of increasing prices. A second option is to double these values to examine the effect of extreme oil prices. As shown in the previous subsection, the oil prices of 2008 and 2010 were as high as the crisis prices of the 1970s and 1870s.

The previous subsection also states that reducing speed saves fuel to the third power of the reduction (per day). While sailing at half the speed is a somewhat unlikely scenario, a reduction of 10% will already result in a reduction of almost 27% in daily fuel consumption at the expense of covering 10% less distance per day. This scenario will also be tested with oil price cases. The further effect of the changes in oil prices on trade and country economies, cannot be predicted beforehand, but will be monitored in the results as well.

Table 6.3 shows the base run oil price and the two scenario prices. The scenarios start in 2005 and the difference in that year is still minimal between the current price and base run. However, the oil prices for the base run moves back to an equilibrium value, while in reality the price development continued for a while longer. At the end of the test period (2015) the prices are 6.5 and over 13 times greater than the base run. The effect of this on both trade and transport prices will be discussed in the next subsection.

Table 6.3: Oil Price input for the two price scenarios and the base run

Year	**Base (USD/barrel)**	**Current price (USD/barrel)**	**Double price (USD/barrel)**
1995	17.26	17.26	17.26
1996	20.86	20.86	20.86
1997	19.36	19.36	19.36
1998	12.76	12.76	12.76
1999	17.39	17.39	17.39
2000	28.31	28.31	28.31
2001	24.27	24.27	24.27
2002	24.50	24.50	24.50
2003	28.88	28.88	28.88
2004	37.22	37.22	37.22
2005	52.30	54.52	109.04
2006	43.70	65.14	130.29
2007	36.00	72.39	144.78
2008	32.63	97.26	194.51
2009	30.53	61.67	123.34
2010	28.80	79.50	158.99
2011	27.46	111.26	222.51
2012	26.47	114.32	228.64
2013	25.72	129.74	259.48
2014	25.15	147.24	294.47
2015	24.70	167.09	334.18

6.2.3 The results

This subsection contains the results for the four options of the second scenario. Option 2a is the current oil price with no speed reduction, option 2b is a doubled oil price with no speed reduction and options 2c and 2d are with speed reduction and with current and double oil prices respectively. The oil price is not only the basis for the bunker price, but also represents the changing trade with the rest of the world from the modelled regions. Before looking at the effect on the fleet and the costs of transport, the effect on the MC-model outcome is first discussed. The effects on GDP, imports, exports, exchange rates and ton*miles are shown in Figure 6.12. While exchange rate and many other variables are not influenced by the change in oil price, there is a rise of about 11% in total GDP in the case where current oil prices are used and a rise of about 17% in total GDP if oil prices are assumed to be double the current values. This should introduce extra activity, especially in the case where the travelling speed of the vessels is reduced as well.

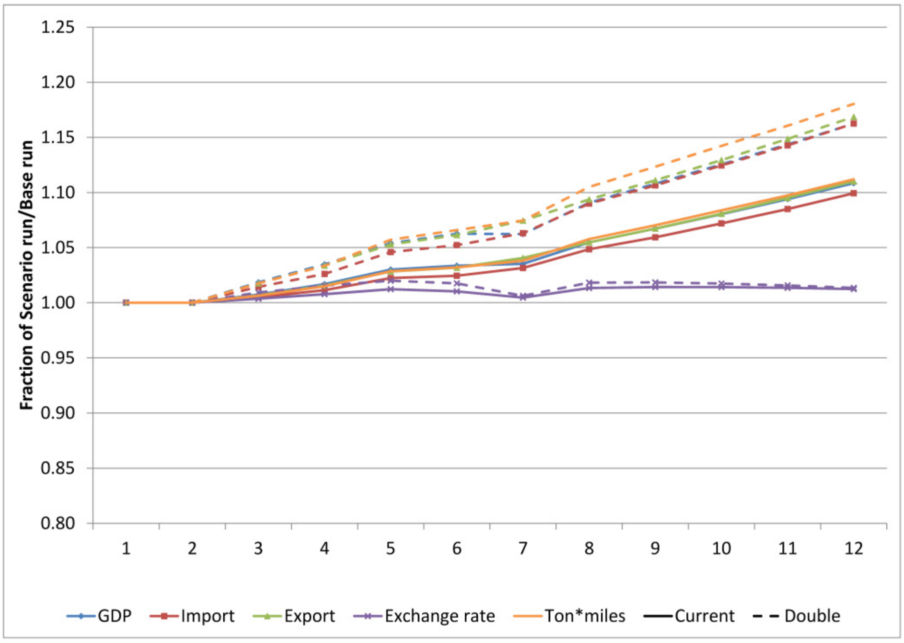


Figure 6.12: Changes to total GDP, import, export, average exchange rate and ton*miles as a result of an increase in oil prices

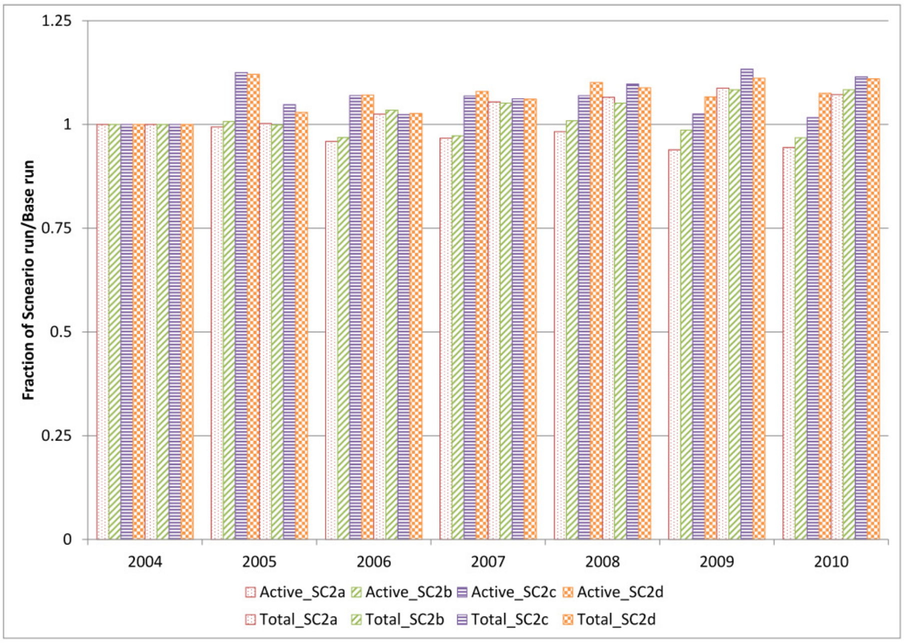


Figure 6.13: Changes in activity and total fleet assignment for scenario 2

Before discussing the vessel activity, it is important to mention that in at least one of the cases the model ran out of available supply. Therefore, it was necessary to increase the fleet size during this run. While increasing orders was initially tried, the model shows a strong return to an equilibrium orderbook of between 10-12% of the current fleet. Therefore, this approach did not lead to a fleet of sufficient size over the entire scenario period. Ultimately, the solution chosen was to double the deliveries of vessels, without changing the orderbook or any other settings. This fixed the shortage in supply. This is another reason to further investigate the ordering of vessels in the future and perhaps to include the amount of the fleet in lay-up in such a model.

Figure 6.13 shows that the expectation of increased activity is not true when considering activity (expressed in weeks). For the first two cases with no speed reduction the activity actually reduces. In the cases with speed reduction activity does increase but the activity is here expressed as weeks active. It could very well be that the types of vessels active have changed. The growth of trade can easily be compensated without showing in this figure, especially with an increase of larger vessels and a decrease of smaller vessels. The increase in total vessels is the result of the increased deliveries described above.

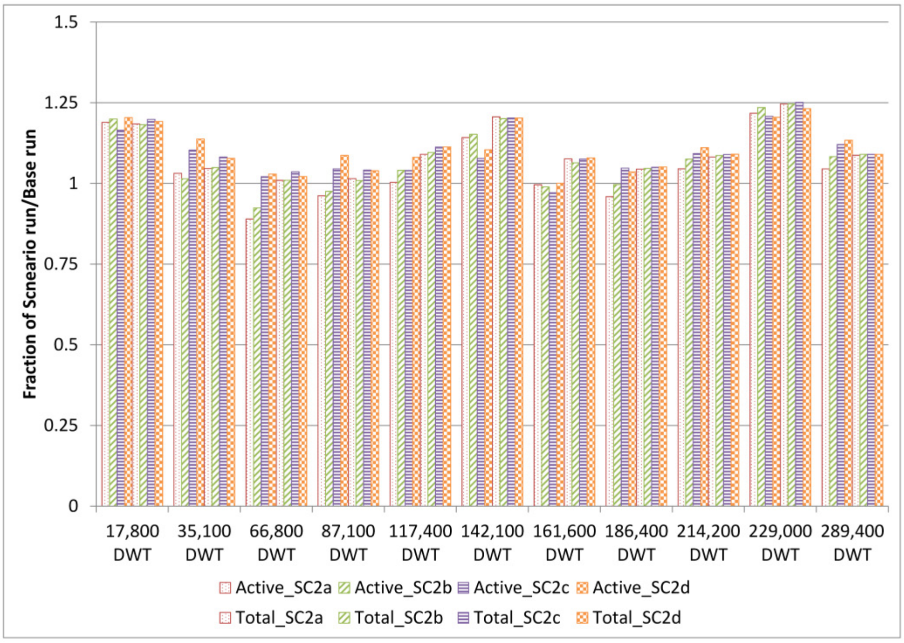


Figure 6.14: Changes in activity and total assignment per vessel size group for scenario 2

Figure 6.14 is presented to check if larger vessels are more active. The result is inconclusive as both small and large vessels experience an increase in activity. The results can also be misleading in the case of low values for the base run. A good example is the 229,000 DWT class, which is relatively small since in 1998 no vessels of this size class were present. The final check done on this data is to compare the sums of a multiplication of activity times vessel size, which is a kind of ton*miles measure representing total active transport capacity. The first two scenario runs show a drop in this activity of 3% and 1% respectively. The last two scenarios show an increase of 5% and 6% respectively. The reaction of the fleet is much smaller than the 18% increase in transport demand. Most likely higher sailing costs force the allocation to further optimise for distance, to minimize the total costs of transport as much as possible. Another explanation is that the filling ratio of the vessels could have increased with the increase in trade.

It is interesting to see what the effect of the increased bunker prices on the freight rates is, especially when examining the difference between the full speed and speed reduced runs of this scenario. These figures per vessel size group are presented in Figure 6.15. In all cases the costs have increased. While there are differences between the different vessel sizes, the speed reduction of 10% also roughly reduces the cost factor by 10%. If this relation holds for all speed reductions, the speed will need to be reduced by about

25% in the situation of the current oil prices and by 50% when the reduction is doubled, allowing it to drop back to the base level.

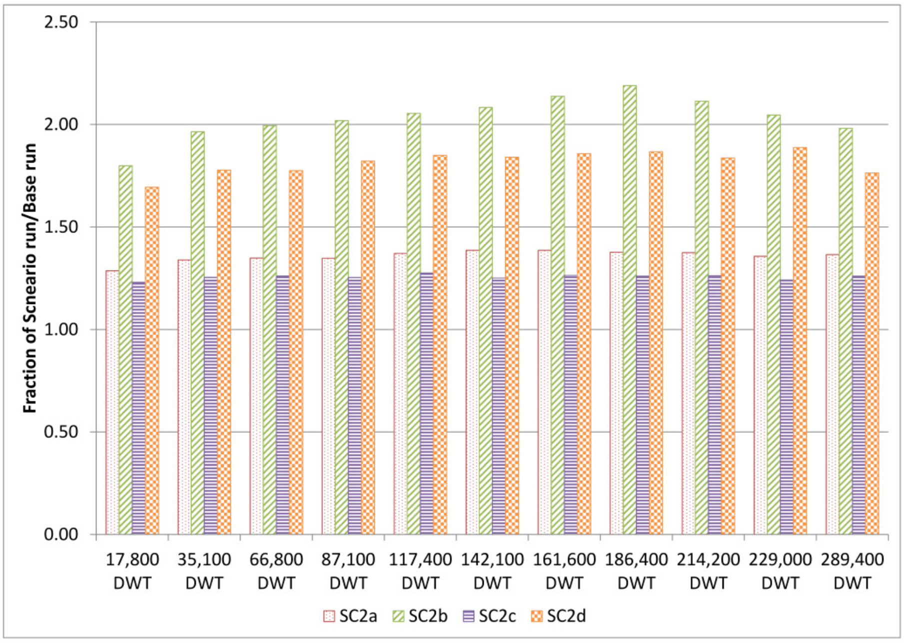


Figure 6.15: Change in average freight rate (USD/ton) per vessel size group for scenario 2

The increase of freight rates is much smaller compared to the average increase in oil prices over the period 2004-2010, 89% for the current option and 250% for the double option. This is logical since the other costs did not increase. In the case of no speed reduction, the freight rates increased by about 40% of the oil price increase. This makes sense since bunker costs roughly make up about 40% of the vessel costs. This percentage could be more, but then the other costs of the vessel will have reduced.

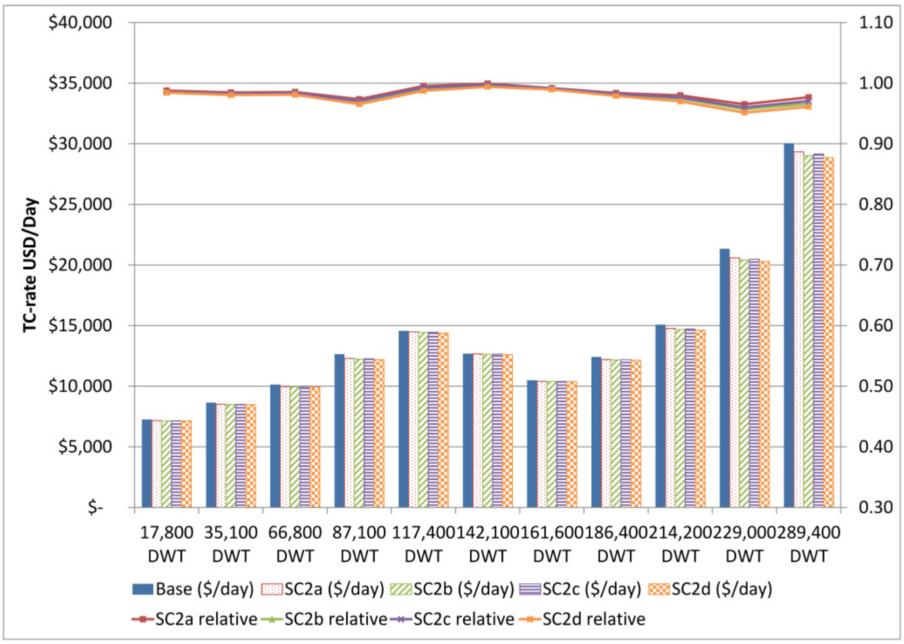


Figure 6.16: Change in TC-rates per size group for scenario 2

Figure 6.16 allows the investigation of the other costs. Here the TC-rate per size group is presented both as an absolute value and relative change. The lines representing the relative rate is below one in all cases. Therefore, the fleet has certainly been optimised to use cheaper vessels. This, in turn, has driven down the prices of secondhand vessels (Figure 6.17a-b), which in turn allows a further reduction of the TC-rate through lower capital costs for the owner.

