AN ECONOMETRIC MODEL OF THE ONE MILLION BARREL TANKER MARKET

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DEDICATION

I give Glory and Honour to Almighty God

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DECLARATION

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ABSTRACT

This thesis presents a disaggregated econometric model and set of forecasts of the supply of one million barrel tankers (100-160,000DWT). The model examined the factors of tanker demand and supply. It looked at the oil imports Western Europe and USA as sources of demand for tankers in this category. It examined tanker demand, freight rate index, time charter index, new order, newbuilding prices, deliveries and scrapping.

The reasons behind this research were enumerated. This is to forecast supply in order to avoid the problem that caused depression of tanker market in the past. The surplus tonnage that made the tanker freight rate collapse in the 70's. Further more, it examined and speculates on the effect of the USA Oil Pollution Act 1990. The background problem of the oil tanker market was examined; oil and tanker markets were analysed. The thesis looks at the effect of oil imports and exports on oil tankers. It examined the structure of tanker market and looked at the product and the market players. The routes and employment of these tankers were examined; these are crucial to tanker supply.

The thesis examined forecasting methods and techniques. It considered past attempts at modelling the shipping markets. It is argued that the structure of existing models of the shipping market is theoretically flawed and also that the existing model is aggregated. These models are freight rate models rather than tanker supply. The forecasting of one million barrel tankers has never been implemented before. Another argument is that any of these forecasting techniques can be used in forecasting oil tanker supply. In addition because the previous models did not test for unit roots in variables and the long run equilibrium of the series, the thesis has tested for these. The time series data are in most case non-stationary and should be made stationary before estimation.

The model of tanker supply was presented to show the behaviour of the market. The assumption is that oil import in Western Europe and USA will be crucial to one million barrel oil tankers. The relationship of factors that affects tanker supply was enumerated and analysed. The tanker supply is an identity equation where deliveries and scrapping play a crucial role. The deliveries will cause increase to supply while scrapping will cause it to reduce. The simultaneous equation model was identified using order and rank condition of identification.

The unit roots and cointegration of the series were computed and analysed. The series were made stationary and first differences of the series were used in the model. The series are also cointegrated, showing a long run relationship.

The econometric version of the theoretical model was estimated. The model is then used in simulating the dynamic response of tanker market to anticipated and unanticipated external shocks. The market plays a crucial role in the adjustment process.

The estimated model was used to forecast the supply of one million barrel tankers. Ten year forecasts of the dependent factors of the model were produced under a number of different assumptions.

The thesis examined and compared the results of the alternative forecasting models with the econometric one. The univariate autoregressive integrated moving average, random walk and exponential smoothing were esimated and analysed. The accuracy of the forecast was tested; using E, RSE, RPE and Theil, with emphasis on RSE.

KEY TO ABBREVIATIONS AND SYMBOLS

Abbreviations

ADF	Augumental Dickey-Fuller
AFRAMAX	A vessel which is capable of using African Ports having regard to it specification embracing draught, beam, shipboard, handling equipment and cargo transhipment facilities[1]
AG	Arabian Gulf
ARIMA	Autoregressive integrated moving average
BIMCO	Baltic and International Maritime Council
BL	Box-Ljung statistic
BP	British Petroleum
BVAR	Bivariate vector autoregression
CRDW	Cointegration Regression of Durbin Watson
COP	Crude oil prices
CUS	Oil consumption USA
CWE	Oil consumption Western Europe
DD	Tanker demand
DEL	Deliveries
DER	Dollar Exchange rate against SDR
DF	Dickey-Fuller
DW	Durbin Watson
E	Error
FR	Freight rates
ICWP	Industrial countries Wholesale price index
ILS	Instrumental Least Squares
LNG	Liquidified natural gas
LPG	Liquidified petroleum gas
LOOP	Louisiana offshore oil ports
LSE	Lloyds Shipping Economist
MARIMA	Multivariate autoregressive integrated moving average
MARPOL	Maritime Pollution (Convention 73/78)
MBT	One million barrel oil tanker
MDWT	Million deadweight tonnes
MFIT	Microfit - Econometric package
NBP	New building price
NOR	New order
OECD	Organisation for Economic Co-operation and Development
OPA	USA Oil Pollution Act
OST	Oil seaborne trade
PE	Percentage error
PMT	Metal price index
RATS	Regression Analysis of Time Series- An econometric package
RPE	Root percentage error
RSE	Root square error

[1] Branch, E. Alan, Dictionary of Shipping International Business, Trade terms and Abbreviations. Fourth Edition, Witherby & Co. Ltd. 1995.

SBC	Shipbuilding cost
SBM	Single Buoy mooring
SC	Tanker scrapping
SE	Square error
SP	Scrap prices
SPSS	Statistical package of the Social Sciences
SS	Tanker supply
TCI	Time charter index
UARIMA	Univariate autoregressive integrated moving average
ULCC	Ultra large crude carrier
URVAR	Univariate vector autoregresion
USES	United State Eastern Seaboard
USI	Oil imports USA
VLCC	Very large crude carrier
WEOI	Oil imports Western Europe

Symbols

α	alpha
β	beta
δ	delta
ε	epsilon
ϕ	phi
γ	gamma
η	eta
φ	psi
λ	lambda
μ	mu
θ	theta
σ	sigma
ρ	rho
τ	tau
ψ	psi*
ζ	zeta
ω	omega
χ	chi
Θ	theta
Σ	sum
Ω	omega
Δ	First difference
Δ^2	Second difference
ln	Natural logrithm

Chapter 1

INTRODUCTION

This thesis is an empirical analysis of oil tankers of 100-160,000 dwt. The intention is to build a disaggregated econometric model of oil tankers in order to forecast demand and supply. To clarify, the thesis analyses the nature of the oil tanker market and uses variables that are most likely to affect demand and supply.

Shipping oil plays an important role in the world economy. Oil is a key input in manufacturing - an essential part of energy that helps drives the manufacturing process. This role is reflected in the importance of crude oil and oil products in international seaborne trade. Global energy demand is dictated by economic activities and it is important to remember that oil is not just for energy industries, but is a feed stock for chemical and plastic industries. When there is growth in the world economy, oil demand would rise; in time of recession oil demand falls. During the times of slump and boom, the market becomes very difficult to plan effectively. It is therefore important to find ways by which better planning and decision making can be achieved.

Over the years many tanker owners have chosen and operated million barrel tankers. One of the reasons for the development of these tankers was for the traders and oil companies who deal in cargoes of multiples of half million barrels. Other reasons are the depth of water; most of the oil ports can accommodate one million barrel oil tankers. In the North Sea these tankers are being used because of the loading time, it is more cost effective because the large vessels take longer time to load and discharge their load. Furthermore, in USA large ships are not allowed in the majority of the shallow waters, as they are more concerned about pollution. The million barrel tankers are constantly used by owners trading to the USA.

The events of the 1970s raised many questions. Such questions as whether there was anything that could have been done to avoid the tanker surplus (the difference between supply and demand) that caused the depression in the shipping market. Furthermore, would more accurate forecasts of tanker supply and demand have helped? In the author's opinion, accurate forecasts of tanker supply would have reduced the effect or caused actions that could have avoided the depression. The forecasts in the 70s were wrong because of the failure to anticipate the emergence of national energy saving policies.

The oil tanker market is volatile. In order to handle difficult situations and alleviate some of the difficulties faced in the volatile market, it is desirable to forecast oil demand and oil tanker supply. This will allow the essential factors affecting the efficiency of the market to be examined when the forecast is in place.

One of the objectives of this thesis is to understand the factors determining the demand and supply for these tankers; especially in the major nations (the major nations are assumed to represent the total market). In particular it is interesting to know how sensitive is demand to supply and the effect of tanker deliveries and scrapping on supply. There are other factors that affect demand and supply; details will be given in chapter 4. This information is an important input in the decisions of shipowners and operators in general.

Tanker supply capacity at any time is subject to demand and the price, which can be referred to as "freight rates". Oil imports, oil consumption and freight rates will affect the capacity supplied. The number of tankers supplied to the market will affect the freight rate. However, when tanker supply-demand balances the freight rate would increase by a small margin. Zannetos described the dynamic relationship of demand and supply and the effect of freight rates on supply and vice versa, using the classical cobweb theory.[1] He emphasised that the dynamic relationship of tanker demand and supply and the volatility of tanker markets are more complicated than those described by the cobweb theory. The oil tankers' supply responds to freight rates and only growth in demand for tankers can have as much effect on supply as freight rates.

Ships can stop moving oil cargos either through lay-up or scrapping. On the other hand additional ships can enter the market through the reactivation of laid-up tonnage or the delivery of new tankers. In addition vessel speed may alter to bring short run success. The speed of a tanker may be reduced during depression, increased during the boom time.

In this thesis, the demand for these tankers will be exercised by modelling the process of oil importation into the USA and Western Europe. The assumption is that oil tanker demand will be determined by the rate of changes of oil consumption in USA and Western Europe. In addition, the rate of oil production in these nations and the rate of changes in nominal crude oil prices will affect oil imports. The supply of tankers is determined by the identity that links deliveries, scrapping and the present stock of vessels. The delivery of tankers' increases the tonnage whist scrapping reduces it.

The percentages of million barrel tankers that are being employed on these major routes are envisaged to increase in the future. However, if these shares fall in the future the demand will fall and the tanker surplus will increase. This could result in a bigger surplus tonnage as a consequence of the shortfall in demand for oil and oil tankers in these vessels.

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[1] Zannetos, Z., *The Theory of Oil Tankership Rates- An Economic Analysis of Tankership Operations*, MIT 1966, 189-201.

The model is derived by identifying and specifying the dependent factors. Also for each of these factors there are independent factors that explain the dependent. The possibility that lagged factors influence both present and future behaviour is allowed in the model. In view of this the number of estimated coefficients increases with the number of dependent variables. This meant that the model dealt apparently with fairly large system, using a relatively short set of data, 1970-1993. The model was estimated and simulated and the responses to the market were analysed. The forecasts of the dependent factors were calculated from the estimated model.

The most important issue in tanker shipping is not only to predict the market but to foresee what is coming in the future and act on these sooner than anyone else.
Chapter 2 examines the background of the problems of the market. It discusses both oil and tanker markets. It also highlights the effect of the past events on the tanker market, and draws on an extended database in order to look at the oil and tanker market.

Chapter 3 reviews the relevant forecasting methods and models. It examines previous attempts at modelling the behaviour of the shipping market. Most of these models are aggregated and did not test for unit roots and long run relationships (cointegration) of the series. The thesis agues that these past studies are flawed in the light of new knowledge about the modelling process.

Chapter 4 develops a disaggregated model that aims to address the deficiency of the existing models. In this chapter lagged variables were considered with the assumption that past affects the future. The relationship of factors affecting the demand and supply is examined within the model.

In chapter 5 tests are carried out for unit roots and cointegration of the variables in the model. The levels of most variable were found to be nonstationary; but first difference are however stationary. The series are examined for cointegration and found to have a long run relationship.

In chapter 6 the theory is used to specify and estimate a simultaneous-equation econometric model of one million barrel oil tankers. This model is also used in order to carry out simulations of the effect of various shocks.

Chapter 7 illustrates how the model can be used for forecasting and scenario planning and presents forecasts of the million barrel oil tanker market up to the year 2005. It examines the ex-post and ex-ante forecasts of these tankers. The implications of the base run scenario are analysed.

In chapter 8 the analysis of the results of alternative forecasting methods are presented. These are compared with econometric model forecasts results and the accuracy of each of the forecasting results are calculated and analysed, using error statistics.

Chapter 2

THE BACKGROUND OF THE MODELLING PROCESS: ANALYSIS OF THE OIL TRADE AND THE ASSOCIATED TANKER MARKETS

2.1 Introduction

In this thesis, the one million barrel tanker is defined to be 100,000-160,000 deadweight in size range. The discussion of other tankers can be found in section 2.3.1.1. This category of tanker is very useful for many reasons. There are some oil traders who because of the size of their oil tonnage prefer medium tanker to the VLCC (very large crude carrier). Port restrictions are another reason; one million barrel tankers can use most ports; they can pass through the Suez Canal without having to go through a lightening operation. The United States of America is a good example where large tankers are restricted because of the depth of water, predominantly in the Eastern Seaboard.

The importance of the sources of employment for oil tankers cannot be ignored; hence there is a need to analyse both the oil market and the tanker market. There is also a need to know the level of reserves, especially in the countries that constitutes the market for million barrel tankers. Despite the fact that further reserves are being discovered there is still enough justification for the update and the analysis. Whatever happens, availability of oil coupled with low oil prices is likely to benefit oil tankers. The reason is that consumption rates can be very high when the economy is growing rapidly, and oil prices are low.

It was reported that a large quantity of oil was discovered in Siberia, this was described as another Saudi Arabia[2]. The assumption is that in the long run the discovery would increase world oil reserves and it could affect oil tankers in the future. For many years the Middle East has contained the world's largest proven oil reserves (further discussion of this can be found in section 2.2.2). The influence of

[2] Vladimir Kvint, "Eastern Siberia could become another Saudi Arabia", ***Forbes***, (September 17, 1990): 130-132.

Middle East crude oil on both the oil and tanker market has been proved several times. It was confirmed in 1990 that there are even bigger oil reserves in Siberia. Kvint said in his report that Russia may be exporting more oil than Saudi Arabia within 10 years[3]. However, since that report little has been heard about the discoveries.

There have been developments in oil tanker shipping both in the total dead-weight tonnage available and total tonne-miles of service provided. Although the oil companies are the main users of tanker services, they only own one third of one million barrel tankers. These companies prefer to balance their needs by chartering from the independent owners. The independent owners own the majority of the remaining capacity. The pattern of ownership is affected by the requirement of the oil companies. This will be further discussed in section 2.3.1.2.

Chartering takes place between tanker owners and the charterers. It is through chartering that tanker owners generate revenue to justify the operation of their vessels. There are various methods by which a vessel can be chartered such as the voyage charter, time charter and contracts of affreightment. Each of these methods has got their advantages and disadvantages that go to the root of the oil tanker shipping. The different types of charter will be explained further in the sections below. Tanker chartering will be further discussed in section 2.3.1.2.

It is important to know the impact that legislation will have on the future of tankers. Drewry Shipping Consultants[4] made a report on OPA 90 and MARPOL double hulls issue. Further discussion will be given in section 2.5. However, the importance of this sort of legislation should not be overshadowed by its implications to tankers.

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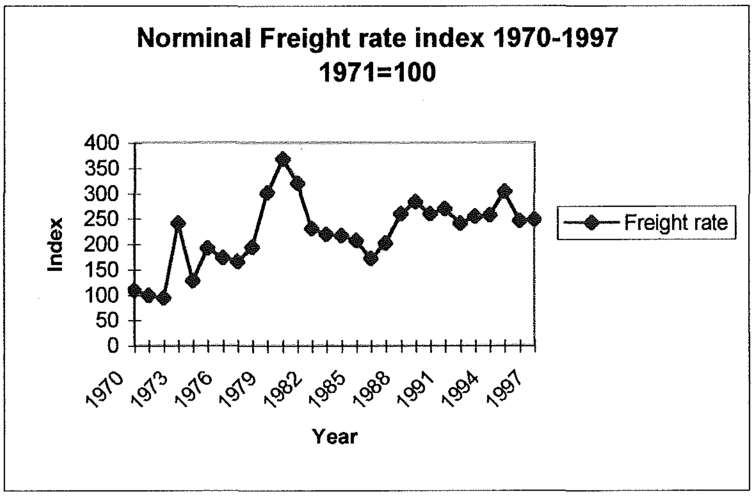
[3] Ibid., Vladimir Kvint, p. 8.

[4] Drewry shipping Consultants, ***Oil Tankers Regulations***, Special Report, published by Drewry Shipping Consultants Ltd., 1991.

2.2 The Need for Research

The oil tanker market is volatile. In order to reduce losses there is a need for a good forecast. The one million barrel tankers have not been examined before in academic literature. Further more, it is very important to examine this disaggregated market in order to determine the long-term future of these tankers.

