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DRY BULK SHIPPING AND BUSINESS CYCLES

Ivar Sandvig THORSEN

This thesis was written as a part of the masterprogram at NHH. Neither the institution, the advisor, nor the sensors are - through the approval of this thesis - responsible for neither the theories and methods used, nor results and conclusions drawn in this work.

Abstract

This thesis studies short- and long-term relationships between freight rates in dry bulk shipping and business cycles. The analysis combines a theoretical specification of the market with an econometric approach to study time series data. In the empirical part of the thesis several of the business cycle indicators, including the gdp for all of the countries tested, turned out to be cointegrated with the freight rates. This result means that there exists an equilibrium relationship between the business cycle and the freight rates in dry bulk shipping. Error correction models were then used to study the short-term dynamics between the cointegrated freight rates and the relevant business cycle measures. The thesis further illustrates the importance of interpreting the empirical results in terms of a competitive equilibrium model.

Foreword

Since I was young I have had a genuine interest in shipping. Therefore, I am very grateful for the unique opportunity working with this thesis has given me to learn more about the shipping industry.

First and foremost, I would like to thank my thesis advisor Professor Siri Pettersen Strandenes. It has been very inspiring and instructive to have an advisor with such a unique insight to the shipping industry. In addition to my thesis advisor, I would also like to thank Associate Professor Jonas Anderson at NHH for helpful comments on the econometric part of my thesis. Finally, I am grateful to my father, Inge Thorsen, who has contributed with valuable comments and ideas to the theoretical part of this thesis, and to Arnstein Gjestland at the Stord/Haugesund University College for technical assistance on the use of LaTeX.

Ivar Sandvig Thorsen¹
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¹Norwegian School of Economics and Business Administration, Helleveien 30, N-5045 Bergen, Norway. e-mail: ivar@krokket.net

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1 Introduction

The main ambition of this master's thesis is to study potential short- and long-term relationships between freight rates in dry bulk shipping and business cycles. Shipping is widely known to be a highly volatile industry. Understanding and predicting this volatility is important for participants of the industry, in making operating and investment decisions. In this thesis the dynamics of the dry bulk shipping market is explained by combining an econometric approach to study time series data with a theoretical analysis of the market. The thesis focuses primarily on the impact of alternative business cycle measures as possible determinants of the volatility.

As for the analysis of most markets, there is ambiguity in defining variables representing price and volume. There are for instance different freight rates depending on factors such as the fixture, route and cargo. In this thesis, however, I will be using the Baltic Freight Index (BFI) as a measure of the freight rates in dry bulk shipping. It is also challenging to find accurate measures of business cycles, representing the demand for shipping services. I will be using quarterly data on gdp for OECD, USA, Japan and China as measures of business cycles. In addition to this, I will study monthly data on industrial production and steel production, as well as data on trade for relevant countries/areas.

Freight rates in bulk shipping result from an equilibrium between supply and demand of transportation of bulk commodities. Several models have been developed to explain and predict freight rates in shipping. Two examples are the NORBULK-model developed by Strandenes and Wergeland (1980), and the Stopford Model (Stopford 2009). The demand for sea transport is derived from the demand for specific commodities, while the supply is represented by the size and the productivity of the fleet. As mentioned above, the discussion in this paper is restricted to dry bulk commodities. According to Stopford (2009, p. 419-421) such commodities are shipped in large, unpackaged amounts, usually divided into major bulks and minor bulks. Examples of major dry bulk commodities are coal, iron ore and grain, while minor bulks include for instance steel, sugar and cement.

In a short-term time perspective the impact of demand shocks may sometimes be studied within a framework where the supply of sea transport is assumed to be inelastic with respect to variation in freight rates. This can at least be argued to apply in scenarios where the market operates close to the capacity constraint, involving all available bulk carriers. The discussion is of course very different in a scenario of recession, with low capacity utilization in the fleet of bulk carriers.

The time perspective is important also in an evaluation of the supply side of the market for transporting bulk commodities. It is reasonable to assume that the size and productivity of the fleet depend on the observed development of the freight rates in dry bulk shipping, and on expectations of future demand and future freight rates. One challenge, however, is that the process between the ordering and the deliveries of new carriers is time consuming; the market conditions may be substantially changed at the time when the deliveries are effectuated.

Both the freight rate and the indicators I will be using for business cycles are expected to be non-stationary. It is well known in the literature that results from times series regressions between non-stationary variables may reflect spurious relationships. If, however, there is a linear combination of the two non-stationary series that is stationary, the two series are cointegrated. In such cases there exists a long-term equilibrium between the two series, and we do not have to worry about spuriousness. We can then use an Error Correction Model to study the short-run dynamics between the two series. Hence, the times series used in this thesis will be tested for stationarity and cointegration. In cases where the series are cointegrated, I will be using an Error Correction Model to study short-term dynamics between the freight rates and the indicators of business cycles.

According to theoretical and empirical analysis, the supply of sea transport is highly non-linearly dependent on the freight rates. This contributes to call for a careful interpretation of econometric results, since the impact of demand shocks depend on the initial capacity utilization of the fleet. This is one example why I have emphasized the importance of supplementing econometric results with a theoretical discussion of the shipping market.

The analysis to follow focuses first on possible relationships between freight rates in dry bulk shipping and business cycles in general. In addition a more disaggregated approach is employed to study freight rates for different categories of bulk carriers, and for transport between geographically different markets for imports and exports. One ambition of this analysis is to test whether the law of one price applies for shipping in such markets. In theory this law applies in competitive markets, relying for instance on the assumption of free entry and free exit, and ignoring transport costs of moving from one submarket to another. Hence, temporary differences in shipping rates between submarkets may reflect both time lags in adjusting the size of the fleet, and costs of moving to another market segment. Such costs may explain persisting differentials in freight rates between submarkets.

The thesis starts with a presentation of some basic definitions and data in Section 2. Based on a literature review, Section 3 provides an introduction to the supply and demand of sea transport. There is a short presentation of how the key variables in this market have developed over time in Section 4. Section 5 focuses on the econometric techniques I will be using in this thesis. Those techniques are then used in Section 6 to study short and long-term relationships between freight rates in dry bulk shipping and different measures of business cycles. In Section 7, the empirical results are interpreted in terms of the partial competitive equilibrium model presented in Section 3. Finally, a summary of the results and some concluding remarks are given in Section 8.

2 Basic definitions and data

The goods that are shipped from an origin to a destination are not homogenous. This does not, however, necessarily mean that shipping services are heterogeneous; the character and costs of shipping may be more or less independent of what goods are being transported. Still, different vessels are to some degree used for transporting different kinds of goods. Despite a relatively high degree of substitutability between different shipping services,

it therefore makes sense to categorize both goods and vessels related to the transportation of dry bulk cargo. In addition, disaggregated information on the production and export patterns of different goods may prove useful in interpreting empirical results on the variation in freight rates. It also gives an opportunity to study the general freight market impact of a demand shock in a specific market for traded goods.

Besides specifying different kinds of bulk commodities this section offers a brief description of different vessels for bulk shipping. In addition, both the empirical and the theoretical analysis call for a precise definition of freight rates. Finally, a brief presentation is offered of the data sources used in the empirical sections of the thesis.

2.1 Bulk commodities, vessels and freight rates

According to Stopford (2009, p. 61) the shipping market is divided in three major segments. These segments are bulk shipping, specialized shipping and liner shipping. The focus of this thesis is bulk shipping and so I will only briefly explain specialized and liner shipping.

Some cargoes can be challenging to transport in standard vessels. There may be several reasons for this. It may for example be the shape or the size of the cargo that is not well suited for standard vessels. For these cargoes shipowners can greatly improve the efficiency of the transportation by investing in specialized vessels (Stopford, 2009, p. 469). Stopford (2009, p. 469) discusses five major cargo groups that falls under specialized shipping; liquified gas, refrigerated cargo, chemicals, passenger shipping and unit load cargoes.

Much of the cargo transported by sea are traded in parcels not large enough to fill an entire vessel. For this cargo we have liner shipping. Liner shipping companies operate a fleet that is sailing a regular route between fixed terminals at set times (Stopford 2009, p. 512). Any cargo owner can ship their cargo with these vessels at a predictable price. Liner shipping is

now almost exclusively operated by container vessels.

Commodities traded in cargo loads large enough to fill up a vessel are transported in bulk. According to Stopford (2009, p. 424-427) the five principles of bulk transport are efficient cargo handling, minimize cargo handling, integrating transport modes employed, and to optimize stocks for the producer and consumer. Bulk shipping can be divided into dry bulk and tanker. The main cargoes that are shipped in tankers are crude oil and oil products (Stopford 2009, p. 422). This thesis focuses, however, on dry bulk cargo. A further distinction can be made between minor bulk and major bulk:

Minor bulk : agribulks, sugar, fertilizers, metals and minerals, steel products, forest products, bauxite and metal concentrates (see for instance Stopford (2009, p. 422) and Laulajainen (2006))

Major bulk : iron ore, coal, grain (inclusive soya)

For the discussion in the analytical parts of this thesis it is useful to add some information on the major bulk commodity trades. The information offered here is based on Stopford (2009, p. 445 - 466). **Iron ore** is the largest of the trades, as the principal raw material of the steel industry. The size of the ships has increased somewhat over time, corresponding to a strategy of using large, specially designed ships on a shuttle service between the mine and the steel plant (Stopford, 2009, p. 446). Australia and Brazil account for around 70% of iron ore exports, and the suppliers compete for the markets in Asia and the North-Atlantic. Distance between origins and destinations has increased, explaining the tendency that larger ships have been employed over time. According to Stopford (2009, p. 450) 80% was carried in ships over 80000 dwt by 2005. Stopford explains this tendency as a result of improvements in port facilities, but also remarks that many small vessels are continued to being used.

Coal represents a more complex trade, with two very different markets (Stopford, 2009, p. 450). Cooking coal is used as a raw material of the steel industry, while thermal coal is used to fuel power stations, in competition

with oil and gas. According to Stopford (2009, p. 452) Australia provides more than a third of the exports, while Europe, Japan and other far east countries are the main importers of coal. Stopford also explains why bulk carriers used in coal trade on average (109000 dwt) are smaller than those used in iron ore trade (an average of 148000 dwt). The explanation is related to volumes to stockpile, value, and the risk of spontaneous combustion in very large cargoes.

The third major bulk, **grain**, is an agricultural commodity, and has very different shipping terms than the two others. Due to a greater demand for meat consumption at higher income levels, there has been an upward trend in seaborne grain imports (Stopford, 2009, p. 454). 46% of total exports is accounted for by the US, while imports are widely spread (Stopford, 2009, p. 455). According to Stopford (2009, p. 455) average trade flows are relatively small, and the transport system needs to be flexible for this agricultural crop.

Notice in particular that both coal and iron ore is used as raw materials of the **steel** industry. It will turn out to be important in this thesis that such steel-related transport is a dominating part of dry bulk shipping.

Different cargo are typically shipped in vessels of different size (see for instance Laulajainen 2006, Table 1.7 and 1.8). The different vessels used for dry bulk shipping can be categorized as follows (Stopford, 2009, p. xxi and p. 591) and Laulajainen (2006):

Capesize : the largest bulk carriers. 100,000+. Usually 170,000 - 180,000 dwt

Panamax : the largest bulk carriers that can transit the Panama Canal. 60,000 - 100,000 dwt

Handymax : 40,000 - 60,000 dwt

Handy : 10,000 - 40,000 dwt

Laulajainen (2006) and Stopford (2009, p. 590-592) offer a detailed description of the different kinds of vessels, and explains the demand for different sizes.

There are several measures of freight rates, corresponding to different bulk cargo, specific vessels, particular voyage routes and different kinds of contracts. According to Laulajainen (2006) freight rates in the Atlantic might for instance differ systematically from freight rates in the Pacific, and the rates reflect for instance the likelihood of obtaining backhaul cargo. The willingness-to-pay for freight services also reflect the price per unit of the specific cargo. The demand for transport of expensive commodities tends to be less sensitive to changes in the freight rates than lower priced commodities.

Hence, it is definitely not possible to identify a single freight rate to be used in an econometric analysis of shipping markets. Not only does the freight rates vary depending on the route and the cargo - there are also several types of fixtures (See Laulajainen (2006, p. 65-67) or Stopford (2009, p. 182-185). The most common fixtures are Contract of Affreightment (COA), voyage charter, time charter and bare boat charter (Stopford, 2009, p. 182-185). The allocation of costs differs between the different fixtures types. In a voyage charter, the owner pays the voyage cost (i.e. bunkers and port charges), while in a time charter, the voyage cost is paid by the charterer (Stopford, 2009, p. 183-185). Hence, the freight rate depends on the fixture. In theory, the time charter rate is the discounted expected future spot rate.

According for instance Randers and Göluk (2007) specific freight rates are strongly correlated over time, in the competitive shipping markets. Hence, any choice of specification may prove to be adequate in an econometric analysis. Since my analysis is not related to a specific route, bulk commodity, or vessel, however, an index is chosen to represent freight rates.

The Baltic Freight Index (BFI) was established by the Baltic Exchange in 1985. It then consisted of 13 voyage routes covering cargoes from 14,000 mt of fertilizer up to 120,000 mt of coal, and no time charter routes.² Handysizes were removed from the index in 1997, and capesizes in 1999

²For more information, see <http://www.balticexchange.com/media/pdf/a%20history%20of%20baltic%20indices%2010610.pdf>, that also offers a detailed information of the changes and amendments that have been introduced since 1985.

(Laulajainen 2006). The Baltic Exchange Dry Index (BDI) was introduced in 1999, as an indicator for the dry bulk market and can be used instead of the Baltic Freight Index, which was discontinued. Kavussanos (2002) claims that the restructuring over time makes the index a less than ideal market indicator. In my analysis I have been using the Baltic Freight Index. Even though the BFI ceased to exist when the Baltic Exchange Dry Index was introduced, it has been calculated and reported by Clarksons Research until today.

As pointed out both by Randers and Göluk (2007) and Glen and Rogers (1997), however, the correlation between the different rates make the index adequately accurate for analytical purposes. Figure 1 illustrates that the freight rates related to different vessel categories are highly correlated. This provides an argument that they could all represent the development of general freight rates in a time series analysis. Notice, however, that despite the high degree of covariation, there may be substantial differences at a specific point in time, as pointed out by Laulajainen (2006).

The representativeness of the indices further has to be evaluated from the fact that the Baltic Exchange handles 30-40% of global dry bulk chartering (Shelley 2003), and that the Baltic Exchange Dry Index (BDI) is made up of 20 key dry bulk routes.³

The Baltic indices are reported on a daily basis. For most of the variables to be introduced in the empirical analysis in Section 6, however, information is only available on a monthly or quarterly basis. To match this information, data on freight rates are converted into monthly and quarterly observations by calculating the averages of daily observations. As a result freight rates may seem less volatile than they would if the time series referred to one specific date each month.

³www.balticexchange.com

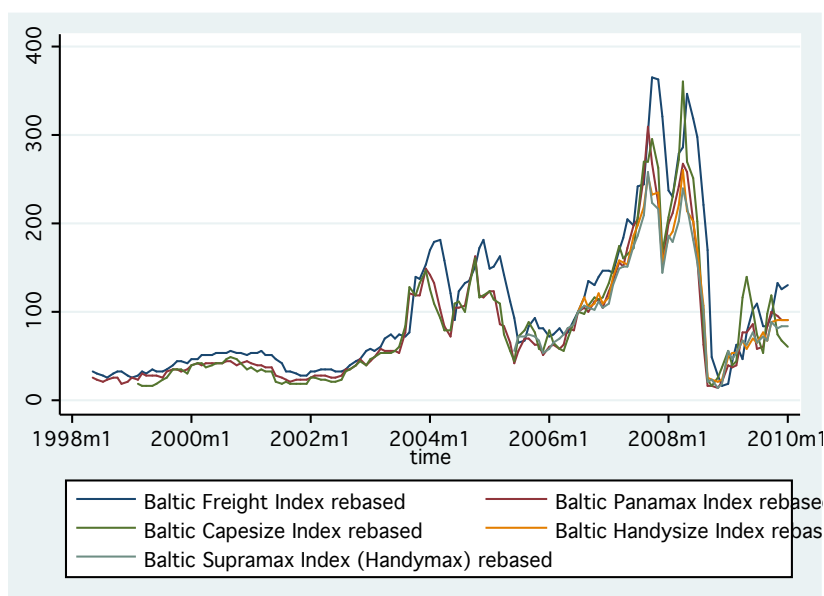


Figure 1: An illustration of freight rate indices for different vessel categories in dry bulk shipping. The indices are rebalanced; defined to be 100 in August, 2006. The figure is based on data from the Shipping Intelligence Network by Clarksons Research.

2.2 Data sources

Most of the data used in this thesis was collected through two sources; Shipping Intelligence Network by Clarksons Research and Thomson Reuters Datastream. According to Clarksons Research⁴, the Shipping Intelligence Network is “the leading on line commercial shipping database”. All of the shipping related data used in my thesis, such as for example the Baltic Freight Index and the fleet size, was collected through the Shipping Intelligence Network. I have used Thomson Reuters Datastream to access data on business cycles. Thomson Reuters Datastream is according to their web page⁵ the largest financial statistical database in the world.

In addition to Thomson Reuters Datastream and Shipping Intelligence Network, some data was collected through the United Nations Statistics

⁴<http://www.clarksons.com/services/overview/?serviceId=418>

⁵<http://online.thomsonreuters.com/datastream/>

Division ⁶ and OECD.stat ⁷.

3 Modeling markets for dry bulk shipping. A literature review.

The freight rates in dry bulk shipping is a result of the demand and the supply of transportation of bulk commodities. The demand and supply of transportation is derived from a geographical imbalance between the production and the processing and consumption of commodities. Hence, the geographically dispersed distribution of resources, consumers, and processing industry introduces an important geographical dimension into the analysis of shipping markets. According to Laulajainen (2006, p. 6) “Atlantic and Pacific are the main operational theaters and the Atlantic is the larger of the two. That was back in 1997. Today, China’s economic growth may have turned the scales in Pacific’s favor. ... The Atlantic and Pacific Spheres have much interaction in cargo, compared to their internal flows. The interaction is not balanced however, and the flows from the Atlantic are in each size segment roughly twice of the opposing flows”.

The supply and demand for sea transport is measured in ton miles, which is defined as average haul multiplied by tonnage of cargo (Strandenes and Wergeland, 1980). Several models have been developed to explain and predict shipping freight rates by studying the factors that influence the demand and the supply for the corresponding services. According to Beenstock and Vergottis (1993, p. 72), one of the earliest econometric applications was Tinbergen (1934). Since then, new models have been developed. The basic ideas are similar, but the models have become more sophisticated as new econometric techniques have been developed. One important contribution to explain and predict freight rates in dry bulk shipping was NORBULK, a model that was developed and presented in Strandenes and Wergeland (1980).