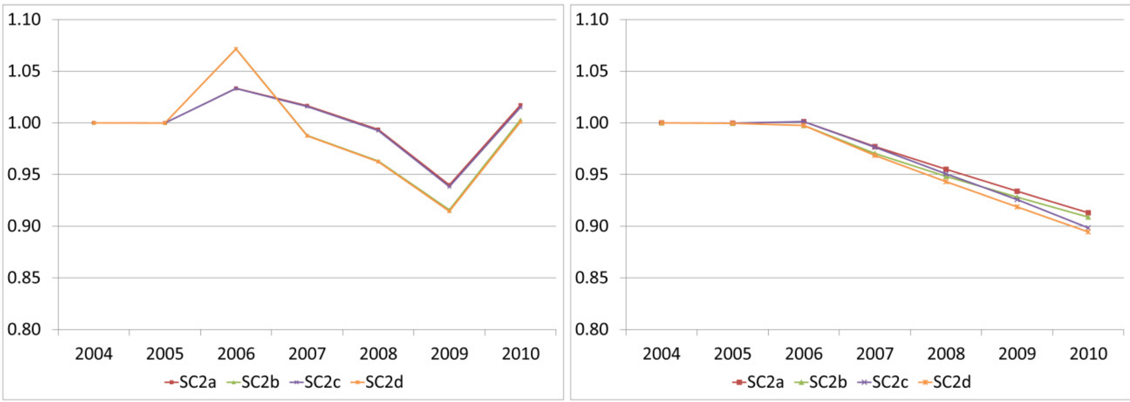


Figure 6.17a-b: Relative price development of average newbuilding prices (a) and secondhand prices (b)

Further study of Figure 6.17a-b shows that while secondhand prices reduce further with time, showing a strong reinforcing loop with the TC-rates, newbuilding prices remain the same on average. Fluctuations of about 5% exist in the newbuilding prices, but these go both in the positive and negative direction. Apparently, the influence of the TC-rate is limited.

6.2.4 Conclusion on Scenario 2

This scenario is interesting, because the consequences of a rise in oil prices are far reaching, not only changing the amount of goods traded on the macro level but also optimising the assignment of vessels to reduce the distance travelled. The elasticity between oil prices and freight rates appears to be about 40%, although this requires the possibility to further reduce the TC-rates of the vessels. In the model these effects are almost instant, although in reality there might be stickiness to both the TC-rates and the prices of secondhand vessels.

6.3 Scenario 3: Limits to Chinese growth

Until 2012 the Chinese economy was somewhat of a miracle, as its GDP kept growing by about 10% per year, despite a large crisis. What would be the effect of the falling away of this continued extreme growth on the world of shipping and shipbuilding? China is not only an important driver for trade, it is also a large shipbuilder. However, will continued development not drive China out of the cheap labour market? These questions form the basis for this scenario. The first subsection contains an introduction to the growth of China. The next subsection discusses how this extreme growth will be implemented and which factors will be studied. Lastly the results will be presented and conclusions are drawn from them.

6.3.1 Introduction

Many papers can be found on the integration of China into the global economy. Fogel [2006], Keidel [2004] believe that China would make its target of quadrupling GDP/Capita by 2020. Others like Dreger and Zhang [2011], Rodrik [2013], Maddison and Wu [2008] identified two critical limits to growth: a trade unbalance in the National Account (more export than import) and a suspicion of undervaluation of the Chinese currency, the Renminbi. The argument of these authors is that in the end these factors will limit the growth potential of China. A paper by Holz [2008], estimated a cooling down around 2015 and seems to be closest to reality since newspaper articles from the start of 2013 show that China has adjusted its growth projections downwards (though still large in a time of crisis).

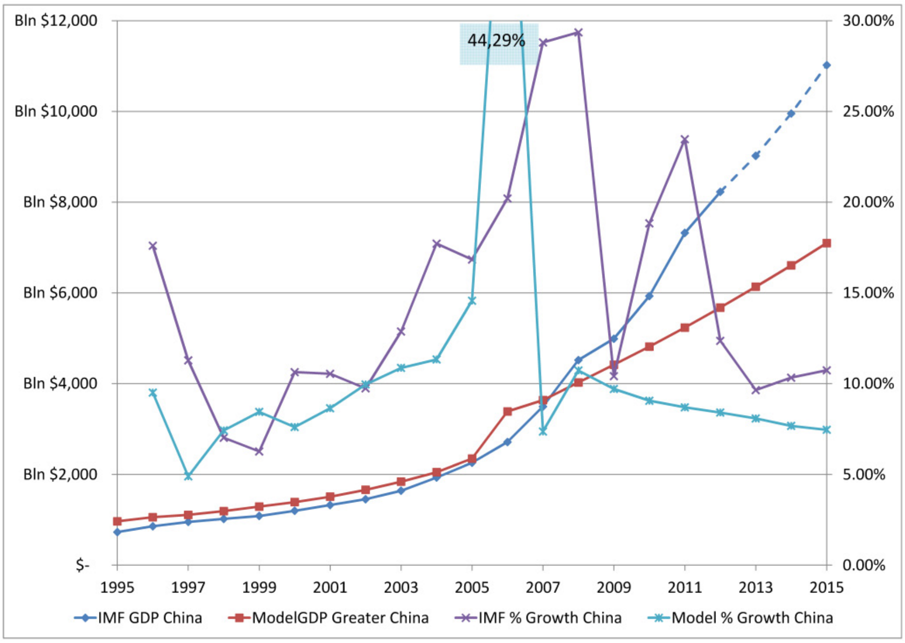


Figure 6.18: GDP development of China and of the modelled region Greater China (Source: Author based on own data and data from IMF [2013])

Although many more papers and references exist on the subject, for the purpose of this scenario, the set above was deemed sufficient since both papers and reality have shown growth is limited and two important elements which limit this growth have been identified. One question however, remains to be answered. Is continued growth already part of the model, or is Chinese growth already limited? Figure 6.18 below shows the development of GDP for both China and the modelled region Greater China. Until about 2005 the data is the same; the model line is slightly higher because the region is larger than just China. After 2005, the model will estimate its own value and continues the growth from the past (with a slight adjustment at the start). However, the growth of the real China is accelerating at this point, and GDP in 2012 is actually almost 50% more than estimated by the model for greater China.

This clearly indicates the need for recent data and updates of the model. The dotted line is the prediction for the future of the IMF. Growth is continued, though at a slightly lower level than before 2011. This is also demonstrated by the purple line, representing the year on year percentage growth of GDP as shown by the blue line.

The line showing the percentage growth of GDP for the model has its peak higher and slightly off. The trend is slightly lower as can be noted in the final values, but over the entire range the growth is near to the IMF values recorded much later. The difference in average growth over the period 2005-2015 is four per cent per year.

As all authors agree that growth is limited the model will investigate a scenario were growth in the period 2006-2010 (the scenario window) is already limited.

6.3.2 Implementation

Three periods can be identified in the GDP growth of China; 1995-2005 with an average growth of 12.05%, 2005-2012 with an average growth of 20.03% and 2012-2015 with an average growth of 10.77%. In the model these are 9.32%, 14.10% and 7.90%. The choice was made to use half of the average growth of the model as presented in Table 6.4. Reality shows the opposite occurred, also an interesting case, but as the previous scenario showed the limitations of the current model in allowing for extra growth of trade, this case will not be investigated here. It would only confirm the limitation found before.

Table 6.4: Greater China GDP for the base and growth scenario

Year	Base (mln USD)	SC3 (mln USD)
2006	3386.8	2512.6
2007	3636.0	2689.8
2008	4025.9	2879.4
2009	4416.7	3082.4
2010	4816.8	3299.7
2011	5235.5	3532.4
2012	5675.5	3781.4
2013	6134.1	4048.0
2014	6604.5	4333.4
2015	7096.9	4638.9

The GDP for Greater China is an identity equation, hence altering the output will cause an inequality between the left and right side. It will, however, allow us to study the effect of GDP alone on all other country values and the trade worldwide. By 2015 the difference in GDP will be reduced to about 65% of the original model value as can be seen in the table below.

As mentioned in the previous subsection, it is important to monitor the exchange rate and the trade unbalance. This is done in the next subsection by investigating their behaviour as well as the changes in fleet development.

6.3.3 The results

The first check done is to see if the implementation of the reduction of GDP has any consequences for the import, export, exchange rate and ton*miles. These are presented all together in Figure 6.19. This figure clearly shows that the impact of a reduction of GDP leads to a reduction of about half that size in import and has almost no effect on export and the exchange rate. The change in GDP thus results in a larger trade imbalance for China with exports exceeding imports by a bigger factor.

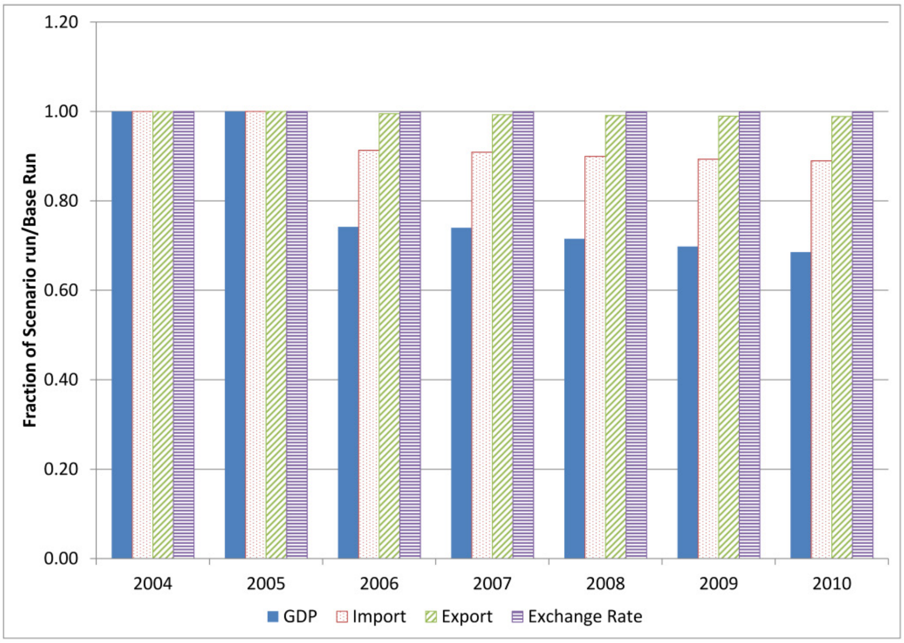


Figure 6.19: Development of trade indicators for China in the case of a severe reduction of GDP growth

The reduction in imports is about 10%. However, the impact of this reduction on the same indicators of the other regions is a maximum change of 1% and can be assumed negligible. The expectation is therefore that few of the changes compared to the base scenario will have taken place in the fleet attributes. The first check is to compare the assignment of the fleet. Figure 6.20a-c present three different cross-sections of the fleet assignments each showing the changes in activity, total fleet, waiting (WAI), Lay-up (LUP) and Ton*Mile travelled.

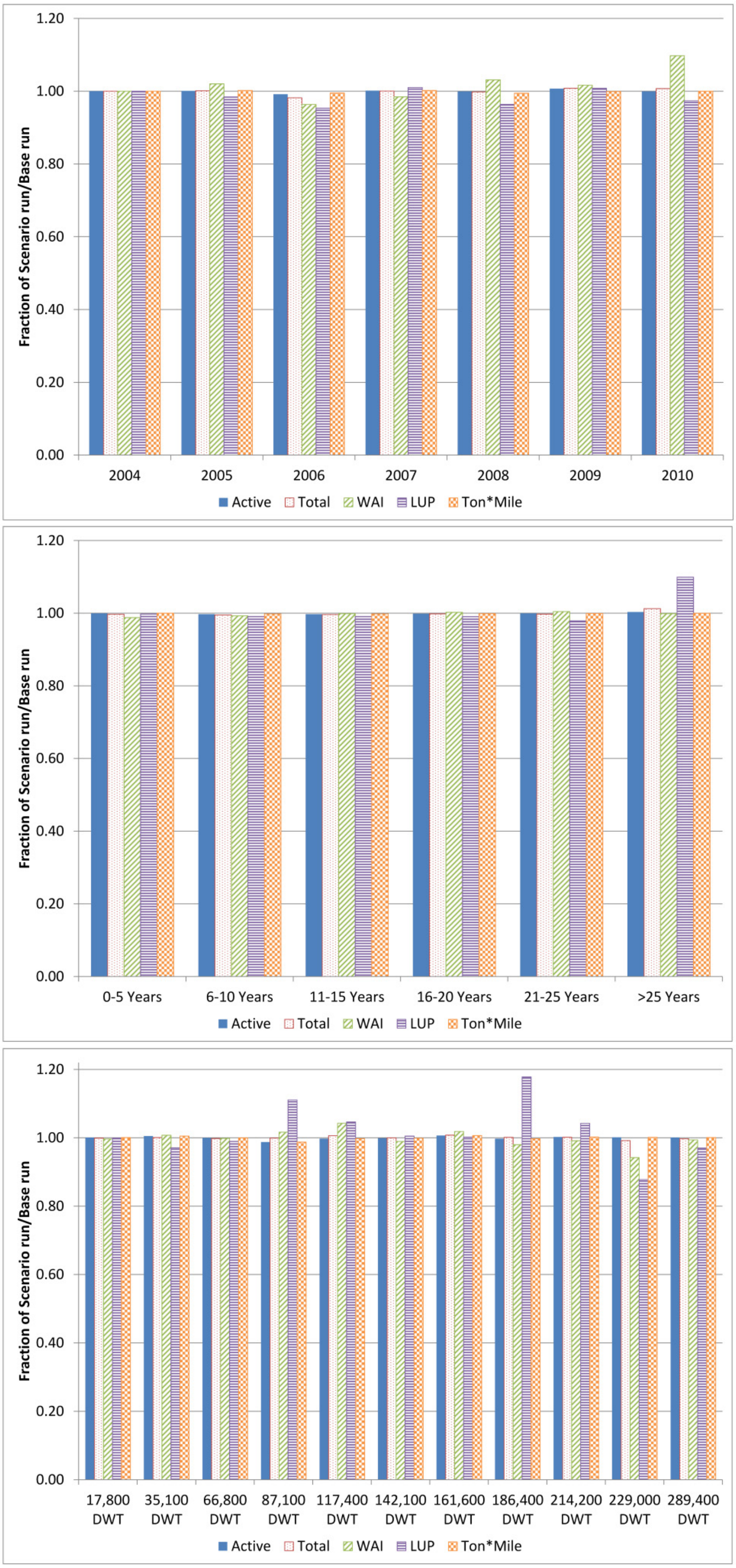


Figure 6.20a-c: Changes in fleet activity averaged per year (a), age group (b) and size group (c)

The changes shown in Figure 6.20a-c are relative to the base scenario and can all be considered small. Even though several spikes can be seen, these spikes represent the groups where the base values are small, resulting in a seemingly large relative change, although the absolute change is perhaps only one vessel more in lay-up over the entire period. To check why this change, of up to 10% less import, is not affecting the fleet usage significantly, the assignment of the fleet to the import and export of the China region are studied. Figure 6.21 compares the changes in cargo volumes for import and export (dotted lines) and compares them with the changes in the assigned fleet.