Figure 2.1 Freight rate Index



Source: ISL, Institute of Shipping Economics and Logistics, YearBook

The story of the tanker industry since the Second World War has been one of boom and slump. Figure 2.1 shows the freight rate index as an indication of the situation in the oil tanker market. World shipping was in depression for a long period in the last decade or so (the 80's). Furthermore, different sectors of the market are at different stages in the shipping cycle and all have had some improvement in the last few years, for very brief periods.

The one million barrel tanker sizes have almost become dominant most especially in the West Africa - USA and Western Europe; the two major loading areas that will be examined. This is as a result of the quantity of oil transported by oil traders and oil companies and the depth restriction in some ports. The employment of one million barrel tankers will depend solely on demand for oil.

2.2.1 The World Economy

Fluctuations in world economic activity when measured by industrial production show a strong correlation with oil tonne mile demand. World economic activity therefore generates most of the demand for sea transport. This is confirmation of a potential relationship between industrial production and transportation demand. [5]The growth in the economy influences the growth of sea trade most especially crude oil. Oil seaborne trade closely follows the growth of the world economy. Figure 2.2 presents the trend growth in both oil consumption and industrial production in the USA. The figure shows that both series are highly correlated over the period 1970-1994.

Whilst there is continued growth in the economy, it can be argued that demand for oil will continue to grow. Oil will continue to be required for heating and transport. In reality, weak prices could even encourage seaborne oil trade, because there will be more long-haul crude demand. This would be emphasised if oil prices were low, making it difficult for local and short-haul crude production sources to remain competitive.

There are other possibilities that are assumed to have an effect on the demand for oil and oil tankers. As the US economy becomes more serviced based, the assumption is made that shifts to services will not significantly affect oil and oil tankers demand.

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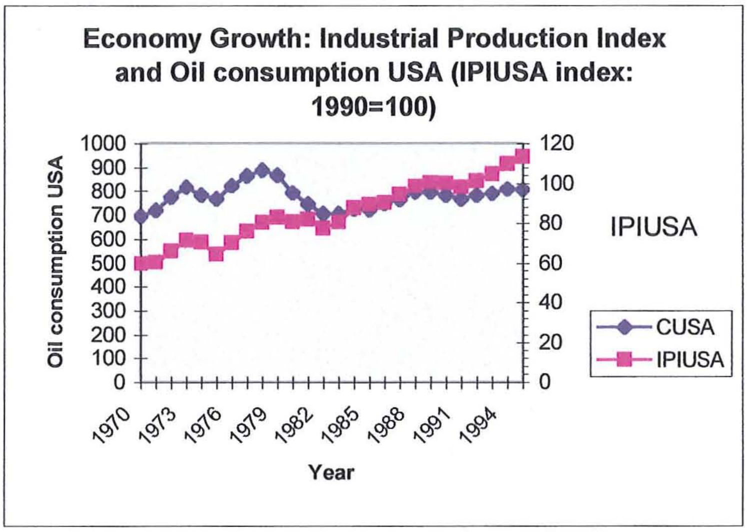
[5] Wergeland, Tor; " Tanker Market responses to changing oil prices." ***Norweigian Shipping News*** 7 (1983): 47-52.

National demand for oil is assumed to increase despite the discoveries of alternative energy sources. (See table 2.1.)

FIGURE 2.2 Oil consumption and Industrial production index

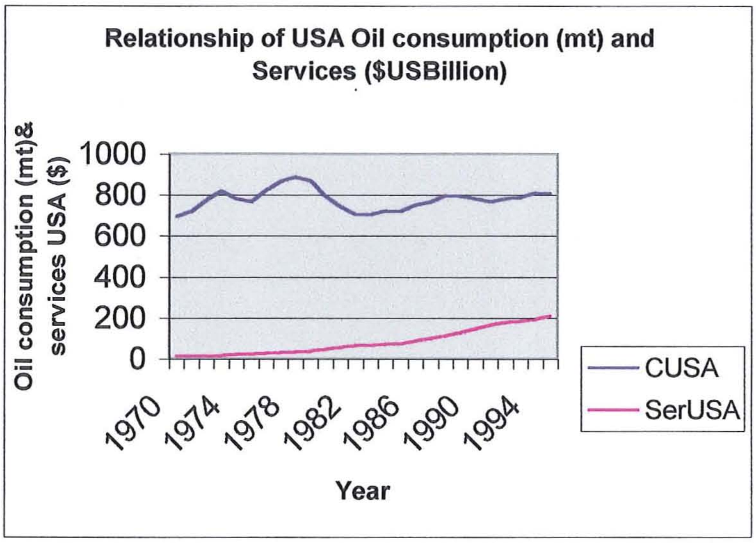


Sources: International Financial Statistics (IPIUSA) and BP statistics (OCUSA)

Further more, it is desirable to examine whether the shift to service-based economy will weaken the link between oil consumption and economic growth. The changes theoretically seem to have a considerable impact, but not necessarily so in practice. After the examination of the relationship between oil consumption and services it is clear that growth in services does not affect the oil consumption. (See figure 2.2 and 2.3.)

There are also issues of growing fuel efficiency and conservation. These have not drastically affected oil consumption. Whether the situation will change in the future, will depend on serious implementation of policies relating to these issues. It was reported in the Guardian newspaper[6] in 1997. The article said that due to the number of big vehicles and the interest of the people, that oil consumption has increased.

Figure 2.3 the Relationship of USA Oil Consumption and Services



Sources: International Financial Statistics and BP Statistics

There have been meetings about the environment, however the effects of these have not significantly affected oil consumption. There have been agreements on policies concerning the environment but these are yet to materialise. In United Kingdom there have been debates concerning the environment.[7] In addition the author of the book[8]claimed that the promotion of energy efficiency has never played a central role in U.K energy policy. The same argument applies to the OECD and industrialised world generally.[9] "The technology already exists to make Western economies far more efficient in their energy use, but unfortunately the ways in which economies are organised at present operates to discourage the use of this technology."[10]

[6] The Guardian, "Inside America- Petrol -guzzlers set new record", ***The Guardian***, (Tuesday, 12 August 1997): 11.
[7] Anderson Victor, ***Energy Efficiency Policies***, published by Routeledge (1993): 36-53.
[8] Ibid.,
[9] Ibid.,
[10] Ibid.

Energy efficiency and conservation have not changed the energy trend. The industrialised countries such as the U.K and Japan have tried, but the result was not encouraging. The UK government declared 1986 as an energy efficiency year and Japan has an energy conservation month once a year, which involved large-scale publicity. This has not significantly altered the trends of oil consumption and other energy factors.[11] The improvements in energy efficiency have failed to keep pace with economic growth, and it is a threat to the benefits of efficiency policies.[12] The evidence is that there have been talks and discussions on the issues but these have not been implemented.

2.2.2 World Oil Supply, Demand and Consumption

In order to understand this market it is important to look at the major product which is crude oil. The demand for oil is directly related to the level of economic activity within a country. This tends to be rather cyclical in nature and oil growth rates often fluctuate widely from year to year. In 1970, 1980 and 1990 the oil consumption was 767.6mt, 881.7mt and 853.7mt respectively. See figure 2.2; the trend in oil consumption has never been seriously affected by past efficiency policies. The assumption is that the trends in oil consumption will remain to grow in the future.

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[11] Ibid.
[12] Ibid.

The Oil Reserves

World oil reserves according to BP Statistics, increased from 1970 to 1994 by 38 percent.[13] This is an average growth rate of 2.2 percent per year. The last five years have witnessed increases in world oil reserves, the average increase since 1990 being 1.01 billion barrels.

Many nations changed from using coal to oil. This was mainly due to improvements in the technology. The change is evident since the discovery of crude oil. Before this time coal[14] was the main energy provider, now crude oil has taken an important place in the world. See appendix B1. Coal consumption (fuel) is low in the major industrialised countries compared with oil, most especially in the last 5 years; these are commercial fuels only.[15] The total estimated average growth in coal was -0.9 per cent, while total growth in oil consumption was 1.4 per cent in real terms. The other consumers, in particular USA and Western Europe recorded a decrease in the last five years (See figure 2.4).

The Middle East, the main producer of crude oil at the end of 1995, has proven oil reserves of 89.3 million tonnes. World proven reserves were 138.3 thousand million tonnes at the end of 1995 (See figure 2.4 and appendix B2). The Middle East region controls more than half of the world's total oil and the region still command a huge amount of world oil proven reserves.

[13] BP Statistics, *Statistical Review of World Energy*, 1996.
[14] Ibid.,

[15] Note: The coal mentioned here is hard coal. (Commercial solid fuels only.) Most of the substantial growth in seaborne coal volume after 1975 was in fact by steam coal.

Table 2.1: World Energy Consumption 1996 – Fuel Million tonnes oil equivalent

Year	Oil (mt)	Natural Gas (mt)	Coal (mt)	Nuclear (mt)	Hydro-electricity (mt)
1970	2281.1	954.6	1622.6	19.8	306.1
1971	2412.2	1022.1	1617.2	28.0	318.2
1972	2591.8	1039.9	1595.4	38.4	326.6
1973	2797.5	1066.1	1668.4	49.4	331.5
1974	2759.3	1088.1	1991.2	62.6	348.6
1975	2724.0	1079.4	1709.1	87.1	358.2
1976	2894.0	1139.8	1786.7	106.4	362.7
1977	2985.8	1161.9	1830.1	132.0	376.4
1978	3082.7	1206.2	1863.3	149.5	403.1
1979	3123.9	1273.4	1975.8	153.0	413.4
1980	2998.4	1296.8	2006.5	190.4	421.6
1981	2899.5	1320.7	2003.0	198.1	430.1
1982	2823.7	1316.9	2047.2	217.5	451.1
1983	2803.7	1328.9	2097.1	263.3	469.2
1984	2831.4	1444.1	2175.4	291.6	493.1
1985	2802.5	1490.5	2099.9	382.2	174.2
1986	2892.5	1502.4	2133.8	411.9	176.5
1987	2948.2	1580.9	2198.4	447.9	179.9
1988	3038.1	1660.0	2244.7	488.3	183.6
1989	3087.0	1734.5	2268.8	502.3	183.7
1990	3137.3	1767.3	2244.3	516.7	189.0
1991	3133.1	1798.7	2193.5	541.3	194.8
1992	3159.2	1801.8	2174.4	545.8	194.6
1993	3131.5	1830.0	2165.7	564.5	205.2
1994	3189.1	1837.6	2184.9	573.5	205.9
1995	3226.9	1883.6	2210.7	596.4	218.5

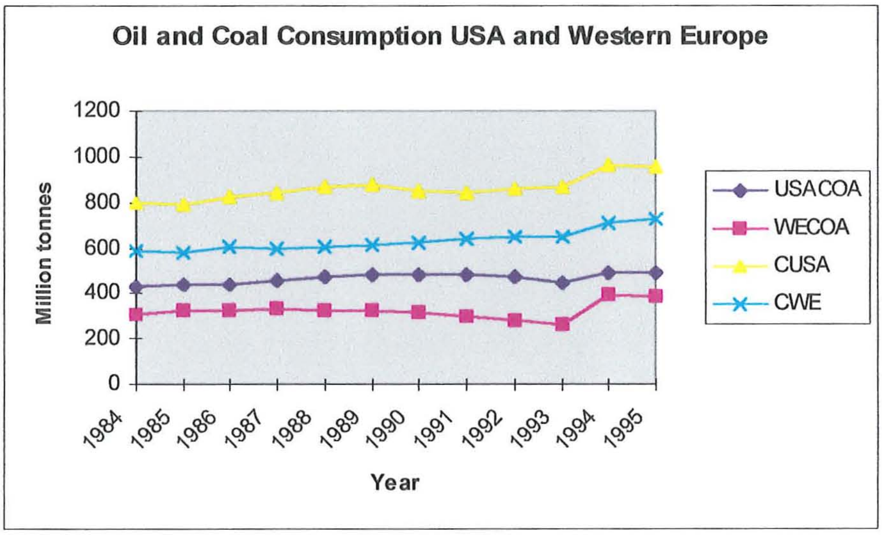
Source: BP Statistical Review of World Energy, various issues[16]
(Figures are for commercial fuels only)

If the proven oil reserves remaining at the end of any year are divided by the production in the year, the result is the length of time that those remaining reserves would last if production were to continue at the then current level.

[16]BP Statistics, Op cit., p. 15.

Proved reserves of crude oil are generally taken to be those quantities which geological and engineering information indicate with reasonable certainty and these can be recovered in the future from known reserviors under existing economic and operating condition. Furthermore, the proven oil reserves to oil producton (R/P) ratio is based on the previous year figure.

Figure 2.4 Trends of Oil and Coal Consumption[17]



USACOA is coal consumption USA, WECOA is Western Europe coal consumption, CUSA is oil consumption USA and CWE is oil consumption Western Europe

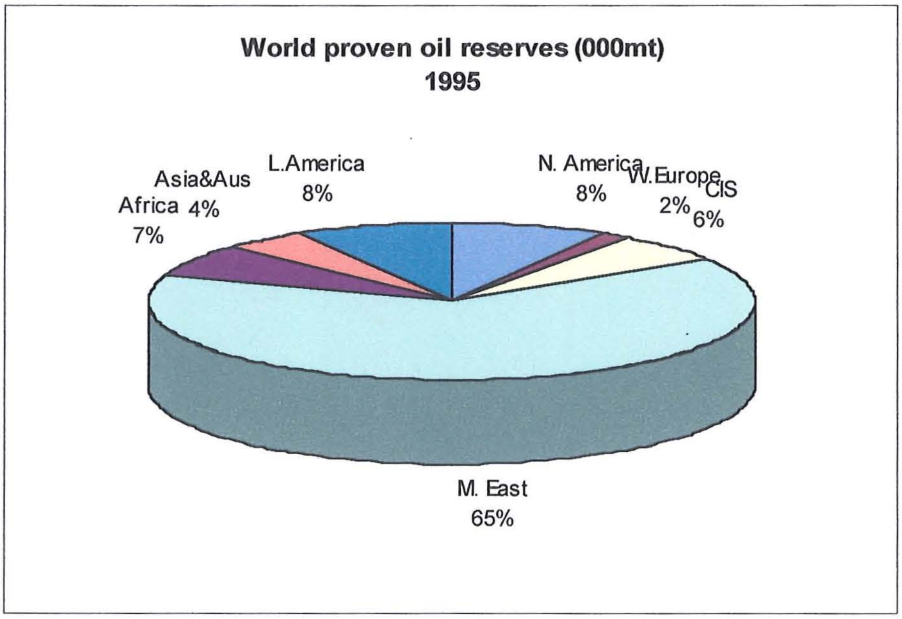
Source: BP Statistics: Statistical Review of World Energy 1996

The level of proven reserves will always be important to oil tankers. The proven oil reserves of 1996 shows a long term reserves to production ratio of over 42 years, with all things being equal this is likely to ensure continuing increase employment for oil tankers. See appendix B2, figure 2.5 and appendix C3 (ratio of oil production to reserves.)

[17] Ibid.,

The ratio of reserves to production for the middle East in 1995 was 92.3 years, this indicates that with the present rate of production the oil will last for more than 90 years. West Africa as the major loading area for a million barrel tankers, particularly Nigeria has a production to reserve ratio of 30.2 years in 1995. Therefore, based on the future employment of oil tankers of this size appears to be assured for the foreseeable future. (See figure 2.4, 2.5 and appendices B2, C3).