⁶<http://unstats.un.org>

⁷<http://oberon.sourceoecd.org/vl=6310340/cl=19/nw=1/rpsv/dotstat.htm>

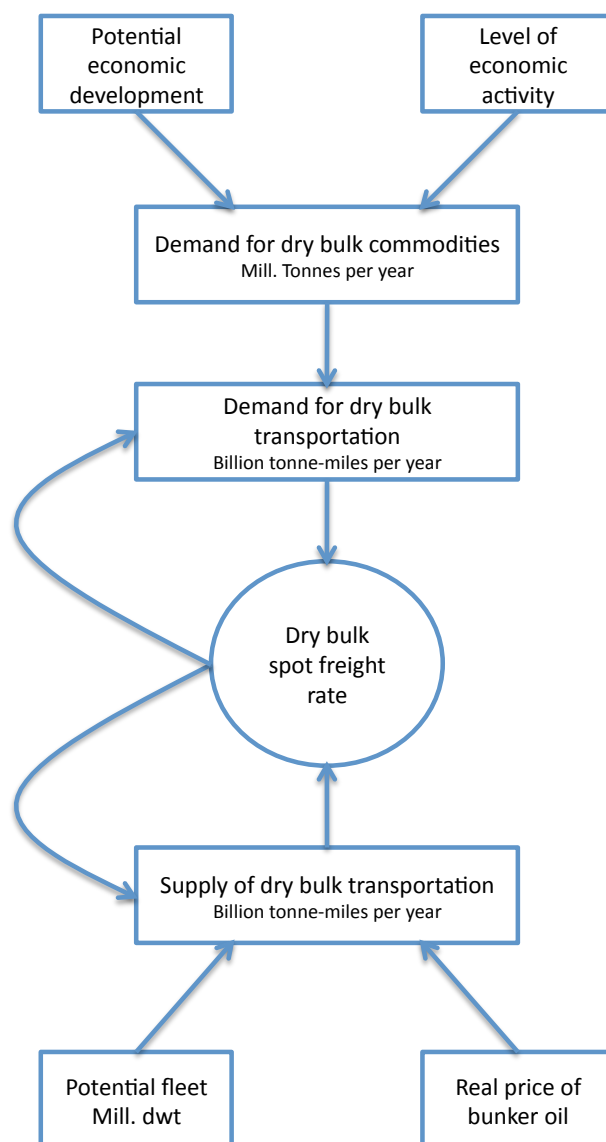


Figure 2: An illustration of the NORBULK model. Source: Strandenes and Wergeland (1980)

A graphical illustration of the NORBULK model is offered in Figure 2. It follows from this illustration that the demand and the supply of shipping services are assumed to be influenced by the freight rates. At the same time the equilibrium freight rates reflect the demand and the supply of shipping services. The model also accounts for the fact that macroeconomic conditions (the production capacity and the business cycle situation) influence the trade of bulk commodities, which further affects the demand for transportation of dry bulk commodities. The specification of the relationship between trade and the aggregated macroeconomic condition is a distinct feature of the NORBULK model. Most other models are focussing on the major bulk commodities, separately. Finally, it also appears from Figure 2 that the supply of shipping services is assumed to reflect the size of the fleet, the fuel price, and the freight rate.

Similar models can also be found in more recent literature, like for example Stopford (2009). The basic elements are the same in the alternative model formulations. The model formulations are made within the framework of a competitive market equilibrium, focussing on the determinants of supply and demand in the market for dry bulk shipping. This section will go into more details on such elements, to prepare for an interpretation of the empirical results to be presented in subsequent sections.

3.1 Competitive and integrated markets

It is often claimed in the literature that the freight markets in bulk shipping serve as examples of perfectly competitive markets, see for instance Norman (1979), Fuglseth and Strandenes (1997), Koekebakker et al. (2006), Adland and Strandenes (2004), and Stopford (2009). The market has a high number of small actors, that individually have only marginal impact on the market price (freight rates). Market information is readily available, and “the vibrant market for second-hand ships is said to manifest the relative ease of overall entry and exit” (Laulajainen 2006, p. 2).

The assumption of homogeneous goods/services is not fulfilled, however. Due to the geographical dimension, reflecting a dispersed distribution of re-

sources and demand for the goods, there exist different routes with different cargos and specific freight rates. Hence, the bulk shipping market can be specified into different submarkets, distinguishing between routes, carriers, and cargo, and “it is generally accepted that freight markets in bulk shipping are examples of almost perfectly competitive markets” (Fuglseth and Strandenes 1997).

In the empirical part of this thesis, however, I consider the market for bulk shipping in general, based on a price index and data of freight flows that are aggregated over all the submarkets. There is a relatively high degree of competitiveness and substitutability between routes, carriers, and cargo, forcing a close connection and interaction between different submarkets. Based on data from the 1960s and 1970s Strandenes (1981) argues that shocks in one submarket spreads to other submarkets, and that the freight market in general can be considered to be integrated. This is for instance reflected by the strongly correlated freight rates over time, see Section 2.1 and Figure 1 above.

There are of course limits to substitution and integration, see for instance Glen (1990) and Adland and Strandenes (2004). Adland and Strandenes (2004) consider the market for Very Large Crude Carriers (VLCCs), modeled as a separate market from the rest of the tanker market. Despite the correlation due to the potential for substitution, they claim that there will exist a positive freight rate differential between e.g. a Suezmax tanker and a VLCC trading on the same route. This differential is explained to result from the economies of scale offered by the VLCC.

It is evident that different vessels cannot always substitute each other, and that differences should be expected between freight rates in specific submarkets. Still, I think that it makes good sense to do analyses based on aggregated models of dry bulk shipping. As stated in Strandenes and Wergeland (1980) there are some advantages of aggregating over separate submarkets, focusing on basic economic relationships rather than getting lost in the specification of a large number of details on submarkets.

3.2 The supply of shipping services

As illustrated in Figure 2 the supply part of the NORBULK model accounts for the size of the fleet, the fuel price, and the freight rates. This is according to a long tradition in studying shipping markets, starting with Tinbergen (1934). The shape of the supply curve in a specific market reflects, of course, the relationship between the freight rate and the supply of shipping services, while, for instance, changes in the size of the fleet cause shifts in the supply curve.

There is also a long tradition concerning the shape of a short-term supply curve. Koopmans (1939) introduced the idea of a highly non-linear supply curve, consisting of two separate segments. The first segment corresponds to situations where the utilization of the fleet is low. In such a situation variations in supply correspond to variations in the utilization of the fleet. If the freight rate falls short of a specific lower limit, then it may turn out to be profitable to pull a ship out of business and into lay-up. Since different vessels are typically operating at similar marginal costs, this first segment of the supply curve in Figure 3 is very elastic. If the freight rate falls below a specific lower limit, then operating a ship will not be profitable. In such a situation even small changes in the freight rate have considerable impact on the tonne miles of shipped commodities (Mossin, 1968).

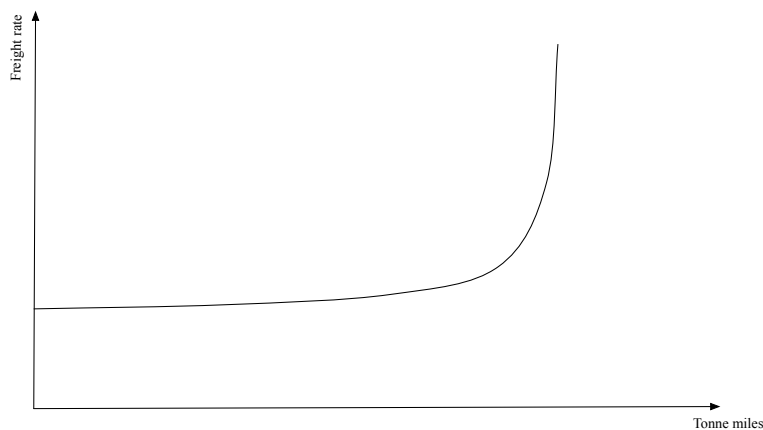


Figure 3: A characteristic shape of a supply curve in dry bulk shipping.

Koopmans (1939) was analyzing the tanker market, but his ideas also apply to the dry bulk shipping market. The second segment of the supply curve depicted in Figure 3 is very inelastic. This corresponds to a situation where the fleet is more or less fully employed, operating close to the capacity limit. In such a situation an increased supply calls for a more intensive utilization of the vessels, through higher speed, shorter time in ports, shorter ballast legs, and delaying regular maintenance (Adland and Strandenes 2004). The increased utilization rates results in increased marginal costs, however, and there are of course limits both on how fast the ships can operate, and how fast turnarounds the ships can have in port. Hence, the flexibility in a situation with a high capacity is limited, and the supply curve eventually gets more or less totally inelastic with respect to freight rates. When all the ships are operating, and the fleet utilization is at its maximum, there is nothing the shipowners can do to increase the supply on the short run.

The characteristic shape of the supply curve in shipping markets has been confirmed in several empirical works. For references, see for instance Adland and Strandenes (2004), who estimated a curve of this shape for Very large Crude Carriers (VLCCs).

As mentioned above shipping supply was claimed to be determined by the size of the fleet, the fuel price, and the freight rates. According to Beenstock and Vergottis (1993, p. 161) the supply depends on the size of the fleet and the speed of the fleet, in addition to some inefficiency parameters. Those parameters capture the time the vessels spend in ballast, as well as the waiting time in port. The speed of the fleet is influenced by the freight rate and the voyage cost, which again include fuel price and port charges. Speed optimization is discussed in most models of shipping markets, see for instance Adland and Strandenes (2004) for a brief review. In even more general terms Stopford (2009, p. 150-160) distinguishes between the world fleet, fleet productivity, shipbuilding production, scrapping and freight revenues as determinants of the supply. The productivity depends on factors such as the fuel price and port charges.

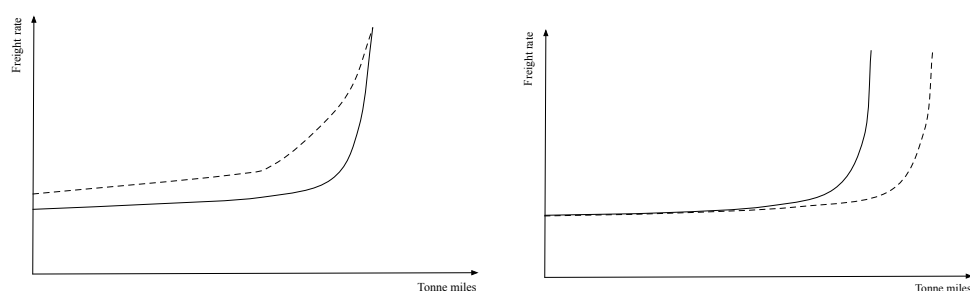
Alternative modeling frameworks apparently differ somewhat in their

treatment of shipping supply, but in large they cover the same set of determinants. One such factor is the fuel price. The fuel price affects the speed at which the ships are operating. Hence, it is indirectly influencing the fleet utilization and productivity (Beenstock and Vergottis 1993, p. 185). If the bunker price is high relative to the freight rates, the shipowners will reduce the speed at which the ships are operating, to reduce the fuel cost. Shipowners will in general increase the speed when the increased revenue by operating at a higher speed is higher than the increased bunker cost.

The fuel price is probably the most volatile of the components included in the fleet productivity, and in recent years it has become a more important component of concern for shipowners. The increasingly higher bunker price means that it represents a considerable part of the total costs of operating a ship. An increase in bunker price affects both the shape and the position of the supply curve. For a given fleet size it affects the relationship between freight rates and supply. A high bunker price means that the shipowners will be less willing to increase the speed in situations close to the capacity limit. Shipowners will require higher freight rates before it is profitable to increase the speed. The marginal costs of operating a ship will be higher also in periods with a low rate of fleet utilization. This explains the upward shift of the supply curve in Figure 4a. Notice from the figure that the new supply curve coincides with the initial supply curve at very high freight rates. This reflects the fact that it will still be profitable for the shipowners to operate at maximum speed if the freight rates get very high.

This is a simplified discussion of how an increased bunker price affects the supply curve. For illustration purposes the supply curves depicted in Figure 4a are smoother than corresponding curves estimated from real world data. For a more accurate and detailed discussion of the relationship between the bunker price and position of the supply curve, see Wijnolst and Wergeland (1996).

Consider next variations in the size of the fleet. Shipowners can control the size of the fleet by ordering new ships, scrap old ships or by putting ships into lay-up. In addition to this, shipowners can take ships out of the market by doing repairs and maintenance during bad times. It takes 12



a) An increased bunker price

b) An increased fleet size

Figure 4: The dashed lines represent the supply curve after the increased bunker price and fleet size.

months to 3 years to have a new ship delivered (Stopford, 2009, p. 639). In the long run the size of the fleet is very flexible. When the freight rates are high, shipowners will order more ships, and the fleet size will increase. When the freight rates are low, not only will shipowners stop the ordering of ships, they may also put ships into lay-up and scrap old, inefficient ships that are costly to run. Part b) of Figure 4 illustrates the effect on the supply curve of an increased number of deliveries to the shipowners. This figure is based on the simplifying assumption that the new vessels have the same voyage cost level as the older vessels.

The time lag from the ordering to the delivery can be challenging. Shipping is a dynamic industry and the market conditions can change rapidly. During the time it takes to have a ship delivered, the market can be completely different from how it was when the ship was ordered. In a discrete-time stochastic equilibrium model of the VLCC market, Adland and Strandes (2004) account for the possibility that the delivery rate is an increasing function of the current freight rate level. They argue that postponements and cancellations of newbuilding projects may occur in periods with low freight rates, while newbuilding projects to some degree may be accelerated through for instance extensive use of overtime in periods with high freight rates.

In a short-term time perspective, the size of the fleet is relatively fixed. Variations in lay-ups correspond to movements along the elastic segment

of the supply curve. The ships will operate as long as the freight rates are higher than the operating cost (Stopford, 2009, p. 161-162). Adland and Strandenes (2004) refer to the classical literature, where the lay-up point is the time charter equivalent spot freight rate at which the shipowner is indifferent between lay-up and operation. The literature also accounts for switching costs related to putting the vessel in lay-up. Due to such costs the ships will operate if the threshold freight rate exceeds the daily operating cost less the daily lay-up cost (Mossin, 1968). When the freight rates are lower than this threshold, the ships will be put into lay-up. All ships do not have the same operating cost, however. Hence, the supply will be gradually lower as the freight rates are reduced.

Scrapping vessels is another relatively fast response to low freight rates. As pointed out by for instance Adland and Strandenes (2004) it is optimal to scrap a vessel if the scrap value exceeds the expected value of continued trading. They also point out, however, that scrapping decisions may partly be strategic, since freight rates are negatively related to the remaining fleet, and the profit of a shipowner tend to increase when other shipowners scrap their vessels. Adland and Strandenes (2004) specify a model for the VLCC supply function where the scrapping volume follows a stochastic Poisson process, letting the expected scrapping volume depend on the freight rates. I will not enter into a more detailed discussion of such a process, however. Graphically, the impact of scrapping the most inefficient vessels is a inward shift of the supply curve, corresponding to a shift from the dashed to the solid line in Figure 4.

3.3 The demand for shipping services

According to Stopford (2009, p. 139-149) there are five key factors that influence the demand for sea transport. These five factors are the world economy, seaborne commodity trades, average haul, random shocks and transport costs.

Stopford (2009, p. 140) further claims that the world economy has the strongest impact on the demand for sea transport. There are two aspects

of the world economy that influence the demand for sea transport; business cycles and the trade development cycle (Stopford, 2009, p. 140). The business cycle is "the most important cause of short-term fluctuations in seaborne trade and ship demand" (Stopford, 2009, p. 142). The ambition of this thesis is to study short- and long-term relationships between business cycle measures and freight rates in dry bulk shipping. The empirical results are presented in Section 6, and a theoretical discussion is provided in Section 7. The trade development cycle involves the ability of a market to meet the demand for resources such as food and natural resources (Stopford, 2009, p. 143).

The second key factor that influences the demand for sea transport is the structure of the seaborne commodity trades (Stopford 2009, p. 143-146). If, for example, the processing of a commodity moves away from the resource, there will be an increased demand for sea transport. It is further obvious that both the average haul of the trade and random shocks influence the demand for sea transport (Stopford 2009, p. 146-149). Random shocks involve for example economic shocks, but can also involve political events such as wars. The last key factor Stopford includes is transport costs (Stopford, 2009, p. 149). It may seem logical that the transport cost influences the demand for sea transport. As I will get back to below, however, there are some controversy on this issue. Stopford (2009, p. 149) argues that the cost of sea transport is an important factor influencing the long-term demand for sea transportation.

The NORBULK model by Strandenes and Wergeland (1980) is based on the assumption that the demand for transportation of dry bulk commodities is determined by the freight rates, the trade patterns, and variables reflecting the macroeconomic situation (see Figure 2).

There seems to be a consensus in the literature on how changes in macroeconomic conditions cause shifts in the demand curve. The literature is more concerned about the elasticity of shipping demand with respect to the freight rates. In early contributions, like Tinbergen (1934) and Koopmans (1939), the demand was assumed to be independent of the freight rates. This assumption that demand is completely inelastic with respect

to freight rates was also adopted for instance by Beenstock and Vergottis (1993, p. 162), who claim that “we have been unable to discover a negative relationship between demand and freight rates”.

Beenstock and Vergottis (1993, p. 162) also acknowledge the fact that theory is in favor of an inverse relationship between freight rates and the demand for shipping services, however, since “higher freight rates will create an incentive to use other forms of transportations and to import more from areas closer to the market” (Beenstock and Vergottis, 1993, p. 162). The reason why freight rates are still often treated exogenously is that there is a very limited scope for substituting between forms of transportation and origins of import, at least within a short-term time perspective. In a longer-term time perspective demand will be more price elastic, since trade patterns will change as a response to high freight rates..

Another frequently used argument in favor of an inelastic demand is that the freight rate in general represents a low cost relative to the value of the commodities transported. This argument in particular means that the demand for transport of expensive commodities is less sensitive to variations in freight rates than the demand for transport of lower-priced commodities.

NORBULK is an example of a model based on the assumption that demand is inversely related to the freight rate. The relationship was estimated to be very inelastic, however. Still, Strandenes and Wergeland (1980) argue that it is potentially important to account for the price elasticity in both supply and demand. More recently, the maritime economic literature has suggested a highly non-linear demand curve, see for instance Adland and Strandenes (2004) for a brief review of this literature. The basic idea is that demand is in general very inelastic, but “that the demand for ocean transportation becomes more elastic with respect to freight rates at high freight rates until the demand becomes perfectly elastic at some unknown but extremely high freight rate level” (Adland and Strandenes 2004). This is illustrated in Figure 5, which also includes a supply curve of the classical shape.

Adland and Strandenes (2004) offer the following set of explanations for the elastic part of the demand curve:

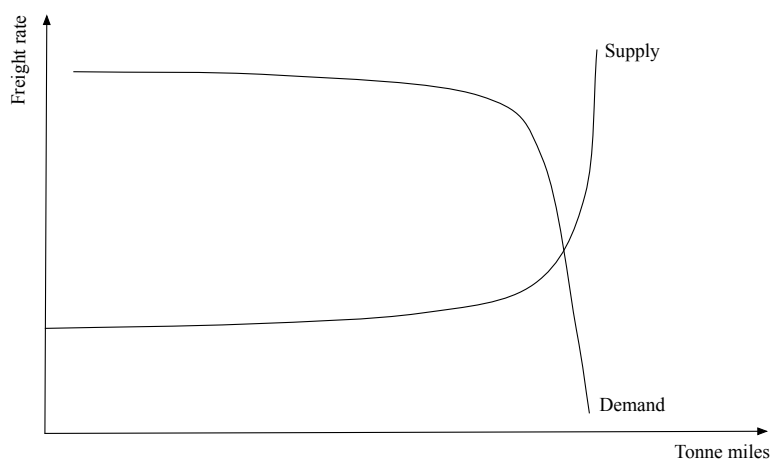


Figure 5: An illustration of an equilibrium solution in a market for dry bulk shipping.