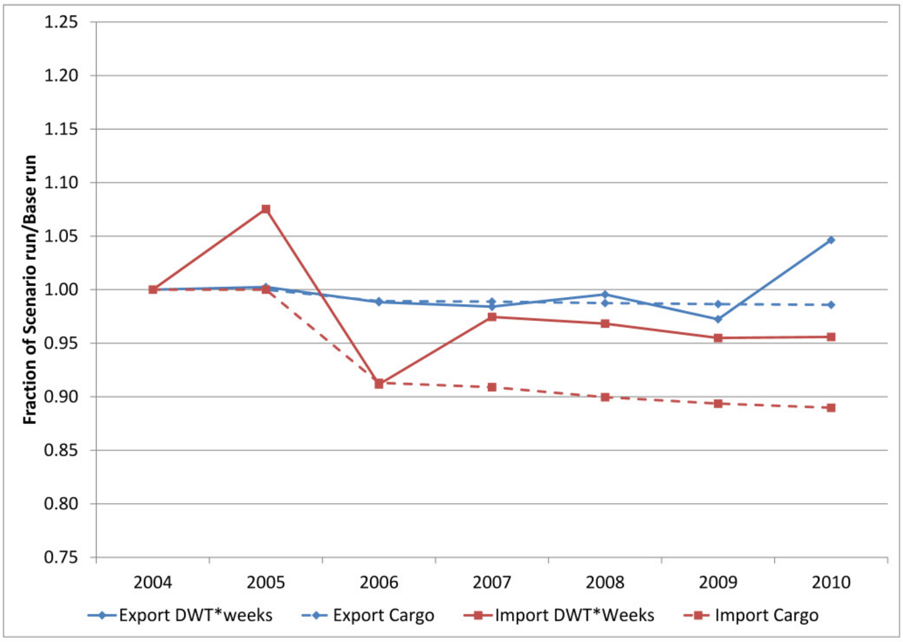


Figure 6.21: Changes in fleet activity expressed as total DWT*weeks compared with the changes in cargo availability

While the changes to the export assignment in total DWT*weeks seem to cancel each other out, changes to imports are present, but smaller than the changes expected based on the reduction of cargo. Apparently there is either overcapacity through the assignment of larger than necessary vessels, or because vessels are travelling a longer distance to get to the loading port before sailing to China. To check this, the changes in assignment of size groups are presented in Figure 6.22. It is immediately clear that the distribution of assignments changed both for exports and imports. However, it is not easy to deduct if the average size of the vessels used increased or decreased. A direct calculation of this shows that for export the size did not change (0.1% increase), while for import the size increased by about 2.5%. The assignment of larger vessels, explains this increase in overcapacity.

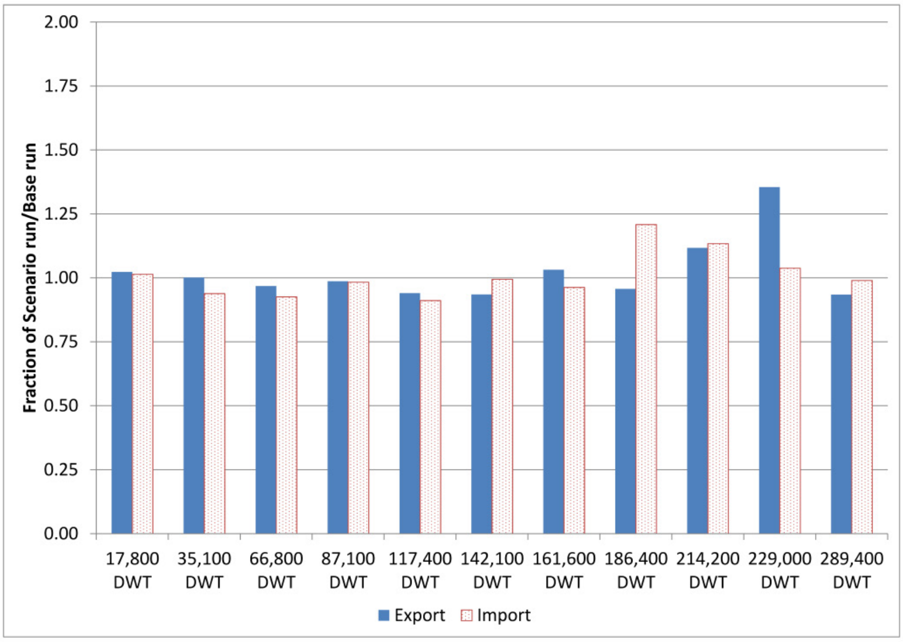


Figure 6.22: Relative changes in fleet activity, compared to the base run, expressed as number weeks per size group for both importing and exporting trade routes of Greater China

While these changes give some insight, it is also interesting to see how these changing trade patterns affect the costs of transport. Figure 6.23 presents the relative change in costs, averaged over all trade routes and with lines representing the maximum and minimum found for each size class. While the shifting does seem to give the China region larger, presumably cheaper, vessels, this affects the freight rates in other regions. In several cases the original rates have either doubled or halved, although the average remains the same.

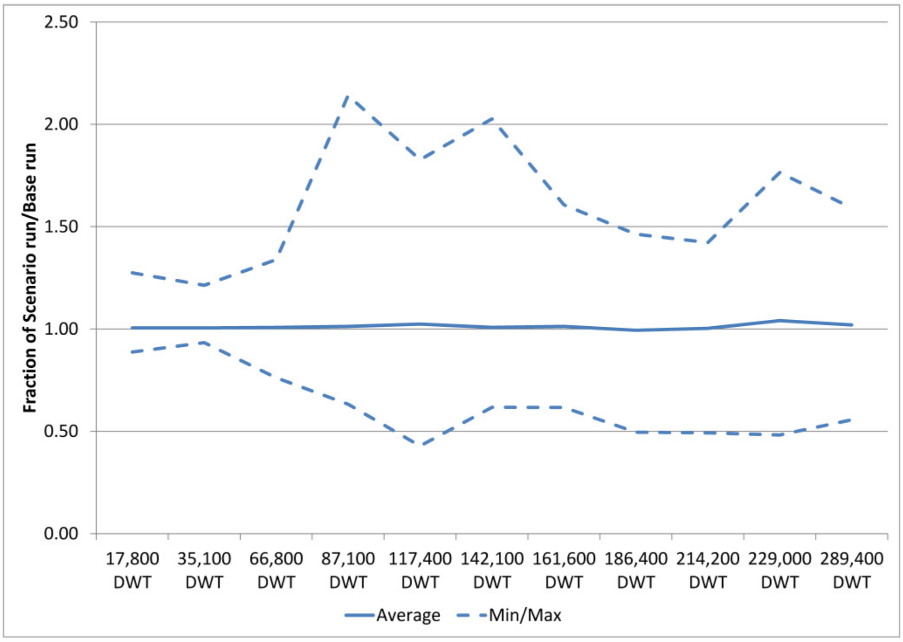


Figure 6.23: Relative average changes in freight rates per size class, combined with the minimum and maximum relative rate for the size class

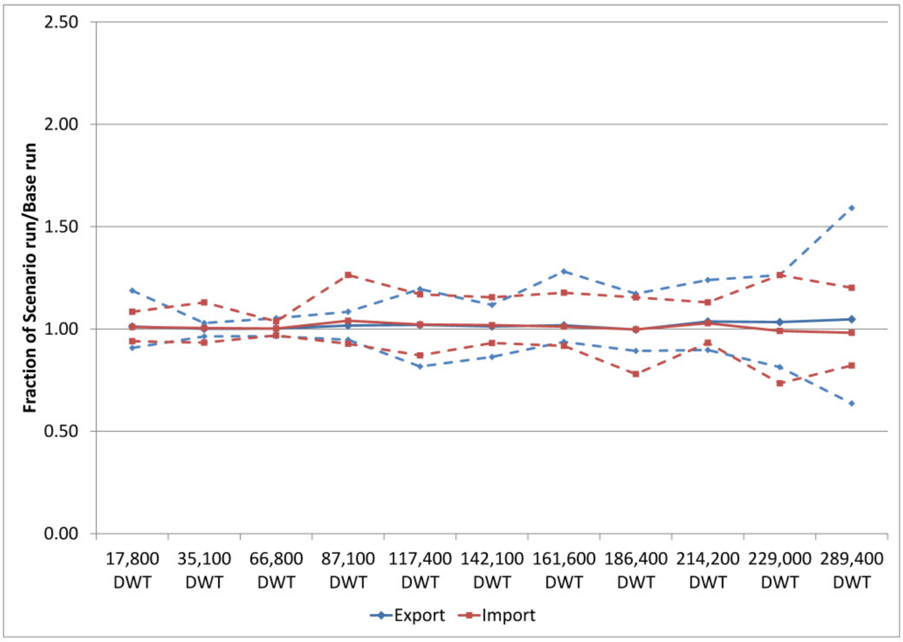


Figure 6.24: Relative average changes in freight rates for import and export of China per size class, combined with the minimum and maximum relative rates

Further investigations showed that these extremes are found mostly on small routes. This combined with the fact that the presented rate is the maximum rate of a certain month, can explain the large changes. The required vessels are most likely not available in the harbour at the required time, and the choice made might be to take a larger than necessary vessel (increasing the cost per ton shipped) or have a vessel move in from another port (increasing the costs per ton shipped). With a small trade the impact of changes in vessels available on the average (maximum) rate can be quite large due to these effects. Because both the import and export from China are large trades, the effect should be much smaller here. This is exactly what is shown in Figure 6.24. The average is still very close to one, but the changes to the maximum and minimum freight rates observed have also been greatly reduced.

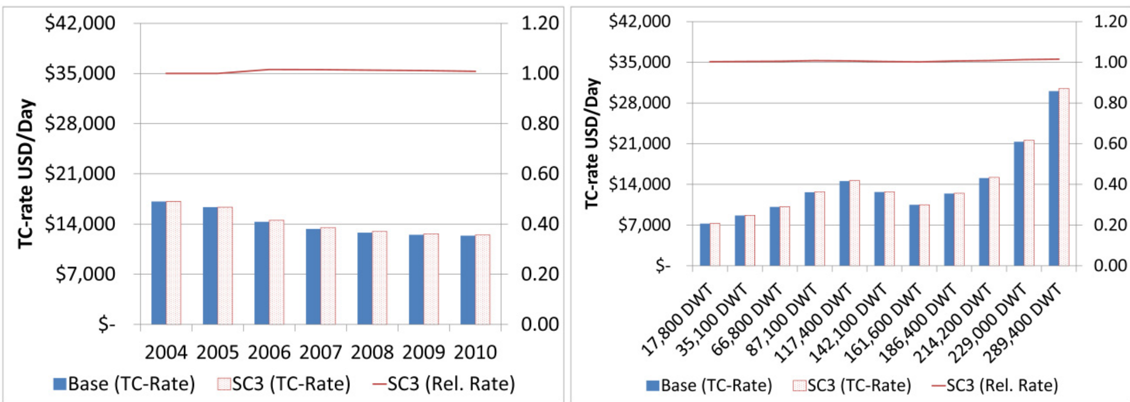


Figure 6.25a-b: Average TC-rates per year (a) and per size group (b) for both the base run and the Scenario 3 run, combined with the relative change in the rates

Because the average freight rates did not change much the expectation is that the TC-rates did not change much either. This is proven by Figure 6.25a-b where the TC-rates and their relative change are shown both as an average per year and per size group. In percentages neither changed by more than 2%. A last check is the newbuilding prices in China and the secondhand prices, but since neither changed by more than 1% the results were not put in a figure.

6.3.4 Conclusion on Scenario 3

The effects of a severe reduction in GDP growth for China has a large effect on its trading potential, but the effect is much smaller than expected on the overall bulk trading. The reduction in demand is absorbed by a different sailing pattern with a slight increase in overcapacity on all routes, but no substantial cargo transport costs alterations occur. Also the TC-rate and consequently the secondhand and newbuilding prices are not affected by this scenario.

6.4 Scenario 4: Changing trade winds

The final and most extreme scenario tested is a severe trade disruption. What will happen if a region suddenly cannot be reached anymore by sea, or a route becomes inoperable? How will trade, export and import be affected? How will this complex model deal with such a situation? The first subsection introduces both the use of blockades and the Suez closure, the most well-known historical example of such a blockade. The second sub-section discusses how such a disruption can be implemented in the model and the final section discusses the results of this scenario.

6.4.1 Introduction

There can be many reasons for a severe trade disruption, both natural and unnatural. In the case of natural disruptions one could imagine a volcano eruption or a tsunami rendering all ports in a region useless. The most obvious example of an unnatural event would be war, either within a region or between regions. Jones [2011] wrote the following about blockades as an instrument of war:

"A blockade is usually defined as a form of economic warfare whereby the enemy's supplies, and in particular their trading routes, are targeted in order to bring about capitulation. The use of the economic blockade in war is a modern variation of the older practice of the siege, whereby ancient, medieval, and early modern cities, fortresses, or similar strongholds were forced into surrender by an opposing force which surrounded them with the purpose of cutting off their access to supplies. While sieges were relatively small-scale operations, however, usually limited to one geographical site, the modern economic blockade marked an escalation of the practice of targeting supply routes to the state or national level. Although blockades historically have been carried out on both land and sea, maritime blockade has been the more prevalent phenomenon of the two and is thus the main focus here. The modern maritime economic blockade is defined by one recent commentator as "essentially a method of naval economic interdiction; its purpose is to prevent the ingress and egress of state vessels moving to and from the coastal areas

of the enemy, resulting in the economic and operational strangulation of the enemy's war effort" (Jones 1983: 762)."

In other words, in a large war, a maritime blockade will be the rule rather than the exception. The only well documented and still researched maritime blockade was the closing of the Suez Canal between 1967 and 1975. Even quite recently papers on this subject have been published such as Feyrer [2009] and Ratner [2011]. Although closing of the Suez Canal would be more in line with a scenario like the first one treated in Section 6.1. The goal of this scenario is to go further than just the trade length, and to first assess the economic impact before the trade impact is examined.

6.4.2 Implementation

The exact choice for this scenario is difficult. A large war in the Middle East is conceivable, although the oil reserves in this region would ensure a global war rather than local trade disruption. A war within the African continent is also not unthinkable, yet the impact on world trade would be low and the effects would therefore be hard to study. On the other hand a trade dispute between the US and China could also be an option and ensure a large impact. If the dispute would be a temporary economic disruption, such as a dispute of only 5 years, it would make a perfect, although not very likely, scenario. A second cold war would most likely be the result of such a scenario. The impact of such an event on the model would be very complex, making the cold war an unpractical scenario to test the model. Therefore, a temporary trade disruption between Greater China and North America was chosen as a suitable test scenario.