Figure 2.5: Proved Oil Reserves 1995



Source: BP Statistics: Review of World Energy 1996

Trends in Oil Production

The rate of oil production is a significant factor in the assessment of tanker market conditions. When the production rate relative to demand is low oil prices will increase as a consequence of the shortage. Saudi Arabia is the greatest oil producer. The oil production of Saudi Arabia stood at 251.6mt and 428.8mt, 1986 and 1996 respectively. This represented 40% and 44% of Middle East oil production. Middle-East oil production is itself 72% of OPEC total oil production. OPEC in the past has been able to implement successfully the production strategy by imposing production quota to boost oil prices. As a result of its vast oil reserves and low production cost,[18] OPEC controlled the marginal supply of oil, and emerged as the dominant player in the world oil industry. OPEC oil production was 41% of world total production in 1996.

Future levels of tanker demand and the resulting trading patterns are likely to be determined by several causative factors.[19] The most important would be the world total distribution of demand and supply of oil and the use of other modes of transportation. The volume and pattern of oil supplies will be another factor. Production areas and their assumed output rates are presented in table 2.2. These would affect oil tanker demand.

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[18] Saudi Arabia's Cost to produce a barrel of oil is in the range of 50 cents to 2 Dollars. *Futures Magazine*, (October 1986): 43.

[19] Drewry Shipping Consultants Ltd., *Forecast of tanker profitability to 1995*, Drewry report, December 1991.

Table 2.2 Assumed Oil Production (mt. / Year)

Year	N. America	W. Europe	Middle East	Africa
1970	609.0	22.8	688.3	299.9
1971	606.6	21.9	807.7	281.1
1975	557.4	30.8	975.1	248.5
1980	567.6	121.5	927.4	301.7
1981	558.7	129.5	789.3	239.6
1982	559.6	147.5	653.1	229.8
1983	565.8	168.4	595.6	227.0
1984	584.3	184.4	583.4	248.7
1985	587.0	192.1	533.3	260.1
1986	572.3	198.0	741.4	257.8
1987	562.2	199.6	643.3	253.8
1988	557.4	199.0	735.7	263.9
1989	525.5	194.2	812.4	288.6
1990	510.9	201.9	843.3	313.5
1991	521.0	214.1	822.9	329.7
1992	514.8	229.9	899.7	332.4
1993	653.8	256.5	947.0	328.9
1994	649.2	300.6	960.7	328.5
1995	644.7	312.8	967.4	334.7

Source: BP Statistics, Statistical Review of World Energy

The rate of oil production in Western Europe grew rapidly during the period; the increase can be linked with North Sea oil production. According to the Department of Trade and Industry 1997[20] the average growth of North Sea oil production since 1992 was 5.8% per annum; it is reflected in the growth of oil production in Western Europe. Production in these countries was much lower than their consumption, the difference being met by oil imports. Production for oil in Africa shows an increase in volume; this is likely to have a considerable effect on the demand for oil tankers. In fact, the West Africa route constitutes a major source of employment for million barrel tankers.

Oil Consumption

Oil consumption as defined, is the direct use of crude plus inland product demand plus international bunkers plus refinery fuel and losses.[21]

In 1973 the world oil demand was increasing at an average rate of 7.5% per annum compared to 1% in 1970.[22] However since the collapse of oil prices in 1986, the rate has gone up a little. World oil demand rose by 1.6% per annum between 1985 and 1992.[23] The demand for oil reflects on the oil consumption; there is evidence of this in the increase in Western European and American oil consumption. Figure 2.6 shows that the oil consumption in USA and Western Europe has increased in the most 20 years, albeit at uneven annual rates.

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[20] Department of Trade and Industry - "The Energy Report", *Oil and Gas Resources of the United Kingdom*, 2, 1997.
[21] Drewry Reports, Op cit., p.19.

[22] Steifel, Shane S. , *Review and Outlook for the World Oil Market*, World Bank Discussion Papers, The International Bank for Reconstruction and Development, 1995
[23] Ibid.,

The increase in the crude oil prices in 1973 helped to deflate economic activities in the main consuming areas; this happened at a time when many economies were entering the depression part of their economic cycle.[24] According to BP[25] the world's total consumption of oil increased at an average rate of approximately 1.1- percent per annum between 1973 and 1980. The low growth rate has been one of the contributing factors to the reduced level of tanker demand. At the time the major nations including USA and Western Europe together accounted for approximately 70 per cent of total world oil consumption (2,000 mt)[26].

However, the geographical location of the consumers of oil will have much bearing on tanker tonnage demand. (See figure 2.6 and appendix B4). The greater the distance between the main oil producing areas and the main oil consuming areas, the higher will be the level of tanker demand when measured in tonne-miles.

Oil consumption for the two major areas that are being examined have an annual average increase of 1.8% over the period of 10 years, 1985-1995.[27] In the author's opinion, low oil prices coupled with strong economic growth particularly in the US and Japan in 1991 to 1993 has caused the increase in demand for oil-generated energy. However, Japanese growth has been regular recently (1995). The reasons are due to the growth in their petrol-chemical industries, and use for transportation. These aspects will feature in the model presented in this thesis.

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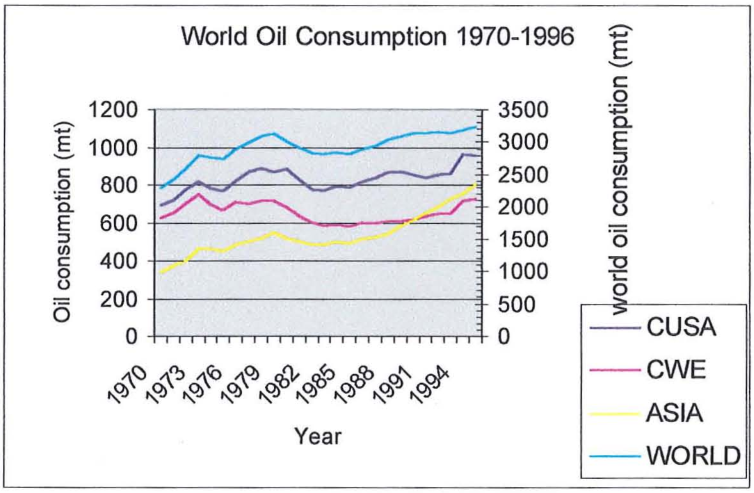
[24] BP Statistics, op cit., p.15.
[25] Ibid.
[26] Ibid.
[27] BP Statistics, Op cit., p.15.

Figure 2.6: World Oil Consumption 1970-1996



Source: BP Statistics: Statistical Review of World Energy

According to the New York Times, as reported in the Guardian, as a result of increased oil consumption, imports reached 10 mb/d in April 1997. Imports accounted for more than 50 per cent of consumption; this was according to America Petroleum Institute.[28]

The average growth of world oil consumption can be seen in table 2.1, 2.3 and the appendix B4. In 1995, North American consumption fell by 0.8 %, when Japanese increased by 0.4%. The table (2.3) demonstrates that oil consumption trend has been positive for many years in most part of the world. But it is also the case that world oil consumption has grown at an uneven rate over the period. Generally, world oil consumption in the 70s grew at 6% per annum. It stood at 1937.4 million tonnes in 1970, it rose to 2040.1 million tonnes in 1971 and by 1975 it was 2192.3 million tonnes, a 7.5% increase from 1970 figure. Between 1975 and 1980 it increased by 37.9%, an average growth of 7% per year.

[28] The Guardian, Op cit., p.13.

Table 2.3 Oil Consumption Average Percentage Change

Year	North America	Western Europe	Japan	OECD	Others
1983	-0.6	-0.1	0.4	-0.3	3.6
1984	0.2	2.6	0.5	1.1	4.1
1985	0.5	2.9	0.3	1.5	3.7
1986	2.9	1.4	1.1	2.3	5.9
1987	4.5	1.0	6.2	3.4	5.8
1988	3.4	1.5	6.9	3.2	5.1
1989	0.4	0.4	3.7	0.9	5.2
1990	-2.1	1.1	5.2	0.1	5.1
1991	-1.2	1.6	1.8	0.2	3.4
1992	-2.0	1.4	2.7	1.9	5.3
1993	2.8	0.2	6.3	2.4	4.8
1994	0.8	-0.3	-2.3	-0.6	4.3
1995	-0.8	1.8	-0.4	1.0	5.2

Source: BP Statistical Review of World Energy

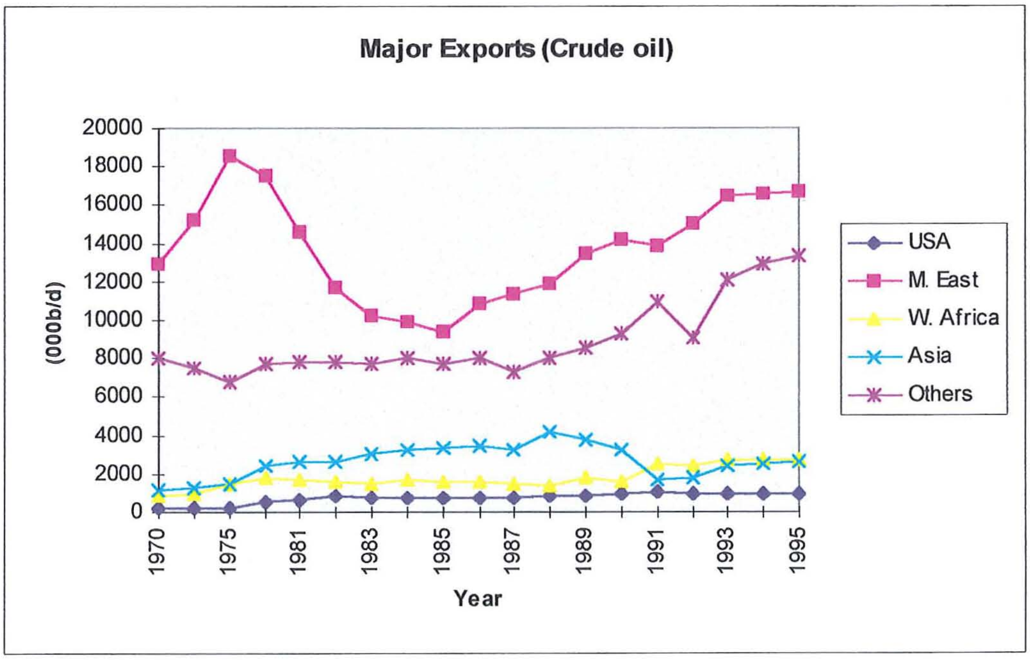
After the year 1980 there was a period of decrease in oil consumption, this lasted for 7 years. At the time the average reduction was 2.0%. However, since 1988 the world oil consumption has steadily increased by an average of 1.5% up to the end of the historical data.

International Trade in Oil

The following data refers to trade flow for all categories of tankers between 1970 to 1995. It is possible to assess tanker supply and demand through the imports and exports of crude oil. In order to assess the future supply of tanker it is imperative to understand the pattern of trade. Tanker employment comes from imports of oil by the consuming nations. The geographical location of production sources and the consumers' demand for oil is an indication that there is always going to be a requirement for tankers. Therefore, increase of imports and exports will create the demand for oil tanker services.

The major trading routes for one million barrel tankers are West Africa - US East Coast, West Africa - Western Europe and West Africa - Far East. As a result, changes in the increase of imports and exports of oil in these areas are important.[29] Oil imports accounted for about three- quarters of oil consumption in the US; BP statistics of World Energy[30] shows the growth in the exports of oil to US to be around 25%.

Figure 2.7 Trade Movements[31] - Exports (000b/d)



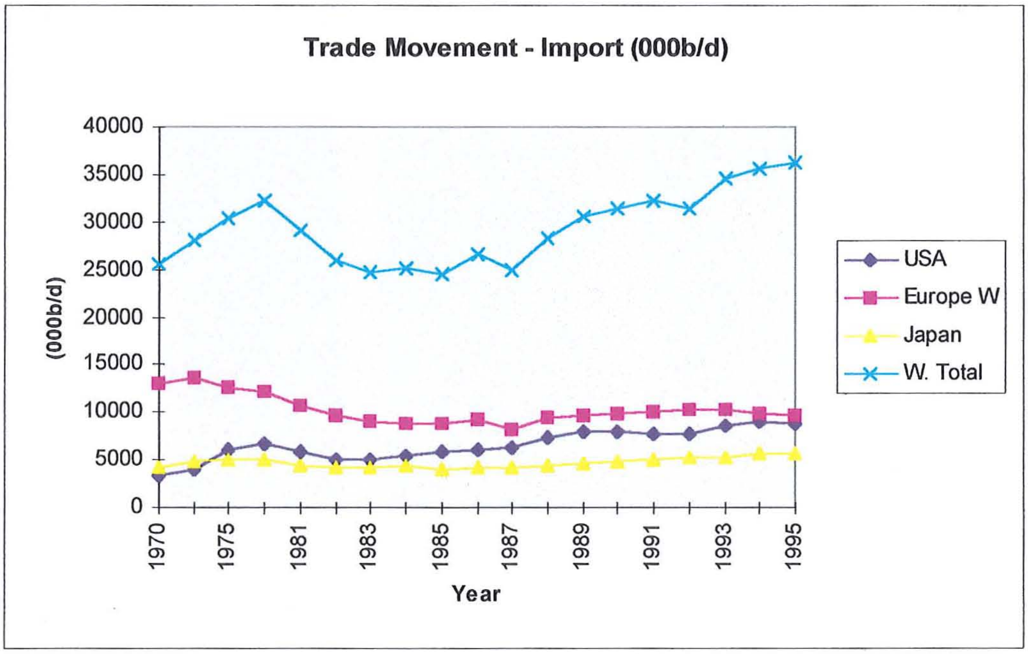
Source: BP Statistics of World Energy 1996

[29] E. A. Gibson Shipbrokers Ltd: "***Tanker Fixtures***" 1996 - 1997(July).

[30] BP Statistics, Op cit., p.15.

[31] Ibid.,

Figure 2.8 Trade Movement[32] - Import (000b/d)



Source: BP Statistics of World Energy 1996

Oil exports to the USA was average 3.4 million barrels per day in 1970, compared with the 7.8 million barrels per day in 1991; percentage increase of 56.4 per cent (see figure 2.7 and appendix B5). These would affect the employment of one million barrel tankers. According to E. A. Gibson shipbrokers Ltd,[33] the West Africa-United States loading accounted for about 32% of employment for the million barrel tanker sizes.

In the Lloyds Shipping Economist[34] the US Department of Energy's Information Administration (EIA) oil imports' level forecast was 9.30 mb/d for 1995. The Imports of oil in Western Europe have increased despite the increase in the North Sea oil production. Since 1991 it has increased by an annual average of 1.2 per cent.

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[32] Ibid.

[33] E. A. Gibson Shipbrokers Ltd., Op cit., p.25.

[34] Lloyds Shipping Economist, "Long-haul US oil imports below forecast", (April 1994) : p.15.

decreasing after 1993 by a small margin. (See figure 2.8.) One million barrel tankers in West Africa-Western Europe route claimed over 11 per cent of the trade in the route.[35] According to Gibson Shipbrokers Ltd., the fixtures of the million barrel tankers to the Far-East was fairly low, for the route West Africa-Far East was 1.1 per cent in 1996.[36]

The oil exporting regions and the distance of the consumer from the producer generates the ton-miles for million barrel tankers. As has already been mentioned, the significance of this area to one million barrel tankers is quite clear from the trends. If the trend continues there is a presumption that the influence will be felt in the million barrel tanker classes. The influence of the growth of oil imports can be seen from the major oil imports table in appendix B6 and figure 2.8. The assumption is that additional imports of oil in these countries would increase the demand of one million barrel tankers. In spite of the lag effect between the demand for oil and supply of tankers, the assumption is that ultimate effect will be an increase in employment of oil tankers.

Oil imports to the USA and Western Europe have exhibited an increase in volume over the period 1983-1995 (See figures 2.8 and 2.9.) Despite the occasional decline, such as USA oil imports in 1991, the data suggests that the long-term trend be for an increase in consumption in these regions. The increase in imports of oil in the region is assumed to generate an increase in demand for the million barrel tankers. The evidence from the data suggests that the million barrel tankers will continue to benefit from the increasing oil consumption.