- For extremely high freight rates there may be a tendency that importers find exporters that are located closer, reducing average transportation distances.
- If the freight rate element in the CIF price is high, and the demand for the commodity is elastic, then the demand for transportation may be elastic.
- For extremely high freight rates in a bulk shipping segment, other vessels, or even modes of transportation (like pipelines for oil and gas) may become competitive.

Notice in particular that the demand curve in Figure 5 defines a level of the freight rate where there is either no demand for the relevant bulk commodities, or where the commodities are transported by other modes of transportation.

3.4 Shipping market equilibrium

According to Stopford (2009, p. 175 - 231) shipowners operate in four separate, but interlinked markets: freight, newbuilding, scrapping and sale & purchase. This thesis focuses primarily on the freight market. It was clear from Section 3.2, however, that decisions made on the other three markets affect the position of the supply curve, and that a new equilibrium freight rate will emerge as a response to shocks in those markets.

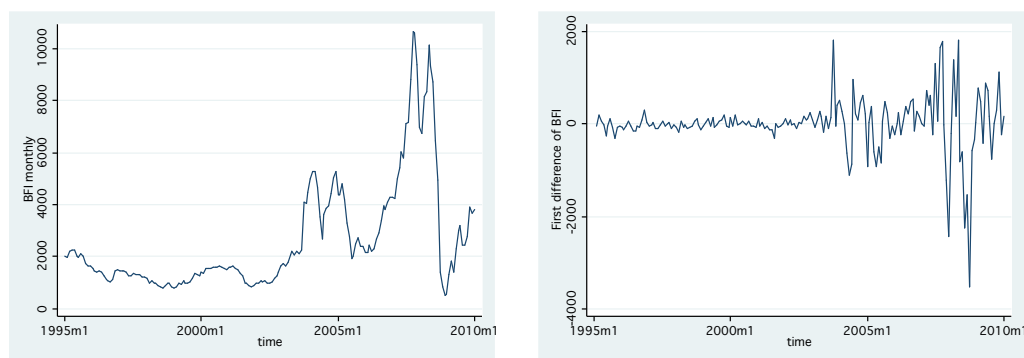
A shipping market equilibrium is represented by the freight rate where the demand equals the supply of shipping services, that is at the point where the two curves intersect in Figure 5. Due to the nonlinearities of the curves it is obvious that the impact of demand and/or supply shocks is highly dependent on the initial situation. Consider a positive demand shock, for instance due to a general economic growth, leading to increased trade and increased demand for ocean transportation. This corresponds to an outward shift of the demand curve. If this happens in a situation with a low degree of fleet utilization, the main effect of the shift is that the number of ships in lay-up will be reduced. Hence, the tonne miles of transported commodities will increase substantially, while the impact on freight rates will be relatively marginal. The situation is the opposite if there is a very high degree of fleet utilization initially. In a short-term time perspective a positive demand shock then leads to a substantial increase in freight rates, while the transported tonnage increases marginally.

I will do more use of this modeling framework in Section 7, attempting to explain some of the empirical results from Section 6.

4 Observed variations in shipping volumes and freight rates

As a starting point for an analysis of the market for transportation of dry bulk cargo it is useful to study how the key variables in this market have developed over time. My information on the BFI refer to daily observations

back to 1985, while data on total bulker sales are available only after 1995. The regressions performed in the empirical section refers to the entire period 1985-2009. For a direct comparison, however, the observations presented below are restricted to the period 1995-2009.



a) The level of the BFI

b) The first differences of the BFI

Figure 6: Observed variations of the Baltic Freight Index after 1995. The figure is based on data from the Shipping Intelligence Network by Clarksons Research

As illustrated in Figure 6 there have been some dramatic changes in the freight rates of dry bulk shipping in recent years. The BFI peaked in October 2007, followed by a dramatic reduction in 2008. According to part b) of the figure the volatility of the freight rates have increased considerably after 2002-03

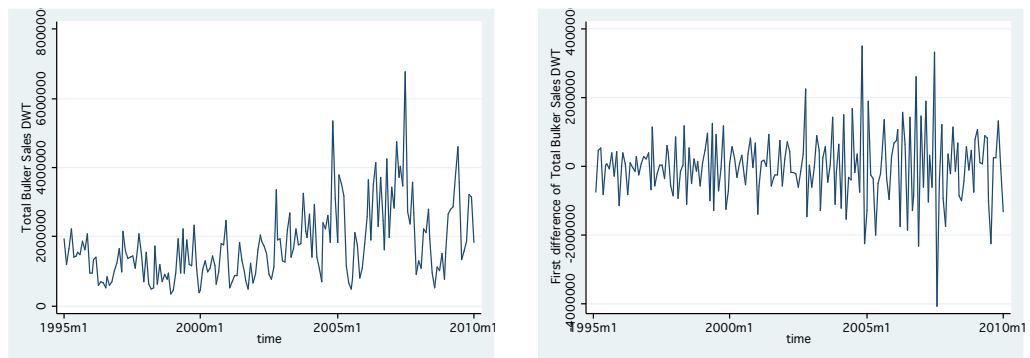
The development in total bulker sales (dwt) is somewhat more confusing and less transparent. Comparing Figure 6 to Figure 7 reveals some similarities between the two time series, however. The increased freight rates in 2003-04 are matched by increased total bulker sales, and so is the considerable increase of freight rates in 2007-08. Similarly, the reduced freight rates in 2005 and 2008 are matched by reductions in total bulker sales. Apparently, there is a tendency that changes in total bulker sales are a bit lagged compared to the changes in freight rates. I will not enter into a more precise statistical test of this hypothesis, however. Figure 7 also reveals a tendency of increased volatility in total bulker sales in the period 2003-2008.

The tendency of a positive covariation between price and volume indi-

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cates that the development is basically driven by demand shifts. At the same time the increased volatility in recent years indicates that the fleet is operating close to its current capacity limit. In periods with a high capacity utilization positive adjustments in supply will be sluggish, and demand shocks have a large impact on freight rates. This is a reasonable explanation of the drastically increased freight rates in the recent periods of boom in the world economy.



a) The level of total bulker sales

b) The first differences of total bulker sales

Figure 7: Observed variations of the total bulker sales in dwt.

The recession following the financial crisis also reduced the demand for ocean transportation of dry bulk commodities, and the BFI was reduced from 10527.45 to 577.28 in 14 months. This reduction in freight rates is not only a result of a reduced demand, however. The recession coincided with an increased fleet size, responding to the high freight rates in the preceding years. The dramatic reduction in freight rates results from the combination of this lagged supply effect and the unanticipated reduction in demand. Eventually, the freight rates reached a level where the ship-owners responded by lay-ups. I will elaborate more on those issues in Section 7.4.

The volatility in freight rates and freight volumes seems to be somewhat reduced towards the end of the period covered by Figures 6 and 7. This probably corresponds to a situation where the market is no longer operating in the most inelastic segment of the supply curve.

5 Some basic issues in time series analyses

As pointed out in the introduction the ambition of this thesis is to study relationships between freight rates in dry bulk shipping and alternative indicators of business cycles. The basic hypothesis is that the business cycle influences the freight rates through the impact on the demand for shipping services. This section focuses on the econometric techniques I will be using to study this hypothesis.

5.1 Stationarity and spurious regression

In time series analysis an important distinction is between stationary and non-stationary variables. For an explanation of this distinction consider first the more general specification of autoregressive time series variables. An autoregressive time series variable, y_t , depends on past values of itself and an independent error term with expectation 0 and constant variance, σ^2 . Consider first the following specification of a time series variable:

$$y_t = \alpha + \sum_{i=1}^n \rho_i y_{t-i} + v_t, \quad (1)$$

Here, v_t is the error term, and y_{t-i} is the value of the variable at time period $t - i$. In cases where y_t has a unit root, α is a drift component resulting in a trended behaviour. The variable y_t is autoregressive of order n , AR(n), if n represents the number of lags that are statistically significant different from 0. In the discussion of stationary and non-stationary variables I will be referring to variables that are autoregressive of order 1, AR(1), defined by Equation (2).

$$y_t = \alpha + \rho y_{t-1} + v_t \quad (2)$$

A stationary time series represents a mean reverting stochastic process, corresponding to a situation where $|\rho| < 1$ in Equation (2). For a stationary variable both the expected value and the variance will be constant; $E(y_t) = \alpha$ and $\text{Var}(y_t) = \text{Var}(v_t) = \sigma^2$. In addition, the covariance between two

values in the series must depend only on the time difference, not the actual time they were observed; $\text{Cov}(y_t, y_{t+h})$ depends on h and not on t (see Wooldridge, 2008, Chapter 11.1).

Assume next that $\rho = \pm 1$. The variance then increases over time, $\text{Var}(y_t) = t\sigma^2$, and so is the expected value for the case with a positive drift component ($\alpha > 0$); $E(y_t) = t\alpha + y_0$ (see Hill et al., 2008, p. 332). Hence, the conditions for stationarity are violated. In the case where $\rho = 1$ the resulting model is represented by $y_t = \alpha + y_{t-1} + v_t$. The variable y_t is then non-stationary, and the model is a random walk with drift. For non-stationary variables a shock has a permanent impact on the stochastic process, which is not mean reverting. The best prediction of a future value will always be the present value (see Wooldridge, 2008, Chapter 11.3).

A random walk is a unit root process. The drift component defines an upward trend in the case with $\alpha > 0$. In such a case the model corresponds to a time series fluctuating without a clear pattern around an upward trend. As pointed out for instance by Hill et al. (2008, p. 333) the trend behaviour may be strengthened, by introducing a time trend, δt , resulting in a quadratic trend in the random walk model:

$$y_t = \alpha + \delta t + y_{t-1} + v_t \quad (3)$$

I do not consider the possibility that $|\rho| > 1$, which corresponds to explosive time series.

A non-stationary variable that becomes stationary if we differentiate it d times is said to be integrated of order d , $I(d)$. Hence, a variable that is $I(2)$ must be differentiated twice to become stationary; $\Delta y_t = y_t - y_{t-1} - y_{t-2}$. A stationary variable is integrated of order 0, $I(0)$.

Consider a regression of y on x ,

$$y_t = \alpha + \beta x_t + e_t. \quad (4)$$

e_t is the error term. Such a regression of two non-stationary variables does not give reliable results. A regression of $I(1)$ variables generally results in low standard errors, inflated t -values and artificially high R^2 -values. Hence,

there is an imminent risk of making type 2-errors is, and the results may indicate a statistically significant relationship even though such a relationship does not exist. This reflects a spurious regression problem.

One obvious solution to this problem is to differentiate each variable the number of times that makes it stationary. Such a model specification only provides an estimate of the short-term effect of a change in the explanatory variable, however. For most problems it is essential to explain and predict more long-term consequences of an exogenous shock. As will be clear from the discussion in the subsequent section, there is one exception where reliable estimates result from OLS regressions on non-stationary variables in level form.

A first step towards such a procedure is to test for unit roots. Several tests have been developed for this purpose. The technique I will be using is the Dickey-Fuller test (Dickey and Fuller, 1979). A variable has a unit root, is non-stationary, if $\rho = 1$ in Equation (2). Hence, the null hypothesis of the Dickey-Fuller test is that the variable has a unit root. The test is based on a model formulation where y_{t-1} is subtracted from both sides of Equation (2):

$$y_t - y_{t-1} = \alpha + \rho y_{t-1} - y_{t-1} + v_t = \alpha + (\rho - 1)y_{t-1} + v_t \quad (5)$$

Hence, testing for nonstationarity is equivalent to testing the hypothesis that $\omega = \rho - 1 = 0$ in Equation (6):

$$\Delta y_t = \alpha + \omega y_{t-1} + v_t \quad (6)$$

We can now test $H_0: \omega = 0$ against $H_1: \omega < 0$. In a case where H_0 is not rejected, we conclude that $\rho = 1$ and that y_t is non-stationary.

In performing the Dickey-Fuller test for unit roots it is important to know that the t statistic does not have an approximate standard normal distribution, since y_{t-1} is $I(1)$ (see for instance Wooldridge 2008, Chapter 18.2). This means that the standard t -distribution does not provide reliable critical values for the Dickey-Fuller test. Instead, critical values are tabulated for the Dickey-Fuller-distribution, originally introduced by Dickey and Fuller, and later refined by others (Wooldridge, 2008, Chapter 18.2).

Many variables are autoregressive of orders higher than one. When this is the case, we must use the augmented Dickey-Fuller test. The augmented Dickey-Fuller test includes several lags in order to control for serial correlation. Enough lags should be included to control for all the serial correlation in the variable. Including too many lags is not recommendable, however, since adding more lags means that we lose degrees of freedom in the regression. The appropriate number of lags involved can for instance be determined from the last significant lag criterion (Ng and Perron, 1995). This corresponds to a method where the number of lags accounted for is reduced successively from a very high number down to the last lag found to be significantly different from zero. A model specification with a drift component α and k lags is given by:

$$\Delta y_t = \alpha + \omega y_{t-1} + \lambda_1 \Delta y_{t-1} + \cdots + \lambda_{t-k} \Delta y_{t-k} + v_t \quad (7)$$

The null hypothesis for the unit root test is of course still that $\omega = 0$ against the alternative hypothesis of $\omega < 0$. Changes in y_t respond to the lagged changes of the variable. If the variable is non-stationary, however, Δy_t is totally insensitive to the value of the variable in the previous period, y_{t-1} .

5.2 Cointegration

There is one situation in which the result from a regression of two non-stationary time series is not spurious. This situation relates both to the integration order of the two variables and to the integration order of the corresponding error term. Assume that the two variables are both $I(1)$, and consider the following regression of y_t on x_t :

$$y_t = \alpha + \beta x_t + e_t \quad (8)$$

The error term is then just a linear combination of y_t and x_t :

$$e_t = y_t - \alpha - \beta x_t \quad (9)$$

In most cases the error term will be non-stationary in such a case, but there may be some exceptions where the linear combination is stationary,

see for instance Koop (2008, p. 218) or Wooldridge (2008, Chapter 18.4). If the linear combination is $I(0)$, y_t and x_t are cointegrated. This will be the case if the two variables follow the same stochastic trend, and are related through an equilibrium relationship. In such a case we can run a standard regression of one variable on the other without having to worry about the spurious regression problem.

There are many examples in the literature on economics and finance where equilibrium relationships give scenarios of cointegrated variables. Wooldridge (2008, Chapter 18.4) refers to results on the relationship between short- and long-term interest rates, while Koop (2008, p.219) studies time series for the prices of close substitutes. Based on arbitrage arguments they explain why differences between such variables tend to be relatively stable over time, and return to an equilibrium level after a shock.

As for stationarity, several tests have been developed to determine whether two variables are cointegrated. The test I will be using is the Engle-Granger test (Engle and Granger, 1987). The first step of this test is to run the regression of y_t on x_t , according to Equation (8). This regression provides estimates of the residuals; $\hat{e}_t = y_t - \hat{\alpha} - \hat{\beta}x_t$. As a next step a Dickey-Fuller test is carried out on the estimated residuals.

$$\Delta\hat{e}_t = \omega\hat{e}_{t-1} + v_t \quad (10)$$

Once again, we test $H_0: \omega = 0$ against $H_1: \omega < 0$. If H_0 is not rejected, the residuals are non-stationary, and the variables x_t and y_t are not cointegrated. A rejection of H_0 means that the residuals are $I(0)$, and that the variables are cointegrated.

Notice that there is no drift component in the Dickey-Fuller test represented by Equation (10). This is important, since the average of the residuals is 0; the idea of cointegration is not consistent with residuals developing according to a trend over time. The estimation of the residuals is, however, based on a model formulation involving a deterministic trend, represented by the drift component α . It makes good sense to account for such a component in model formulations focusing on the impact of alternative business cycle measures, as in the analysis to follow in Section 6.

The Engle-Granger test is simple to perform, but it has some limitations. One limitation is that the two variables that are being tested for cointegration have to be integrated of the same order. As will be clear in Section 6, however, this is not a problem in my dataset, and this potential limitation of the testing procedure is not a problem in my analysis.

A very common mistake when performing the Engle-Granger test is to use the critical values tabulated for the Dickey-Fuller-distribution when the residuals are tested for stationarity. This is not correct, since we are testing estimated rather than actual residuals. A more appropriate approach is therefore to use critical values originally tabulated by Engle and Granger (1987) and MacKinnon (1991). MacKinnon has recently (MacKinnon 2010) made available a working paper providing more accurate critical values, covering more cases than the original paper. The new critical values are based on simulations with far more replications than in the original paper. The critical values used in Section 6 are calculated from the tables and functional forms presented in MacKinnon (2010).

5.3 The error correction model

A conclusion that two variables are cointegrated offers very interesting and important information. Cointegration means that there is an equilibrium relationship between the two variables. There can be several reasons for such an equilibrium relationship. One of the variables can for example depend on the other, or they may both depend on the same exogenous factors. Either way, establishing an equilibrium relationship is an important finding.

It is also important that cointegration justifies the use of an error correction model. This result is based on the Granger representation theorem (Engle and Granger, 1987). An error correction model is more specific on the dynamics involved in a relationship between two variables, it captures both short-term dynamics and long run effects. The estimate of the cointegration parameter β in Equation (8) provides information on the long-term influence of a shock in the exogenous variable. The short-term dynamics

are represented by the contemporaneous change in x_t , and by the introduction of the error term of the previous period (Wooldridge 2008, Chapter 18.4). It follows from Equation (9) that this error term is defined by $e_t = y_t - \alpha - \beta x_t$, while the estimated error term from the cointegration regression is $\hat{e}_t = y_t - \hat{\alpha} - \hat{\beta} x_t$. An error correction model is then defined by the following equation:

$$\Delta y_t = \mu + \gamma \Delta x_t + \delta \hat{e}_{t-1} + u_t = \mu + \gamma \Delta x_t + \delta (y_{t-1} - \hat{\alpha} - \hat{\beta} x_{t-1}) + u_t \quad (11)$$

u_t is the error term in the error correction model, corresponding to the standard assumption of an OLS regression. In some applications of the error correction model β is assumed to be known, and the error correction term defined to be $y_t - \beta x_t$. The version represented by Equation (11), based on the cointegration regression, is often called the Engle-Granger two-step procedure, see Wooldridge (2008, Chapter 18.4) or Koop (2007, p. 224). It is also possible to find applications of the error correction model where the changes in the exogenous variable is lagged one period, which means that Δx_{t-1} rather than Δx_t appears in the model formulation (see for instance Verbeek (2008, p. 332)). For the problems I will be studying, however, I find the model formulation with a contemporaneous change in x_t to be a reasonable representation of the short-term relationship between the variables. This is also according to the procedure recommended by for example Koop (2008, p. 225). The lagging of the error correction term, \hat{e}_{t-1} , contributes with an adjustment to the deviation from equilibrium in the previous period.

As mentioned above $\hat{\beta}$ in Equation (11) is the long run multiplier related to a change in x_t from its equilibrium value, while γ represents the short-term effect. The parameter δ reflects the equilibrium adjustment mechanism. If $y_{t-1} > \hat{\alpha} + \hat{\beta} x_{t-1}$ the dependent variable is higher than the equilibrium value. The error correction term contributes to close this gap, corresponding to a situation with $\delta < 0$. Similarly, a value of $\delta < 0$ contributes to increase the prediction of the dependent variable towards equilibrium in cases where $y_{t-1} < \hat{\alpha} + \hat{\beta} x_{t-1}$. The parameter estimate $\hat{\delta}$ offers an estimate of how long time it takes before a deviation from the long

run equilibrium is corrected for. A value of $\delta = -0.5$ for example means that half of the error is corrected for in the next period.