Table 6.5: Changing trade to simulate a (trade) conflict between China and North America

Export	Greater China (Base)	Greater China (SC4)	North America (Base)	North America (SC4)
Hamburg - le Havre Range	0.1392	0.1777	0.1318	0.1374
Baltic Area	0.0431	0.0550	0.0130	0.0136
Black Sea Area	0.0114	0.0146	0.0025	0.0026
Mediterranean Area	0.0456	0.0582	0.0324	0.0338
North Africa	0.0088	0.0112	0.0059	0.0062
West Africa	0.0076	0.0097	0.0025	0.0026
South Africa	0.0071	0.0091	0.0038	0.0040
Middle East	0.0292	0.0373	0.0166	0.0173
India	0.0274	0.0350	0.0127	0.0132
Southeast Asia	0.0461	0.0589	0.0210	0.0219
China	0.0032	0.0041	0.0410	0.0000
Fareast Asia	0.1296	0.1655	0.0600	0.0626
Oceania	0.0270	0.0345	0.0161	0.0168
North America	0.2168	0.0000	0.5129	0.5348
West coast South America	0.0077	0.0098	0.0169	0.0176
East coast South America	0.0156	0.0199	0.0276	0.0288
Rest of the world	0.2345	0.2994	0.0831	0.0867
Total	1.0000	1.0000	1.0000	1.0000

Import	Greater China (Base)	Greater China (SC4)	North America (Base)	North America (SC4)
Hamburg - le Havre Range	0.0882	0.0966	0.1304	0.1537
Baltic Area	0.0324	0.0355	0.0202	0.0238
Black Sea Area	0.0025	0.0027	0.0027	0.0032
Mediterranean Area	0.0230	0.0252	0.0332	0.0391
North Africa	0.0041	0.0045	0.0117	0.0138
West Africa	0.0012	0.0013	0.0142	0.0167
South Africa	0.0078	0.0085	0.0044	0.0052
Middle East	0.0473	0.0518	0.0225	0.0265
India	0.0175	0.0192	0.0136	0.0160
Southeast Asia	0.0460	0.0504	0.0245	0.0289
China	0.0922	0.1010	0.1516	0.0000
Fareast Asia	0.2479	0.2716	0.0922	0.1087
Oceania	0.0421	0.0461	0.0123	0.0145
North America	0.0874	0.0000	0.3373	0.3976
West coast South America	0.0166	0.0182	0.0151	0.0178
East coast South America	0.0293	0.0321	0.0329	0.0388
Rest of the world	0.2144	0.2349	0.0812	0.0957
Total	1.0000	1.0000	1.0000	1.0000

The impact on the economic model is the removal of trade streams from both regions' import and export dividers. Also the determination of the exchange rate will be altered for this scenario, excluding the other nations from the equation. The changes are shown in Table 6.5. As a result of this scenario, trade between the regions becomes zero, so no alternations to the shipping model are necessary.

6.4.3 The results

The rerouting of trade has almost no effect on GDP; the GDP of both China and North America does not change compared to the base run. Also, the GDP of the other countries remains the same with one exception, the Westcoast South America. This region shows an increase of 14% on average. The effect of this increase on global trade is negligible as changes in total import and export are (far) less than 1%. The imports and exports of China and North America are affected as well, as seen in Figure 6.26. Remarkably, North America benefits from this conflict by increasing its exports slightly. China, on the other hand, sees a large effect on imports but minimal changes in its exports.

As discussed in Chapter 5, the model uses imports to determine the global trade patterns. This might result in a different pattern than when considering the macroeconomic version of import and export. Figure 6.27 shows the changes to the dry bulk cargo imports and export for China, North America and the rest of the world. While the dry bulk trade for North America increases slightly, it is completely the opposite for China. Export is reduced by about 20% and imports by up to 15%. There are two causes for this; as can be seen in Table 6.4 of the previous section. First, trade between North America and China is in all cases a much bigger portion of Chinese trade than North American trade. The second element that is important for this change is the division of trade over dry bulk, wet bulk, general cargo and fiscal trade for each of the routes in the region. Apparently the change of trade resulted in a growth of the dry bulk portion of trade for North America. For China the result was the opposite, less dry bulk was transported, aggravating the loss of imports.

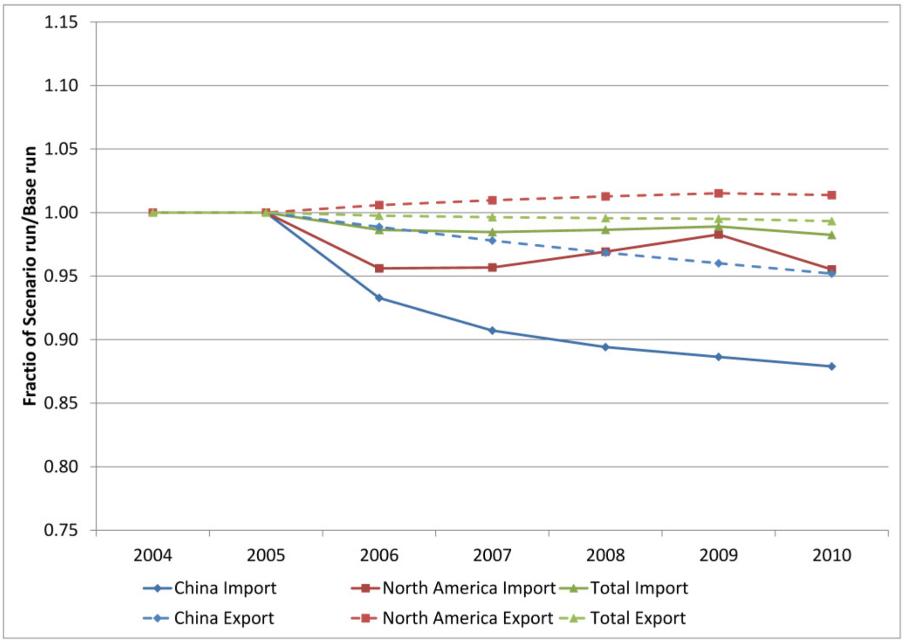


Figure 6.26: Changes in import and export (USD) for China, North America and global totals

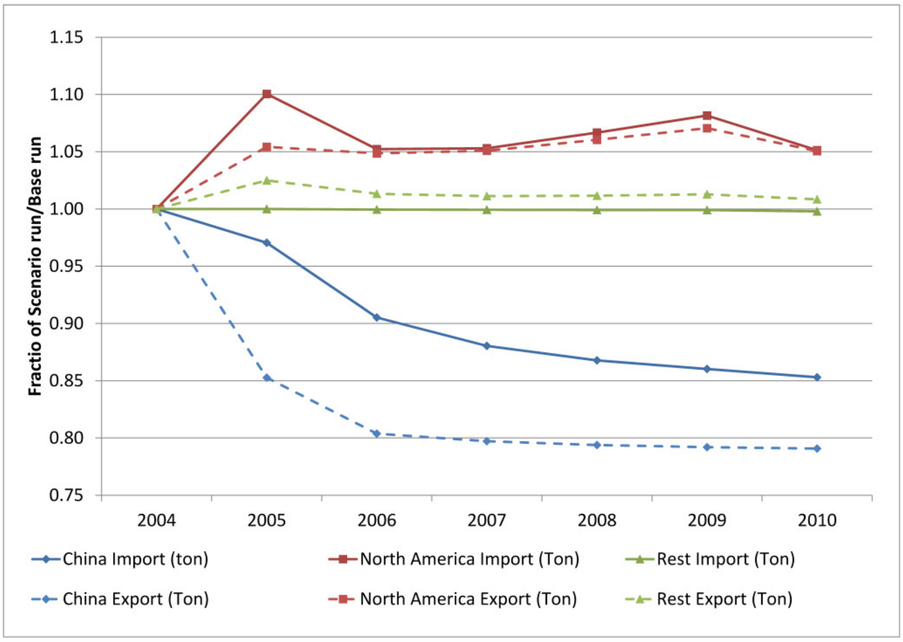


Figure 6.27: Changes in import and export (ton) for China, North America and the average of the rest of the regions

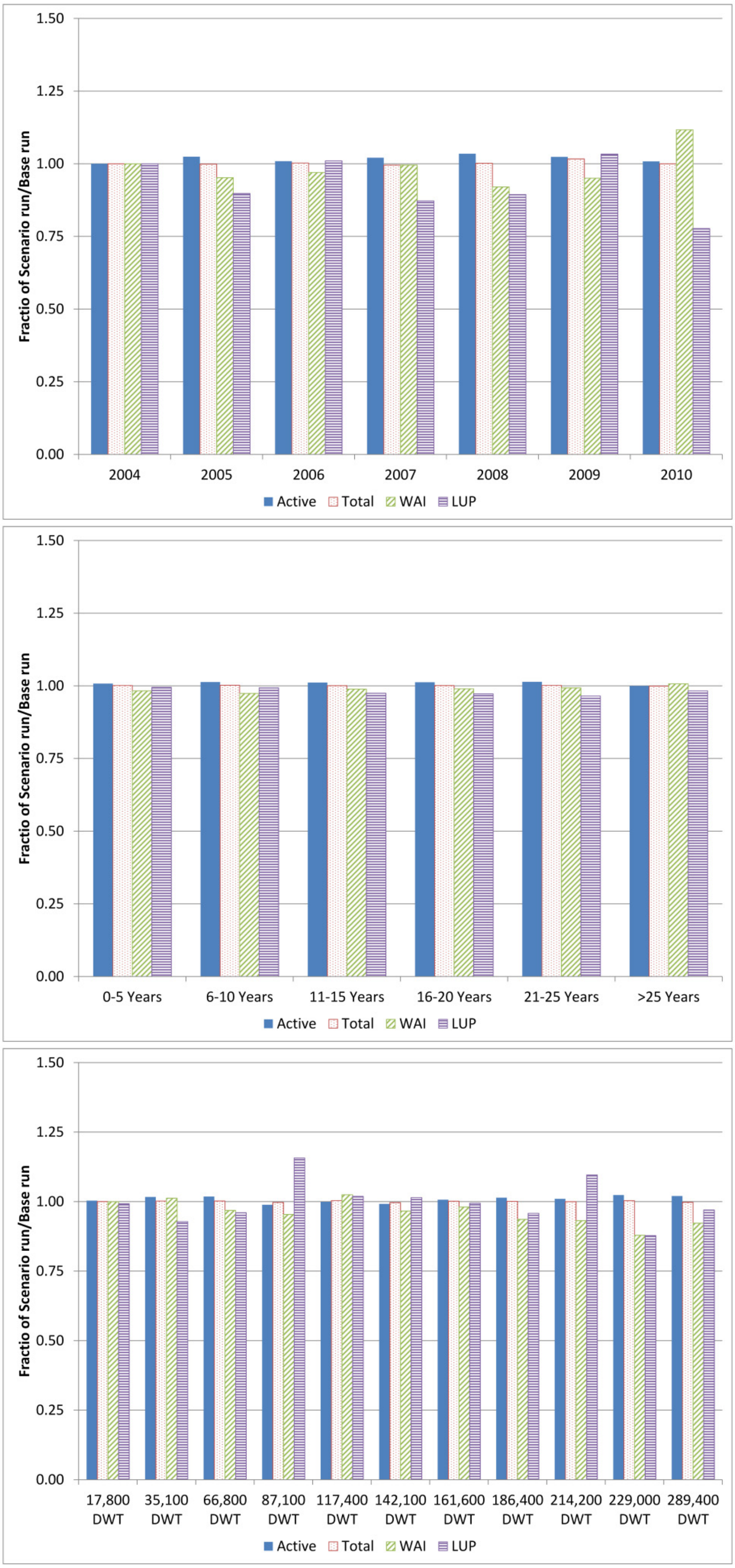


Figure 6.28a-c: Changes in the Activity, totals, waiting (WAI) and Lay-up (LUP) of vessels averaged per year (a), age group (b) and size group (c)

Does the change in trade have any consequences for the vessels providing the transport capacity? When considering the activity and inactivity of vessels in Figure 6.28a-c, the total fleet remained equal, while activity of the fleet increased and on average waiting and lay-up declined slightly. The overall fleet activity did not change much, only a slight increase in activity (expressed in sailing weeks). However, when focussing on China and North America changes are expected, since trade patterns changed significantly here. Figure 6.29 shows the fleet activity per size group just as the light blue columns of Figure 6.28c, but this time focussed on both the import and export of China and North America.

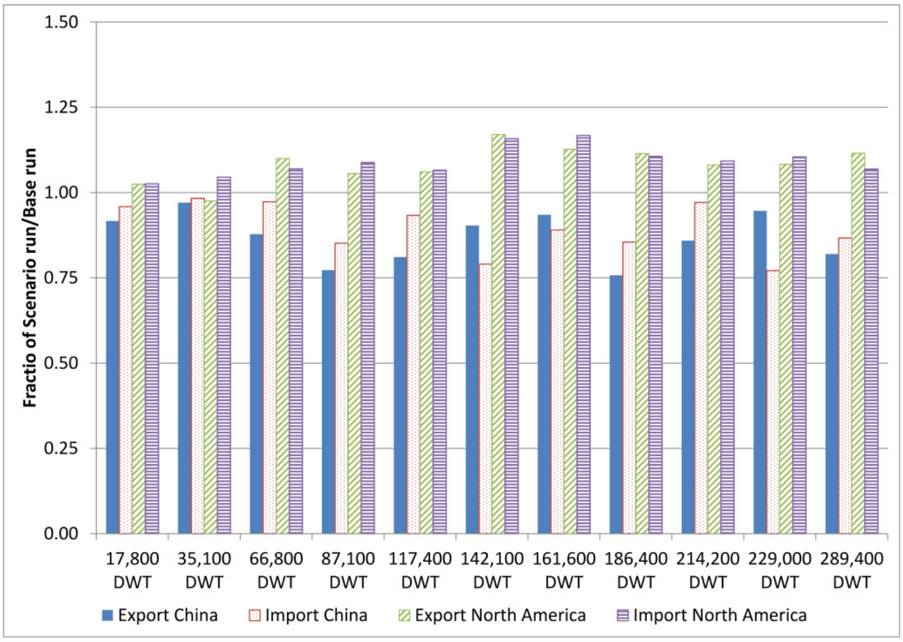


Figure 6.29: Activity changes per size group for im- and exports of China and N-America

From Figure 6.29 two things are clear. First, the changes in trade are not divided equally over the size groups, but instead each trade and direction has its own preferences. Next to that, it seems that the average reductions or increases are not in line with the reduction in cargo. To check this Figure 6.30a-b shows both the changes in cargo and in DWT*Week (the total activity on a route taking into account the difference in vessel sizes). With at most one exception per series it is clear the overcapacity in all four cases has grown in this situation (the thick line is almost always higher than the dashed line).

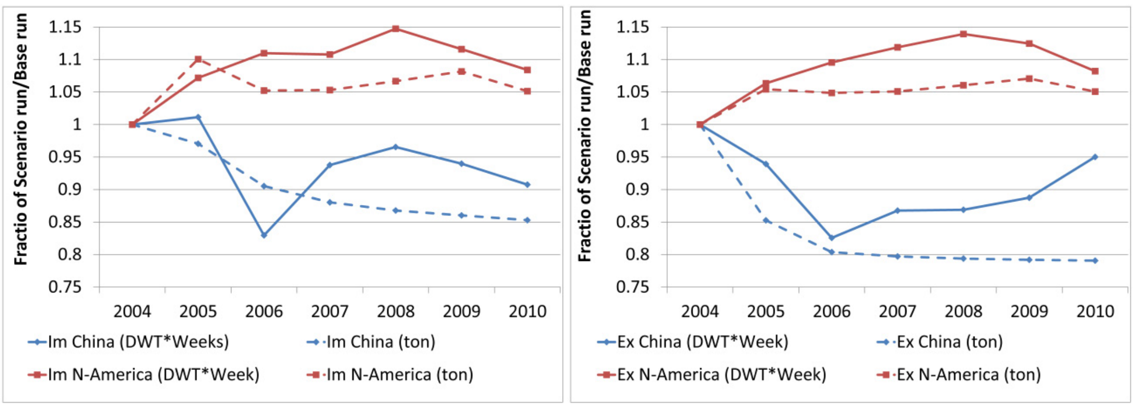


Figure 6.30a-b: Activity and trade changes for im- and exports of China and N-America

The effect of these changes in fleet assignment on the freight rate is studied next. Figure 6.31 shows the overall changes to the freight rates, by presenting the average change, the maximum and minimum change, as shown in Section 6.3.3. Just as before, the influence on the average freight rate can be neglected. However in several cases the maximum has increased by more than two times the original value. These changes are more the exception than the rule, as most of the times changes to the maximum rates lay between plus or minus 20%.