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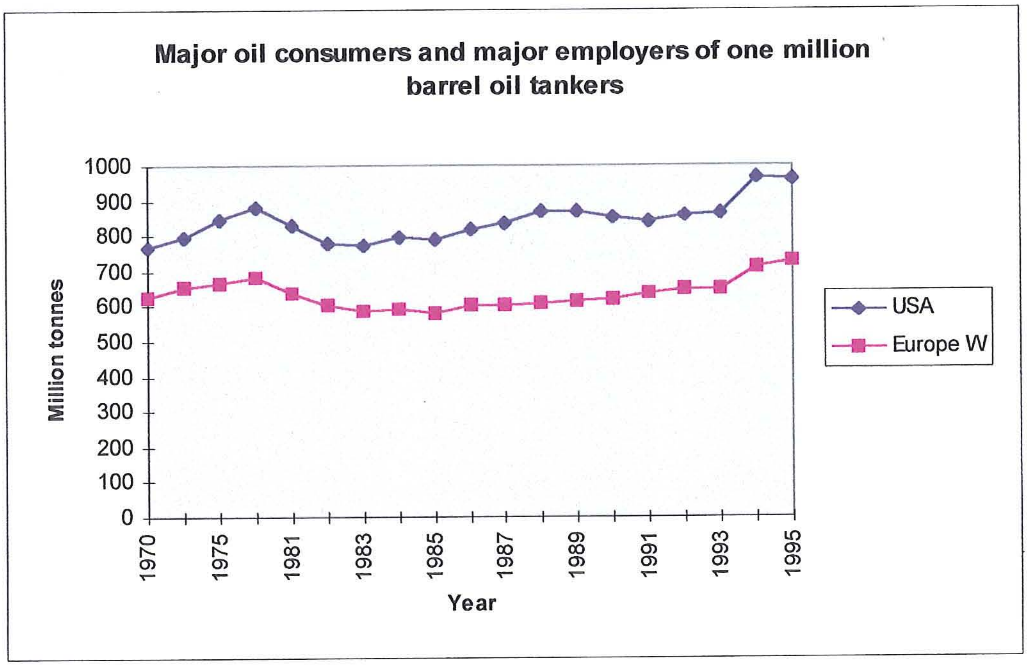
[35] Ibid.,

[36] Ibid.,

Figure 2.9 Major Oil Consumers[37]



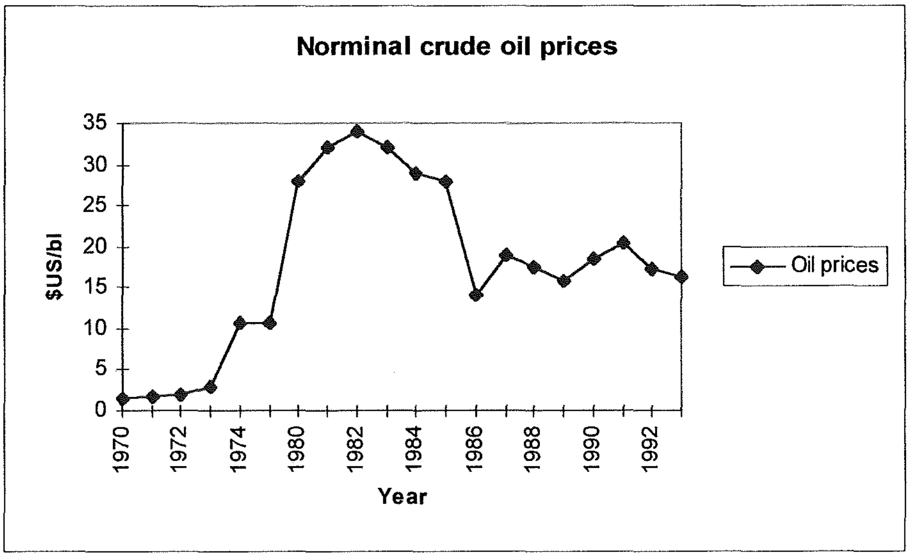
Source: BP Statistics of World Energy 1996

[37] Ibid.

2.3 The Oil Tanker Market

The crisis of 1974, is a historic event that people who were concerned with tanker shipping will remember for years. The sequence of events at the time led to the collapse of the tanker market. Oil prices increased by more than 400%. (See figure 2.9.) During that time there were surplus in total tankers ordered due to the market speculation that resulted in tankers being ordered in quantities that later depressed the freight rate market, when they were transformed into deliveries.

Figure 2.10: Nominal Crude Oil Prices[38]



Source: BP Statistics: Review of World Energy, various issues

Based on Lloyd's register of Shipbuilding Returns, new orders were increasing in the early 70s and 80s. In 1975 the tanker order book stood at 46.3 million dwt (40% of total fleet), by 1985 it was 5.6 million dwt (6.4% of total fleet). There was a very large newbuilding programme in the early 70s and the deadweight tonnage in the market rapidly expanded. However, the market did not envisage what was to follow the

[38] BP Statistics, Op. cit., p.14.

boom. According to J. I. Jacobs[39] the large building programme during the boom period later created depression in the tanker market.

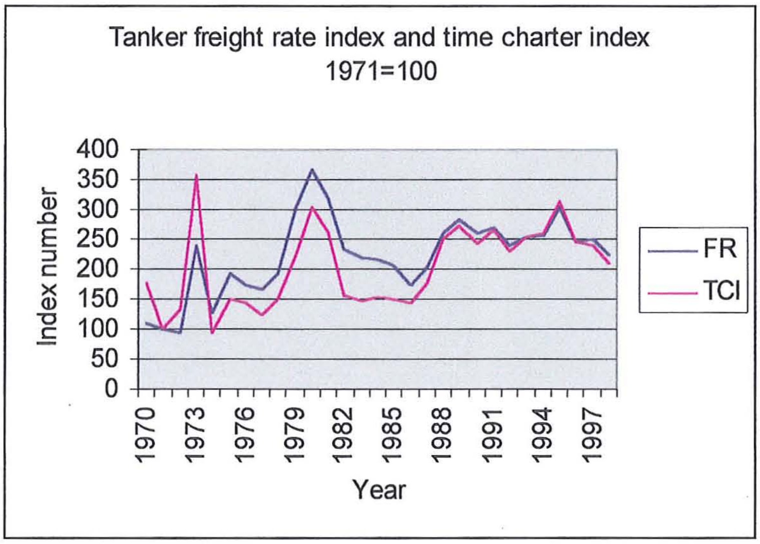
At the beginning of September of that year freight rates were at such a level that ships commanded substantial incomes. The newly built vessels with high cost were able to get 3 year time charter at rates that enabled half of the construction costs to be written off during the charter period. Large oil tankers, such as VLCC's were commanding Worldscale 350 level at the time, and it reached WS 450 at a particular time. [40]

Later in that year the oil embargo was carried out against USA and the Netherlands and within a short time tanker freight rates fell to WS 80[41] and the market was flooded with excess tonnage. As a result of this the bunker situation became very tense. Bunker prices that were US$14 a ton in Arabian Gulf and US$19 in Europe increased to US$260 in Europe and in the Arabian Gulf; in Japan it was US$300.[42] There was slight improvement in freight rate to average of WS 100. At the time it cost between US$20,000-30,000 a day to have a large vessel (VLCCs) laying idle.[43] For the freight rate movement see figure 2.9.

In the 1970s the oil imports and the world tanker total increased. The world tanker fleet grew by 66% (212 to 326 million dwt) between 1973 and 1976; but trade expressed in ton-miles increased only by about 50% In the same period.[44] See figure 2.10 and the appendix C2 (World oil imports 1970-76.)

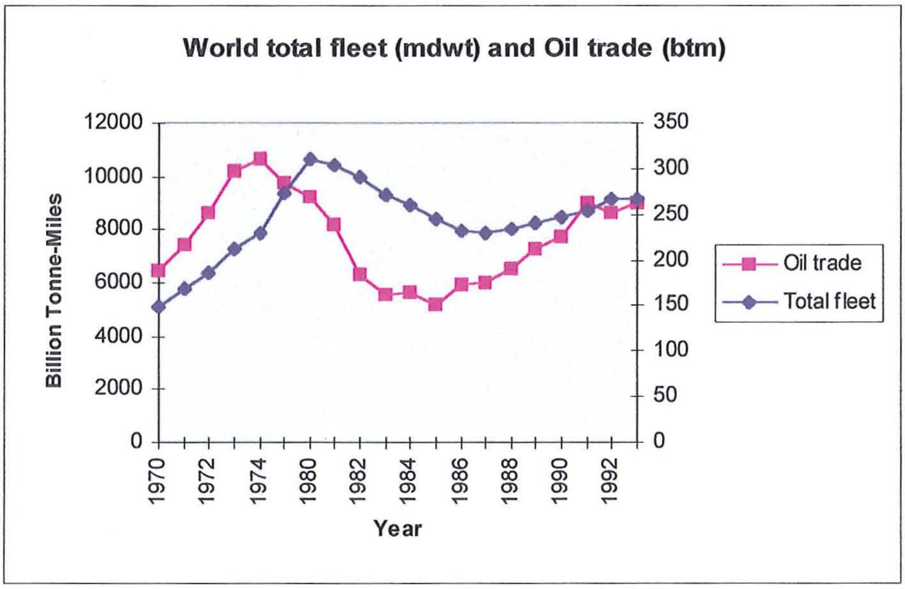
[39] Jacobs, J. I. World Oil Tanker Review, 1970-1997.
[40] Rinman Thorsten and Rigmor Brodefors, *The Commercial History of Shipping*, Published by Rinman and Linden AB Goteborg (1983): 149-153.
[41] Ibid.
[42] Ibid.
[43] Ibid.
[44] Op cit., BP Statistics, p. 14.

Figure 2.11: Oil Tanker Freight Rates and Time Charter[45]



Source: ISL: Institute of Shipping Economics and Logistics: Statistics Year Book 1988-1997

Figure 2.12: World Total Fleet[46] **and Oil Seaborne Trade**[47]



Sources: Jacobs, J. I. ; Review of World Oil tankers, various issues
Fearnleys and Egers, World Bulk Trade Report, various issues

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[45] ISL, Institute of Shipping Economics and logistics, Shipping Statistics YearBook, published by ISL Bremen 1988-1997.

[46] Jacobs, J. I., Review of world oil tankers, Op cit., p.28.

[47] Fearnley and Egers, ***World Bulk Trade***, Oslo, Norway. 1970-1996.

One hundred and thirty-five million DWT (135 mdwt) were reported ordered in 1972 and 1973.[48] It ensured a continued high rate of growth in tanker supply, despite subsequent cancellation of tanker orders. Tanker supply measured in deadweight tonnes increased from 1970-1975. Even if the 400% increase in the price of crude oil that followed the 1973 crisis had not taken place, in the author's opinion the depression in the tanker market was inevitable. The increase in crude oil prices also added to the scale of the tanker demand and supply imbalance.

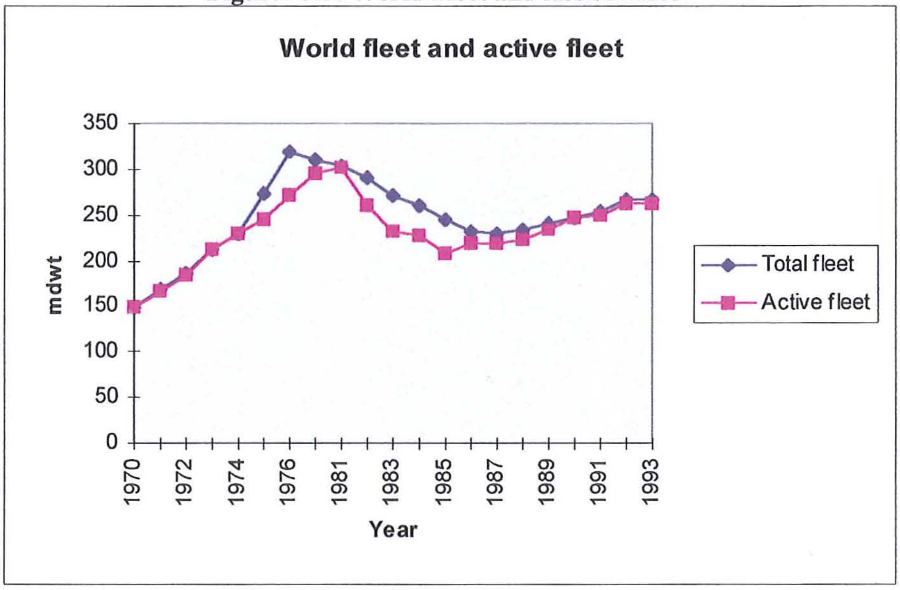
The size of this can be seen from the number of tankers that was inactive. During the period of low tanker rates in 1971 and 1972 tanker inactivity stood at about 6 million DWT. In the depression period of 1976 the inactivity reached 48 million DWT. See figures 2.13.

According to J. I. Jacobs[49] many tankers reduced their speed because of lack of trade and in order to cut down on fuel. At certain point, the average speed recorded was 12 knots. Generally, the average speed in the eighties was 11 knots. In view of this, J. I. Jacobs estimate[50] that on average the capacity absorbed through reduced speed at the time was 15.2 million dwt.

As already being mentioned the understanding of demand and supply of tanker is very important in order to understand the tanker market. Demand for tankers are characterised by certain factors. The factor that affects tankers will be dealt with in chapter four. However, lagged tanker supply deliveries and proportion scrapped are reckoned to be major determinants of tanker supply.

[48] Op cit., Jacobs, J. I. Review of World Oil Tanker,p.30.
[49] Ibid.
[50] Ibid.

Figure 2.13: World Fleet and Active Fleet[51]



Source: J.I. Jacobs, World Oil Tanker Review 1970-1993

2.3.1 The Structure of Oil Tanker Market

The tanker market can be said to be competitive. There are no barriers to entry and to a certain extent there is no barrier to exit from the market. It has to be said that taking the extra tonnage off the market could pose a problem. So exit might not be that easy. Though it is easy to mobilise the tankers, that is the movement of tankers from market to market. According to Zannetos the tankers owner needs no administrative superstructure in order to operate efficiently.[52] The author said that it was the imbalances between the production and refineries capacities as well as between geographical regions for the various oil companies that brought about the independent tanker market. If the oil companies own all the tonnage needed, the market could have been unstable with surplus tonnage. So the independent owners and the oil companies tend to complement each other. As mentioned above, capital mobility reduces the cost

[51] Lloyds Shipping Economist, Various monthly publications
[52] Zannetos, Z. S. The theory of oil tankership rates, An economic analysis of tankership operations, The MIT press 1966; p.180.

of exit from any particular market. In addition, there is no unnecessary national and international control as to entry and exit.

2.3.1.1 Types of Tankers

There are three types of tankers, and these are classified into crude oil tankers, oil product tankers and gas or chemical tankers. The crude oil tankers are mainly designed to carry crude oil from the production source to the refinery. The crude oil can also be classified into other categories. Product tankers are designed to transport refined oil products from refinery to consumer. They distribute the products from the refineries to other areas where there are no facilities for refining oil. Product tankers are classified under clean products such as petrol, paraffin oil, gas oil, etc. and dirty product such as fuel oil, marine diesel fuel, lubricating oils and bitumen. The total number of product tankers over 10,000 dead weight as at 1994 was 1367, and the dead weight was 47,514,859. Approximately 2 million dead weight of the product tankers are well over 100,000 dead weight.[53]

It is very important to increase the awareness that there are other tankers besides crude oil tankers. Gas and chemical tankers are highly specialised tankers. Gas tankers are in the business of carrying liquidified gas, such as LNG and LPG, the liquidified natural gas and liquidified petroleum gas. The chemical product carriers are different from the oil product tankers. The product being carried by these tankers are Petrochemicals, coaltar, Molasses, Inorganic chemicals such as sulphuric acid, phosphoric acid, caustic soda, etc.