The error correction model in Equation (11) has all the properties related to standard OLS regressions, with statistics like t -values, P -values and R^2 available for the evaluation of results. Equation (11) is, however, a simple version of the model; neither the dependent nor the independent variables are lagged.

6 Short- and long-term relationships between freight rates and business cycle measures

In this section the econometric techniques explained above are used to study possible short and long-term relationships between freight rates in dry bulk shipping and some measures of the business cycle and trade flows. Variations in economic activities may differ considerably between continents and countries; business cycles are not always closely geographically coordinated. An increased economic activity in one geographic area may have a larger impact on trade flows and the demand for shipping services than a corresponding increased activity somewhere else. Hence, measures of production are introduced for different geographies. In addition the analysis focuses on how information on specific trade flows contributes to explain variations in shipping freight rates.

As stated in the introduction my ambition is to study short and long-term effects of demand shocks in the market for shipping services. First, testing for cointegration gives important information on possible long-term equilibria between the relevant time series. If variables are cointegrated, an error correction model contributes with more specific information on the short- and long-term dynamics involved. The presentation of results will be organized as follows:

- testing the time series for stationarity

- finding the integration order
- testing for cointegration
- running error correction models

This procedure will be performed for both quarterly and monthly data, in Section 6.1 and Section 6.2, respectively.

Some of the time series used in the analysis to follow were adjusted for seasonal variations. To make the results from the regressions as comparable as possible, the rest of the times series were also adjusted for seasonal variations. This adjustment was done according to the technique X-12-ARIMA⁸, which is a software used for all official seasonal adjustments by the US Census Bureau. Alternatively, seasonal variations can be accounted for by introducing seasonal dummies. Since seasonal variations were already removed from some of the available time series, however, I chose to adjust the time series according to the described technique for all the regressions to follow.

Notice also that all the variables are represented by their logarithmic values in the regressions to be presented. Interpretations in terms of elasticities facilitate the analysis in a framework where the variables are measured in very different units, and the choice of logarithmic specifications are according to standard procedures in the literature.

6.1 Testing based on quarterly data

One basic hypothesis to be studied is that both the demand for shipping services and shipping rates are positively related to the business cycle. The most obvious choice of a business cycle measure is the gross domestic product (gdp) for relevant geographies. Data on gdp are not available for shorter time periods than quarters. As mentioned in Section 2.1 the daily time series on shipping rates are converted into quarterly series, by simple averaging. Due to the considerable noise involved in data defined for a very short

⁸See <http://www.census.gov/srd/www/x12a/>

period, a conversion into monthly or quarterly averages may be a preferred approach even if daily data were available.

6.1.1 Stationarity of freight rates and some business cycle measures

In this section the augmented Dickey-Fuller test for stationarity is used on quarterly times series for shipping rates and gross domestic product for different geographical areas. The gdp of OECD is used as a proxy variable for world production, while the gdp of the US, Japan, and China represents the economic activity and demand for shipping services in three very important countries in world trade. The number of lags involved is determined from the last significant lag criterion, see Section 5.1.

As mentioned in Section 5.1 a unit root process may incorporate both a drift and a trend component, see Equation (3). In testing for stationarity it is in general not clear, however, that drift (α) and trend (δt) components should be included. The choice of a model specification depends on a priori knowledge of the specific variable. Concerning freight rates in dry bulk shipping, there is no a priori reason to expect a specific trend development, see for instance Figure 14a and Figure 14b in Appendix B. Observed time series of gdp, on the contrary, tend to reflect a rising trend. Only if the observations indicate a convex trend the model formulation should include both the drift and the trend component in Equation (3). Such observations are the rationale for the model specifications underlying the results in Table 1, ignoring trend components. I have, however, experimented with model formulations with and without time and trend components. The conclusions on stationarity proved not to be sensitive to how such components are accounted for in the model specifications. The model specification underlying the result for the Baltic Freight Index (BFI) in Table 1 ignores both a drift and a trend component. The results for the gdp-measures are based on model specifications with a drift component, but without a trend component.

According to the results referred in Table 1 all the quarterly variables are

non-stationary. As stated in Section 5.1 the null hypothesis in the relevant kind of tests is that of nonstationarity ($\rho = 1$). This hypothesis was not rejected for any of the time series, since the test statistic does not exceed the critical value in any case. Recall from Section 5.1 that the critical values of this test is based on the Dickey-Fuller-distribution rather than the standard t -distribution. Only the critical levels corresponding to the 5% significance level are reported in Table 1, but the conclusions of nonstationarity would apply also if the tests were based on a 10% level of significance.

Variable	Test statistic	Critical value, 5%	Lags	Observations
BFI	0.434	-1.950	4	95
GDP, OECD	-1.735	-2.892	1	98
GDP, USA	-1.208	-2.898	9	90
GDP, Japan	-1.805	-2.895	5	94
GDP, China	0.520	-2.952	0	42

Note: significance levels: * : 10%, ** : 5%, *** : 1%; loglinear models

Table 1: Results of the augmented Dickey-Fuller test for stationarity in some quarterly time series.

The number of observations referred in Table 1 of course reflect both the number of quarters observed and the number of lags used in the model specification. Observations for GDP in China span over the period 1999-2009, while the remaining time series are from the period 1985-2009.

6.1.2 Testing for integration order

In testing for cointegration I will be using the Engle-Granger test. As stated in Section 5.2 this test is based on the assumption that the variables involved are integrated of the same order. The discussion in Section 5.1 made clear that a nonstationarity variable that becomes stationary when it is differentiated d times is integrated of order d , $I(d)$. A variable is for example integrated of order 1, $I(1)$, if its first difference is stationary.

According to the results presented in Table 2 the first difference of all the variables are found to be stationary. The null hypothesis is of course once again that of nonstationarity. This means that all the variables are $I(1)$. It follows from the results presented in Table 2 that H_0 is rejected

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for all the time series. Except from the gdp in the US the hypothesis of nonstationarity would be rejected also at a 1% level of significance. Hence, the conclusion will be that the Engle-Granger procedure can be used in testing for cointegration.

Variable	Test statistic	Critical value, 5%	Lags	Observations
BFI	-8.410***	-1.950	0	98
GDP, OECD	-2.841***	-1.950	0	98
GDP, USA	-2.361**	-1.950	1	97
GDP, Japan	-7.053***	-1.950	0	98
GDP, China	-3.404***	-1.950	0	41

Note: significance levels: * : 10%, ** : 5%, *** : 1%; loglinear models

Table 2: Results of the augmented Dickey-Fuller test for stationarity in the first differences of the quarterly time series.

The model specifications underlying the results in Table 2 did not incorporate drift or trend components. Figure 12b and Figure 12d in Appendix A offers an illustration of the first differences in BFI and the gdp of OECD.

6.1.3 Cointegration

Now that the relevant time series are found to be non-stationary and $I(1)$, the next step is to test for cointegration. According to the basic problem of this thesis, the alternative indicators of business cycles have been tested for cointegration with the freight rates, represented by the Baltic Freight Index (BFI). The first step of the Engle-Granger test is then to run a regression of BFI on the alternative business cycle measures. This provides estimates of residuals, which are then tested for stationarity by the Dickey-Fuller procedure (see Equation (10)). Once again, the null hypothesis is that of nonstationarity. If H_0 is rejected, the conclusion is that the variables are cointegrated. H_0 is rejected if the test statistic has a more negative values than the critical value. Recall from Section 5.2 that the critical values are calculated from tables presented in MacKinnon (2010) rather than from the Dickey-Fuller-distribution. The MacKinnon values account for the fact that the Dickey-Fuller test is based on estimated rather than actual residuals.

The results of the Engle-Granger test is presented in Table 3.

Variable	Test statistic	Critical value, 5%	Lags	Observations
GDP, OECD	-3.485**	-3.3992	1	98
GDP, USA	-3.444**	-3.3992	1	98
GDP, Japan	-4.012**	-3.4005	3	96
GDP, China	-3.893**	-3.4973	3	39

Note: significance levels: * : 10%, ** : 5%, *** : 1%; loglinear models

Table 3: Results of the Engle-Granger test for for cointegration with the Baltic Freight Index (BFI)

According to the results presented in Table 3, the H_0 of no cointegration is rejected for all the time series, at a significance level of 5%. Hence, the conclusion is that the alternative business cycle indicators are cointegrated with the BFI. The conclusion for the gdp of Japan is almost valid for a significance level of 1%, which corresponds to a critical value of -4.013 .

The conclusion that the business cycle measures are cointegrated with the BFI is interesting and important. It means that there is an equilibrium relationship between the business cycle and the freight rates in dry bulk shipping. This corresponds to an interpretation where the demand for shipping services reflects the variations in production. Changes in the business cycle situation then initiate forces pulling the market for shipping services towards a new equilibrium. In other words, the relationship between the BFI and alternative gdp indicators tend to converge towards a long-term equilibrium solution. The fact that all the gdp-measures are cointegrated with the BFI may reflect a tendency of long-term covariation between the business cycles in different geographies.

A reasonable hypothesis is that short- and medium-term consequences of changes in production are sensitive to where such changes find place. This hypothesis will now be discussed within the framework of the error correction model.

6.1.4 Results based on Error Correction Models

According to the Granger representation theorem (Engle and Granger, 1987), the presence of cointegration justifies the use of an error correction model. The results to be presented follow from an Engle-Granger two-step procedure, based on estimated error terms from the cointegration regression ($\hat{e}_t = y_t - \hat{\alpha} - \hat{\beta}x_t$), represented by Equation (11).

Let y_t denote the freight rate in dry bulk shipping (BFI) at time period t , while x_t denotes the gdp in a specific geography at the same period and u_t is a log normally distributed error term. Since all the variables are represented by their natural logarithm, the relevant error correction models is then given by the following regression model:

$$\Delta(\ln y_t) = \mu + \gamma\Delta(\ln x_t) + \delta\hat{e}_{t-1} + u_t \quad (12)$$

This is basically according to the model formulation suggested by both Wooldridge (2008, p. 643) and Koop (2008, p. 224). An estimate of the parameter γ represents the immediate percentage change in the BFI as a response to a 1% change in the relevant gdp measure. The value of the parameter δ captures the time required before a deviation from equilibrium is corrected for. In other words, $\hat{\delta}$ represents the percentage of the deviation that is corrected for within one time period.

Consider first the results for the gdp of the entire OECD area:

$$\Delta(\ln y_t) = -0.082 + 15.210 \Delta(\ln x_t^{\text{OECD}}) - 0.161 \hat{e}_{t-1}^{\text{OECD}} \quad (13)$$

(0.036) (4.316) (0.053)

Here, the standard errors are given in parentheses under the parameter estimates. All the parameter estimates are significantly different from zero. The P -values corresponding to $\hat{\gamma}$ and $\hat{\delta}$ are 0.001 and 0.003, respectively. The results mean that

- a 1% change in the gdp growth in the OECD area immediately causes a 15.2% change in the growth rate of the BFI

- about 16% of the deviation from the equilibrium between the BFI and the gdp of OECD will be corrected in the subsequent quarter

Those estimate results are based on 99 observations (quarters), and the model explains about 16.6% of the variation in the logarithm of the *changes* in dry bulk freight rates ($R_{\text{adj}}^2 \approx 0.1658$).

The results from an error correction model specification for USA, Japan, and China are given by the following equations:

$$\Delta(\ln y_t) = -0.048 + 9.009 \Delta(\ln x_t^{\text{USA}}) - 0.145 \hat{e}_{t-1}^{\text{USA}} \quad (14)$$

(0.037) (4.218) (0.055)

$$\Delta(\ln y_t) = -0.006 + 1.892 \Delta(\ln x_t^{\text{Japan}}) - 0.203 \hat{e}_{t-1}^{\text{Japan}} \quad (15)$$

(0.024) (0.456) (0.064)

$$\Delta(\ln y_t) = -0.111 + 4.233 \Delta(\ln x_t^{\text{China}}) - 0.314 \hat{e}_{t-1}^{\text{China}} \quad (16)$$

(0.078) (1.733) (0.111)

Notice first from the results that the immediate relative effect of a change in the gdp is larger for the OECD as a whole than for each of the three countries separately. It is not obvious how this should be interpreted. In such an interpretation care should be taken to the fact that gdp and business cycles tend to spread across countries and continents. Hence, the gdp of different countries tend to covariate. One possible explanation of the results is, however, that the gdp of OECD is a more satisfactory measure of the worldwide business cycle than the measures covering smaller geographies. An increased overall production in the OECD area is typically followed by increased trade and increased demand for shipping services. The US economy can also be argued to be a good proxy variable of global growth, trade and shipping volumes, while the economic development in Japan probably is more weakly related to the global business cycle. This may also apply to China, but China represents a very large and strongly growing market

for trade and shipping services. This is one possible explanation for the different estimates of the contemporaneous change in gdp's, $\hat{\gamma}$.

Recall that the estimates for China are based on a relatively small number of observations, quarterly for the period 1999-2009. Still, the estimates reflect significant effects. The impact of the error correction term is estimated to be considerably larger than for the other geographies; about 31% of the deviation from the equilibrium between the BFI and the gdp of China will be corrected in the subsequent time period. Assume that the Chinese economy is exposed to a shock. The value of $\hat{\delta}$ means that it takes a relatively short time to restore a state of equilibrium between the production level in China and the freight rates in shipping.

The adjusted R-squared for the error correction regressions of USA, Japan, and China are, respectively, 0.1027, 0.1670, and 0.1658.

6.2 Results based on monthly data

The results in the previous section were based on quarterly observations of highly aggregated proxy variables representing changes in the level of trade and the demand for shipping services. What would the results be like in a more disaggregated approach? One impulsively appealing approach would be to study time series of trade flows for a specific commodity, between specific geographies. What would be the relationship between such trade flows and the freight rates for this specific shipping? Giving it a second thought, this approach is not as appealing as it first seems. First, data is not easily available at this level of aggregation. Second, there is a high degree of substitutability between separate markets, with respect to bulk commodities and routes, and freight rates of different shipping services are highly correlated (see, for example, Glen and Rogers, 1997 and Figure 1 in Section 2.1). Hence, it can be argued that different services should be considered simultaneously, and it is not obvious that a relatively simple econometric time series approach benefits from using very disaggregated data.

Still, it can be argued that quarterly observations of gdp measures rep-

resent a level of aggregation that is perhaps not adequate for studies of shipping flows and freight rates. A compromise may be to study exports and/or industrial production for specific countries or continents. The production and exports may also be specific to certain bulk commodities. For Japan, I have decided to include the imports in addition to the exports. I found a correlation coefficient of 0.965 between the two time series. Both series can be used as indicators of business cycles in Japan. However, as my focus in this thesis is in dry bulk shipping, the Japanese imports may be more relevant than the Japanese exports. Japan is importing commodities transported in dry bulk shipping, such as steel and iron ore while Japan is typically exporting finished goods, which are mainly transported in liner shipping.

As pointed out in Section 2.1, major dry bulk is represented by iron ore (steel), coal, and grain. The North Atlantic area is of course a very important destination for this commodity trade. I consider time series for both the US and the OECD area in general. According to for example Tvedt (2003), however, the market for dry bulk shipping is even more influenced by the situation in Japan than the state by the US economy. Based on the more recent development, it is a reasonable hypothesis that the substantial economic growth in China has had an important impact on the major bulk commodity trades. Hence, I test for the possible impact on freight rates of the production and trade flows in China and Japan. In addition, I consider Australia, Asia as a whole, and the combination of China, Japan, and South-Korea.

As stated above the focus in this section will be on more disaggregated time series, referring to various combinations of geographical areas and trade or production of different bulk commodities. The gdp measures were to a large extent covarying over time. This is not necessarily the case for the production and trade of different commodities, at least not to the same extent. The development in demand, production, and trade of one commodity may deviate substantially from the development of another commodity. The results to be presented in this section are further based on a higher number of observations of the variables, since information is available for

monthly time series.

All of the variables to be studied are related to the market for dry bulk shipping. Steel, for example, represents about 50% of total dry bulk shipping. My ambition is to test if the corresponding time series are cointegrated to freight rates in dry bulk shipping, and to study the dynamics in such relationships.

Illustrations of the time series are attached in the appendix. For the time series representing the Japanese steel production I have removed the observation in January 1987, as it was an obvious outlier.

6.2.1 Stationarity of freight rates, trade flows and production measures

As pointed out in Section 5.1 regression results between non-stationary variables probably will reflect spurious relationships. Hence, the time series to be studied are first tested for nonstationarity. Once again, the number of lags involved in this testing is determined from the last significant lag criterion.

Some of the time series are tested from a model specification including both a trend and a drift component, while one or both of those components are ignored in testing other time series for unit roots. The choice of model specifications is based on observations of the relevant time series in addition to a priori knowledge on the series. If, for example, observations indicate a convex trend, both a trend and a drift component are included. The choice of model specification affects the critical values of the test. The cases in Table 4 with a 5 % critical value of -1.950 are based on a model specification where neither a drift nor a trend component are accounted for. A critical value of -2.878 corresponds to a case where the drift component is included while the trend component is ignored. Model specifications with both a drift and a trend component resulted in a critical value of -3.434 .

For some of the time series it is not obvious what model formulation is appropriate. Most of the results, however, turned out to be insensitive to the chosen model formulation of trend behavior. There were, however, some

exceptions. The conclusion of the stationarity tests on the steel production in Japan and Australia are sensitive to whether or not drift is included. Steel production can be expected to have an upward drift over time. This does not mean, however, that the steel production is expected to increase in all steel-producing countries. Based on Figure 16c in Appendix B. I have decided to not include a drift component for the steel production in Japan. Based on the shape of the curve in Figure 17a, on the other hand, I decided to include a drift component for the Australian steel production. If I had decided to include a drift for steel production in Japan, the test would conclude that the variable is stationary. For the Australian steel production, the opposite is the case. If a drift component was not included, the test would have concluded that the variable is non-stationary. Hence, some results are sensitive to the choice of model specification.

The meaning of the variables in Table 4 are self-explained, except from the “Ironoreprod., E-Asia”, and “Coalimp., E-Asia”. Here, E(ast)-Asia refers to the countries China, Japan, and South-Korea.

Variable	Test statistic	Critical value, 5%	Lags	Observations
BFI	0.511	-1.950	7	293
Ind. prod., OECD	-0.658	-1.950	2	296
Ind. prod., Asia	0.210	-1.950	14	284
Ind. prod., USA	-1.646	-2.878	7	292
Ind. prod., Japan	-3.261**	-2.878	2	297
Steel prod., World	-2.816	-3.434	9	218
Steel prod., Japan	0.138	-1.950	4	290
Steel prod., China	1.058	-2.881	1	239
Steel prod., Australia	-3.668***	-2.878	1	298
Iron ore imp., E-Asia	-2.109	-3.433	2	224
Exports, OECD	-1.485	-2.878	4	293
Exports, Japan	-1.296	-2.878	10	289
Imports, Japan	-0.866	-2.878	3	297
Coal exp., total	-2.626	-3.434	4	221
Coal exp., USA	0.176	-1.950	11	286
Coal exp., China	-1.933	-2.878	5	295
Coal imp., E-Asia	-2.464	-3.434	5	221

Note: significance levels: * : 10%, ** : 5%, *** : 1%; loglinear models

Table 4: Results of the augmented Dickey-Fuller test for stationarity in monthly time series related to the market for dry bulk shipping. The test statistics are based on logarithmic values of the variables.