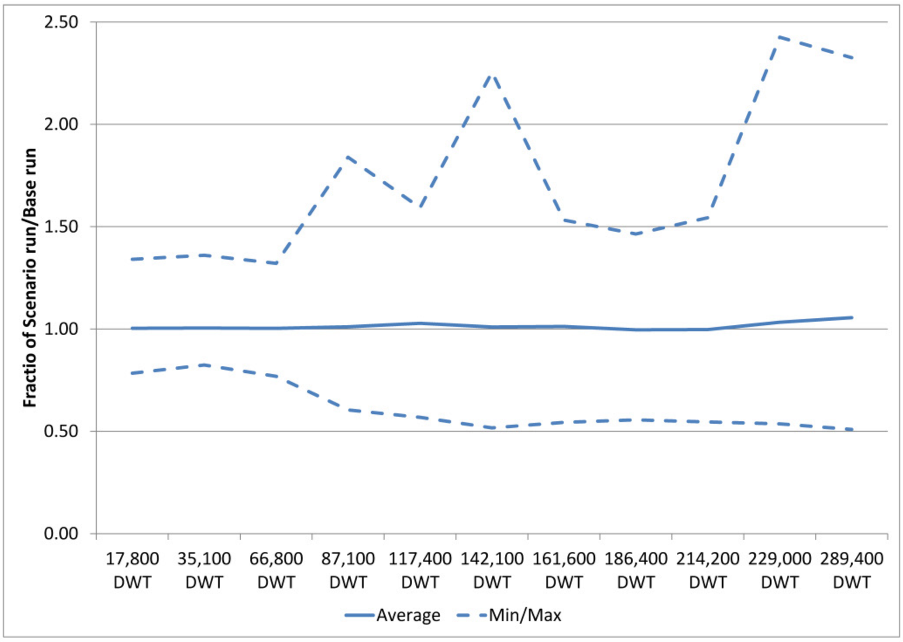
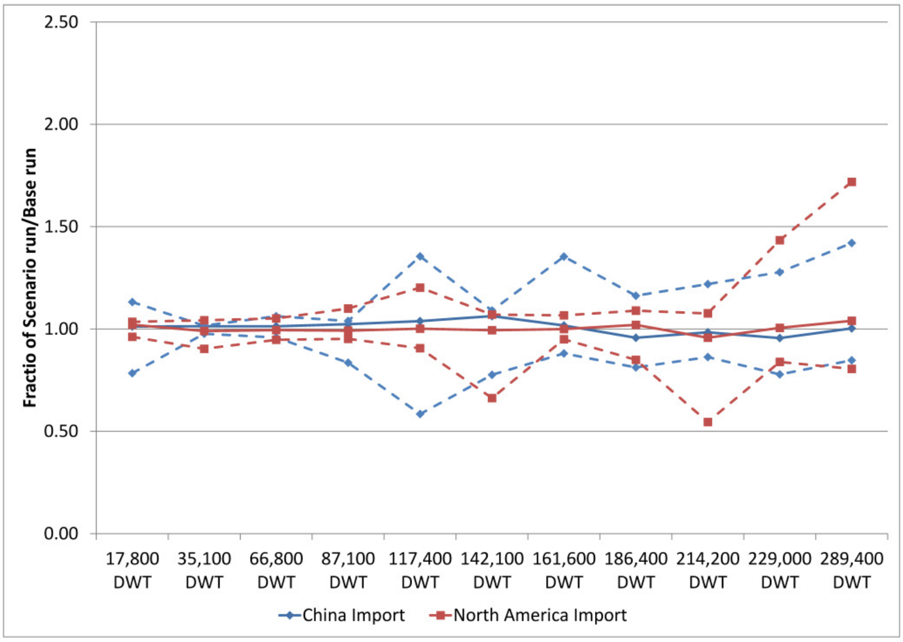


Figure 6.31: Changes in the average freight rates per route averaged per size group

Figure 6.32a-b shows the same results for the import and export from these two regions, because China and Northern America are the subject of this investigation. The average rates per size group remain unchanged, however, the spread between the minimum and maximum has greatly reduced. In the majority of the cases it is now within the 20% difference mentioned before. Actually, the minimum rate should be zero as there is no rate between North America and China and vice versa. However, as many freight rates have a zero value, these have already been filtered out of the data before representing it.

The large change in the maximum freight rate for Chinese export of the 87,100 DWT vessels seems peculiar. Large changes are also seen for larger sizes, but their number is much smaller, which would allow for such randomness. In this case the source of the problem lies in the route Middle East to China. Only 9% of the observations show a freight rate at all (about 370 observations out of 4000). Of these observations in the base case only two involve a vessel of 87,100 DWT. In the scenario case, there are 8 observations, increasing the chance of a vessel coming from further away, as was the case here.



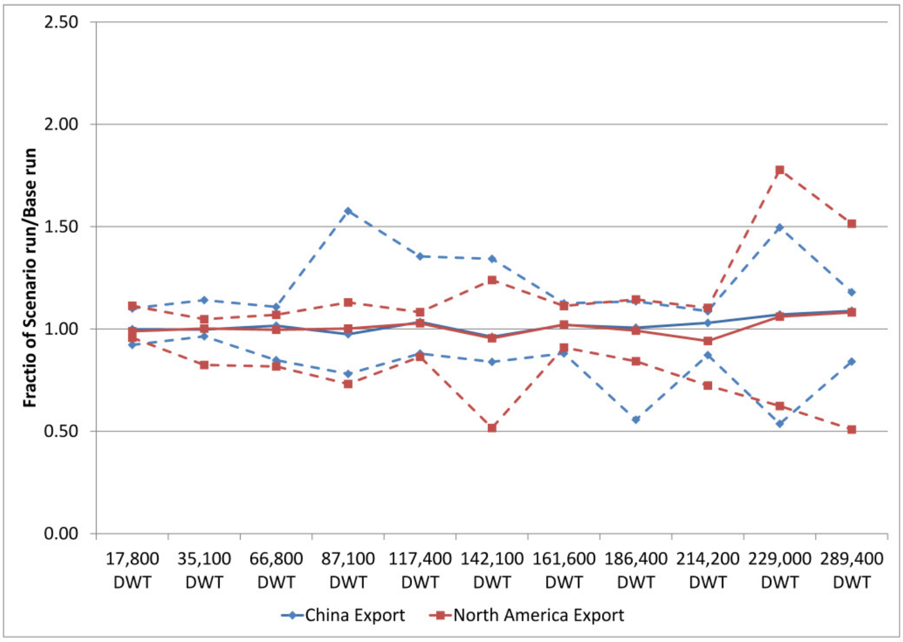
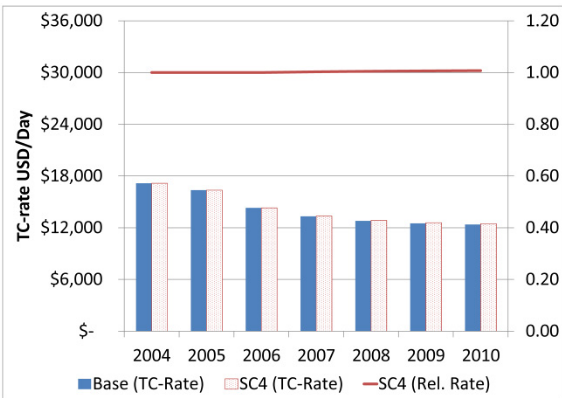


Figure 6.32a-b: Changes in the average freight rates per route averaged per size group for the import (a) and export (b) for China and North America



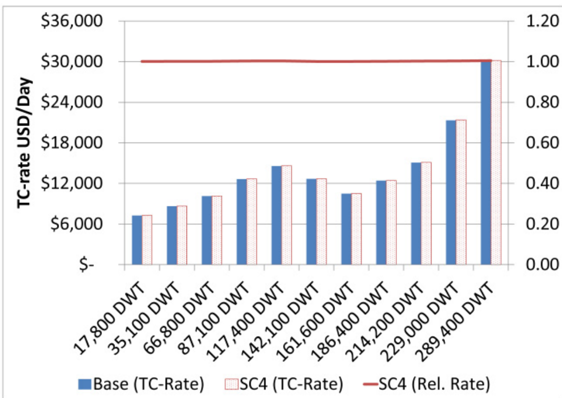


Figure 6.33a-b: Changes in the average TC-rates per year (a) and per size group (b)

With such small effects on the Macro-Economic level and on the average freight rates, the expectation is that the TC-rates will not be different from the base run. This is shown in Figure 6.33a-b, with both bars for the absolute TC-rates and lines for the relative difference. All rates are nearly identical, with maximum differences of about 0.5%. This means that no changes are found for the newbuilding and secondhand values of the vessels either.

6.4.4 Conclusion on Scenario 4

The conclusion of this scenario is quite unexpected; when considering only the bulk trade, North America will benefit from a trade dispute between them and China, while China will suffer. Of course, this is a very limited approach. For a more complete picture the wet bulk, general cargo and money flows should also be considered. The current model allows the scenario to be studied and provides results that can be explained, although they are not always as one would expect beforehand.

6.5 Combining all four scenarios

In this section the last main question of this thesis plays a central role: what are safe investments given a set of scenarios? In the previous four sections a number of scenarios have been tested and investigated. This section will re-evaluate the results from the point of view of a ship owner. While many options are possible, the purpose of this section is to show what else is possible with the data available from the model. Each option would require many detailed calculations and overviews without adding much new insight into the model and its results. The example worked out here is that of a new investor in shipping. This investor wants to buy a vessel, but is not sure whether it should be a new, young or old vessel. The amount of money assumed available for the investment is about 30-35 mln USD.

At the end of 2004 this will allow him to buy one of the following vessels:

- A 66,800 DWT Panamax vessel to be delivered in 3 years for 34.0 Mln USD
- A 66,800 DWT Panamax vessel of 5 years for 30.3 Mln USD
- A 289,400 DWT Capesize vessel of 21 years for 29.9 Mln USD

To compare these options a Net Present Value (NPV) calculation is made for each of the options. It would be possible to do the calculations with weekly values, but for convenience yearly values are chosen here. The vessels will not be time chartered but will sail only voyage charters. However, this choice for voyage charters brings an extra complication: which routes shall the vessel normally sail and how often will it find cargo on this route? To solve this issue, the assignments for the years 2005-2010 for the base run are consulted and ordered in descending order of popularity for each of the vessels. The most popular route is taken first, and the next route will start in the destination of this first route and will again be the most popular. This process continues until a round trip is created. The assumed fraction of time cargo is available on that trip is loosely based on the difference in route popularity. The result of this process is presented in Table 6.6.

Table 6.6: Roundtrip choices for each vessel size option

66,800 DWT	**Abbreviation**	**Weeks sailed**	**Fraction of cargo assumed available**
Hamburg/Le Havre - Mediterranean	HAMMED	33366	1
Mediterranean - Hamburg/Le Havre	MEDHAM	11512	1/3

289,400 DWT	**Abbreviation**	**Weeks sailed**	**Fraction of cargo assumed available**
Fareast Asia – North America	FEANAM	559	1
North America – North America	NAMNAM	1414	1
North America – Hamburg/Le Havre	NAMHAM	327	1
Hamburg/Le Havre – Fareast Asia	HAMFEA	88	0

With the routes known, the yearly income can be calculated using the average freight rate (USD/ton) per year for each route and scenario and combining this with the cargo capacity of the vessel and the time it takes to complete the roundtrip to scale up the route income (Table 6.7). The cost side of the vessel exploitation exists of a fixed part, which depends on the scenario and year. This fixed part is already expressed as yearly costs. The second part is the consumption, which is related to the distance sailed. With the distance as well as the duration of a roundtrip available, it is possible to calculate the consumption costs per roundtrip and scale the results up to a yearly value.

Table 6.7: Overview of distances and durations of the selected roundtrips

	FEANAM	**NAMNAM**	**NAMHAM**	**HAMFEA**	**Total**
Distance	5730	13980	5552	11291	36553
Duration	4	7	4	6	21

	HAMMED	**MEDHAM**			**Total**
Distance	2708	2708			5416
Duration	2	2			4

With both the investments and the cash flows known for all scenario cases, the only thing missing is the sales price of the vessel in December 2010. This is easily retrieved from the available data. It is possible to construct a NPV calculation with these three elements. For this case the discount rate is set to 10%. Table 6.8 shows the discounted cash flows and resulting NPV for the Young vessel case (the 66,800 DWT vessel of 5 years).

This table clearly shows that each of the options has a very different development of the discounted cash flow and thus a different NPV. The NPV is spread over a large range, from negative 15 Mln USD up to more than 50 Mln USD, in the same 6 year period. Figure 6.34 shows the division of NPV outcomes for all three options given to the owner. The new Panamax vessel has a very small change of a positive NPV while the old Capesize vessel shows a 50/50 division. In half the cases the old Capesize will result in a negative cash flow of about 20 Mln USD, and in the other half in a positive cash flow of around 10 Mln USD. The best option seems to be the young Panamax, although in this case there is also a 20% change of not obtaining enough cash to turn the NPV positive.

Table 6.8: Discounted cash flows and NPV for each scenario for the Young vessel option

Cash flow	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	NPV
Base	M$-30.30	M$9.99	M$7.62	M$5.72	M$4.90	M$4.60	M$15.33	**M$17.85**
SC1a	M$-30.30	M$8.48	M$6.41	M$5.29	M$4.36	M$4.05	M$15.02	**M$13.32**
SC1b	M$-30.30	M$8.62	M$6.60	M$5.36	M$4.41	M$3.87	M$14.96	**M$13.50**
SC1c	M$-30.30	M$8.47	M$6.59	M$5.27	M$4.54	M$3.91	M$14.87	**M$13.35**
SC2a	M$-30.30	M$9.80	M$9.11	M$8.76	M$9.24	M$6.59	M$15.87	**M$29.07**
SC2b	M$-30.30	M$9.54	M$14.69	M$14.59	M$15.36	M$9.49	M$18.06	**M$51.43**
SC2c	M$-30.30	M$0.26	M$0.21	M$1.09	M$1.35	M$1.55	M$10.73	**M$-15.11**
SC2d	M$-30.30	M$-0.43	M$1.14	M$3.76	M$4.16	M$2.99	M$12.63	**M$-6.05**
SC3	M$-30.30	M$9.91	M$7.14	M$5.94	M$4.77	M$4.56	M$15.22	**M$17.23**
SC4	M$-30.30	M$9.55	M$7.19	M$5.67	M$4.27	M$4.32	M$14.77	**M$15.48**

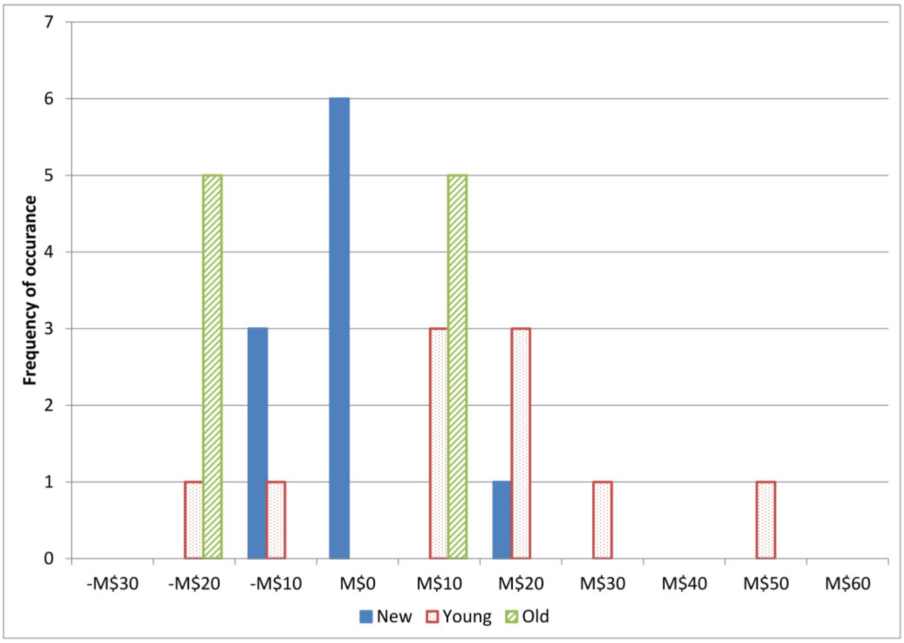


Figure 6.34: Overview of NPV outcomes for all three vessel options in steps of 10 Mln USD

The outcome described above is admittedly disputable, since some scenarios are taking part more than once in the final overview and many more options might be more likely than the ones chosen here. Still the large variations, even within the same scenario, also shows the power such a comparison can offer to a ship owner, bank or someone else interested in investing in shipping.