[53] Jacobs, J. I. Review of World Tanker Fleet, published by Jacobs and Partners Ltd., 1995

Crude Oil Tankers

There are certain predominant tanker size ranges. This will be discussed under four main sub headings:

Ultra Large Crude Carrier (ULCC). This vessels' range is 300-550,000 dead-weight tonne. These are being used for carrying crude oil on long haul routes from the Arabian Gulf to Europe, America and the Far East. They normally discharge at specialised custom-built terminals or refinery. The smaller oil tankers then may take the oil to the destination ports.

Very Large Crude Carrier (VLCC) range is 200-299999 dead-weight tonnes. It uses the similar routes to the ULCC's but with a greater flexibility in discharging port options owing to less draft. Because of these reasons there is acceptance of these tankers in other routes such as the Mediterranean, West Africa, North Sea terminals, etc. They can also be ballasted through the Suez Canal.

One Million Barrel Tankers (MBT) is defined earlier as oil tanker of 100-160,000 dead-weight tonnes. They are mainly used on short hauls in such area as the Mediterranean, West Africa, Indonesia and North Sea terminals to major nearby consuming areas. As a result it provides the charterer with a greater range of oil tankers. This tanker size can transit the Suez Canal laden or part laden.

The Aframax tanker's range is 80-99,999 dead-weight tonnes. These tankers mainly use the same route with the million barrel tankers and are accepted in most of the ports.

Aframax tankers can potentially compete with one million barrel tankers (see table 2.4). The reason is that the class uses the same route with one million barrel tankers. There has been a considerable growth in the Aframax class over the years. The percentage growth of demand for these tankers was an average of 10% from the previous years. However, the West Africa route for the Aframax is not significant to constitute a threat to the one million barrel tankers.[54] Lloyd's Maritime fixtures confirmed this.[55]

Table 2.4: Existing Crude Oil Tankers (mdwt)

Year	ULCC/VLCC		MBT		Aframax	
	No.	mdwt	No.	mdwt	No.	mdwt
1985	422	117.4	263	34.2	340	19.7
1986	394	109.0	262	33.8	353	21.3
1987	382	107.8	266	34.2	355	22.2
1988	391	108.1	276	35.5	363	23.4
1989	402	111.0	291	37.5	375	24.9
1990	413	114.0	303	39.1	396	27.0
1991	430	118.6	327	40.1	403	28.2
1992	434	120.2	334	43.8	415	30.8
1993	448	125.1	326	43.3	425	32.1
1994	438	122.9	320	42.1	437	33.6
1995	428	120.4	323	44.4	437	38.8
1996	437	124.2	326	44.1	448	39.6

J. I. Jacobs, World Tanker Fleet Review (1985-96)

The VLCCs could have been a major threat but have a disadvantage, because there are restrictions on draft in many of the ports, and one million barrel tankers are able to trade.[56] The employment pattern given below will reveal more about, West Africa - United States Eastern Seaboard (USES) and West Africa-Western Europe, they have generated most trade for the million tankers.

[54] Lloyds Shipping Economist, Maritime ship fixtures, various issues 1994.
[55] Ibid.

[56] Drewry Consultants Ltd., "A Million Barrel Oil Tanker", published by Drewry Consultant Ltd., 1991.

The tanker market sector accounted for over 60% of the bulk ocean transportation industry, both in terms of total dead-weight tonnage available and total ton-miles of services provided.[57] In 1996 oil companies own approximately 48 per cent of the fleet while the independent owners own the rest that is 52 per cent. (See world tanker fleet, division of ownership in table 2.5 and appendix C5 for the division of ownership.)

Table 2.5 Tanker Ownership and Trends (100-160, 000dwt)

Year	Independent mdwt	Oil company mdwt	Total mdwt
1984	21.7	13.7	35.4
1985	20.6	13.4	34.1
1986	20.7	13.1	33.8
1987	19.1	15.2	34.3
1988	20.3	15.1	35.4
1989	21.8	15.7	37.6
1990	23.3	15.7	39.0
1991	26.2	16.0	42.2
1992	27.4	16.4	43.8
1993	26.9	15.8	42.7
1994	27.1	15.0	42.1
1995	29.7	14.7	44.4
1996	28.7	14.0	42.7

Source: J. I. Jacobs, World Tanker Review

The following are the reasons for this ownership pattern:

1. The transportation requirements of oil companies are uncertain. If they depend completely on their own capacity, surpluses or shortages would easily occur. The independent market on the other hand, provides the required services. This is because the needs of each individual company fluctuates on average, more than those of the industry, the independent then pools the risks inherent in such uncertainties.

2. Sometimes changes in ton-miles capacity requirements of one company are negatively related to the changes of another company's requirements. Thus

[57] Fearnleys Review, *World Bulk Fleet*, Oslo, Norway, 1996.

independent tanker owners provide the necessary balancing mechanism. According to Drewry Report[58], most companies require more capacity to cater for the unexpected increase in the demand; thus in the short run it is from the independent owners that the balance will come.

Also oil companies because of the capital needed to acquire and maintain vessels will prefer to hire from independent tanker owners. Another reason is because of pollution problem; Oil Company does not want to own tankers, as bad publicity would considerably affect the company if there were an oil spill.

The three main operators in the tanker market are oil companies, independent tanker owners and state oil companies. According to the tanker tonnage statistics, the state oil companies' percentage of the tankers in this category cannot be significantly separated from the other company's figure. However, it is included in the company's total dead-weight tonnes. (See table 2.5 and figure appendix C5.)

The International oil companies have to operate large tanker fleets to meet their transportation requirements. The independent owners purchase new or second-hand vessels for the express purpose of hiring out their services to oil companies. The important differences can be seen between individual tanker owners concerning their chartering policies. However, tanker supply will much depend on the freight rates. These rates constitute the hiring price and the incentives for the tanker owners.

Both the charterer and tanker owners can not only rely on the theories and intuitions, but also must construct a good forecast and use as an aid to decision making in the

[58] Drewry Shipping Consultants Ltd, op cit. P.19

future. Forecasting would allow the market to react to any changes that might be on horizon.

2.4 Tanker Demand and Supply

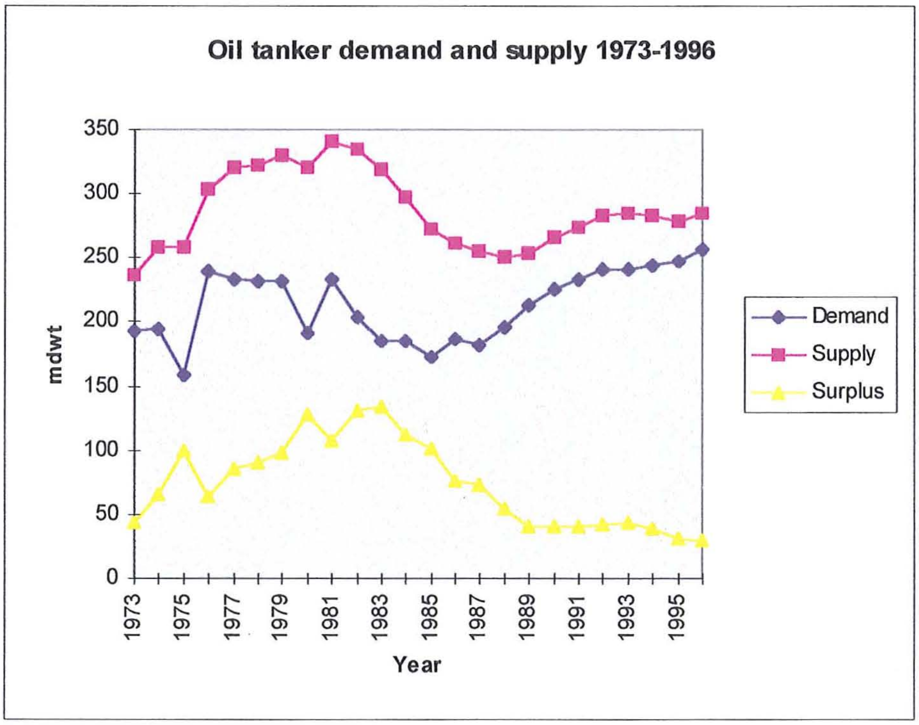
During the period of 1973 to 1980 tankers supply outstripped tanker demand, with the result that tanker spot rates remained firmly depressed. See the table of tanker demand and supply in appendix B7 and figure 2.14. The figures for the 70's were taken from Drewry reports, while the 80's and 90's were from Lloyds Shipping Economist.

Since 1973 the pattern of seaborne oil movements has changed considerably in terms of oil quantity and capacity of tankers. The period of low demand affected different vessels; including large tankers. The worst affected were VLCC's many of which were ordered during the high rate period prior to the 1973 war and delivered in 1974 and 1975. The result was that many vessels were laid-up, some without ever carrying revenue earnings cargo. Some of these vessels earned rates that barely covered their voyage costs.

2.4.1. One Million Barrel Tanker (100-160,000 dwt)

There are about 7.5 barrel to the tonne; thus one million barrels are approximately 137,000 tonnes. However, when bunker, water and stores' capacity are added, it will be around 140,000 dead-weight tonnes. One of the reasons for the development of the "million barrel tanker" was for the oil traders and oil companies who deal in cargoes of multiples or 'lots' of half million barrels. Other reason for the development of tankers of this size is the role of the Suez Canal. The transportation of oil from the Middle East to Europe and the Western Hemisphere is mostly through the Suez Canal.

Figure 2.14: World Oil Tanker Demand and Supply (Mdwt)



Source: Drewry Shipping Consultants (1973-1980)
Lloyds Shipping Economist, various issues

The largest tankers that are able to transit with full cargo are about 140 - 150,000 DWT. Lloyds list in 1994 confirms that the size of the tanker that can transit the canal has been increased; however, this does not affect the West Africa - USA route. Chapters 4-9 are basically based on the million barrel tankers.

2.5 Tanker Age and the Effect of Legislation

The examination of age of tanker of this size in deadweght reveals that 58.1% were over 15 years. (See table 2.6 and figure 2.15). As at 1995 the number of tanker that are over 15 years was 57.3%. As a result there may be replacement programme in the next 5-8 years of aged vessels. The vessels ordered at this time are now coming to the end of their trading life.

Table 2.6 Age Profile of One Million Barrel Tanker 1995

Year		0-4	5-9	10-14	15-19	20-24	25 +
Number		72	53	15	97	84	4
DWT(000)		9566	6499	2070	13532	11102	556

Source: Review of Shipping Statistics and Logistics

Institute of Shipping Statistics & Logistics 1995

There is a need for replacements. The trading life of a vessel of this class is assumed to be between 20 and 23 years. Based on the Market analysis during the five years to 1994, the average life of ships was 25 years.[59] However the latter date depends on the maintenance of the vessels including the hull. Careful planning is needed to minimise the problems in the tanker market. There have been reports and argument as a result of life extension of tanker age. Some authors have suggested that the life of tanker could be increased by 5 to 10 years.[60]

[59] Institute of Shipping Economics and Logistics, *Shipping Statistics and Market Review*, (January/February 1994): 6.
[60] Thomas Aquinas, "Extended Life Options for existing vessels," *Lloyds List*, (Monday, October 28, 1996): 6-7.

There must be a caution in increasing age because of the pollution legislation such as "OPA" The US Oil Pollution Act of 1990 and MARPOL (13G). In fact, the present fleet may have to be scrapped as a result of statutory law on Double Hull and Double Bottom from "OPA" and the amendments to MARPOL 73/78. Knowledge of the capacity needed to replace the aged vessels would be of immense help to the tanker market.

The legislation stipulates double-hulled tankers in order to reduce oil pollution, in cases of accidents such as collision and grounding. As most tankers have single hulls the deadline for the enforcement of the regulation is in place for all tankers. (See table 2.7)

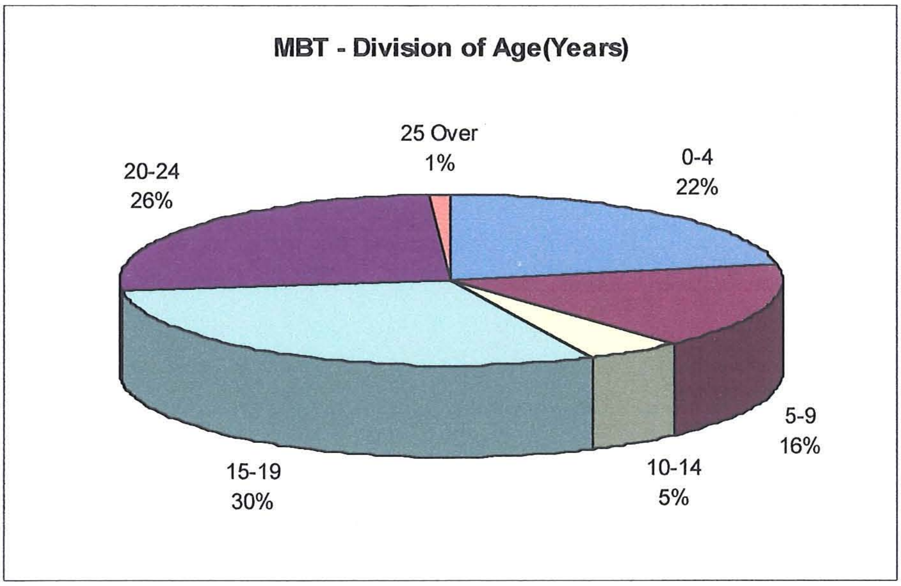
BIMCO has published a series of reports both before and after the Oil Pollution Act of 1990. It explains the statue and the implications; the extraction will be given below. Drewry shipping consultants[61] has also reported on the same issue. MARPOL regulation 13G requires that 'single skin' tankers are fitted with double hulls on a schedule that differ from OPA.

Basically, tankers contracted before July 1993, or lacking a contract, keel laid before January 1994, must be fitted with double hulls at 25 years of age. If the tankers are fitted with segregated ballast tanks, double hulls are not required until the vessel is 30 years old. MARPOL 13G requirement is not considered a problem for tanker owners to refit existing tankers with double hull; the tanker would probably have reached the

[61] Drewry shipping consultants Ltd, "Oil Tankers Regulations, 1991, Op cit., p.9.

end of their economic lives before the designated deadlines. However, the importance of this sort of legislation should not be overshadowed by its implications to tankers. It is believed that this is good for the reputation of tanker market.

Figure 2.15: Age profile of One million barrel tankers



Source: ISL: Institute of shipping Economics and Logistics, Shipping statistics year book, 1995

2.5.1 *The US Oil Pollution Act of 1990* [62]

The fact about OPA is that all vessels must have double hulls. The requirement of the legislation is that all single hulls will be prohibited from US waters as from 1 January 2010. All new ship construction must have double hulls if they are to continue trading; MARPOL legislation covers many countries including the USA (see table 2.7).

[62] *OPA Q's & A's: Overview of the Oil Pollution Act of 1990*, United State Environmental Protection Agency and Publication 9360.8-01FS, December 1991.

Existing tankers without double hulls are to be phased out by size, age and design. In 2015 most tankers without double hulls will be banned.

Table 2.7 US Oil Pollution Act of 1990: Double Hull Implementation Schedule

Single Hull	**Double Bottom or Double Sides**	
Year for Double Hull Compliance	**Year of Build**	
1995	Pre – 1968	Pre – 1963
1996	1968-1969	
1997	1970-71	
1998	1972-73	
1999	1974-75	
2000	1976-77	1972
2001	1978	1973
2002	1979	1974
2003	1980	1975
2004	1981	1976
2005	1982	1977
2006	1983	1978
2007	1984	1979
2008	1985	1980
2009	1986	1981
2010	1987+	1982
2011		1983
2012		1984
2013		1985
2014		1986
2015		1987

Sources: US Oil Pollution Act of 1990[63]

In the short term the number of vessels that will be affected by the legislation will be small. In the long run, by the year 2000 over 50% of the vessel would have to be fitted with double hull if they are to continue trading in the international waters. This could mean that most vessels currently trading would end-up in a scrap yard or modified. The latter might not be possible because of the cost of modification to these vessels.