According to Table 4 the null hypothesis of nonstationarity is rejected

only for two of the time series. The industrial production of Japan and the steel production of Australia are found to be stationary, while the rest of the variables are concluded to be non-stationary. If a trend component is included in the model specification of the industrial production in Japan the conclusion is reversed for this variable. On the other hand, the exports and imports of Japan turns out to be stationary variables if a trend component is included in the model specification in addition to the drift. For the rest of the variables, the conclusions are the same, no matter how trend behavior is represented.

6.2.2 Testing for stationarity of the first differences

The results presented in Table 5 mean that the first differences of all the variables are found to be stationary. The null hypotheses of nonstationarity are rejected in all the cases, also at a level of significance of 1%. In the previous section we have seen that the industrial production of Japan and the Australian steel production are $I(0)$. The results in Table 5 mean that the rest of the variables are $I(1)$. This further means that the Engle-Granger procedure is appropriate in testing for cointegration.

Variable	Test statistic	Critical value, 5%	Lags	Observations
BFI	-5.756***	-1.950	11	288
Ind. prod., OECD	-4.485***	-1.950	3	294
Ind. prod., Asia	-5.183***	-1.950	13	284
Ind. prod., USA	-5.674***	-1.950	2	296
Steel prod., World	-4.976***	-1.950	8	218
Steel prod., Japan	-7.379***	-1.950	3	290
Steel prod., China	-4.565***	-1.950	5	234
Steel prod., Australia	-20.982***	-1.950	0	298
Iron ore imp., E-Asia	-17.697***	-1.950	1	224
Exports, OECD	-6.842***	-1.950	3	293
Exports, Japan	-5.381***	-1.950	10	288
Imports, Japan	-7.851***	-1.950	2	297
Coal exp., total	-13.847***	-1.950	2	222
Coal exp., USA	-4.438***	-1.950	10	286
Coal exp., China	-13.788***	-1.950	4	295
Coal imp., E-Asia	-9.836***	-1.950	4	221

Note: significance levels: * : 10%, ** : 5%, *** : 1%; loglinear models

Table 5: Results of the augmented Dickey-Fuller test for stationarity in the first differences of the monthly time series.

6.2.3 Cointegration

According to the Engle-Granger procedure the time series of production and trade are first regressed against the BFI, before the residuals of this regression are tested for stationarity. The results of this procedure are presented in Table 6.

Section 6.1.3 proved that quarterly observations of the gdp's of different geographical areas are cointegrated to the BFI. Based on this result it seems reasonable to expect that monthly time series of aggregate industrial production in the same areas are cointegrated to the BFI. The data does not provide sufficient evidence to confirm such expectations, however. The null hypothesis of no cointegration between monthly observations of industrial production and the BFI is not rejected for any of the geographical areas.

Variable	Test statistic	Critical value, 5%	Lags	Observations
Ind. prod., OECD	-1.724	-3.357	9	289
Ind. prod., Asia	-2.078	-3.357	4	294
Ind. prod., USA	-2.436	-3.358	12	287
Ind. prod., Japan	-1.606	-3.358	14	285
Steel prod., World	-4.689***	-3.364	10	217
Steel prod., Japan	-2.169	-3.357	4	290
Steel prod., China	-4.560***	-3.363	9	231
Steel prod., Australia	-2.613	-3.357	1	298
Iron ore imp., E-Asia	-4.237***	-3.364	9	217
Exports, OECD	-3.081*	-3.358	12	285
Exports, Japan	-3.821**	-3.357	9	290
Imports, Japan	-4.443***	-3.357	10	290
Coal exp., total	-2.704	-3.364	4	221
Coal exp., USA	-2.176	-3.358	13	284
Coal exp., China	-2.060	-3.358	13	287
Coal imp., E-Asia	-3.524**	-3.364	9	217

Note: significance levels: * : 10%, ** : 5%, *** : 1%; loglinear models

Table 6: Results of the Engle-Granger test for cointegration with the Baltic Freight Index (BFI). Monthly observations.

This conclusion is modified when industrial production is disaggregated to specific bulk commodities. As mentioned several times above, steel represents about 50% of major bulk shipping. According to the results in Table 6 the world production of steel comes out to be cointegrated with the BFI for the period considered. This also applies to the production of steel in China, while data does not provide sufficient evidence to reject the null

$$\Delta(\ln y_t) = 0.005 + 0.219 \Delta(\ln x_t^{\text{Imports, Japan}}) - 0.027 \hat{e}_{t-1}^{\text{Imports, Japan}}$$

(0.008)
(0.157)
(0.019)

(21)

$$\Delta(\ln y_t) = 0.005 + 0.027 \Delta(\ln x_t^{\text{Coal imp, E-Asia}}) - 0.041 \hat{e}_{t-1}^{\text{Coal imp, E-Asia}}$$

(0.100)
(0.165)
(0.021)

(22)

The estimation results presented in Equation (18) are based on 240 observations and an adjusted R-squared of 0.0522. The corresponding figures are 226 and 0.0323 for Equation (19), 299 and 0.006 for Equation (20), 300 and 0.003 for Equation (21) and 226 and 0.009 for Equation (22).

It is according to expectations that the freight rates in dry bulk shipping respond strongly to shocks in the world steel production. This applies both for the short-term, contemporaneous, effect, and in terms of time needed to restore a state of equilibrium between steel production and freight rates. The explanatory power of the model specification based on the world steel production is further substantially higher than the explanatory power related to the other variables considered. In evaluating the estimates related to the error correction term it is of course important to account for the fact that the time period is now a month rather than a quarter. Notice further from Equation (22) that changes in the import of coal to East Asia (China, Japan, and South-Korea) have no significant contemporaneous impact on the BFI. Notice also that the error correction model does not reveal possible differences with respect to how exports to and imports from Japan influence the freight rates in dry bulk shipping. This result, of course, reflects the fact that the two series are highly correlated.

6.3 Critical remarks on the empirical results

It can be argued that the error correction models in Section 6.1.4 and Section 6.2.4 are too basic to capture the true relationships between the freight rates and the various business cycle measures. The adjusted R-squared, which represents the explanatory power of the models, ranges from less than 1% to about 20%. Hence, the volatility in the freight rates is only to a modest degree explained by the models.

To increase the explanatory power it is possible to include explicitly components influencing the demand and supply in the market for dry bulk shipping. Recall that the ambition of this thesis is to study the relationship between business cycles and freight rates in dry bulk shipping, rather than developing an econometric model attempting to explain all the volatility of the freight rates. This does not mean that additional variables are irrelevant, however, for instance to avoid problems related to omitted variables.

The demand for sea transport was represented by measures of gdp, production and trade flows in the preceding sections. Based for instance on Stopfords (2009, p. 139-149) five key factors influencing the demand for sea transport, it is of course possible to specify other demand factors in the regressions. According to Stopford (Stopford, 2009, p. 140), the business cycle is “the most important cause of short-term fluctuations in seaborne trade and ship demand”. I will not enter into details on other demand related variables that could be included in the model.

The major driver of short-term variation in freight rates is expected to be the demand, as there is a time lag in the adjustment of the supply. Still, supply factors also have an impact on the determination of freight rates. It is beyond the scope of this thesis to take such factors explicitly into account in the analysis, but I will briefly mention some relevant aspects. In Section 3.2 there was a discussion of the supply of sea transport. In order to fully control for the supply of sea transport, one needs data on the size of the fleet as well as of the fleet utilization. Data on the size of the fleet are easily available, see Figures 20a and 20b in Appendix B for time series on

the fleet size. Fleet utilization, on the other hand, must be calculated based on factors such as waiting time in port and operating speed. This is a time consuming and complex task, and if the calculations are not done properly the results may confuse more than they help.

Shipowners investment decisions are of course also important in explaining the supply of shipping services. Most of the literature considers exogenous demand factors to be the main determinants of freight rates. According to Randers and Göluke (2007), however, shipowners are to a large degree responsible for the high volatility in the market: “In our view ship owners contribute to their own difficulties. The shipping community creates the cyclical and adds significantly to the volatility of the business environment through their own investment and allocation decisions. We call this perspective the ”self-infliction view” ”(Randers and Göluke (2007). According to Randers and Göluke (2007) the rationale for this behaviour is that increased volatility improves the chances of making fortunes in shipping. Analogously, Stopford (2009) claims that the risk profile for investors in shipping may differ systematically from the risk profile of investors in other sectors, being less risk averse.

It is possible to incorporate hypotheses of investments decisions, for instance by introducing adaptive expectations of some kind, based on the observed development of the freight rates in previous periods. Another supply factor that may be explicitly included is the bunker price. There is a discussion of the effects of an increased price of bunker fuel in Section 7.3. Studying the short and long-term relationship between the supply of sea transport and freight rates in dry bulk shipping is, however, beyond the scope of this thesis. Hence, I will not enter into a discussion of how such factors could be made operational in a model formulation. I have chosen to keep the model simple, rather than experimenting with additional factors influencing the supply and demand in shipping markets. If such factors were included I also had to deal with problems related to multicollinearity and identification, in addition to testing for stationarity etc. This is left for future research.

In Section 6.1.1 and Section 6.2.1 the freight rates in dry bulk shipping

were found to be non-stationary. These results are in line with most empirical studies on stationarity of freight rates (see for example Berg-Andreassen (1996) or Veenstra and Frandes (1997)). There are, however, some empirical studies that reach the opposite conclusion. According to Tvedt (2003), the freight rates in dry bulk shipping become stationary if they are converted from US dollars to Japanese yen. He argues that the main driver of the dry bulk shipping industry is the Japanese economy. Therefore, he claims, it is more appropriate to study the freight rates converted to Japanese yen. Tvedt (2003) uses data from 1985 - 1999. In the 2000s, China has strengthened its position in dry bulk shipping, and it can be argued that the Chinese economy now is the main driver of the industry.

The most commonly used test for stationarity is the traditional Dickey-Fuller test (Dickey and Fuller, 1979). This test was used in Section 6 above, as in most of the empirical research on stationarity of freight rates in shipping. The traditional Dickey Fuller test is a linear stationarity test. Koekebakker et al. (2006) claim that there are empirical evidence and theoretical support of a non-linear behaviour of the spot freight rates. When the spot freight rates are tested for stationarity with a nonlinear version of the (Augmented) Dickey-Fuller test, Koekebakker et al. (2006) found that the freight rates both in dry bulk shipping and in tanker shipping are nonlinear stationary. They also claim that maritime economic theory supports this finding. The argument is that over time it is not sustainable with extremely high or extremely low freight rates, and hence, "the freight rate cannot exhibit the asymptotically explosive behaviour implied by a non-stationary process" (Koekebakker et al. 2006). They further argue that the standard conclusion of non-stationary freight rates is due to the weak power of the stationarity tests being used. Still, I have chosen to proceed according to the traditional approach. This controversy of stationarity is, however, an example of a discussion that I would like to enter more thoroughly into if I had more time available for this thesis.

7 Interpreting results in terms of a competitive equilibrium model

According to the empirical results presented in Section 6 there is an equilibrium relationship between freight rates in shipping and some business cycle measures. The error correction model further provided results on the dynamics involved in this relationship, distinguishing between the contemporaneous effect of a demand shock, and the time it takes to restore an equilibrium situation. The next challenge is to interpret those results in terms of the partial competitive equilibrium model presented in Section 3. The discussion to follow focuses on alternative scenarios of demand and supply shocks, as well as on possible short- and long-term dynamics following from such shocks. As a convenient simplifying assumption the illustrations ignore the possibility that freight rates reach a level corresponding to the elastic part of the demand curve, see Figure 5.

7.1 A general demand shock

The results presented in Section 6.1 proved that

- all the quarterly time series of alternative gdp-measures are non-stationary; $I(1)$
- the first differences of those time series are stationary, $I(0)$
- all the tested quarterly gdp-measures are cointegrated with the Baltic Freight Index

This means that the relationship between the business cycle situation and the freight rates in dry bulk shipping tend to converge towards a long-term equilibrium solution. There are several possible reasons for such an equilibrium relationship. As pointed out in Section 5.2 one of the variables can for example depend on the other, or they may both depend on the same exogenous factors. In the relevant example it is natural to consider the freight rates in shipping to depend on the business cycle situation.

Changes in the business cycle situation appear as exogenous demand shocks, followed by some forces pulling the market for shipping services towards a new equilibrium solution.

The error correction model is more specific both on the contemporaneous effect of a demand shock, and on the dynamics towards a new equilibrium solution. Consider for example the results from the error correction model based on the gdp of the OECD as a measure of the business cycle situation. Recall from Section 6.1.4 that the estimated elasticity of freight rates with respect to changes in the gdp of the OECD is about 15.2. According to the shape of the highly nonlinear supply curve a demand shock will influence strongly on the freight rates especially in situations where the supply is close to its capacity limit. Hence, the high elasticity estimate indicates that the market has been operating close to its capacity limit in the period covered by the data.

The nonlinear character of the supply curve is of course a challenge if the results from the error correction model are used to predict the contemporaneous effect of a demand shock. The prediction has to be based on an assumption of the capacity situation of the shipping market. The elasticity estimate is not reliable for prediction purposes if the capacity situation in the prediction period differs from the situation in the period covered by the data.

Assume that point A in Figure 8 corresponds to a long-term equilibrium solution, where the freight rate equals the average cost of dry bulk shipping. Hence, the profits are equal to zero, and there are no incentives for shipowners to exit from the market, nor to enter the market.

The system is next disturbed by a positive demand shock, represented by the shift from D_0 to D_1 in Figure 8. The immediate effect is to increase the freight rates from P_0 to P_1 , while the freight volumes increase from Q_0 to Q_1 . This increased freight volume is explained by a more intensive utilization of the fleet, see Section 3.2 for more details on how vessels can be more intensively utilized.

There are reasons to believe that the short-term equilibrium solution A will not be stable, however. The freight rate P_1 is substantially higher than

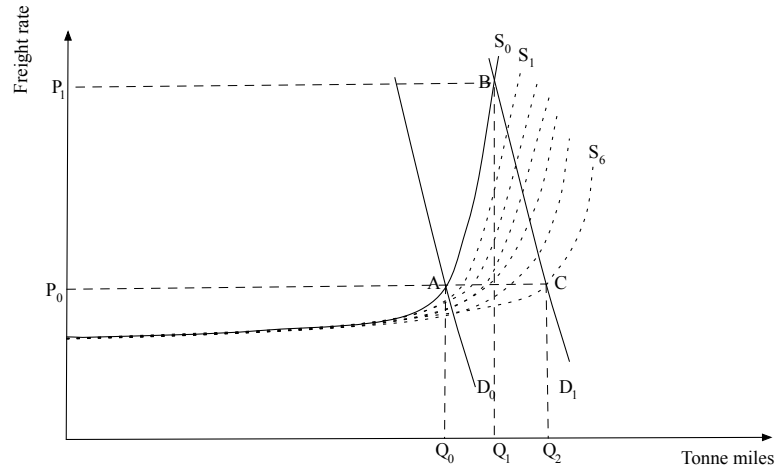


Figure 8: Short- and long-term effects of a positive demand shock.

the average costs, and there will be an incentive for shipowners to expand in this market. The no-entry condition is not fulfilled.

Expansion is time-consuming, however. Even in a long-term equilibrium solution, like point A in Figure 8, there are of course some dynamics in the shipping market for dry bulk. Some old vessels are being scrapped, and substituted by more modern vessels. This may affect marginal costs and the shape of the supply curve, but this possibility is ignored in the discussion to follow. The large increase in the freight rate may prevent shipowners from scrapping vessels, even if new ships are being delivered. At the same time, shipowners may postpone to take vessels out of the market, for repairs and maintenance. Such decisions represent a relatively fast supply response to the increased freight rate, and explain the shift in the supply curve from S_0 to S_1 in Figure 8.

As pointed out in Section 3.2 some newbuilding projects to some degree can be accelerated in periods with high freight rates, though it normally takes from 12 months to three years to have a ship delivered. In general, the time it takes before the shipowners make decisions of building new ships and the ships are delivered may vary considerably. In Figure 8 this explains the sequences of supply shifts towards the new long-term equilibrium solution

in point C. Each supply curve represents the situation in a specific quarter. According to the results following from the error correction model about 16% of the deviation from the equilibrium level between the BFI and the gdp of the OECD will be corrected in the subsequent quarter. This means that it takes about 6 quarters to get back to a stable equilibrium solution, where the freight rate reaches the level prior to the demand shock. As the freight rate is successively reduced, the incentives for new deliveries comes to an end, until a new equilibrium is reached, with a balance between deliveries and scrapping of vessels.

7.2 A demand shock in a separate submarket

As pointed out in Section 2.1 and illustrated in Figure 1 there is a high degree of covariation between the freight rates of different submarkets of dry bulk shipping. The literature also provides arguments that shocks in one submarket tend to spread to other submarkets, and that the freight market in general can be considered to be integrated (see for instance Strandenæs 1981). At the same time, however, there may be substantial differences between the freight rates of different submarkets at a specific point in time, as pointed out for instance by Laulajainen (2006). In this section such observations are interpreted in an analytical framework.

A worldwide economic upturn is expected to affect the market for dry bulk shipping in general. It is of course possible, however, that the increased demand is restricted to a specific geography and/or to a specific commodity. In such a case the demand for shipping services is increased for a few routes, and left unchanged in the rest of the system. One example may be an increased Chinese steel production. According to the results presented in Section 6.2.3 the Chinese steel production is cointegrated to the freight rates in dry bulk shipping. The results from the error correction model means that an increased production has a significant contemporaneous effect on the freight rate, and that about 5.4% of the deviation from the equilibrium

7. INTERPRETING RESULTS IN TERMS OF A COMPETITIVE EQUILIBRIUM MODEL

between the BFI and the Chinese steel production will be corrected in the subsequent month. This further means that it will take about 18 months to restore the equilibrium solution after a shock has occurred.

Figure 9 offers an illustration of such a scenario. The figure is based on the assumption that only submarket A is affected initially. This submarket is represented by the left part of the figure, while the rest of the market for dry bulk shipping is represented by the right part, denoted as submarket B. The analysis starts from a long-term equilibrium solution where the freight rate (P_0) is assumed to equal the average cost of dry bulk shipping, and equal in different submarkets. The system is then disturbed by an exogenously increased demand in submarket A, represented by the shift from D_0^A to D_1^A in the left part of the figure.

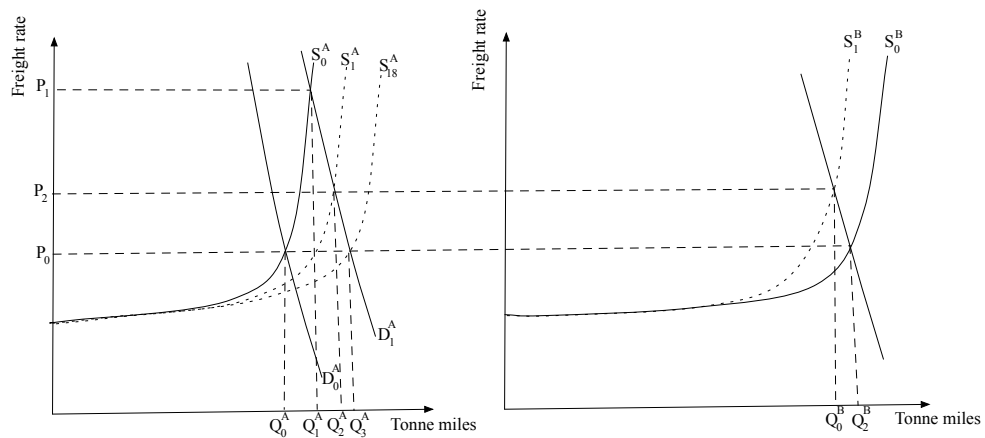


Figure 9: Short- and long-term effects of a positive demand shock in a specific submarket.