6.6 Conclusions

This chapter has tested the capabilities of the developed model. Four scenarios were set up to demonstrate the effect of changes on different levels of the model. The scenarios were also used to answer the research questions asked in section 1.2. The first four questions relate to changes in outcome (compared to the base scenario). These were answered per scenario. In almost all cases the ordering of vessels was on the low side, just below what is required to maintain the current fleet, and also the changes to the TC-rates were often lower than expected. In turn this resulted in minimal changes in the development of secondhand and newbuilding vessel prices.

It has been demonstrated that the four sub questions can be answered when studying a scenario. However, for the main research question a number of scenarios are required. As the four scenarios plus the base run resulted in an output of 10 runs, these were all used to test if the model can also be used for the investment analysis of an individual ship owner. The potential profitability of the selected vessels showed large variations. This is not only the case between vessels or between scenarios, but especially within a scenario. In the cases where 3-4 different options for a scenario were tested the outcome for the vessels could differ significantly.

The large variations and especially the sometimes unforeseen side effects of a shock or change in the economic situation allow users to learn much about the maritime economy. Examples of such unforeseen effects are the fact that the North American bulk trade will benefit from a disruption of trade with China and that the opening of the NSR will not offer great benefits to bulk shipping.

Several parts of the model require some improvements, the fact that these restrictions apply to both the base run and the scenario make the relative outcome of a scenario a valuable asset in studying the potential of a vessel or group of vessels and in how to best deal with potential threatening situations.

7. Conclusions and recommendations

The first section of this chapter draws the conclusions in relation to the research targets set out in section 1.2. This is followed by a number of recommendations that are the result of observations and intermediate conclusions on the functionality of the model.

7.1 Conclusions

In Chapter 1 the Phoenicians were used to introduce the uncertainty about the future when considering an investment in the maritime industry. The power of scenario analysis was also highlighted as an option not only to gain insight in the future, but also to learn about the workings of the (maritime economic) world. The goal of this research centred on the following questions in light of changes to the macro economy, the shipping market and a single company:

Main. What are good investments given a set of scenarios?
1. What will the demand for transport be on the most important routes?
2. What fleet development will be required to support this demand?
3. Which type of vessels will be built and which will be phased out?
4. How will the newbuilding sector react to these changes?

Although many models exist that can offer answers to some of these questions for one of the three mentioned levels (macroeconomic, shipping market and business level) there were no models available that are able to span two, let alone all three of these levels or answer all questions satisfactory. Therefore it is not possible to test scenarios of the future in a consistent model spanning all three levels of detail.

The investigation of the available models and the further investigation of these models brought much insight, especially in the latest status of maritime economic research for each of the levels. The fact that both large multi country models (MC-models) and structural shipping models have not been the subject of research for several decades is one of them. The trend has been towards models using large time series, but with a limited number of variables, fed by the more recent availability of this data and the study of individual aspects of the (maritime) economy. Still, with so much new knowledge it is almost a shame to not combine this once more in larger models, as the computer power to do so is easily available nowadays.

In contrast to the above described trend, data is still an issue especially when a large MC-model is focussed on some, economically seen, small countries. Especially reliable data on countries in e.g. Africa, or the former eastern bloc, is hard to come by. The fact that the results of the MC-model are still promising, despite several smaller weak points, is seen as a clear incentive to continue along this line of research. The insight and power offered by such models is large.

For the estimation of the secondhand and newbuilding prices as well as the ordering of new vessels, data from the period 2000-2010 was available. This is the same period in which the largest boom (and bust) of the past 40 years took place. Though definitely interesting to study, this boom also brought TC-rates and ordering levels with it that were not seen for those same 40 years. As the model is based on real costs, this did affect the applicability of these estimations in the model. Especially the ordering of vessels seems to suffer from this boom scenario, although the equilibrium ordering seems to be about 12%, this is only stable with a contract duration of 3 years. This low level of ordering was also the reason to adjust the scrapping of the vessels. With these adjustments the model runs smoothly and the assignment of the fleet based on costs, gives a lot of insight in how the world fleet can effectively deal with changes of its environment.

In Chapter 6 the four research sub questions were answered for four different scenarios which spanned the entire range of levels, using a model that is consistent over these three levels. Also the main research question was answered in this chapter. A surprising conclusion was that the Northern Sea Route (NSR) is economically not viable with rates close to the costs of transport. Even with only half the fee for the NSR, the freight rates could not drop to the same level as going through the Suez Canal. In this scenario no costs or limitations for ice strengthening were taken into account, which would make reality most likely even more pessimistic.

In case fuel prices keep rising as tested in the second scenario, the effects seen in the model are twofold. First of all, the total volume of trade increases as more countries have access to money. Secondly the size of the fleet does only change a little, as the increased costs ensure a higher efficiency in the transport of cargo. The latter could be a side effect of the fact that the fleet was increased artificially to deal with a lack of supply. In a normal case a lack of supply would lead to very high rates. Another unexpected relation that was found is that a reduction of 10% in the speed of the vessel only results in a reduction of 10% of the freight rate, compared to the higher speed scenario. Based on the rule of thumb that consumption is related to the roughly the third power of the speed. This linear relation is lower than expected.

In the third scenario the GDP of China stops growing at its previous 10% year-on-year rate. The effects on China’s trading potential are certainly measurable, however, the world dry bulk fleet does not need to suffer from this, as the reduction in trade is absorbed by sailing a different pattern and has no effect on the TC-rate and the prices of vessels.

In the last scenario, an economic boycott between North America and China, the effects on the bulk trade were somewhat unexpected. Looking only at dry bulk, North America actually benefits from not trading with China, while China feels the effects not only in its trade, but even in the GDP levels. Clearly an effect of the (assumed) redivision of trade.

Such insights as described above can be a great asset, when determining the strategies for the future of a company, no matter if it is a shipping firm, a shipyard, or a bank/investing firm. Being able to predetermine your actions, based on known effects if a certain scenario takes place, can be crucial to your existence.

While the individual and, in this research, sometimes unlikely scenarios were certainly revealing. The potential of this complex model was shown especially by answering the main research question. For this 3 investment options for a new owner using an ordinary net present value (NPV) calculation were compared over all available scenario runs. The results could change drastically between runs, even for two runs within the same scenario. The best option (out of 3) would also change depending on the scenario. The resulting distribution of NPVs can help an owner, bank or other investor to establish the risks involved in this investment, not only for a single ship, but also for sectors or strategies doing the same calculation for multiple vessels. The weighing of scenarios was skipped here, but is an important part in determining the best option, though it is highly dependent on the preferences of the company/user. Instead of investment options also the fleet of an owner can be studied, predicting changes in income, given a certain scenario, or testing hiring and releasing strategies.

The final conclusion of this research is that bridging the previously existing gaps between models is possible and necessary to capture the complex nature of global and maritime economics. The approach has the potential to offer great insight in a large number of problems using a consistent environment. The fact that a problem is not studied in isolation reduces the risk of drawing the wrong conclusions by excluding an important variable by accident. The current model is a major step in the right direction, though exact predictions were never the goal. The power of this model lies within describing the differences between scenarios. This means that growth of e.g. GDP is relatively dependable, the exact level of GDP ten years into the future is not. Even more reliable is the difference in growth between two scenarios. As discussed in the overview of macroeconomic models, many such models are used to study the propagation of a shock, not the absolute value, this model is derived from such a model and therefore no different.

These factors make the model most suited for medium and long term decisions, as these concern deviations from the current path, and strategies to cope with potential hazardous changes to the environment of the company.

Unfortunately in such a multi-level model, the mistakes of the previous level are carried over to the next. The model is therefor only as good as its weakest part. Hence, several improvements could be made to further improve upon the workings of the model and to make it suited for practical applications in the future. These are discussed in the next section.

7.2 Recommendations

A number of improvements have been mentioned throughout this thesis. This section will summarise the most important ones per detail level of the model. The first one will be related to the macroeconomic level, the second and third one concern the shipping market modelling and the fourth one relates to the fleet allocation module. The final recommendation concerns all levels.

The re-estimation of the MC-model is currently the weakest point of the model. Estimations might currently need to be based on as few as six data points. More data about these regions should be collected or purchased. Buying such data was unfortunately outside of the possibilities of this research but most likely would allow for better estimations in the future. If data is updated anyway, it will also be good to extend the horizon of the model by moving the start of the model to 2010 or later. The current model starts a modelled run in 2005, which puts the horizon in the near future. Still, the main interest in this research is in the differences between scenarios and between e.g. trades. For this consistency of the model is more important than the actual value of a trade in a certain year. This will allow the model to be used longer without the need for continuous updates of the model data and estimations. Un update is only required if the economic circumstances in which we operate change significantly. The effort involved in both updating the timeline and improving the estimations is large, at least several months work. The outcome is also unsure, only if it results in a better model, it is worth the effort, and unfortunately this cannot be determined beforehand.

For the shipping markets the newbuilding ordering part poses some issues as it consistently orders too few vessels, as shown in section 0. Unfortunately not much research has been done on this aspect of the shipping market. A first step should be to investigate if data from a different time period (excluding the boom of 2008) would yield better results. After this re-estimation, further research could be done to acquire data currently not available or not used in the current estimation, such as lay-up statistics, other investment markets, etc. The effort of improving this part is quite large, especially if new data sets are required. On the other hand, it is a unexplored research area within maritime economics. Its exploration should not be without benefits, as it will in any case help in the understanding what governs ordering at a macroeconomic level.

While the above recommendations will further improve the validity of the current model, they do not complete the model. In light of time and data restrictions (a.o. the fact that the Middle East did not show very realistic behaviour) only the dry bulk model has been modelled. However, wet bulk and general cargo, including container transport, are two other very important maritime markets that currently are not included in the model. An investigation of these markets should be done to make the model relevant for the shipping industry. The effort in this case is large, and is more likely years' work instead of months'. On the other hand, this work is absolutely necessary to complete this model. The conclusions drawn here are only valid for the dry bulk sector, these conclusions are interesting, but do not provide the complete picture. Only with the addition of wet bulk and general cargo can the model be deemed complete and relevant for most of the maritime market.

In this research the choice was made to use a linear programming solution to optimize the fleet allocation since the optimal solution is known in such a case. This forces the found integer solution of the problem to be very close to the optimal solution (within 2.5%). However, the technique does not allow the optimisation of the assignment to be based on the costs of transport of the most expensive vessels, since the costs of transport for a vessel has to be a linear expression. In a rational world with full information disclosure (as assumed here), the cargo tariff on a route for a certain vessel size will be based on the costs of transport for the most expensive vessel of that size. To allow this aspect to be taken into account, perhaps a different optimization technique may be better suited to solve this problem. Most of these techniques, like a genetic algorithm, pick a number of random solutions and calculate the (total) costs of this solution. The outcome is used to populate the next round of random solutions and find an optimal solution. The downside of such an approach is that there is no guarantee that the discovered solution is the optimal solution. The benefit would be that the optimization takes account of the costs of the most expensive vessel on the route. The effort is again a couple of months work, though if testing a large number of solutions is foreseen this will turn into years easily. It will benefit the reality of the model as TC-rates can then be based on freight rates, rather than costs of the vessel, making the link between freight rates, TC-rates and secondhand and newbuilding prices much stronger.

The final recommendation does concern all levels of the model. In retrospect all vessels are modelled individually. This means that for the calculation time of a scenario it does not matter if vessels are grouped or truly individual vessels. If enough data can be found it would pay out to further detail the bulk trade and limit the transportation of each trade to a limited number of vessels. This would increase the reality in the model as with more trades, smaller cargo shipments will be available and this will reduce the preference for large vessels, also the behaviour of and mitigation between trades could be studied in this way. Although not certain, the model might find a solution quicker as the difference between vessels is larger, though it will certainly also run out of supply faster as more smaller supplies will need to be managed. The effort involved is large, as many parts of the model will need to be extended to cope with the increase in freight types.

The order in which to implement these changes will depend on many elements. As the outcome of updating the MC-module are unsure, it might be wise to first focus on the other updates of the model. Extending the model with wet bulk and general cargo will be the most work, but will also go a long way in the acceptance by industry of such complex, consistent multi-level scenario models.

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List of Abbreviations

ACO	Ant Colony Optimisation
ARCH	AutoRegressive Conditional Heteroskedasticity
ARIMA	AutoRegressive Integrated Moving Average
ARMA	AutoRegressive Moving Average
B	Breadth of the ship
BAL	Baltic Area
BCO	Bee Colony Optimisation
BLA	Black Sea Area
Bln	Billion
CHI	Greater China Area
CGT	Compensated Gross Tonnage
D	Depth of a ship
DSS	Decision Support System
DWT	DeadWeighT
ESA	Eastcoast South America Area
Est	Estimation
FEA	FarEast Asia Area
GAM	General Additive Model
GARCH	Generalized AutoRegressive Conditional Heteroskedasticity
GDP	Gross Domestic Production
GT	Gross Tonnage
HAM	Hamburg-Le Haver range
IND	Greater India Area
k$	Thousand US Dollar
L	Length of a ship
LIBOR	London Inter Bank Offered Rate
LNG	Liquid Natural Gas
LPG	Liquid Petroleum Gas
LUP	Lay-Up time
MC-Model	Multi Country Model
MCM	Multi Country Model
MED	Mediterranean Area
MEMMOD	Macro-Econometric Multi country Model (Deutche Bank)
MIE	Middle East Area
Mln	Million
M$	Million US Dollar
NAF	North Africa Area
NAM	North AMerica Area
NB	National Bank
NPV	Net Present Value (calculation)
NSA	National Statistical Agency
NSR	Northern Sea Route (North or Russia)
OCE	Oceania
OPEX	Operating Expenses

OR-Models	Operation Research Model
P	Paper
PDPTW	Pick-up and Delivery Problem with Time Window
PPI	Production Price Index
PPP	Purchase Power Parity
PSO	Particle Swarm Optimisation
SAF	South Africa Area
SCxx	Scenario xx
SEA	SoutEast Asia Area
SITC	Standard International Trade Classification
TC-rate	Time Charter rate
Tln	Trillion
USD	US Dollar
VAR	Vector AutoRegressive
VAT	Value Added Tax
VRP	Vehicle Routing Problem
WAI	Waiting Time
WAF	West Africa Area
WSA	Westcoast South America Area

Appendix A Multi-Country Model; Equations and Estimations

Variables used in the model are listed in Table A.1, both the abbreviation used in the equations as well as their full name. The last column indicates if a variable is determined by the model, or has to be set by the user.