[63] USA Congress Legislation "*US Oil Pollution Act of 1990, Establishment of Double Hull Requirement for Tank Vessels*", Section 4115, pp 34-37.

2.6 The Employment Pattern of 100-160,000 DWT Tanker

The employment pattern of these tankers varies, depending on the market situation and the routes are unique. They trade in specific routes most of the time. The major source of employment for the one million barrel tankers is the West Africa - USES trade.

Table 2.8: The Employment by Size and One Million Barrel Tanker's Routes in 1996

Major Routes	% of employment
W. Africa - USES	32.6
Med - Med	14.4
Med - UK/Continent	1.9
W. Africa - UK/Continent	5.2
AG - SE Asia	2.8
Caribbean - USES	1.7
SE Asia - SE Asia	0.5
W. Africa - Far East	0.3
AG - UK/Continent	0.7
AG - Australasia	1.5
AG – Mediterranean	0.6
UK/Continent - UK/Continent	6.2
Total	68.4

Sources: E. A. Gibson Shipbrokers Ltd.; Ship Fixtures 1996

See table 2.8. The employment for this route in 1996 accounted for almost 33 per cent of the total trading tonnage in the size.[64] Generally, the trade is evenly spread among the different routes for these vessels.

[64] E. A. Gibson, Ship Fixtures, Op cit., p.24.

According to E. A. Gibson Shipbrokers ship fixtures[65] employment on the West Africa-USES route far outstrips that of any other route within this vessel size category. The shares of the next two most popular routes, West Africa-UK/Continent and Mediterranean-Mediterranean together did not add up to half of this figure. Tonnage trading out of West Africa to all destinations accounted for 51 per cent of the total. There are four further major routes where their share of tonnage exceeded 20 per cent. These were Arabian Gulf-Australasia 37 per cent, Mediterranean - UK/Continent 35 per cent, Caribbean - USES 28 per cent, Southeast Asia- South East Asia 23 per cent. There are other significant routes in which this category of tanker has captured 64 per cent of the employment on the Mediterranean - USES route and 55 per cent of the West Africa-UK/Continent route.

As explained above there is no rigidity in owners of these tankers; they are prepared to trade in any of the routes. The strategy is spot trading, that is to look for employment anywhere within the routes specified above. For instance a tanker owner who found that Arabian Gulf - Australasia is not generating enough trade may switch to other route, such as Arabian Gulf - India Subcontinent. The awareness of the developments in the tanker and perfect knowledge of the routes is very important. These routes will be examined taking into consideration the loading and discharge zones.

In some of these ports it is possible for VLCCs to load and discharge, in view of this it is felt that VLCCs do compete with one million barrel tankers for employment. These tankers can be used as an alternative to VLCCs, thus it has an impact on the employment pattern of the medium sized tankers, most especially the million barrel tankers. However, the loading ports that accommodate VLCCs are very small, about

[65] Ibid.

10% compared with the ports that accommodate medium oil tankers. The one million tankers share of West Africa route was about 75% in 1996.[66]

The major factor determining the size of a vessel calling at ports is the water depth, which places a constraint on the vessel's laden draft. As the size of a tanker increases, so does its draft. The one million barrel tanker size ships have drafts of 16 - 17 metres, compared with the VLCCs that require a minimum of 18 metres.

2.6.1 The *Loading Zones*

The following loading points have been considered to account for more than 70 per cent of one million barrel tanker employment,[67] including West Africa, Arabian Gulf, Mediterranean, UK/Continent, South East Asia and Caribbean, Red Sea.

West Africa

This is the most important loading area for the million barrel tankers. The route was responsible for the greatest percentage of employment of this category of tanker. Over 50 per cent of the ship size tonnage found employment on the loading area, with the loading at West Africa ports close to 75%; all tonnage loading are coming from million barrel tankers.[68] There are six major ports frequently used by this range of oil carrier. The top three are Nigerian ports, Forcados, Bonny and Escravos; the three ports can also accommodate very large crude carriers (VLCC).

[66] Ibid.
[67] Ibid.
[68] Ibid.

As pointed out, the destination of the cargoes from this region is very important. The most popular discharge area for voyages originating in West Africa is the US Eastern Seaboard (including Gulf ports) about 32%. The call at Nigeria ports exceeded the combined total of loading at all other West African ports. Other ports that are being used by the million barrel tankers are categorised into three headings, namely restricted, partly restricted and VLCC ports.

Restricted draft terminals are ports that have total restriction to large tankers due to the depth of the water. In most cases this can be considered to be an advantage to the MBT size. The restricted ports are Djeno terminals in Congo and Banana in Zaire.

The partly restricted draft ports are ports that can accommodate large tankers such as 150 - 175,000 dead weight; also it could be that part of the ports can accommodate larger tankers. The million barrel tankers can also use it. This shows that the million barrel tankers are capable of using many of these ports, e.g. Kole terminal in Cameroon.

The VLCC ports are ports whose draughts are adequate to accommodate very large tankers. It also shows that other lower size can as well use the ports, including the million barrel tankers. These ports are in Nigeria: Forcados, Bonny, Escravos, Qua Iboe, and Brass terminal. The other ports are Cabinda in Angola and Cap Lopez in Garbon. This was the report as of 1996.

Arabian Gulf

One million barrel tankers accounted for less than 10% of all oil lifting in the Arabian Gulf, but the area still accounts for 18 per cent of medium tonnage employment. There are eight ports that received visits from medium - sized tankers. The top three ports are Ras- Tanura, Jebel Dhama and Mina Al Fahal. The number of calls to Ras Tanura outnumbered those to other ports. In terms of countries, there are more visits to United Arab Emirates ports than to Saudi Arabian. Gulf ports despite the high ranking of Ras Tanura. Calls at ports in the area are spread between terminals.

The restricted draft port is Umm Said - Qatar. The partly restricted draft ports are: Das Island - Abu Dhabi, Ras Al Khafji - Saudi Arabia, Mina Al Ahmadi - Kuwait. The VLCCs ports are: Ras Tanura - Saudi Arabia, Mina Al Fahal - OmanZirku Island - Abu Dhabi, Kharo Island - Iran, Fateh Island - Dubai. The importance of the route can be assessed through its throughput, with reference to the discharge ports.

Mediterranean

The total employment for one million barrel tanker in the area is 10 per cent.[69] The tanker category focuses on two ports, Sidi Kerir in Egypt and the Ceyhan in Turkey (temporarily closed). Both terminals are at the end of oil pipelines. Sidi Karir is a VLCC port, and most of the oil exported was transported in medium size tankers. The ultimate destination of these cargoes is UK/Continent (UKC) and it is about 75 per cent of the crude oil. The partly restricted ports in the area are Sidi Kerir in Egypt. The employment tonnage in this route is about 1.7 million dead-weights.[70]

[69] Ibid.,
[70] Ibid.

UK/Continent

North Europe loading accounted for 9 per cent of World employment for medium size tonnage.[71] Not surprisingly two of the three most frequented loading terminals in North Europe are SBMs in the North Sea, Statjford and Gulfs terminals. The second most popular is Sullom Voe in the Shetland.

The restricted draft port in United Kingdom is Tees and the partly restricted draft port is Sullom Voe. The VLCC ports in Europe are Sture in Norway and Europoort in Netherlands. ***SBMs***: Statfjord in Norway; the maximum capacity is 150,000 dwt. Gulfaks also in Norway; the maximum capacity is 150,000 dwt. One million barrel tanker sizes are considered as the most popular size of the route. The vessels in the size band make up half the tonnage employed on the route. The total throughput for the medium tankers on the route was 2.4 million dead weights and the million barrel tankers claimed half of the throughput.[72]

The Caribbean

Employment volumes in the Caribbean are similar to those in south East Asia, 8 per cent of the world total. The most popular port for loading in the Caribbean is Chirigin Grande, where the eastern discharge point of the Petro-terminal Transhipment terminal is located. This is an outlet for the Alaskan crude oil; the one-way oil flow from the Pacific to the Atlantic. Although the port has a maximum draft allowance of 21.9 meters there is nonetheless a restriction on size, a limit of 150,000 dead weight. Most of the vessels loading in the Caribbean discharge at US ports. However, there

[71] Ibid.
[72] Ibid.

have been voyages to the Far East, notably Japan. The terminals in St. Lucia along with the facilities in Bonaire, Bullon Bay and St. Croix are being used as a transhipment point. VLCC discharge into storage tank and the oil is then taken off in smaller tanks destined for US ports.

The restricted draft port in the Caribbean is Puerto La Cruz in Venezuela and the partly restricted draft port is Chirigin Grande in Panama. The VLCCs ports are Cayo Arcas and Dos Bocas both in Mexico; also Cul De Sac Bay port of St. Lucia. The million barrel tankers accounted for about 44 per cent of the throughput on the route, while vessels less than 100,000 dead weight accounted for 56 per cent of the trade on the route. The two most important routes are the Caribbean - USES and Caribbean - UK/Continent and Mediterranean.[73]

2.6.2 The *Discharge Zones*

The West Africa - USES, the route is considered to be the most important that provides employment for the million barrel tankers. The employment figure for the route is greater than the employment on the other routes. On the route 7.4 million dead-weights of the vessel found employment.[74] Discharges from these vessels are being divided between Atlantic and Gulf ports. On the Atlantic port of Philadelphia was by far the most frequented discharge port while New Orleans had that honour among Gulf ports.

Crude oil imports into the US East Coast has been shown to be the largest single generator of employment; it accounted for a quarter of the World total. A number of Eastern Seaboard ports in the United State are incapable of handling vessels much

[73] Ibid.
[74] Ibid.

above 80,000 dwt fully laden. All larger vessels arriving at one of these ports would have to lighten their vessels. This lightening will be done in a special anchorage before proceeding to the terminal or for the cargo to be directly discharged into barges. The Louisiana Offshore oil ports (LOOP) provide one of the few VLCC facilities. Tankers calling here can either fully discharge their load or use the facilities. They could part discharge before proceeding to one of the limited draft Gulf ports. Philadelphia was the port most visited by this class of tanker; it commands 50% more than the other ports.[75]

Tanker traffic calls on the West Africa - USES route provides most of the crude oil, though voyages originated in the Caribbean, particularly from one of the transhipment depots was frequent. The Arabian Gulf operators choose to transport crude oil in VLCCs to the Caribbean and then transfer USES in smaller tanker. Most of these ports are restricted draft ports; they are Philadelphia, New Orleans, Texas City, Beaumont, Houston, Corpus Christi, New York and Lake Charles. The only port that has facilities for VLCC is the Louisiana offshore oil ports (LOOP) terminal.

Mediterranean

The second most important discharging area for the employment of one million barrel tankers is the Mediterranean.[76] The most frequently used port for this tanker type is Fos, on the Mediterranean coast of France. Essentially those categories of tanker discharge in south Europe from the cross- Mediterranean traffics, with the majority of them loading in the East Mediterranean or in North Africa. The category of tanker employed in this route are mainly tankers greater than 120,000 dead-weight. The more

[75] Ibid.,
[76] Ibid.

established ports of the region have overcome limitations on draft by installing Offshore SBMs that enable the larger tankers to be accommodated. The restricted port is Trieste in Italy. The partly restricted ports are Fos - France, Genoa - Italy, Algeciras - Spain, Sines - Portugal, Malaga - Spain and Milazzo - Italy. The VLCC ports are Augusta in Italy and Sarroch in Italy and Bilbao in Spain. All these ports are suitable for one million barrel tankers.

UK/Continent

North European crude oil discharges generated 12 per cent[77] of World employment of all tanker sizes. A significant proportion of the crude oil discharged at North European ports recently was North Sea oil. When oil is loaded directly from an SBM in an offshore field, chances are that there will be a limitation on vessel size, particularly in the Norwegian fields. The short voyages' distances involved and the trade practice of dealing in cargo lots of a half or one million barrels militate against the use of VLCCs.

Other reasons for using one million barrel tankers include the infrastructure at discharge ports and the time it takes to load, that is port time. Though there would be sufficient draft to take a VLCC, berth length and storage facilities do not always meet the requirements for berthing or discharging of VLCC. The restricted draft ports are Fawley and Liverpool in the United Kingdom, Rotterdam in Netherlands and Donges in France. The partly restricted ports are Wilhelmshaven of W. Germany and Gothenburg in Sweden. The VLCC ports are Europoort in Netherlands, Le Havre in France, Milford Haven in United Kingdom and Mongstad in Norway.

[77] Ibid.

Far East

The development of the Japanese economy created more usage of oil. It generates about five per cent of world employment for tanker tonnage and about 0.9 per cent of one million barrel tankers.[78] There are nearly 2.0 million dead-weights employed on the West Africa route.[79] The Japanese discharge ports are seen to be a small fraction of the traffic originated in south East Asia, with a significant proportion also coming from the Arabian Gulf and the Caribbean. Yokohama was most visited by one million barrels with a frequency that is more than double the next largest; the port Kiire. The restricted ports are Sakaii and Iwakuni. The partly restricted ports are Yokohama, Kiire, Chiba, Shimotsu and Kashima.

2.7 Reasons for modelling and Forecasting

There is a need to forecast tanker supply requirements. It has to be recognised that there is a limitation in shipbuilding capacity. In view of this a proper spreading of tanker orders will considerably reduce overcrowding in the yards. This will probably reflect on the prices of tankers. The demand and supply from shipyards point of view comes into play; when demand is high in relation to the capacity of the yard ship prices will increase. However, if the orders can be spread over time, shipyard congestion will be reduced, thus creating an influence on prices. Examination of what

[78] Ibid.
[79] Ibid.

the supply of tanker is likely to be in ten years to come should be of immense help to the investors in order to plan ahead. This includes both ship owners and bankers.

The tanker shipping cycle is an area of interest to consider and one way of tracking the cycle is by forecasting. The market is volatile, comprising peaks and troughs. As argued by Alderton, an acceptable decision strategy (from the owner's point of view) is to spot charter on a rising market and when the peak is reached, to sell or take a time charter long enough to carry the vessel through the depressed period[80]

Before any good decision could be made it has to be thoroughly examined lest problems occur. As it was said by Zannetos (1972), "What I plead is for better analytical model and better data to support managerial decisions. Intuition is great, but intuitive solutions must be tested for validity".[81] The most important issue in tanker shipping is not to predict the market but to foresee what is coming in the future and act on these sooner than anyone else. A good forecast would improve any decision that has to be made. The decision to order vessels when a rise in demand is anticipated could prove fatal if the future rates are not properly examined.

The tanker market is volatile as already been said and written by Zannetos[82] when he described the shipping cycle with the classical cobweb theorem. Hampton (1986) also summarised the economic mechanism that generates the cycle. He said "starting with growing economy and a depressed shipping market, freight rate rise with an increase in transport demand. An entire cycle might take about three to four years from trough

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[80] Alderton, P.M., Sea Transport Operation and Economics. (London, Thomas Reed 1995) : 170-171

[81] Zannetos, Z. "Market and cost structure in shipping", Proceeding of shipping management seminar (Bergen, Institute of shipping Research) 1972: 43.

[82] Zannetos, Z., *The Theory of Oil Tankership Rates* - An Economic Analysis of Tankership Operations MIT Press 1966 :189-201.

to trough."[83] When the volatility of the tanker market comes to mind, forecasting should be accepted as a vital tool. A good forecast will aid future decision making in the oil tanker industry. Forecasting would help in a way to prepare for the future. However, the cycle in the author's opinion cannot be static at three to four years; this would vary from period to period.

2.8 Sources of Data

The above discussions both of the oil trading and tanker market have been based upon the following data sources. These sources also provide the basic data for the development of the econometric model in later chapters. The data was obtained from different sources and in different measurements. Oil consumption and oil imports' figures were obtained from various issues of BP Statistical Review of World Oil Energy and Oil industry outlook ninth edition 1993 -1997, the projection to 2001 by Beck, R. J. OECD- International Energy Agency "Oil and Gas information 1992". This publication itself uses data from BP's Statistical Review. The freight rate index was taken from the Maritime Transport Review of the OECD. Crude oil prices and Nigerian oil production were obtained from the BP Statistical Review.