The contemporaneous effect of the demand shift is to raise the freight rate in the relevant submarket substantially, from P_0 to P_1 in the figure. According to the results in Section 6.2.4 the contemporaneous effect of an increased steel production in China is represented by an elasticity of 0.7, see Equation (18). This relatively low elasticity apparently does not correspond to the large contemporaneous increase of the freight rate in Figure 9. Recall, however, that the price variable used in the error correction model is a

freight rate index, while the freight rates in Figure 9 applies for the specific submarkets. Hence, the fact that an increase in the Chinese steel production is estimated to have a moderate impact on the Baltic Freight Index does not mean that the contemporaneous effect on the freight rate of specific routes is moderate.

The increased freight rate from P_0 to P_1 in Figure 9 of course refers to a very short-term time perspective, for which the capacity on the specific route is more or less given, corresponding to a given number of vessels operating here. Extending the time perspective, however, means that a freight rate level of P_1 does not represent an equilibrium solution. This freight rate is substantially higher than the average cost of dry bulk shipping, and the law of one price for homogeneous services (shipping) is violated. Hence, shipowners may increase their profits by moving their vessels to routes transporting steel produced in China. This explains the positive supply curve shift from S_0^A to S_1^A in the left part of Figure 9, and the negative shift from S_0^B to S_1^B in the right part of the figure. In the medium-term equilibrium solution corresponding to a freight rate of P_2 the potential for profit by switching between submarkets is exhausted.

The solution with a freight rate of P_2 and transportation volumes of Q_2^A and Q_2^B does not meet the no-entry condition, and hence is no long-term equilibrium solution. The return on the shipowners capital is higher than the normal return in the market, and the fleet should be expected to expand until the point where there is no more room for supernormal profits. According to the results based on the error correction model, this process will take about 18 months, and it goes on until the position of the new supply curve is S_{18}^A in Figure 9. The supply curve in submarket B will eventually shift back to its initial position, from S_1^B to S_0^B .

In the long-term equilibrium solution in Figure 9 the freight rate has returned to its initial level. The distribution of transportation volumes and capacity between the different submarkets has changed, however. The transportation volume in submarket B is unaffected by the demand shock in submarket A, in a long-term time perspective, but the transportation volumes in submarket A has increased. The increased Q^A can be explained

as the result of a sequence of adjustments. First, the increase from Q_0^A to Q_1^A is explained by a higher utilization of the initial fleet. The increased transportation volume from Q_1^A to Q_2^A reflects the fact that vessels are attracted from other submarkets, while the increase towards Q_3^A is a response of gradual expansions of the fleet.

The process leading from the initial to the final equilibrium solution in Figure 9 represents a reasonable explanation of the empirical finding that the time series of Chinese steel production is cointegrated to the freight rate in dry bulk shipping.

The analysis in this section is based on the assumption that the long-term equilibrium freight rates will be equal in the separate submarkets. As pointed out in Section 3.1, however, there are limits to substitution and integration. Adland and Strandenes (2004) for instance claim that there will exist a positive freight rate differential between a Suezmax tanker and a VLCC trading on the same route, due to economies of scale offered by the VLCC. The possibility of persistent differentials is not accounted for in the analysis above.

7.3 Effects of an increased price of bunker fuel

The price of bunker fuel probably is the single factor that has the strongest influence on short-term fluctuations in the supply of sea transport. Most of the commercial fleet is operating on bunker fuel, but there are several types of fuel used. According to Wang et al. (2010), bunker fuel is a residual fuel which originally was defined as the liquid that was left after removing the most valuable products in the petroleum distillation process. Wang et al. (2010) further write that the two basic grades of bunker fuel are IFO 180 and IFO 380. IFO 380 represents 60% of the world volume in bunkers, while IFO 180 and some other grades represent 30%. 10% of the world volume in bunkers is in Marine Diesel Oil (Alizadeh et al., 2004).

The price of each grade further varies between ports. I have tested time

and vessel scrappings, reflecting the reduced profit resulting from increased operating costs. Eventually, a new stable equilibrium is reached where the freight rate has increased to a level, P_1 in Figure 10, where shipowners earn no supernormal profits.

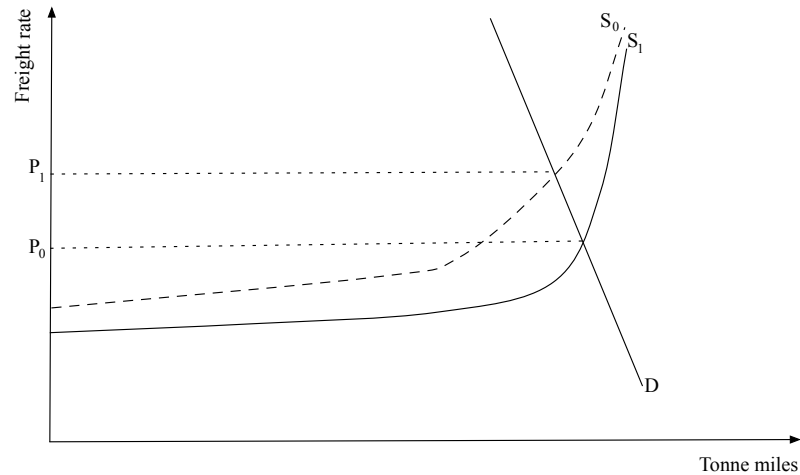


Figure 10: Effects of an increased price of bunker fuel.

It is worth mentioning that in addition to influencing the supply of sea transport there is another reason why the bunker price may be cointegrated with the BFI. Bunker is, as discussed above, a petroleum product, and hence the price of bunkers is expected to be strongly correlated with the oil price. According to Mork (1994) the oil price is correlated with business cycles. In Section 6 it was proven that the BFI is cointegrated with several measures of business cycles. Hence, the bunker price and the BFI can be argued to depend on the same exogenous factors.

7.4 The dramatic recent fall in freight rates

So far in this thesis, I have not explicitly addressed the role of expectations. Studying the role of expectations is a complex task. It can be argued that both the supply and the demand for sea transport is a result of expectations.

If shipowners expect the freight rates to be increasing in the coming period, they tend to increase their fleet.

The role of expectations in shipping markets can be studied by looking at the second-hand price of vessels. According to Strandenes (1986), the price of second-hand vessels depend on expectations about the future of the shipping industry worldwide. Merikas et al. (2008) studied the relationship between the price on second-hand vessels (SH) and the newbuilding price (NP) for tankers by studying the ratio SH/NP. Merikas et al. (2008) found that the SH/NP price ratio is positively related to the freight rate. This result is not very surprising. According to Stopford (2009, p. 639) it takes 12 months to 3 years to have a new vessel delivered. A second-hand vessel can, on the other hand, be delivered on a relatively short notice, as it is already in the market.

The value of a vessel is its discounted expected future income. If freight rates are very high shipowners want ships delivered as soon as possible in order to exploit the high freight rates. Hence, second-hand vessels are then priced relatively high compared to newbuildings. Assume for instance a period with high but falling freight rates. The value of a second-hand vessel delivered today, with 20 years left before scrapping, may then exceed the value of a newbuilding delivered in 5 years, even if the new ship will be operating for 25 years. Merikas et al. (2008) also pointed out that when the freight rate falls, the SH/NP price ratio drops not only because of the reduced price on second-hand vessels. The shipowners also tend to believe that there will be a recovery of the market in the future, and hence order new vessels based on this expectation. As mentioned Merikas et al. (2008) studied the market for tankers, but there is no reason to believe the results would differ for bulk vessels.

It can be argued that expectations depend on the recent development in demand and freight rates. In a period where both the demand and the freight rates increased substantially, shipowners expect this development to continue, or at least the market demand to stabilize at a very high level. As a response, new ships are ordered, leading to an increased fleet. As discussed in Section 3.2 this causes a shift of the supply curve towards the

right.

It followed from Figure 6 that the freight rates, represented by the BFI, were very high in 2007. This reflected a period where the demand for shipping services was very high. This situation, however, was followed by a dramatic fall in freight rates. A possible explanation is offered by studying Figure 11. Initially, the situation is represented by the demand curve D_0 and the supply curve S_0 .

As a next step in the line of arguing underlying Figure 11 the shipowners are assumed to respond to the high freight rates by ordering new ships, causing a larger fleet, and a supply curve shift from S_0 to S_1 . If the business cycle situation remained this would be a reasonable adjustment towards a new equilibrium solution. At the same time, however, (in 2008) there was a collapse in capital markets worldwide, and a financial crisis affecting the demand for goods and services hit most economies. This led to a decrease in the world trade, and hence, a reduced demand for sea transport. This is illustrated in Figure 11 by the shift of the demand curve from D_0 to D_1 .

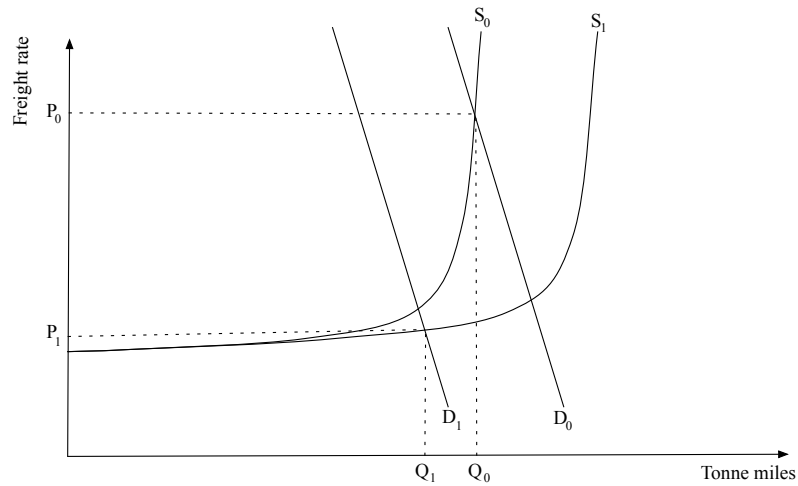


Figure 11: Supply adjustments and demand shocks explaining the dramatic recent fall in freight rates.

The very unfortunate combination of a negative demand and a positive supply shock was leading to a dramatic fall in the freight rates, represented

by the reduction from P_0 to P_1 in Figure 11. As illustrated in the figure the combination of the shifts in the demand and the supply curve also leads to a reduction in tonne miles transported. In a short-term time perspective this leads to a low utilization of the fleet. Starting from an equilibrium represented by the intersection of D_1 and S_1 , moderate shifts in the demand curve will not result in large changes in the freight rate. Even an increased demand back to the initial level represented by the curve D_0 would just have a modest impact on the freight rate. As a next response the number of lay-ups can be expected to increase, before the shipowners may decide to scrap their oldest and least efficient ships. Eventually a new equilibrium arises with freight rates approximately equal to marginal and average operating costs and a normal degree of fleet utilization.

Once again there will of course be lags in the adjustments of the fleet. This is another example of a complex and time-consuming mechanism explaining why business cycle measures tend to be cointegrated with the freight rate, and why the results from the error correction model suggest a slow adjustment towards a new equilibrium solution.

8 A summary of results and some concluding remarks

The empirical section of this thesis was focusing on short- and long-term relationships between freight rates in dry bulk shipping and alternative measures representing the demand for dry bulk shipping services. As a first reasonable hypothesis the demand for shipping is assumed to be positively dependent on trade flows, which further are assumed to reflect the business cycle situation. Next, business cycles are represented by quarterly observations of the gross domestic product. The shipping market effects of a demand shock may depend on where the shock originates. Hence, the analysis accounts for gdp variations for some geographies/countries that are potentially important in studying markets for dry bulk shipping.

All quarterly variables, the gdp of OECD, USA, Japan, and China, are

found to be non-stationary, as is the relevant time series for the Baltic Freight Index. Fortunately, both the BFI and the gdp variables were found to be integrated of order 1, $I(1)$, making them appropriate for the Engle-Granger procedure in testing for cointegration. This procedure further led to the conclusion that all the alternative business cycle measures are cointegrated with the BFI.

This important empirically based conclusion further means that there is an equilibrium relationship between the business cycle and the freight rates in dry bulk shipping. Hence, demand shocks caused by a changed business cycle situation initiate forces pulling the dry bulk shipping market towards a new equilibrium. It further follows from the observed time series that the relationship between the BFI and the alternative gdp indicators converge towards a long-term equilibrium solution.

The presence of cointegration justifies the use of an error correction model, and which allows for a short- and medium term analysis of demand shocks. The contemporaneous effect of a change in the gdp is found to be larger for OECD as a whole than for each of the three countries separately. This supports the hypothesis that the gdp of OECD is a more appropriate measure of the worldwide business cycle. The results also provide evidence of the increasingly important position of China in the market for dry bulk shipping over recent years. Finally, the results offer information on the dynamics of the process towards a new long-term equilibrium after a shock has occurred. About 12% of the deviation from the equilibrium between the BFI and the gdp of OECD is predicted to be corrected in the subsequent quarter. For the gdp of China the corresponding estimate is 31%.

The results following from monthly data on more disaggregated variables are somewhat more ambiguous. The disaggregation refers to various combinations of geographical areas and trade or production of different bulk commodities. Most of the time series were found to be non-stationary, and all the corresponding variables were integrated of order 1. Data does not, however, provide sufficient evidence that all the variables are cointegrated to the BFI. Still, the experiments prove that the freight rate in dry bulk shipping is at least related to some trade flows and production measures

through long-term equilibrium market forces. This applies, for instance, to the world steel production and the steel production in China.

Results based on the error correction model are also ambiguous. For most of the variables the term representing the contemporaneous effect did not come out to be significantly different from zero. This did not apply for the world steel production, however. The freight rates in dry bulk shipping were found to respond strongly to shocks in the world steel production. According to the estimate of the error correction term, it takes about 18 months to restore a state of long-term equilibrium following from a shock in the world steel production. The time needed for adjustments is estimated to be longer for the other variables that are cointegrated with the BFI, but the estimates are still within a sensible range of values.

An ambition of this thesis has been to interpret the empirical results in terms of a competitive equilibrium model. Considering the dynamic adjustments incorporated in the econometric approach, such an interpretation ideally calls for a dynamically formulated modelling framework. The competitive equilibrium model that is used in the analysis is basically constructed for comparative static analyses. By introducing some ad hoc dynamics, however, I think that the model is appropriate for explaining both the results from the cointegration tests and the results based on the error correction modelling approach.

The theoretical interpretation of results is based on case studies. The study of a general demand shock is motivated to explain both the contemporaneous shipping market effect of a world economy upturn, and the competitive forces bringing the market back to a state of long-term equilibrium. Next, the study of a demand shock in a separate submarket focused on the interrelationship between submarkets in shipping. The substitution of vessels causes integrated markets, and competition contributes to a solution where the law of one price holds in markets for dry bulk shipping. This competition of course also involves variations in the fleet, including new deliveries of ships, or lay-ups and scrapping in the case of less optimistic market prospects.

As another case study, cointegration tests, the error correction model,

and the competitive equilibrium model are used to discuss the short- and long-term effects of an increased price of bunker fuel. Once again, the theoretical model is well suited to explain and illustrate the empirical results. Finally, the competitive equilibrium model is used to explain the increased volatility and the dramatic changes in freight rates in the market for dry bulk shipping in recent years.

It was made clear in the empirical section of this thesis that the results are based on very simple versions of the error correction model. An interesting topic for future research would be to incorporate explicitly components influencing the demand and supply in the market for dry bulk shipping. As an example, investments decisions of shipowners could perhaps be represented by some kind of expectation mechanism, for instance based on the recently observed development of the freight rates. In such a setting it may be possible to see if shipowners contribute to their own problems, or if the volatility in freight rates is primarily a result of exogenous demand shocks.

It is of course not obvious how specific components of demand and supply should be made operational. There may also be econometric problems of an extended model formulation, for instance related to identification problems and multicollinearity between the explanatory variables. Adding more variables may improve the explanatory power significantly, but at the cost of a more complex model and, perhaps, less obvious interpretations.

The results following from the error correction model in principle can of course be used to predict the effects of an exogenous demand shock. Based on theoretical studies of the shipping market, however, it follows that such predictions should be interpreted with care. As has been made clear in this thesis, both theoretically based analysis and empirical results are in favour of highly nonlinear supply curve of shipping, changing from a very elastic curve at low utilization rates to become very inelastic as the shipping volumes approach the capacity limits. In such a scenario the contemporaneous effect of a demand shock on freight rates depends crucially on the initial capacity situation. This is an example that the relevant kind of econometric analysis should be combined with a thorough knowledge and theoretical analysis of the market being studied.

Another topic for future research would be to distinguish between different time periods in the data set, to search for possible systematic changes in the way shipping markets behave. What would for instance the conclusions be if my study was done in the spring of 2005? What has been the impact of the dramatic development in the recent years, with the strongly increased volatility in freight rates? Those are examples of questions that I would like to address if I had more time for this thesis.

It will be very interesting to follow the future development of the dry bulk shipping market. In my opinion both econometric and theoretical analysis are very important in understanding the basic forces determining the development of freight rates and shipping volumes. Such an understanding is of course important for those who demand shipping services for the commodities they produce, and for the suppliers of shipping services. It is also important for shipbrokers, in linking the supply and demand for such services, and for shipowners in making investment decisions on their fleet.