Table A.1: Variables used in the model

Abbreviation	Variable	Type
A	Labour demand / Employment	Endogenous
A_frac	Unemployment fraction	Endogenous
co	Production Costs	Endogenous
Cons	Real private consumption	Endogenous
depr	Depreciation rate for capital	Exogenous
E	Labour supply /Labour force	Endogenous
E_frac	Labour supply as fraction of the population	Endogenous
Ex	Exchange rate against the US-Dollar	Endogenous
G	Real government demand (Consumption and Investments)	Endogenous
GDP	Gross Domestic Product	Endogenous
I	Real private investments	Endogenous
IM	Real imports	Endogenous
IM2000	Imports in year 2000 prices	Endogenous
IM_p	Price deflator of imports (2000=100)	Endogenous
IMAK	World import demand for exports of this country	Endogenous
K	Real private capital stock	Endogenous
LAS	Long-term income	Endogenous
LPAC	Foreign competitors' deflator	Endogenous
M	Broad money stock	Endogenous
p	Price deflator of domestic demand (2000=100)	Endogenous
PEx	Deflator of export goods and services (2000=100)	Endogenous
PExA	World export deflator for imports of country	Endogenous
pi	Inflation rate	Endogenous
pi_{target}	Infation target rate	Exogenous
Priv_C	Real private consumption per capita	Endogenous
r	Long-term interest rate (government bond yields)	Endogenous
rs	Short-term interest rate (3 month deposito)	Endogenous
RSST	Short-term interest rate (long-run)	Endogenous
SB	Social benefits (transfer payments to households)	Endogenous
t	time	Exogenous
td	Direct taxes	Endogenous
td_frac	Direct tax-rate	Exogenous
ti	Indirect taxes	Endogenous
ti_frac	Indirect tax-rate	Exogenous
VE	National Income	Endogenous
w	Wage rate	Endogenous
Wo	Population	Endogenous
X	Real exports	Endogenous
Y	Real final demand	Endogenous
YV	Disposable income of households	Endogenous

Identity equations

$$Y = Cons + I + G + X \qquad (8.1)$$

Final demand (Y) is equal to the sum of consumption (Cons), investments (I), government spending (G) and exports (X) [Memmod, 2000].

$$VE = GDP * p - depr * K * p - ti \qquad (8.2)$$

National income (VE) is equal to the nominal GDP (GDP*p) minus the writing off of capital stock (depr*K*p) and minus the indirect taxes (ti) [Memmod, 2000].

$$YV = VE + SB - td \qquad (8.3)$$

Disposable income (YV) is the national income supplemented by the social benefits (SB) minus the direct taxes paid [Memmod, 2000].

$$K = (1 - depr) * K_{-1} + I \qquad (8.4)$$

Capital stock (K) is a level which is changed only by depreciation of present stock (depr*K_{-1}) and increased by new investments (I) [Memmod, 2000].

$$td = td\_frac * VE \qquad (8.5)$$

The amount of direct taxes (td) is calculated based on an average percentage (td_frac) levied on national income (VE) [Memmod, 2000].

$$ti = ti\_frac * Y * p \qquad (8.6)$$

The amount of indirect taxes (ti) is calculated based on an average percentage (ti_frac) levied on real final demand (Y*p) [Memmod, 2000].

$$GDP = Y - IM_{2000} \qquad (8.7)$$

Gross Domestic Production (GDP) is equal to final demand (Y) minus imports (IM_{2000}) [Memmod, 2000].

$$A\_frac = (E - A) / E \qquad (8.8)$$

The unemployment fraction (A_frac) is the fraction of the labour force (E) not active (A) [Memmod, 2000].

$$Cons = Wo * Priv\_C / 1000 \qquad (8.9)$$

Consumption (Cons) is equal to the population amount (Wo) times their private consumption (Priv_C). The factor thousand is only there to correct for differences in magnitude of the variables [Memmod, 2000].

$$E = E\_frac * Wo \tag{8.10}$$

The labour pool (E) is equal to the labour fraction (E_frac) times the total population (Wo) [Memmod, 2000].

$$IM = IM\_p * IM_{2000} \tag{8.11}$$

Nominal import (IM) is equal to Import at the 2000 price level (IM_{2000}) times the price deflator for import (IM_p) [Memmod, 2000].

$$RSST = \Delta \log(Y) + pi_{target} \tag{8.12}$$

$$Log(LAS) = Log(p) + 0.8 * Log(Y / E) + 0.8 * Log(1 - A\_Frac) \tag{8.13}$$

The long term wage level is dependent on the inflation (p), the average final demand (Y) created per unit of labour force (E), corrected for the unemployment rate (A_Frac) [Memmod, 2000].

$$IMAK_i = 1/(1 - h_{17,i}) * \sum_{j=1}^{16} (h_{i,j} * Country_j\_IM) \tag{8.14}$$

The foreign activity measurement is the weighted average of the imports of all other countries. The weights are taken from a table which specifies the division of exports over the trading partners [Memmod, 2000].

$$\begin{aligned} LPAC_i = {} & \log(Country_i\_Ex) + \\ & 1/(1 - h_{17,i}) * \sum_{j=1}^{16} (h_{j,i} * \log(Country_j\_p / Country_j\_Ex) \end{aligned} \tag{8.15}$$

The weighted price developments in other countries (LPAC) is based on the fraction of export a certain country receives combined with the exchange rate development (Ex) [Memmod, 2000].

$$PExA = \log(Country_i\_Ex) + \sum_{j=1}^{16} l_{j,i} * \log(Country_j\_p / Country_j\_Ex) \tag{8.16}$$

The weighted average of export prices (PExA) is based on the fraction of imports each countries delivers combined with their price deflator for demand (p) corrected by their exchange rate change (Ex) [Memmod, 2000].

The fractions of import and export used in equations 8.14-8.16 can be found in Table A.2 (h) and Table A.3 (l).

Table A.2: h, fractions of import per origin region

h	HAM	BAL	BLA	MED	NAF	WAF	SAF	MIE
HAM	0.4539	0.3689	0.3204	0.4059	0.2565	0.1376	0.2717	0.0456
BAL	0.0973	0.1851	0.1730	0.0686	0.0060	0.0127	0.0136	0.0027
BLA	0.0227	0.0584	0.0759	0.0345	0.0027	0.0008	0.0024	0.0018
MED	0.1584	0.1164	0.1917	0.1523	0.2582	0.1099	0.0956	0.0451
NAF	0.0102	0.0078	0.0183	0.0257	0.0360	0.0030	0.0085	0.0143
WAF	0.0044	0.0018	0.0041	0.0030	0.0125	0.0945	0.0140	0.0022
SAF	0.0062	0.0029	0.0023	0.0045	0.0008	0.0331	0.1108	0.0035
MIE	0.0168	0.0122	0.0237	0.0303	0.0234	0.0008	0.0207	0.0840
IND	0.0096	0.0082	0.0094	0.0086	0.0358	0.0792	0.0205	0.0581
SEA	0.0094	0.0052	0.0070	0.0082	0.0053	0.0016	0.0142	0.0205
CHI	0.0210	0.0262	0.0088	0.0162	0.0146	0.0025	0.0573	0.0317
FEA	0.0202	0.0219	0.0074	0.0184	0.0239	0.0453	0.0997	0.2084
OCE	0.0083	0.0051	0.0034	0.0092	0.0044	0.0016	0.0193	0.0045
NAM	0.0909	0.0390	0.0288	0.0782	0.2161	0.3997	0.1095	0.1042
WSA	0.0025	0.0018	0.0018	0.0043	0.0002	0.0078	0.0021	0.0003
ESA	0.0083	0.0069	0.0038	0.0115	0.0248	0.0351	0.0098	0.0007
WO	0.0600	0.1321	0.1204	0.1206	0.0788	0.0349	0.1303	0.3725
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

h	IND	SEA	CHI	FEA	OCE	NAM	WSA	ESA
HAM	0.1770	0.1001	0.1392	0.1019	0.0861	0.1318	0.1158	0.1316
BAL	0.0176	0.0106	0.0431	0.0323	0.0107	0.0130	0.0143	0.0251
BLA	0.0059	0.0034	0.0114	0.0078	0.0027	0.0025	0.0054	0.0041
MED	0.0648	0.0213	0.0456	0.0312	0.0343	0.0324	0.0935	0.0609
NAF	0.0127	0.0038	0.0088	0.0052	0.0057	0.0059	0.0012	0.0168
WAF	0.0159	0.0034	0.0076	0.0034	0.0028	0.0025	0.0007	0.0086
SAF	0.0177	0.0048	0.0071	0.0061	0.0117	0.0038	0.0021	0.0106
MIE	0.1442	0.0219	0.0292	0.0311	0.0323	0.0166	0.0034	0.0218
IND	0.0281	0.0322	0.0274	0.0149	0.0535	0.0127	0.0184	0.0094
SEA	0.0555	0.0832	0.0461	0.0702	0.0880	0.0210	0.0048	0.0121
CHI	0.0687	0.0948	0.0032	0.1765	0.1091	0.0410	0.0981	0.0570
FEA	0.0354	0.1061	0.1296	0.0743	0.2563	0.0600	0.1075	0.0279
OCE	0.0190	0.1165	0.0270	0.0342	0.0837	0.0161	0.0051	0.0071
NAM	0.1656	0.1264	0.2168	0.2056	0.0952	0.5129	0.2641	0.2503
WSA	0.0065	0.0024	0.0077	0.0085	0.0024	0.0169	0.0782	0.0647
ESA	0.0146	0.0061	0.0156	0.0108	0.0080	0.0276	0.1122	0.1396
WO	0.1507	0.2630	0.2345	0.1859	0.1176	0.0831	0.0750	0.1524
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table A.3: l; fractions of export per destination region

l	HAM	BAL	BLA	MED	NAF	WAF	SAF	MIE
HAM	0.4490	0.3980	0.3298	0.4225	0.2566	0.3035	0.2213	0.1749
BAL	0.0974	0.2094	0.2184	0.0812	0.0683	0.0200	0.0345	0.0284
BLA	0.0183	0.0420	0.0629	0.0294	0.0314	0.0099	0.0065	0.0124
MED	0.1193	0.0847	0.1345	0.1190	0.1771	0.0597	0.0517	0.0989
NAF	0.0124	0.0020	0.0016	0.0365	0.0318	0.0106	0.0015	0.0077
WAF	0.0032	0.0006	0.0025	0.0078	0.0028	0.0919	0.0181	0.0007
SAF	0.0074	0.0022	0.0017	0.0084	0.0084	0.0215	0.1379	0.0149
MIE	0.0096	0.0015	0.0042	0.0293	0.0669	0.0139	0.0871	0.0600
IND	0.0101	0.0055	0.0052	0.0112	0.0209	0.0421	0.0248	0.0792
SEA	0.0147	0.0083	0.0061	0.0085	0.0119	0.0299	0.0253	0.0224
CHI	0.0664	0.0736	0.0492	0.0585	0.0707	0.1126	0.0966	0.0952
FEA	0.0344	0.0517	0.0390	0.0310	0.0459	0.0521	0.0733	0.0968
OCE	0.0080	0.0057	0.0045	0.0083	0.0137	0.0211	0.0241	0.0307
NAM	0.0755	0.0359	0.0235	0.0444	0.0908	0.1146	0.0766	0.0956
WSA	0.0054	0.0042	0.0037	0.0086	0.0022	0.0037	0.0050	0.0012
ESA	0.0125	0.0124	0.0068	0.0152	0.0436	0.0310	0.0292	0.0142
WO	0.0564	0.0623	0.1064	0.0803	0.0567	0.0618	0.0863	0.1669
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

l	IND	SEA	CHI	FEA	OCE	NAM	WSA	ESA
HAM	0.1064	0.0836	0.0882	0.0830	0.1307	0.1304	0.0766	0.1239
BAL	0.0297	0.0139	0.0324	0.0260	0.0207	0.0202	0.0174	0.0318
BLA	0.0089	0.0030	0.0025	0.0018	0.0038	0.0027	0.0022	0.0044
MED	0.0650	0.0251	0.0230	0.0222	0.0416	0.0332	0.0464	0.0550
NAF	0.0199	0.0018	0.0041	0.0032	0.0047	0.0117	0.0006	0.0197
WAF	0.0276	0.0007	0.0012	0.0020	0.0031	0.0142	0.0058	0.0256
SAF	0.0135	0.0033	0.0078	0.0109	0.0059	0.0044	0.0014	0.0033
MIE	0.2420	0.0766	0.0473	0.1548	0.0355	0.0225	0.0024	0.0122
IND	0.0175	0.0204	0.0175	0.0101	0.0126	0.0136	0.0102	0.0139
SEA	0.0456	0.0710	0.0460	0.0451	0.1401	0.0245	0.0114	0.0153
CHI	0.1174	0.1312	0.0922	0.1951	0.1402	0.1516	0.1068	0.1042
FEA	0.0547	0.1734	0.2479	0.0853	0.1276	0.0922	0.0827	0.0555
OCE	0.0571	0.0625	0.0421	0.0868	0.0889	0.0123	0.0073	0.0108
NAM	0.0754	0.0993	0.0874	0.1299	0.1228	0.3373	0.2696	0.1931
WSA	0.0084	0.0016	0.0166	0.0172	0.0028	0.0151	0.1068	0.0554
ESA	0.0134	0.0078	0.0293	0.0113	0.0087	0.0329	0.1882	0.1787
WO	0.0974	0.2246	0.2144	0.1154	0.1103	0.0812	0.0642	0.0971
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Appendix B Newbuilding variable pre-selection

For size only one option is considered, DWT. Gross tonnage or compensated gross tonnage, might also be considered, but will have to be estimated on the basis of DWT, as details were not provided in the available data for all vessels. Both options for pricing show a relation to size as would be expected. Rising for price and declining for price/DWT. Both show flattening after about 200.000 DWT, making non-linear estimation necessary. Also both have high significance values, though for price the R^2 is much higher than for price/DWT. At least the conclusion for now should be to keep DWT in both equations.

Income can be estimated by using the 1-year time charter at the time of the contract signing. However as operating expenses (OPEX) are also known in the model, it could be a better option to look at the difference between the TC-rate and the OPEX, as this is the money available to the owner. In case of price, both options show a clear rise and flatting at the high end. In case of price/DWT, there is sharp rise in the beginning, after which the price/DWT slowly declines with increasing profit. Not what would be expected a priori (a slow rise after an initial jump would be more likely), but considering the fact that there is no size taken into account, the larger profits could be ascribed to larger vessels and these have lower costs/DWT.

The production costs will be difficult to incorporate. The data in the model relates the costs to the costs in 2000, but does not differ per country, so all countries have the costs off 100 in 2000. Steelprice is not an element of the model and would need to be linked to an index, like the industry index (PPI). The graphs show large swings and no real trend in the results. Also when estimating a linear OLS equation, the signs of the coefficients are negative, indicating decrease in price with rising production costs. This is counterintuitive, higher costs should result in higher prices. Also just having a country indicator, might replace the need of production costs, however, this will exclude new regions from entering into shipbuilding within the model. Production costs are therefore dropped from the model until better data is available.