Interest rate figures, the industrialised countries' Wholesales price index (ICWP), World GDP at constant prices, the metal price index (MPI), the Industrial production index USA, the Industrial production index Europe and the Exchange rate of the dollar against Special Drawing Right (DER) index were taking from IMF - International Financial Statistics. The average price of crude oil was calculated from BP Statistics

[83] Hampton, M., "Shipping Cycle" Seatrade, January 1986; in Stopford, M., *Maritime Economics*, Harper Collins Academic 1992: 52.

Review of the World Energy. Oil seaborne trade was obtained from Fearnley and Egers World Bulk Trades, including the Annual Review of Fearnleys. This is a review of the oil tonnage's and oil tonne miles together with the official posted price of Arabian Light Oil, and world oil income figures from the United Nations. Scrap prices were obtained from various monthly publications of Drewry Report and Institute of shipping Economics and Logistics.

Demand and supply figure for one million barrel oil tankers were obtained from Drewry Reports. There are various special reports by Drewry on medium oil tankers that contain substantial information. The voyage freight index and time charter index, Newbuilding and second-hand price were taking from OECD Maritime Transport Review.

A considerable amount of data was obtained from J. I. Jacobs, Review of World Oil tankers. This is a bi-annual publication. The following are from Review of World Oil Tankers: tanker new orders, Newbuilding price, Tanker Deliveries, Tanker scrapping, One million barrel tanker totals, Very large crude oil tankers (VLCC), combination carriers, the age analysis of one million barrel oil tankers.

Other data have been calculated from the above sources, such as the shipbuilding cost index. This was estimated from the data collected from International Financial Statistics.

2.9 Conclusion

The oil and tanker markets have been analysed in order to provide a background to the main study. The oil market has been shown to be crucial to the development of the world tanker market. The state of oil reserves, oil production and consumption and their relevance to tanker market are crucial. The regional pattern of consumption and production are taken to be fixed or constant for the purpose of the model. The historical pattern is assumed to remain the same for the period examined. The exports and imports of oil that creates employment for tankers are equally important, given their use as indicators of the sources of demand for tankers. The review of trend in both the oil and tanker trade can be kept to proportion when further analysis of the dynamic behaviour of one million barrel tanker forecast will be of benefit to academic and practitioners in the industry. It also shows the importance of freight rates as the sole incentives for tanker operators. The employment pattern of the million barrel tankers was examined; this will enable the tanker operators to be aware of the loading areas and the ones that are generating better trade.

There were events in the past that gave clear indication for a need for forecasting. The volatility of the market and the influence of the exogenous and endogenous factors on tanker supply. Assumptions and expectation of these factors are essential for better forecasting of the oil tanker market, especially tanker supply.

Chapter 3

A REVIEW OF THE LITERATURE ON FORECASTING TECHNIQUES

3.1 Introduction

This chapter has two objectives. Firstly, it critically reviews previous attempts at modelling oil tanker markets; secondly, it examines forecasting techniques that have been applied to them (these previous attempts have generated the contribution made by the thesis itself). Thirdly, it examines the relevant data for stationarity, and finally develops and estimates an econometric model of the one million barrel tanker market.

The freight market is one of the very earliest examples of applied econometric analysis, although the applications of forecasting techniques are not new to other area of tanker shipping. There are several attempts to model tanker markets either in whole or in part, but none on the modelling and forecasting of oil tanker supply. Thus this will be the focus of the chapter.

As has already been mentioned, most of the existing works or models are on the freight rates market rather than tanker supply. However, the argument is that freight rate and tanker supply markets are so interdependent that we can only have a proper understanding of the dynamics of one by analysing both. Existing models have failed to consider the expectations that could have improved the forecasts. There have been only occasional applications of the more recent techniques such as unit root, cointegration analysis and the modelling of error correction mechanisms in time series data. Will these developments improve the reliability of the resulting forecasts? The literature on different forecasting techniques will be examined with emphasis on econometrics (unit root, cointegration analysis and error correction mechanism) and time series models.

3.2 Forecasting Techniques

"When looking at forecasts made in the 1960's and early 1970's one can find many failures but few successes. Indeed one may be shocked at the extent to which the most important forecast and their surrounding assumption had turned out to be wrong".[84] It is asserted that that many are wrong because the methods and the software that were available at the time could not match the volatility of the market. Furthermore, there were many events and qualitative factors that were unable to be incorporated into the model, hence which may explain the inaccuracy of the forecast. Some of the forecasts were wrong because of the use of inadequate techniques. However, technology has improved and better techniques can be used with different types of computer software packages.

[84] Beck, P., "Forecasts opiates for decision makers" A Lecture to the Third International Symposium on Forecasting, June 5, Philadelphia. In: Stopford, M. *Maritime Economics*, Routledge, 1992, p. 325.

Forecasts are either subjective or model-based;[85] subjective forecasts are based on guesses, experience or intuition. This particular method does not follow any clear information in a formal way. This type is very common with some shipowners, they rely much on the past efforts, with the belief that the future should follow the same rule. There is a possibility that the same information given to two different people will yield different results. The example thus shows the inconsistency of the method. Also the analysis of such a method in particular is very difficult. It is not possible to say whether it is bad or not and learn from the past forecast error. Dawes(1986)[86] compares the result of making decisions based on intuition:

(a) Subjective 'gut feelings' for the situation, this can be said to be a decision based on one's idea about the situation or the reasoning level of the person in question. In this case no other knowledge is involved.

(b) A rational consideration of the relevant positive and negative points takes into consideration all other information available from the present and the past. These are assumed to improve decision-making.

However, the conclusion is that while method (a) is popular (particularly with the experts) there is a strong reason to believe that formal approach of method (b) will give better results. This thesis will confirm the evidence of the statement made in

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[85] Holden, K.., *Economics Forecasting- An Introduction.* Cambridge University Press, 1991.

[86] Dawes, R.M., "Forecasting ones own preference", *International Journal of Forecasting*, 1 2, pp. 5-14.

(b), when the model considers the various factors and their causal inter-relationships before making decision.

Delphi Techniques - This is a technique based on expert survey or sometime called 'Jury of executive opinion' relies on combining the views of experts in a series of forecasting rounds. The basic idea is that a number of experts are asked independently, to forecast some particular event, such as the growth in total market supply over the next 5-10 years. The results are collected together and discussed by the expert. They will then have to justify their results. It takes many rounds before any conclusive result can be obtained. The advantage is the combination of views of several experts, and the disadvantage is the effect of the individual personalities. However, the method is based is an intuitive one and cannot be guaranteed. Parent et al (1987).[87]

The model-based forecast arises from a rule that formalises the relationship between the variables that are considered pertinent in the circumstances. In much of the literature on forecasting, attention is focused on the distinction between causal and non-causal models.

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[87] Parent, F.J. and Anderson-Parente, J.K.., "Delphi Inquiry Systems", In: G Wright and P. Ayton (editions). *Judgmental forecasting Chichester*: John Wiley and Sons, 1987, pp. 125-156.

The causal type utilises an explanation of how the values of variables are determined, while non-causal are solely concerned with predictions rather than with understanding behaviour. Non-causal models, such as extrapolation, do not present any explanation of the mechanism generating the variables but simply provide a method for projecting the historic data. The other common complex non-causal method is the Box-Jenkins univariate time series model. This method uses the current value of a variable and expressed it as a function of a selection of past values of the same variable and past errors. Also by given past observations, it is possible to predict future values. This is useful for predicting future values of the exogenous variables in an econometric model, which are then substituted in the relevant equation for estimation.

Causal models are intended to explain behaviour by identifying the links between different variables. The correct causal model is assumed to give better forecast than a non-causal model. Causal models assume that the factors to be forecasted show a cause-effect relationship with one or more independent variables. Thus the purpose of causal modelling is to discover the form of that relationship and use it to forecast future values of the dependent variables. The importance of these variables has called for the analysis of unit roots, and the application of cointegration analysis and error correction mechanisms where relevant. This will enable the author to justify the use of the variable by avoiding problems generated by non-stationary data. The importance of this is to eliminate properties of spurious regressions.

3.2.1 *Regression Model*

Regression analysis is a causal explanatory approach to forecasting. The model attempts to predict the future by discovering and measuring the effect of important independent variables on the dependent variable.

An important procedure in regression is to obtain valid economic data. Belsley(1980)[88] emphasised the need for regression diagnostics in identifying influential data and sources of collinearity. It is very important to discover and measure the relationships of variables and use them to forecast.

The reason for regression diagnostics is to test the equation for weakness. The t-statistic test whether the dependent variable depends on the independent variables. The t-values are determined by the ratio of the estimated regression coefficient to its standard error. It also tests the significance of the coefficients. The R-squared (R^2) and bar R-squared (R^2) measures the dispersion of observations around the regression line. F-statistics shows the percentage of dependent variable that is explained by the independent variables. This is the null hypothesis that the

[88] Belsley, D.A., E. Kuh and R.E. Welsch, *Regression diagnostics: Identifying influential data and sources of collinearity*. (Willey, New York), 1980.

regression equation coefficients are not equal to zero; except the intercept. The Durbin Watson tests for the presence of first order serial correlation among the error terms. The presence of serial correlation leads to an incorrect estimation of the regression coefficients. The Box-Ljung statistic takes account of the residual autocorrelation. Therefore, the diagnostics test examines the statistics of an equation using different methods to evaluate the equation statistics. The remainders of these tests are in appendix D.

In section 3.4.2 the argument that the regression analysis leads to the estimation of econometric model can be confirmed. The application is the same since they both use endogenous and exogenous variables. See section 3.2.2 on econometrics. The statistical bases for the regression equations will be examined in appendix D. The idea here is to explain the techniques and not to go into detail. The thesis has used the computer packages SPSS (Statistical Package for Social Sciences), Microfit and RATS (The regression analysis and time series) to calculate the parameters. Almost all the econometric literature examined has in one way or the other employed regression method. For example, Beenstock and Vergottis (1989),[89] applied regression analysis in their econometric model of the dry cargo and tanker markets.

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[89] Beenstock, M. and Vergottis, A. "An Econometric model of the world Tanker Market", *Journal of Transport Economics and policy*, September 1989, pp. 263 - 279.

The Reasons for Using Regression in the Thesis

Economists and other social scientists rely heavily upon the use of linear regression analysis when investigating behavioural relationships. This tool aids considerably the understanding of economic and other social phenomena.[90]

Regression analysis has been used in many of the papers examined as a means to forecasting. However, as it was stated above, there are numerous examples from other fields besides shipping. Jonsson(1994),[91]examined car expenditure by chosen the relevant variables and regressed the dependent and the independent variables to obtain the regression equation. Sjognist(1974)[92] said that the regression analyses relates various social variables together. The author applied regression analysis to obtain a model that was later used in forecasting car expenditures. Other authors who have employed regression analysis in their work are Zellner (1962)[93] and Carlson (1978).[94] Both have applied linear regression to determine the demand for automobiles in different sizes. The author assumed that

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[90] Sjognist, David L., Scroeder Larry D. & Stephan Panda E., "Interpreting Linear regression analysis: A heuristic approach" *University Programs Modular, Georgia State University*, University Learning Corporation 1974.

[91] Jonsson, Bo and Anders Agren, "Forecasting Car Expenditures Using Household Survey Data", *Journal of Forecasting*, 13, 1994, pp 435-448.

[92] Sjognist, et al., Op cit., p.67.

[93] Zellner, Arnold, "An efficient method of estimating seemingly unrelated regression equations and tests for aggregation bias". *Journal of the American Statistical Association* 57, June 1962, pp. 348-368.

[94] Carlson, R.L. (1978), "Seemingly Unrelated Regression and the Demand for Automobiles of Different Sizes, 1965-75: Disaggregate Approach". *Journal of Business* 51, (2) 1978, pp. 243-262.

a linear model is the best functional form for the analysis. Carlson(1980)[95] used regression model to appropriate the effect of energy shortages on the demand of automobiles and generate forecasts. The method enabled the author to examine the relationship of the economic variables in the equations. Pucher et al.(1983),[96] McGeeham(1984),[97] Dielman(1985),[98] Holden et al.(1985),[99] Mohammed(1988),[100] Sandbach(1988),[101] Lacivita et al.(1988)[102] and Pain(1994)[103] all have applied regression analysis in building models to forecast different economic variables. Including the papers mentioned above Evans (1968)[104] has used regression analysis in building an econometric model, this is

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[95] Carlton et al. , "Statistical Demand Functions for Automobiles and Their use for Forecasting in an Energy Crisis", *Journal of Business* 53, (2) 1980, pp. 192-204.

[96] Pucher John, Anders Markstedt and Ira Hirschman, "Impacts of Subsidies on the Costs of Urban Public Transport", *Journal of Transport Economics and Policy* 17, (2) 1984, pp. 155-176.

[97] McGreeham, H., "Forecasting the demand for Inter-Urban Railways Travel in the Republic of Ireland" *Journal of Forecasting* 18, (3) 1984, pp. 275-292.

[98] Dielman, Terry E., "Regression Forecasts when Disturbances are Autocorrelated". *Journal of Forecasting*, 4, pp. 263-271.

[99] Holden, K. and Peel, D.A., "An Evaluation of Quarterly National Institute Forecasts". *Journal of Forecasting* 4, pp. 227-234.

[100] Mohammed A. Al-Sahlawi, "Gulf Corporation Council Energy Demand Outlook to 2000". *Energy Economics*, January 1988, pp. 42-46.

[101] Sandbach Jonathan, "The Sensitivity of Consumption of Oil Products to Price Changes - An Econometric Investigation". *Energy Economics* (October, 1988): pp. 261-270.

[102] Lacivita Charles J. and Seaks Terry G., "Forecasting Accuracy and the choice of first difference or percentage change in regression models", *International Journal of Forecasting* 4, 1988, pp. 261-268.

[103] Pain Nigel, "Cointegration and Forecast Evaluation: Some Lessons From National Institute Forecasts". *Journal of Forecasting* 13, 1994, pp. 481-494.

[104] Evans, Michael K. and Klein, Lawrence R., *The Wharton Econometric Forecasting model*, Economic Research Unit, Department of Economic, University of Pennsylvania, 1968.

called the Wharton Econometric Forecasting Model. Cargill(1971)[105] estimated the demand for electricity using linear regression, this econometric model was built with the assistance of regression analysis. The author estimated a 24 equation system that was later used in estimating the demand for electricity by time of day.

3.2.2 Simultaneous-equation Forecasting Models

The single equation model was discussed in the previous section. However, there are situations where a one way or unidirectional cause-and-effect relationship is not appropriate. This can happen where Y, the dependent variable, is not only determined by X's, but some of the X's are determined by Y. When these occur there is a simultaneous relationship between Y and the X's; for a more efficient result there is a need for a joint estimation of the coefficients.

The simultaneous equation method will estimate the model with due consideration to all the variables and equations in the system. The parameters will then take into account the information provided by the equations in the system. The application of systems estimation will eliminate bias that is peculiar to single equations.

[105] Cargill, Thomas F. and Meyer Robert A., "Estimating the Demand for Electricity by Time of Day". *Applied Economics* 3, pp. 233-246.

Many econometricians have extensively use simultaneous equation models. One of the pioneers in this area was Professor Lawrence Klein of the Whaton School.[106]

The modelling of simultaneous equations implies that there is interdependence among the endogenous variables. As a result these variables are not independent of the stochastic disturbance terms. Therefore, it renders OLS inappropriate to the individual equations of the system. The application of OLS will result in the inconsistent and biased results.