Bibliography

- [1] Adland, R., Strandenes, S. P., 2004, "A discrete-time stochastic partial equilibrium model of the spot freight market", SNF Report No 04/04, Centre for International Economics and Shipping, Bergen, Norway
- [2] Alizadeh, A., Kavussanos, M.G. and Menachof, D.A., 2004, "Hedging against bunker price fluctuations using petroleum futures contracts: constant versus time-varying hedge ratios", *Applied Economics*, 36, 1337-1353
- [3] Beenstock, M., Vergottis, A., 1993, "Econometric Modelling of World Shipping", London, Chapman & Hall
- [4] Berg-Andreassen, J. A., 1996, "Some properties of international maritime statistics", *Maritime Policy and Management*, 23(4), 381-395
- [5] Dickey, D. A., Fuller, W. A., 1979, "Distributions of the estimators for autoregressive time series with a unit root", *Journal of the American Statistical Association*, 74, 427-431
- [6] Engle, R. F., Granger, C. W. J., 1987, "Co-integration and error correction: Representation, estimation and testing", *Econometrica*, 55, 251-276
- [7] Fuglseth, A. M., Strandenes, S. P., 1997, "Norship: A decision support system for analyses of bulk shipping markets", *Computers in Human Behavior*, Vol 13, No 4, 517-541
- [8] Glen, D. R., Rogers, P., 1997, "Does weight matter? A statistical analysis of the SSY capesize index, *Maritime policy and management*, 24, 351-364
- [9] Glen, D. R., 1990, "The emergence of differentiation in the oil tanker market, 1970-1978", *Maritime Policy and Management*, 17, 289-312
- [10] Glen, D. R., 2006, "The modelling of dry bulk and tanker markets: a survey", *Maritime Policy and Management*, 33: 5, 431-445

- [11] Hill, R. C., Griffith, W. E., Lim, G. C., 2008, "Principles of Econometrics", 3rd edition, Hoboken, N.J., John Wiley & Son
- [12] Kavussanos, M. G., 2002, "Business risk measurement and management in the cargo carrying sector of the shipping industry", *The Handbook of Maritime Economics and Business*, London, Lloyd's of London Press (LLP), 661-692
- [13] Koekebakker, S., Adland, R., Sødal, S., 2006, "Are spot freight rates stationary?", *Journal of Transport Economics and Policy*, Volume 40, Number 3, 449-472(24)
- [14] Koop, G., 2007, "Introduction to Econometrics", Chichester, John Wiley & Son
- [15] Koopmans, T., 1939, "Tanker Freight Rates and Tankship Building", Harlem, De Erven F. Bohn
- [16] Laulajainen, R., 2006, "The Geographical Foundations of Dry Bulk Shipping", Gothenburg School of Business, Economics and Law
- [17] Laulajainen, R., 2007, "Dry bulk shipping market inefficiency, the wide perspective", *Journal of Transport Geography*, 15, 217-224
- [18] MacKinnon, J. G., 1991, "Critical Values for Cointegration Tests", in *Long-Run Economic Relationships*, R.F. Engle and C.W.J. Granger (eds.), London, Oxford, 267-276.
- [19] MacKinnon, J. G., 2010, "Critical Values for Cointegration Tests", Queen's Economics Department Working Paper No. 1227
- [20] Merikas, A. G., Merika, A. A., Koutroubousis, G., 2008, "Modelling the investment decision of the entrepreneur in the tanker sector: choosing between a second-hand vessel and a newly built one", *Maritime Policy & Management*, 35:5, 433-447
- [21] Mork, K. A., 1994, "Business Cycles and the Oil Market", *The Energy Journal*, 15, 15-38

- [22] Mossin, J., 1968, "An optimal policy for lay-up decisions", *The Swedish Journal of Economics*, Vol. 70, No. 3, 170-177
- [23] Norman, V., 1979, "Economics of Bulk Shipping", Institute for Shipping Research, Norwegian School of Economics and Business Administration
- [24] Ng, S., Perron, P., 1995, "Unit Root Tests in ARMA Models with Data-Dependent Methods for the Selection of the Truncation Lag", *Journal of the American Statistical Association*, Vol. 90, 429, 268-281
- [25] Randers, J., 1984, "The Tanker Market", BI Working Paper 84/9
- [26] Randers, J. and Göluke, U., 2007, "Forecasting turning points in shipping freight rates: lessons from 30 years of practical effort", *System Dynamics Review*, Vol. 23 No. 2/3, 253-284
- [27] Shelley, T., 2003, "China's rapid expansion boosts world shipping industry", *Financial Times*, 25 November, 3
- [28] Stopford, M., 2009, "Maritime Economics", 3rd edition, London, Routledge
- [29] Strandenes, S. P., 1981, "Demand substitution between tankers of different size, *Norwegian Maritime Research*, 11, 27-36
- [30] Strandenes, S. P., 1986, "Norship: A Simulation Model of Markets in Bulk Shipping", Discussion paper 11, Norwegian School of Economics and Business Administration
- [31] Strandenes, S. P., Wergeland, T., 1980, "Estimering av elastisitetene i NORBULK", Arbeidsnotat nr. 4/1980, Senter for anvendt forskning, Norwegian School of Economics and Business Administration
- [32] Tinbergen, J., 1934, "Scheepsruimte en vrachten", *De Nederlandsche Conjunctuur*, March, 25-31
- [33] Tvedt, J., 2003, "A new perspective on price dynamics of the dry bulk market", *Maritime Policy and Management*, 30 (3), 221-230

- [34] Veenstra, A. W., Franses, P. H., 1997, “A co-integration approach to forecasting freight rates in the dry bulk shipping sector”, *Transportation Research*, 31(6), 447,458
- [35] Verbeek, M., 2008, “A guide to modern econometrics”, 3rd edition, Chichester, John Wiley & Sons Ltd
- [36] Wang, D-H., Chen, C-C., Lai, C-S., 2010, “The rationale behind and effects of Bunker Adjustment Factors”, *Journal of Transport Geography*, Forthcoming
- [37] Wijnolst, N., Wergeland, T., 1996, “Shipping”, Delft University Press
- [38] Wooldridge, J. M., 2008, “Introductory Econometrics, A Modern Approach”, 4th edition, Mason, Ohio, South-Western

Appendices

A Illustrations of the quarterly time series used in this thesis

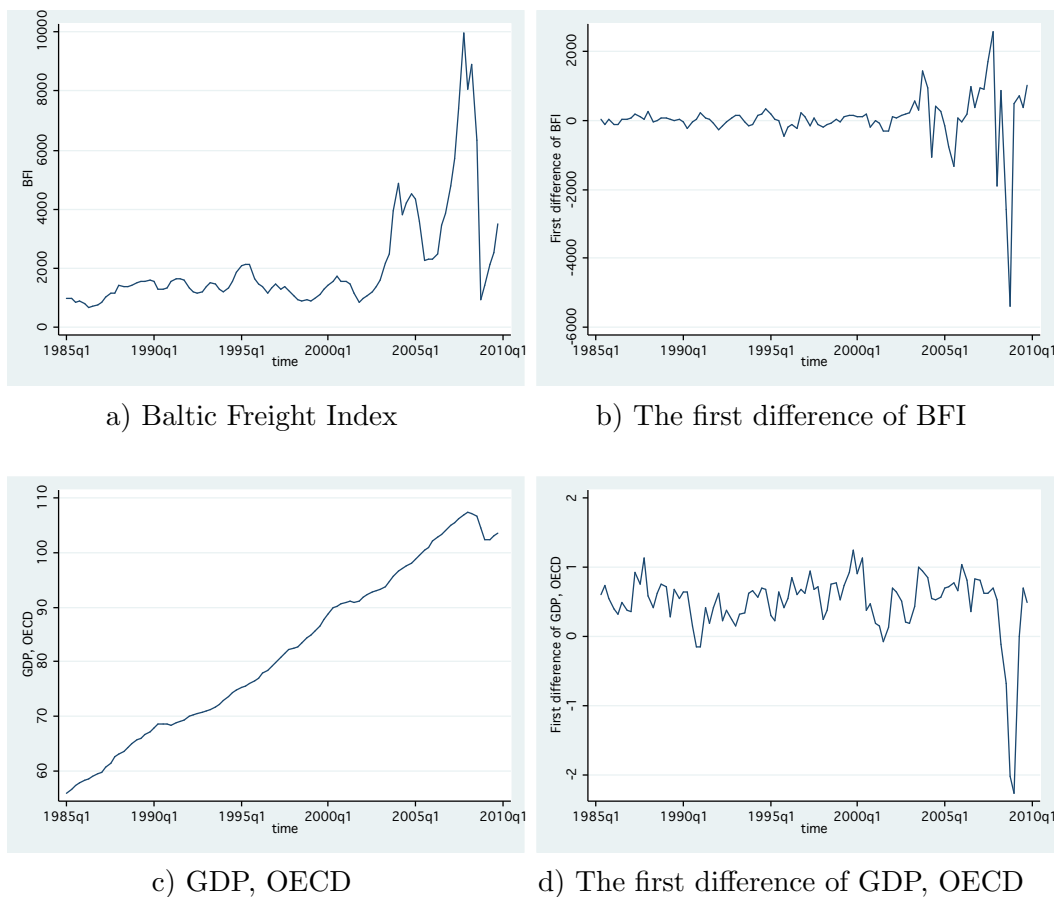
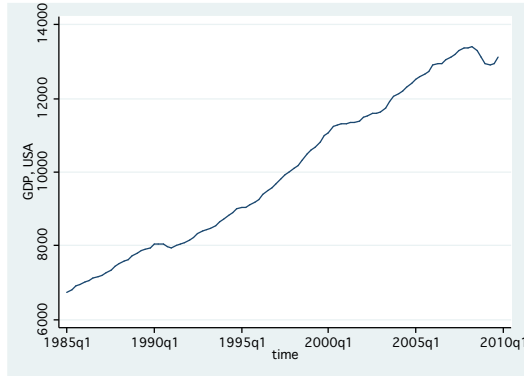


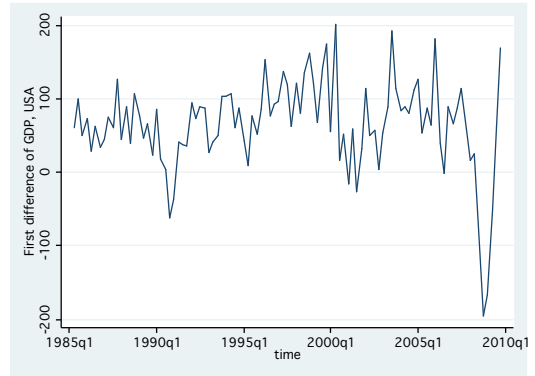
Figure 12: Time series of alternative business cycle measures and freight rates in dry bulk shipping. The figures are based on data from the Shipping Intelligence Network by Clarksons Research and Thomson Reuters Datas-tream

APPENDIX A. ILLUSTRATIONS OF THE QUARTERLY TIME SERIES USED IN THIS THESIS

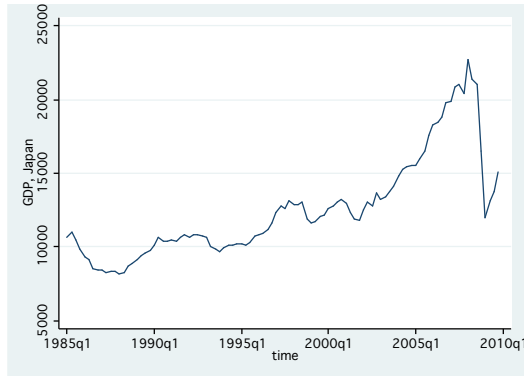
80



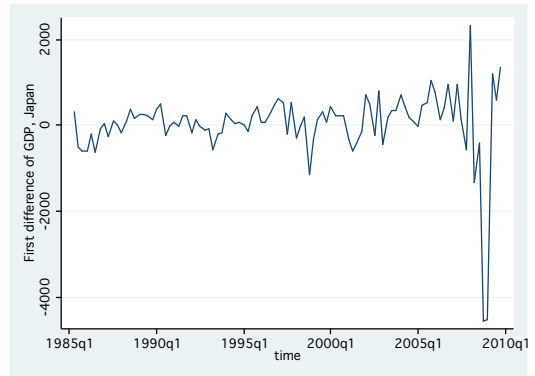
a) GDP, USA



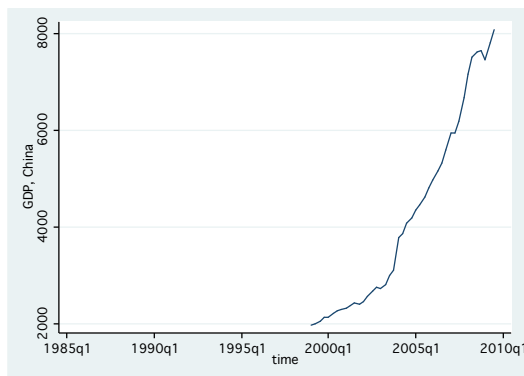
b) The first difference of GDP, USA



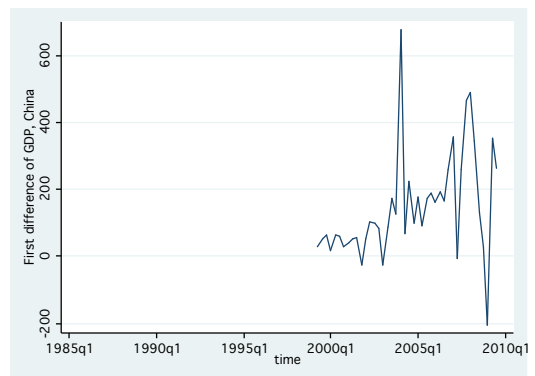
c) GDP, Japan



d) The first difference of GDP, Japan



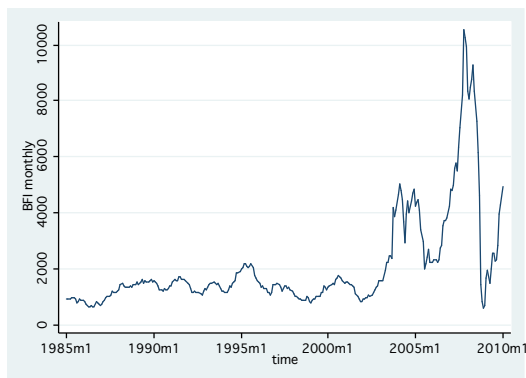
e) GDP, China



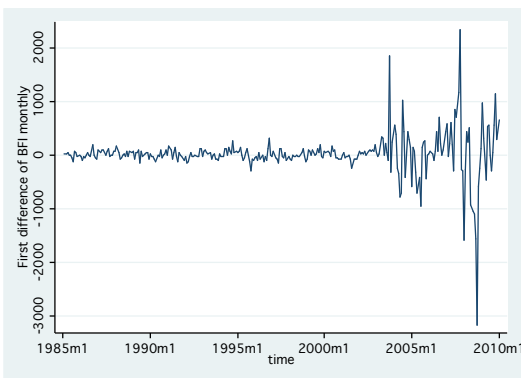
f) The first difference of GDP, China

Figure 13: Time series of alternative business cycle measures. The figures are based on data from Thomson Reuters Datastream

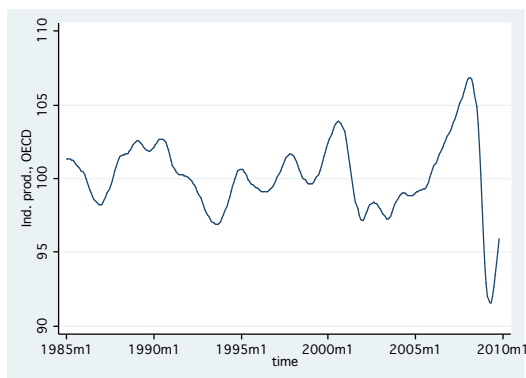
B Illustrations of the monthly time series used in this thesis



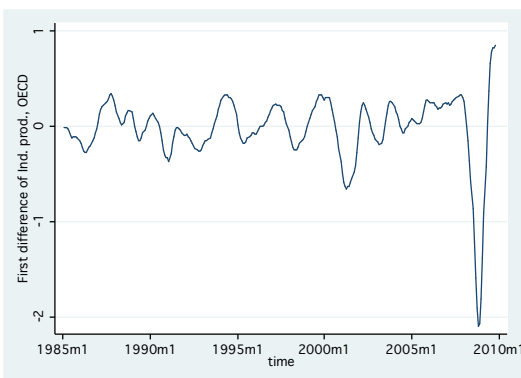
a) Baltic Freight Index



b) The first difference of BFI



c) Ind., prod., OECD



d) The first difference of Ind., prod.,
OECD

Figure 14: Time series of alternative business cycle measures and freight rates in dry bulk shipping. The figures are based on data from the Shipping Intelligence Network by Clarksons Research and Thomson Reuters Datas-tream

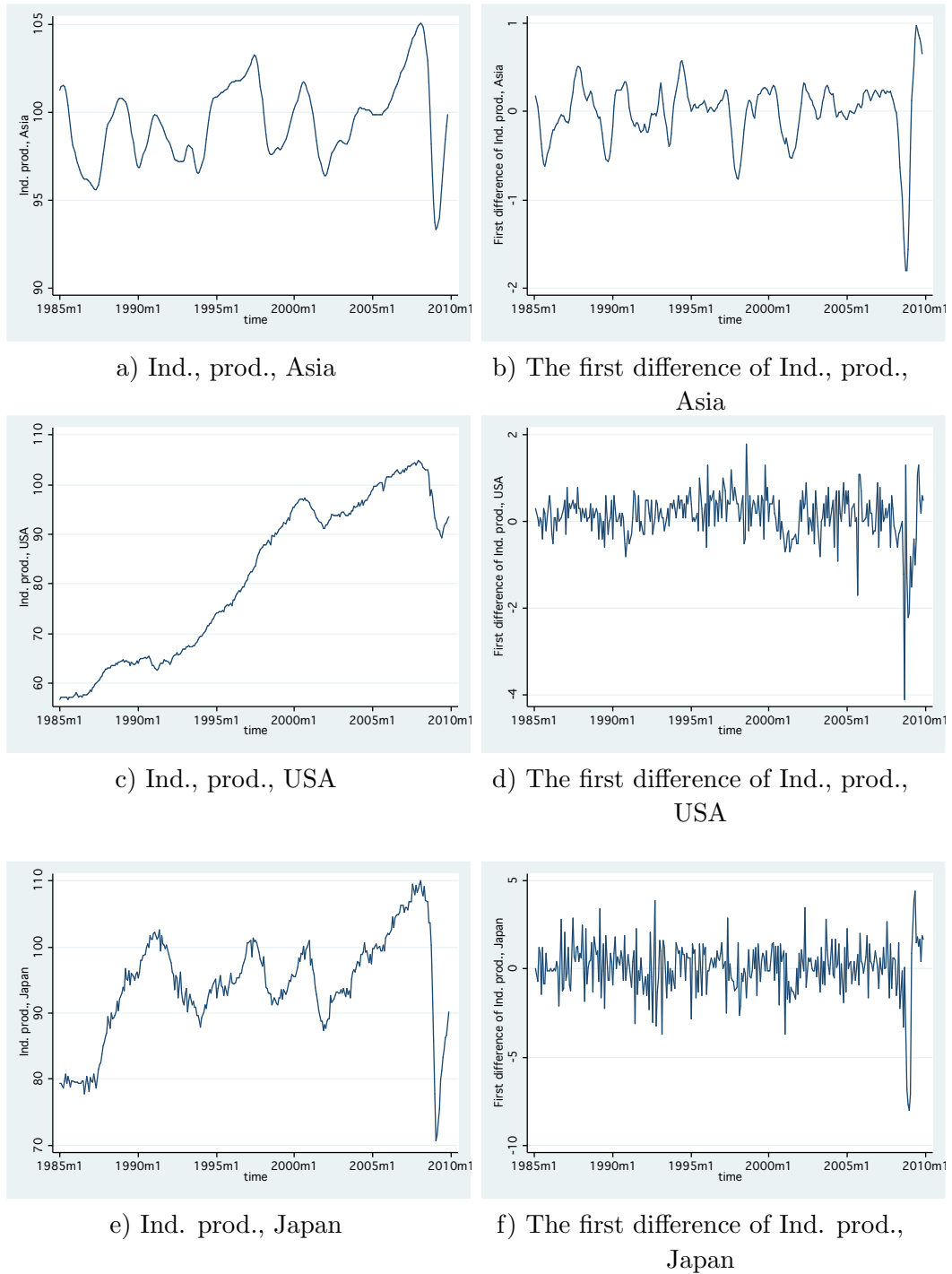
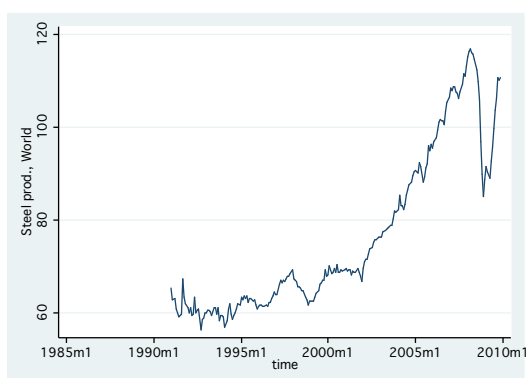
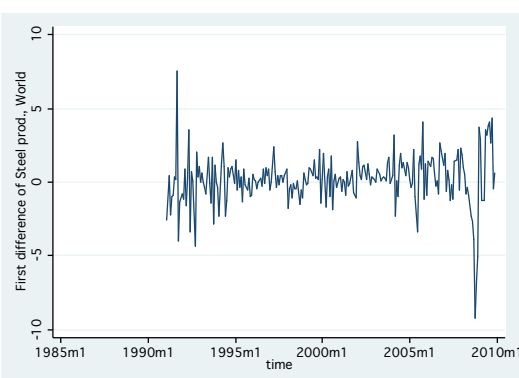
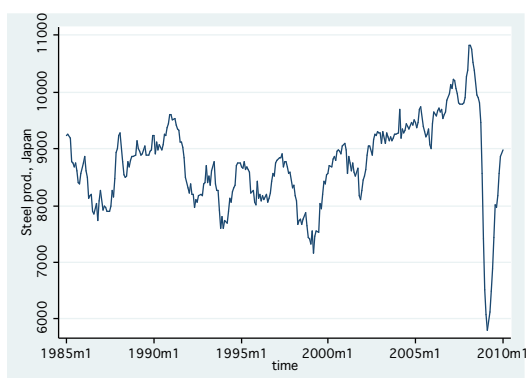