While wages could suffer the same problem as production costs, here the average wage for 2000 is known, and the data can be converted to absolute wages. Wages can also serve as a proxy for the production costs, due to the fact that most production for shipbuilding is still labour intensive and mostly driven by these costs, also for sub-contractors. The results of the estimation are reasonable for the areas with several data points, but in the range 9,000.- USD till 38,000.- USD there are only two data points and the graphs behave strangely. This might be solved when more elements are taken into account, but currently the value of wage for estimating newbuilding price is disputable based on these results.

The exchange rate is the last of the cost variables. In this case a higher exchange rate would mean less USD for the same local currency and should indicate a lowering of the price. To make the rates comparable they were indexed at 2000 = 1. In both cases there is very little data for the region 0.3 to 0.8, resulting in very unrealistic behaviour in this area. For the remainder the trend is downwards, but in a wave-like pattern. Both for wages and for the Exchange rate a normal linear estimation, might be a solution to the lack of data points in a part of the region covered. It could also be, that together with other variables the problem is solved already on its own, but this will be dealt with later on.

As an owner has the choice between investing in a new vessel or in a secondhand vessel the secondhand value should have a large impact on the price of new vessels, though compensated for the risk of market changes after the building of the vessel has been completed. In this case the secondhand value is estimated for a 5 year old vessel of the same size with the model derived in the previous paragraph. For the relation with price the expectations are fulfilled, the relation is positive, though flattens at the high end of the secondhand value spectrum as nobody believed that the boom of 2008 and its inflated prices would last forever. The case of the price/DWT is different however. It makes sense to relate the secondhand value/DWT to it rather than the secondhand value alone, but still major fluctuations occur.

In the case of interest two options need to be considered, interest as it is received, or interest corrected for the inflation, so called real interest. Due to the fact that interest is taken yearly, very little variation is available for estimation. In essence there are 3 clusters of values and large gaps between them. This results in unstable behaviour of the values and large uncertainty regions for the graph. Interest data is available at a daily basis, but later on in the model only yearly values are available. Due to this, interest rates do not provide any good support for the estimation of newbuilding prices and are dropped from the final model.

Although interest does not play a role, inflation, also on a yearly basis, might still be important. However after a first inspection of the graphs, the results in both cases are very unstable, with no clear trend or pattern. In this case local inflation was used, this does seem to indicate that at least yards don’t compensate their prices for the local inflation. On the other hand, this will be partially done through the exchange rates already. When testing if US inflation has an influence on the price, the problem arises that there are only 11 inflation observations, but still there seems to be a slight increase. Perhaps in the final model a linear implementation of this variable could be an option.

The final element of the asset option variables is building time. The expected influence is a rise in uncertainty with longer building times and therefore a lower price is demanded by the buyer. However both graphs clearly show that prices are rising with increasing building times. This could be caused by the fact that longer building times were only found at the height of the 2008 boom and this meant that orderbooks were full and the yards had the power to charge more for the same vessel. An interesting observation, but it might not hold in the combined model, where demand itself is also present.

Supply and demand are expressed the same way the newbuilding market was expressed in the secondhand value estimation model. By dividing the current orderbook through the existing fleet. Three options are tested at this stage; the fraction itself, the difference between the fraction now and six months earlier and the fraction now divided by the fraction six months earlier. In the model using price only the second options seems very unstable, with no clear trend, the other two show fluctuations, but also a trend of increasing price with increasing demand, though levelling off at about 30-40% of fleet on order and again at 85% of fleet on order in the first case. This 30-40% could be the ceiling mentioned by Dikos [2004]. After the existing yards have filled their orderbooks for several years. The price levels off. When demand did not drop, new yards were constructed and prices were including these costs as well, increasing them to a new level. When using price/DWT, the only graph that seems explainable is the last option for demand growth. The other two show a decline of price with increased demand as a trend, though this is obscured due to large fluctuations. In summary the option of difference used in the secondhand model leads to the worst results in both newbuilding models and is not considered for the final model. The other two options will still be tested and show non-linearity.

Table B.1: Summary of single variable test results

Y	Element	DWT	TC-rate	Profit	Pord. Costs	Wage	Exchange rate	Secondhand value
Price	R^2	0.758	0.696	0.679	0.178	0.126	0.126	0.734
Price	Signif-icance	***	***	***	***	***	***	***
Price /DWT	R^2	0.559	0.217	0.273	0.198	0.196	0.158	0.577
Price /DWT	Signifi-cance	***	***	***	***	***	***	***

Y	Element	Interest	Interest (real)	Inflation	Inflation (US)	Contract dura-tion	Orders	Diff. in orders	Div. of orders
Price	R^2	0.136	0.0665	0.075	0.174	0.0478	0.594	0.191	0.081
Price	Signif-icance	***	***	***	***	***	***	***	***
Price /DWT	R^2	0.185	0.12	0.0458	0.188	0.0509	0.186	0.167	0.0662
Price /DWT	Signifi-cance	***	***	***	***	***	***	***	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Before continuing with the final model a summary of the results so far will be given. In Table B.1 an overview of the variables tested, their R^2 and significance are given. The dark grey columns are variables that have been disregarded in the evaluation above. The italic and underlined columns are still considered, but in a linear form, not a non-linear form. In total 9 explanatory variables are considered, of which one has two options (income).

Appendix C Vessel costs determination

When looking at vessel costs, many lists and divisions are possible. Stopford [2009], has 5 main categories, covering 14 sub-categories. Moore Stephens, a large shipping accounting firm, has 5 categories for the operating costs, containing in total 12 sub-categories. Many more are used by individual companies, but at least all have a division into direct costs and indirect costs. The first one, direct costs or voyage costs, are costs only incurred when the vessel actually sails a particular route. These costs tend to have a per trip/passage basis, though for example fuel costs are usually considered here as well. The second set, the indirect costs or operating costs, are the costs the owner will have to pay no matter if is ship is sailing a trip or not. These costs have a monthly, or daily basis.

In general the cost model used here is based on the costs identified by Stopford [2009]. In his overview cargo handling costs are mentioned, but not specified and as they are not directly related to the vessel and will be paid for by the cargo owner, they are left out of the overview here. Voyage costs are split in 3 categories, Fuel, Port fees and Canal fees. Fuel costs combines the original division in HFO and Diesel. For the operating costs Stopford distinguishes regular and periodic repair and maintenance, within this overview the two are combined in one post, which also includes the stores. The remaining posts are the same; General costs, Insurance costs, Depreciation costs and interest costs. Though strictly speaking the last two are capital costs. In his overview Stopford uses debt repayment instead of depreciation, but in business economics, debt repayment cannot be a cost, but is an expenditure.

The final lists of costs for which estimators will need to be found is:

- Capital Costs
  - Interest Costs
  - Depreciation
- Operating Costs:
  - General Costs
  - Insurance Costs
  - Maintenance Costs
  - Crew costs
- Voyage Costs
  - Fuel Consumption
  - Port fees
  - Canal fees

In each of the next three sections a category will be treated, while the fourth section will provide a summary and overview of the final data and formulas implemented in the model.

C.1 Capital costs

The most straightforward costs are the capital costs. The depreciation will be discussed first. In this model there are no owners, which means that sales between owners are not registered, but the secondhand or current value of the vessel is. This leaves two options for the depreciation. The real depreciation can be taken, this is the difference between the current vessel value and the value of the vessel which is one year older. Implicitly this assumes the non-existing owner is selling his vessels yearly. The other option uses the assumption that the non-existing owner never sells his vessel. He depreciates his vessel linearly and bases this solely on the purchase price (at the time of purchase. Both are not very realistic; an owner will not yearly have his vessel surveyed to know his depreciation, also he'll try to make use of the tax benefits different depreciation options offer him. On the other hand vessels will be sold between owners, though not all vessels every year. The compromise made in this model is that vessels will be linearly depreciated over there remaining life time, but the depreciation will be based on their current value (as if the vessel has just been bought for that price).

When considering the interest costs three elements are important the percentage of the value of the vessel under loan, the duration and maturity of the loan and the interest paid. Starting with the last one, the interest value is available from the Multi Country Module of the model. The most difficult one is the mortgage percentage. There are many publications on the theoretical optimisation of this debt/equity ratio, but none claim to reflect the real market condition. On the other hand the equity provider will also need to be reimbursed for his risk. While in general this is a higher percentage than on the loan, he will also lose more money on his investments. Therefore the assumption is made that in the end on average all investors will earn about the same as the banks and this allows the dividend to be seen as a percentage equal to the interest on the loan. This assumption also solves the last issue of the duration and maturity of the loan, as repayments do not affect the interest anymore.

C.2 Operational costs

The operational costs of the vessel are divided into four categories; The general costs, the insurance costs, the maintenance costs and the crewing costs. The general costs are mainly made up of a management fee, registration costs and sundries/small miscellaneous. The last two are size related and the management fee is usually related to the fixtures made for the vessel, which in turn are larger for larger vessels. Based on the few values found in Stopford [2009] a fixed amount per DWT was assumed to differentiate them between the classes, but not for age. This post is relatively small compared to the others and not a lot of data in its exact value is available in literature.

The insurance cost of a vessel consist of a obliged Protection & Indemnity (P&I) insurance and a (voluntary) Hull & Machinery (H&M) insurance. Several P&I clubs (Standards[2010], North P&I[2010], UK P&I[2010]), were consulted on their total fee income and fleet size. It was discovered that their average fee per GT was very close to one another, hence the average of these three values has been taken as the fee per GT. Based on information in Stopford [2009] the relation between age and the P&I insurance fee was determined as well as the fee for H&M as a factor on top of the P&I was calculated. To solve the missing link between the DWT and the GT of bulker vessels a formula from Wang et al.[2007] was used to estimate this. The approach described is a rough first estimation of the insurance costs and on top of that assumes that all vessels will have H&M insurance. The ballpark of the cost figure is right also when comparing it to the percentages found in Stopford [2009] and Pocuca [2006].

The total maintenance cost of the vessel are based on the research of Bitros and Kavussanos [2010] into this aspect of vessel costs. They use a large data set to come up with a formula that relates the maintenance costs to distance sailed by, the age of and the size (DWT) of the vessel. Finally for the crew costs 5 crewing sets were designed based on the information in Stopford[2009]. The total costs of each category were estimated using the information published by the ITF[2008]. The choice for a limited number of crewing sets was based on the fact that not enough detailed info was available to make a smooth crew cost set. The choice for five sets is based on the fact that with increasing Size (Handy, Panamax and Capesize) the crewing costs increase, but it also increases with age (0-5, 6-15, 16-30). The choice for these specific age categories is based on the fact that work on the vessel increases with age, but on the other hand the state of the vessel is allowed to deteriorate with age as well. This allows the crew costs to remain the same for a longer period, once the vessel gets older. The division as presented here is a decent assumption and increases the length of the age group by the same amount for each consecutive group (5 years). This approach does bring in an abrupt increase, which would be more smooth in reality and it might make vessels just on the start of a group less interesting in the model, this is tested in section 5.6.

C.3 Voyage costs

The voyage costs consist of three elements, the fuel consumption, the port and canal fees. The first one is speed dependant, the other two depend on the route sailed. A quick look at the canal fees for the Suez canal, reveal a very complex system that takes into account, the type of vessel, the size, its cargo size, destination, etc. This is not the detailed level looked for within this model, as the accuracy of the other cost estimations will be a lot rougher. Therefore for both the port and canal fees a value is assumed, which can be varied by the user to test the strategic importance of such a fee on shipping.

That leaves the consumption costs to be determined. A report by MAN[2008] gives a lot of data on vessel sizes and there average speed and installed power. In combination with the admiralty constant as described by Schneekluth, H. and Bertram V. [1998], it is possible to estimate formulas for the different 3 bulker classes that base consumption on the speed of sailing and the DWT of the vessel.

C.4 Summary of the vessel cost estimators

The first 3 sections described the considerations applied to select the estimators of the vessels. The final result of this is summarised in Table C.1 and the values of the coefficients are provided in Table C.2. There is a special situation concerning vessel costs that has not yet been dealt with, lay-up of the vessel. While many fixed costs will continue to run during lay-up, it is chosen to save a big amount on operational costs, as only a minimal crew is required. Table C.3 shows the percentage of cost which are assumed to be paid no matter what state the vessel is in and which costs only are paid when the vessel is active, also when it is awaiting cargo. Unfortunately exact numbers could not be found and the values represent the authors best estimates of this division.

Table C.1: Summary of the cost determination per vessel

Cost group	Formula	Source
Depreciation Costs ($/Year)	(Secondhand Value - Scrap Value) / (31-Age)	-
Interest Costs ($/Year)	Interest rate * Secondhand Value	-
General Costs ($/Year)	a * DWT	Stopford[2009]
Insurance Costs ($/Year)	10.28 * (b * Age^2 + c) * (0.5409 * DWT)	Standards[2010], North P&I[2010], UK P&I[2010], Stopford[2009], Wang et al.[2007]
Maintenance Costs ($/Year)	d * ((365 - port days) * average speed * 24)^e * Age^i * DWT^j	Bitros and Kavussanos[2010]
Crew Costs ($/Year)	f, age < 6; g, age < 16; h, age >15	ITF[2008], Stopford[2009],
Consumption Costs ($/Mile)	(i * (DWT * l)^(2/3) * Speed^2)	Schneekluth, H. and Bertram V. [1998], MAN[2008]
Port Fees ($)	j * GT	-
Canal Fees ($)	k * GT	-

Table C.2: Cost coefficients for vessel cost formulas per vessel type

Coefficient	Handy	Panamax	Capesize
a	246,667	305,333	528,000
b	0.0016	0.0019	0.21
c	0.4426	0.5118	0.559
d	9.956	9.956	9.956
e	0.190	0.190	0.190
f	513,924	598,812	687,072
g	598,812	687,072	771,960
h	687,072	771,960	847,596
i	3.296E-07	3.000E-07	2.656E-07
j	2	2	2
k	2	2	2

Table C.3: Cost division by type of costs

Cost group	Fixed costs (USD/year)	Active costs (USD/year)	Voyage costs (USD/mile)
Depreciation Costs	100%	-	-
Interest Costs	100%	-	-
General Costs	100%	-	-
Insurance Costs	100%	-	-
Maintenance Costs	-	100%	-
Crew Costs	20%	80%	-
Consumption Costs	-	-	100%
Port Fees	-	-	100%
Canal Fees	-	-	100%

Curriculum Vitea

Jeroen Pruyn was born on June 4 1979 in Rotterdam, the Netherlands. He started to study Maritime Technology in 1997 at the TUDelft. In 2003 he graduated on the simulation of the building costs and risks of the Pieter Schelte at Allseas. After graduation he took on a project to design a Maritime Business Game to be used as a course at the TUDelft. In this course students would play either a ship owner or a shipyard. The development of this game sparked his interest in economics.

After 1.5 years he left University to explore the world, literally. He travelled for almost one year around the world as a backpacker. Upon returning halfway 2006 he was offered once more a temporary job at the TUDelft. At the start of 2007 the idea was born to stay longer at the TUDelft and further elaborate on the Maritime Business Game through a PhD. In principle the PhD would be half of his work. The rest was made up of education and projects both for the EU, Dutch Government and industry.

In 2010 his first period was finished and he got offered tenure as an assistant professor in Ship Production. His work did not change much, though he did take up the role of Master Coordinator and set-up a Minor together with another colleague. As experience abroad is important and to boost progress of his PhD, he spend 3 months at the University of Antwerp in 2011.

After the completion of his PhD he can now focus full time on his work as an assistant professor and he will be in search of new challenges in ship production, a field dominated by both economics and processes.