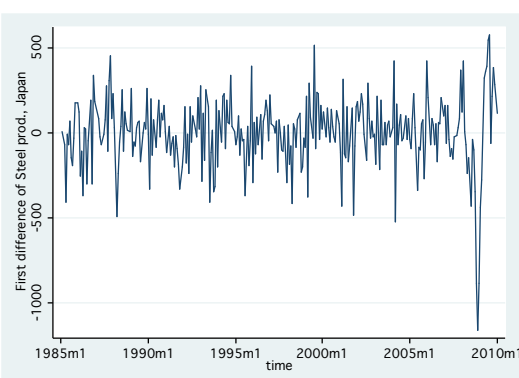
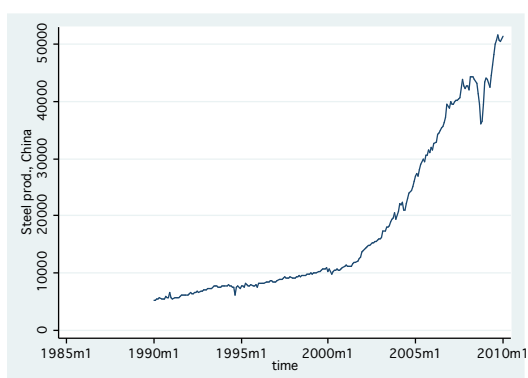
Figure 15: Time series of alternative business cycle measures. The figures are based on data from Thomson Reuters Datastream



a) Steel prod., World

b) The first difference of Steel prod.,
World

c) Steel prod., Japan

d) The first difference of Steel prod.,
Japan

e) Steel prod., China

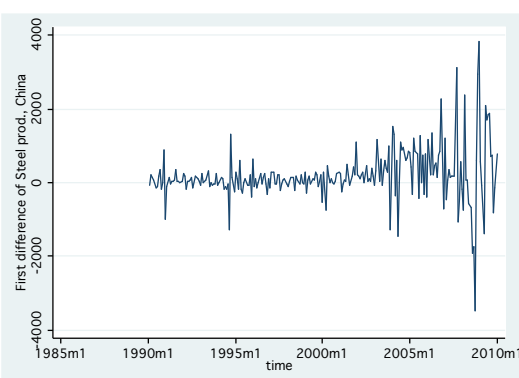
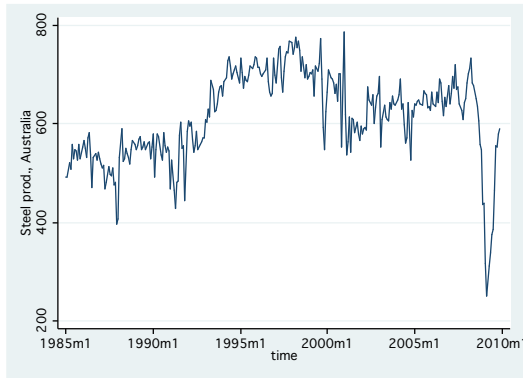
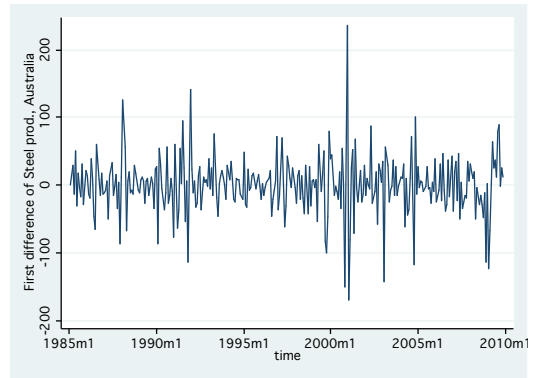
f) The first difference of Steel prod.,
China

Figure 16: Time series of alternative business cycle measures. The figures are based on data from Thomson Reuters Datastream

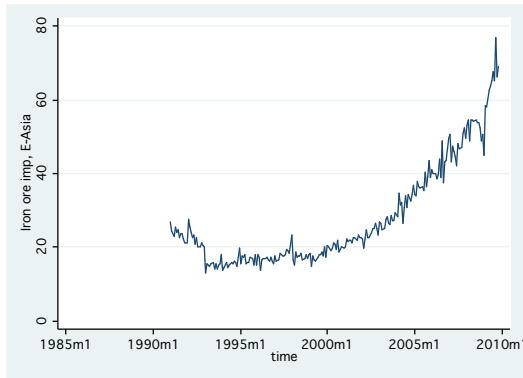
APPENDIX B. ILLUSTRATIONS OF THE MONTHLY TIME SERIES
 84 USED IN THIS THESIS



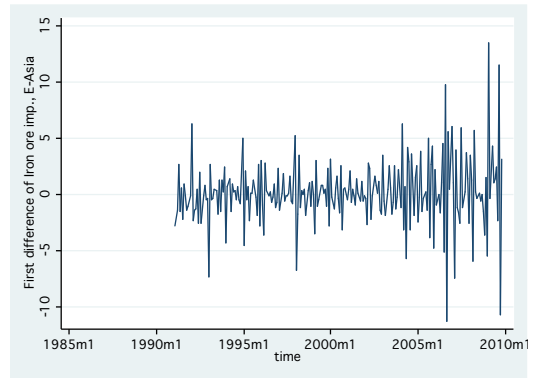
a) Steel prod., Australia



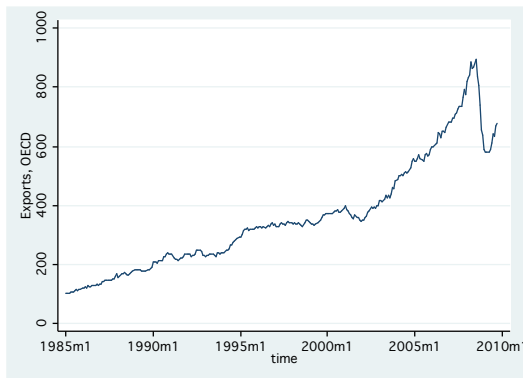
b) The first difference of Steel prod.,
 Australia



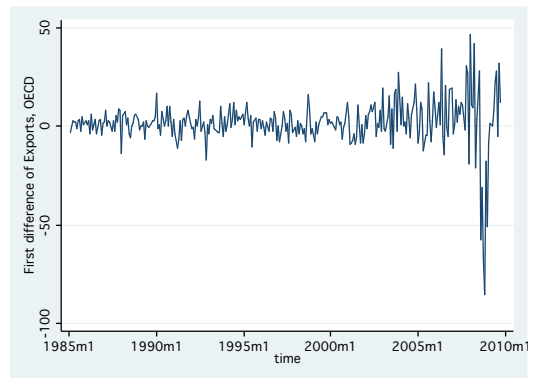
c) Iron ore imp., E-Asia



d) The first difference of Iron ore
 imp., E-Asia

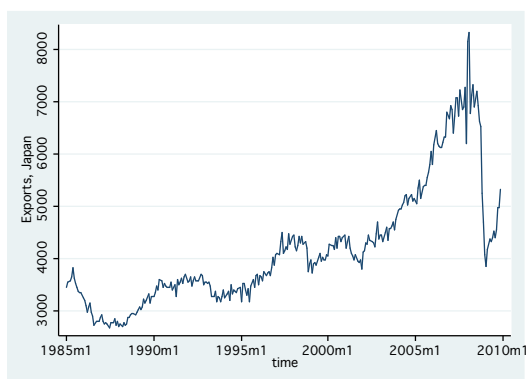


e) Exports, OECD

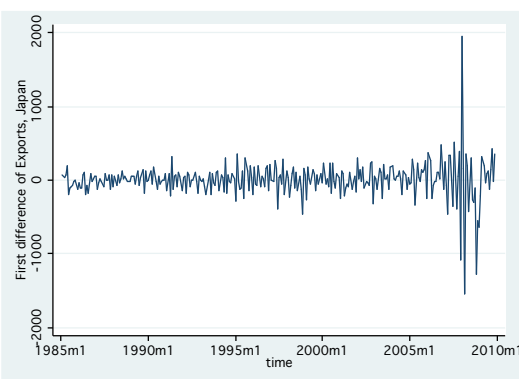


f) The first difference of Exports,
 OECD

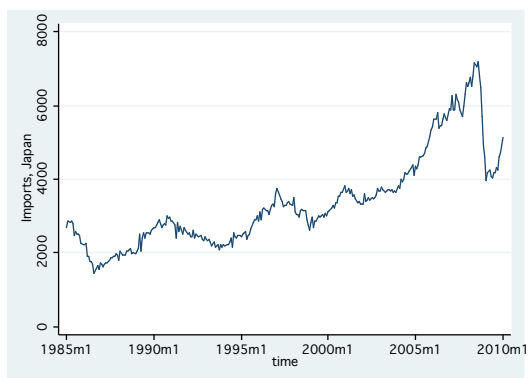
Figure 17: Time series of alternative business cycle measures. The figures are based on data from the Shipping Intelligence Network by Clarksons Research and Thomson Reuters Datastream



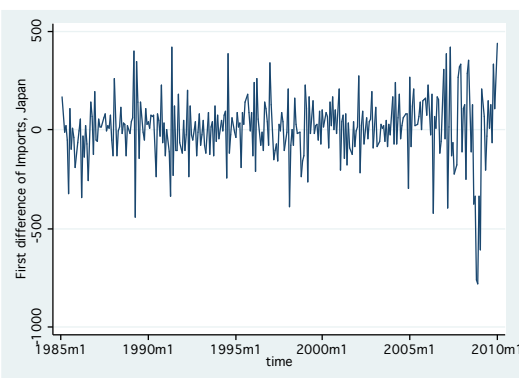
a) Exports, Japan



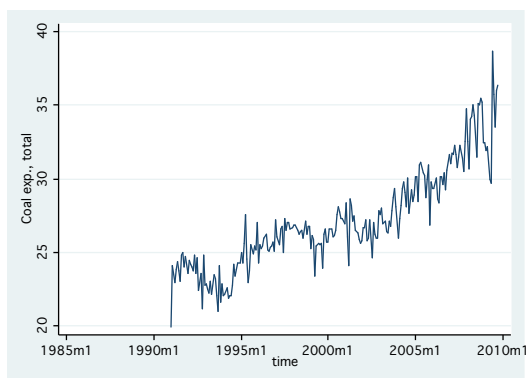
b) The first difference of Exports, Japan



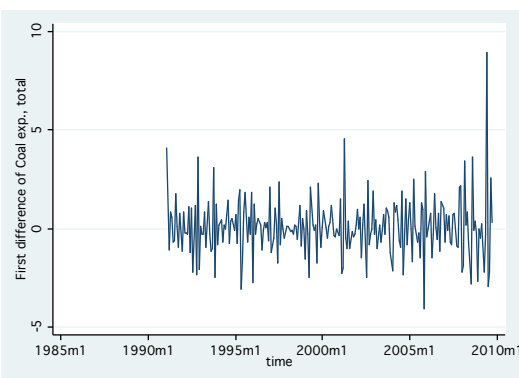
c) Imports, Japan



d) The first difference of Imports, Japan



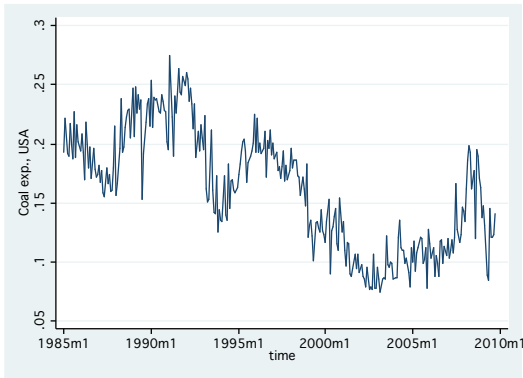
e) Coal exports, total



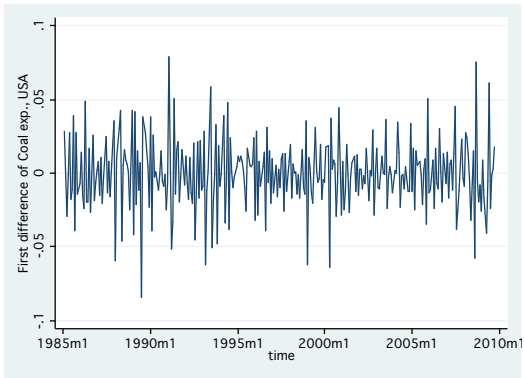
f) The first difference of Coal exports, total

Figure 18: Time series of alternative business cycle measures. The figures are based on data from Thomson Reuters Datastream

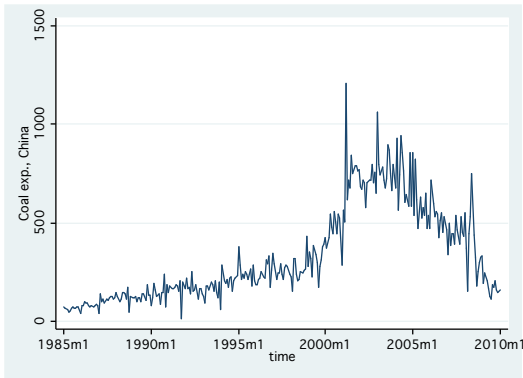
APPENDIX B. ILLUSTRATIONS OF THE MONTHLY TIME SERIES
 86 USED IN THIS THESIS



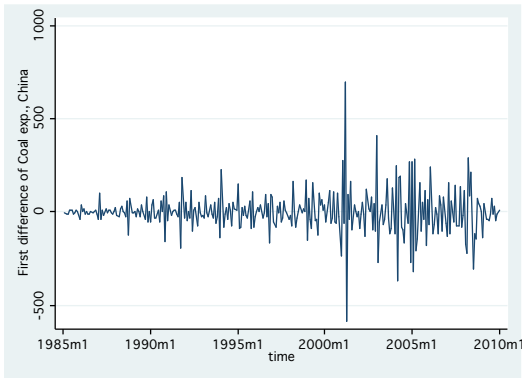
a) Coal exports, USA



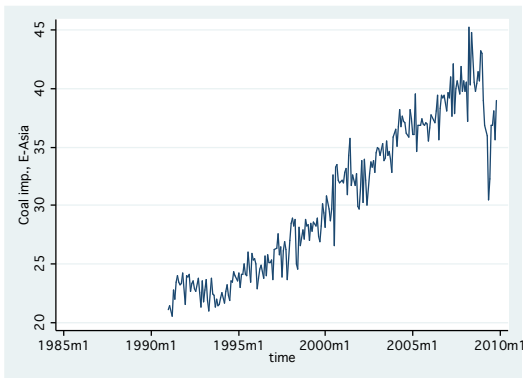
b) The first difference of Coal exports, USA



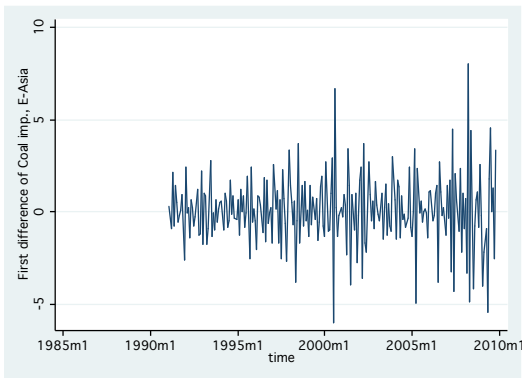
c) Coal exports, China



d) The first difference of Coal exports, China

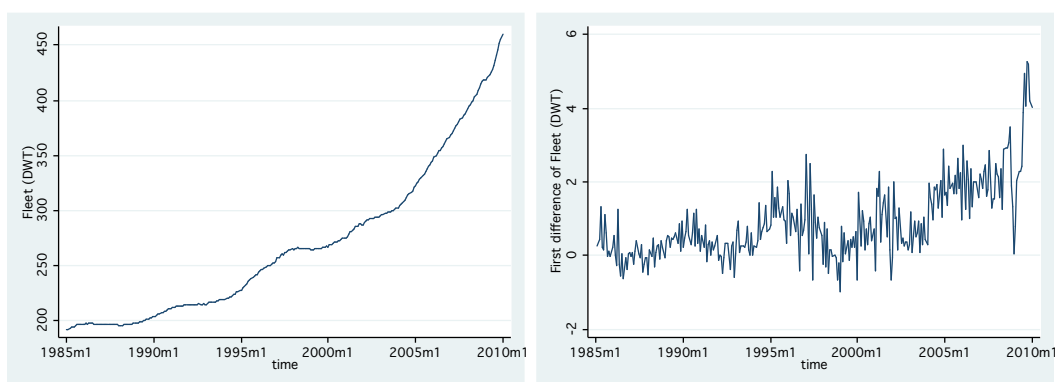


e) Coal imports, E-Asia



f) The first difference of Coal imports, E-Asia

Figure 19: Time series of alternative business cycle measures. The figures are based on data from the Shipping Intelligence Network by Clarksons Research and Thomson Reuters Datastream



a) Fleet (measured in DWT)

b) The first difference of Fleet (DWT)

Figure 20: An illustration of the fleet measured in deadweight tonnes (DWT). The figures are based on data from the Shipping Intelligence Network by Clarksons Research

C Stata commands

This appendix offers a presentation of the Stata commands that are most frequently used in this thesis. In order to make it more reader-friendly, commands that are not considered to be of particular importance have been omitted from the appendix. Let the BFI be defined as variable Y , while the various business cycle measures are represented by the variable X .

Declare data to be time-series data

```
generate time = m(1985m1) + _n - 1
format time %tm
tsset time
```

Transform the data into logarithmic form

```
gen lnY = log(Y)
gen lnX = log(X)
```

Calculate the first difference of the variables

```
gen dlnY = lnY - l.lnY
gen dlnX = lnX - l.lnX
```

Dickey Fuller-test for stationarity of the time series and their first differences (The Stata command depends on the model specification. Lags($\#$) tells Stata how many lags to include in order to adjust for autocorrelation.)

```
No drift or trend: dfuller variable, regress nocons lags( $\#$ )
Drift, but no trend: dfuller variable, regress lags( $\#$ )
```

Drift and trend: dfuller variable, regress lags(#) trend

Cointegration-test

```
reg lnY lnX  
predict r_lnYlnX, resid  
dfuller r_lnYlnX, noconst regress
```

Error Correction Model

```
reg dlnY l.r_lnYlnX dlnX
```