Many articles have demonstrated the use of the simultaneous equation method. Bass studied the relationship between advertising expenditure and the sales of cigarettes.[107] One of the criteria is that the simultaneous equation must be identified.[108] The identification processes will be examined in chapter 4. There are other authors who have contributed to the formulation of simultaneous equations, such as Fair (1972) who examined the efficiency of simultaneous equation with autoregressive errors using instrumental variables as instruments.[109] Hausman

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[106] Klein, L. R., *Economic Fluctuations in the United States, 1921-1941,* New York: John Wiley and Sons Inc., 1950.
[107] Bass, Frank, "A simultaneous Equation Regression Study of Advertising and Sales of Cigarettes", *Journal of Marketing Research,* 6, (August 1969), pp. 291-300.
[108] Green, W. H., *Econometric Analysis*, 2nd Edition, Macmillan Publishing Company 1993. pp.585-598.
[109] Fair, R., "Efficiency Estimation of Simultaneous Equations With Autoregressive Errors by Instrumental Variables", *Review of Economics and Statistics* 54, 1972, pp. 444-449.

(1983) is another contributor to the specification and estimation of simultaneous equation model[110]

The estimation technique and the model specification of this thesis is different from others. Beenstock et al., (1989) use system estimation methods for freight rates and time charter equations. These authors simply use this method for two equations within their single (OLS) equation model. This thesis will use simultaneous equations for this model. This is a system of equations; a jointly estimated model. Many of references cited above have used single equation methods to estimate models. However, simultaneous equation methods have been used in other areas such as the modelling the macro economy, marketing research and other areas besides shipping.

3.2.3 *Econometric Forecasting*

Econometric forecasting has been used in various macro economic models. It is a special case of multiple regression models. The model can include any number of variables or number of simultaneous multiple regression equations. It also denotes a system of linear equation involving several interdependent variables. In order to build an econometric model with a purpose of forecasting, it is important to follow these procedures:

[110] Hausman, J. A., "Specification and Estimation of Simultaneous Equation Models", Z. Griliches and M. D. Intriligator, Eds, *Handbook of Econometrics,* vol. 1, Amsterdam: North Holland Publishing Company,

1. The use of the relevant theory for explaining economic behaviour. The decisions as to which variables are of interest; those to be explained are the endogenous variables and those that are determined outside the model are the exogenous variables. Also, within the variables there are predetermined variables that may have lagged or lead values. The idea is that the variables must directly affect oil tanker supply, otherwise the result could be wrong and biased.

The advantage of this method is that it can make use of as many as possible exogenous variables. However, according to Armstrong (1978),[111] it is not necessary. The author surveyed the published studies concerning econometric models and his conclusion was that complex econometric models did not perform better when compared with simpler econometric models. Fair, R. C. (1974)[112] and McNee, S.K.,(1973) econometric model forecasts of ex-ante and ex-post was tested by these authors and compared for accuracy.[113] What is important to determine the accuracy of the model is the relevancy of the variables coupled with simple and valid equations.

1983, pp.392-438.

[111] Armstrong, J.S., *Long Range Forecasting: From Crystal Ball to Computer.* New York: Wiley Interscience, 1978.

[112] Fair, R.C., "An Evaluation of Short-Run Forecasting Model", *International Economic Review* 15, (2), 1974.

[113] McNee, Stephen K., "The Predictive Accuracy of Econometric Forecasts," *New England Economic Review*, (September/October, 1973): pp. 3-27.

2. The theory looked at the series of equations linking together these variables. Particular attention was given to the leads and lags variables in the equation. The examination of the information that are available from the historic data and the anticipation of the future is always considered as "market expectations" of the tanker operators. These variables are known to be pre-determined.

3. The data are collected on the selected variables; the idea is to keep the data as close as possible to the theoretical concept. Freight rate index is a determinant factor of tanker supply. The economic reason behind this is that the freight rates represent the price paid to shipowner, for the use of tankers. This has happened as a result of the price mechanism of demand and supply. It is an assumed situation where the "freight rate" influences the level of tanker supply.

4. Then there will be an estimation of the numerical values of the unknown parameters using the simultaneous-equation methods.

5. After estimating the equations, the future of the exogenous variables will be predicted in order to obtain forecast of endogenous series.

It is understandable that accurate forecasting would require not only the correct economic theory but also correct decisions at each of the stages in the forecasting procedures. The importance of this method will be further discussed in chapter 4 and 6.

Exogenous variables are being used in order to explain the endogenous variables. The techniques of unit roots, cointegration and error correction mechanism will be used in determining the long run relationship of the series. The short run relationship through ECM will be left for further studies. These are to show the causality, and to determine whether there is a long-term equilibrium. The stationarity of the variables is always going to be an important issue to achieve a better forecasting result.

3.2.4 Econometrics Investigation

In order to ensure that the variables in the regression equation constitute formalised relationship, it is very important to look at the statistical properties of the chosen variables.[114] Granger first suggested the relationship between cointegration and error correction models.[115] An individual economic variable viewed as a time series can wander extensively and yet some pairs of series may be expected to move so that they do not drift too far apart. A similar idea arises from considering the equilibrium relationships; where the equilibrium is in a

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[114] Robert F, F. Engle and C.W.J Granger, "Cointegration and Error correction: Presentation. Estimation and Testing". *Econometrica* 55, 2, (March 1987): pp. 251-276.

[115] Granger, C.W.J., *Some properties of Time Series Data and Their Use in Econometrics*, New York: Academic press, 1981, pp. 121-130.

stationary point characterised by forces that tend to push the economy back toward equilibrium whenever it moves away.

The author put the idea of cointegration and error correction into practice. What he is just pointing out is that class of model known as error correction allows long run components of variables to obey equilibrium constraints, while short run components have a flexible dynamic specification. Evidence of this can be seen in Granger and Weiss (1983).[116] However, the economic variable or series must be differenced if they are non-stationary, before being incorporated into a regression model. It is very important to test whether a set of variables is cointegrated.

The authors proposed three test statistics and these were calculated by analysing least squares (OLS). The critical values were estimated for each of these statistics by simulation using 10,000 replications. When using these critical values, the powers of the test statistics are computed by simulation under various alternatives.

1. CRDW[117]: After running the cointegrating regression, the Durbin Watson statistic is tested to see if the residuals appear stationary. If they are non-stationary

[116] Granger, C.W.J., and A.A. Weiss, "Time Series Analysis of Error-Correcting Models", in *Studies in Econometric, Time Series, and Multivariate Statistics*. New York: Academic Press, 1983, pp. 255-278.

[117] CRDW - Cointegration regression of Durbin Watson

the Durbin Watson will approach zero and the test rejects non co-integration if DW is high.

2. DF - This test the residuals from the cointegrating regression by running an auxiliary regression as described by Dickey and Fuller.[118] The statistic is compared with DF statistics to know whether it is significant or not.

3. ADF - The augmented Dickey Fuller tests allows for more dynamic in the DF regression and consequently is over-parameterized in the first order case, but correctly specified in the higher order case.

Banerjee, A. et al (1992)[119] examined the tests for integration and cointegration. In order to get a proper result, the series must be stationary. The integration must be of the order of one I(1). The propositions of these authors are not different from the one proposed by "Granger et al 1987". The representation theorem links cointegration to error correction mechanism (ECMs), so that ECMs do not necessarily violate rationality in an I(1) world. By examining the level of integration and cointegration, it is then possible to know the existence of a long run relationship of the series before devoting resources to modelling. Once a long run relationship is established, then conditional on a reduction from I(1) to I(0) the analysis proceeds much as it used to, although many difficult empirical problems

[118] Dickey, D. A. and W.A. Fuller, "Distribution of the Estimations for Autoregressive Time Series With a Unit Root", *Econometrica* 49, 1981, pp. 1057-1072.
[119] Banerjee, A. and D.F. Hendry, "Testing integration and Cointegration: An Overview", *Oxford Bulletin of economics and statistics* 54, 3(1992), pp. 225-255.

remain. More explanation on stationarity, co-integration and Error Correction Models can be found in Banerjee, A. et al (1993)[120]

Blough, S. R. (1992)[121] examined variables with unit roots and the power of generic unit root tests in finite samples. He argued that the relationship is close for a given sample size; the power against any stationary alternative can be no greater than the true level of the test. He confirmed that "unit root tests are often used to provide information about the distribution of statistics. The asymptotic distributions of such statistics often depend crucially on whether the underlying processes have unit roots."[122]

It is important to distinguish between test of the unit root hypothesis for its own sake and unit root test as diagnostic for purposes of empirical model specification using OLS regression of two independent processes. The property of the unit root test follows from the fact that any stationary process can be reached as the limit of a sequence of unit root processes. Any stationary process has unit root processes.

[120] Barnerjee, A. , J. J. Dolado, J. W. Galbraith and D. F. Hendry, *Co-integration, Error Correction and the Econometric Analysis of Non-Stationary Data*. Oxford University Press, 1993.
[121] Blough, S.R., " The Relationship between Power and Level for Generic Unit Root Tests in Finite Samples", *Journal of Applied Econometrics* 7, 1992, pp. 295-308.

[122] Ibid.

An in-depth test of unit autoregressive root in time series was also conducted by Leybourne(1992).[123] The author has tested for unit autoregressive roots in observed economic time series. As in papers, such as Grangers and Weiss discussed above, it is important to be able to establish whether a particular series has a unit root or is stationary, as the properties of the series depend concisely on the characteristics. The result of the sample was compared using DF and ADF (Dickey-Fuller and Augmented Dickey- Fuller) statistics.

Dolado, J. J. et al (1990)[124] also emphasise the importance of cointegration and unit roots. The authors conclude that economic theory dealt generally with equilibrium relationships and that most empirical econometric studies are attempts to evaluate such relationships. In order to apply standard inference procedures the variables have to be stationary, since most econometric theories are built upon the assumption of stationarity.

The integrated variable is a specific class of non-stationary variables with important economic and statistical properties. Box and Jenkins (1970)[125] argue that a non-stationary series can be transformed into a stationary one by successive

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[123] Leybourne, S. J., *A simple test for a unit root*, Discussion Paper in Economics and Econometric (no.92/20), Department of Economics, University of Nottingham, 1992.

[124] Dolado, J. J., Jenkinson, T. and Sosvilla-Rivero, S., "Cointegration and unit Roots", *Journal of Economic Surveys* 4,. (3), 1990, pp. 249-273.

[125] Box.G and Jenkins, G., *Time Series Analysis, Forecasting and Control*. San Francisco: Holden Day, 1970.

differencing of the series. Furthermore, the concept of cointegration tries to portray the existence of a long-run equilibrium to which an economic system converges over time. The author of this thesis believe that if two variables are cointegrated, then there must exist an error correction model (ECM). Test for cointegration can be carried out by estimating the OLS of the series that should show whether the series are cointegrated of the order of I(1).

Dickey, D.A. et al(1986)[126] examined the implications of unit roots in time series models. The author in order to illustrate the implication of unit roots, used the models; $(1-\alpha_1 B - .... - \alpha_{p+d} B^{p+d})(Y_t - \mu) = (1 - \theta_1 B - ... - \theta_q B_q) e_t$. Where $t=1,2,3,....$, B is the backshift operator ($BY_t = Y_{t-1}$), $\alpha_1....\alpha_{p+d}$, $\theta_1,....\theta_q$ and σ^2 are parameters and e_t is a series of iid random shocks with mean 0. Therefore, $p+d = 1$ and $\mu = 0$. It was accepted that depending on the result, the present can be as important as the past, where $0 < \alpha < 1$, for when $\alpha = 1$ the past is equally in important as the present, and for $\alpha > 1$ the past is more important than the present. There was a study of implication of unit root and the use of the non-stationary in series. The author examined non-stationary data, he differenced the series and he looked at the effect of removal of a linear trend. There is a suggestion that without differencing, time series variables will be incompletely analysed. The result from such an analysis cannot be relied upon.

[126] Dickey, D.A., William, R. Bell, and Robert B. Miller, "Unit Roots in Time series Models: Tests and Implications", *The American Statistician* 40, (1), 1986, pp. 12-26.

Engle, R.F. et al (1989)[127] emphasised the use of short and long run models in order to allow for comparisons. They looked at data for electricity sales, they found existing models inadequate. The model seriously omits the long run or trend component in its modelling. As a result, a possible improvement to the short run model is to impose the unit root restriction and estimate the model in differences. Application of the suggested method considerably improved the result of their forecast of electricity sales.

Bentzen, Jan (1994)[128] examined the demand for gasoline by using functional variables such as consumption, the real price of gasoline, and real income. He assumed that the variables such as the ones used in his work will be non-stationary (most time series data are) which means that the first difference is more appropriate in regression. However, he opted to develop a cointegration and error correction model. This shows the long run relationship of the variables and he estimated the error correction model. The Dickey-Fuller test for stationarity was performed for all series, and the results of the t-values for the parameters' estimates were compared with the critical value specified in the Dickey-Fuller table. In his example the series happened to be non-stationary, I(1) variable, the t-

[127]Engle, R. F., C.W.J. Granger, and J.J. Hallman, "Merging short and Long run Forecasts: An Application of Seasonal Cointegration to Monthly Electricity Sales Forecasting". *Journal of Econometrics* 40, 1989, pp. 45-62.

[128] Bentzen, Jan, "An Empirical Analysis of Gasoline Demand in Denmark using Cointegration Techniques", *Energy Economics* 16, (2) 1994, pp.139-143.

values in the DF/ADF test are far below the critical level. The unit root hypothesis in this case cannot be rejected for any of the series. When he confirmed the long run relationships of the series he then estimated the short run by the application of error correction mechanism.

Perron, Pierre (1989)[129] observed that the most important implication of the unit root revolution is that under this hypothesis random shocks have a permanent effect on the system. As a result the idea that unit root hypothesis is an empirical fact was tested for reliability. The author concluded that most time series are not always covered by the presence of a unit root and that the fluctuations are indeed moving from time to time.

3.2.5 *Time Series Forecasting*

Time series are certainly one of the oldest and most widely used techniques. The Box-Jenkins forecasting technique seeks in systematic manner the forecasting model that is best suited to each item under investigation. ARIMA model is the name given to the Box-Jenkins (Autoregressive Integrated Moving average) time series model. These approaches are theoretically and statistically very appealing.

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[129] Perron, Pierre, "The great crash, the oil price shock, and the unit root hypothesis". *Econometrica* 57, (6) 1989, pp.1361-1401.

3.2.5.1 *Box and Jenkins Techniques*

Box and Jenkins (1970)[130] the technique is highly sophisticated in both mathematics and computational aspects. Anderson (1976)[131] suggests that the number of observation for time series should be fifty and above. However, all the authors who propagate this have never given any reason for their suggestion other than for better results.

Autoregressive Models(AR) are based on the application of regression analysis to lagged values of the Y_T series (AR(p)). Autoregressive processes have always been popular, partly because they have a natural interpretation, and partly because they are easier to estimate than (MA) or mixed processes. The first point to establish about an AR model is the conditions under which it is stationary.

Moving Average (MA) the moving average forecasting techniques are one of the easiest time series model to use and understand. With this technique, it is assumed that the pattern exhibited by the historical observations can best be represented by an arithmetic mean of past observations. The presence or absence of seasonal, cyclical and irregular forces in the moving average depends on the length of the moving average.

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[130] Box and Jenkins, Op cit., p. 82.

[131] Anderson, O. D., *Time Series Analysis and Forecasting - The Box-Jenkins Approach*, Butherworth, London and Boston, 1976.

There are two limitations to the moving average techniques. First, the data storage requirements, thus costs are sometimes high. In the computation of a moving average the previous number of observations must be available. Secondly, a moving average is influenced only by those periods included in the average and each period shares equally in the forecast. It can be argued that more recent observations are likely to contain more pertinent information, hence should have a greater effect on future forecast values. This has led to the weighted moving averages and double moving average. By using a linear or weighted method, greater importance can be given to more recent observations. Despite the more complex systems, a simple moving average appears to be the most widely used form. There must be emphasis on the length of moving average system to use. This is held to be particularly important as short or long-term averages can give very different signals. The detailed application of Box-Jenkins will be given in chapter 8 and appendix E.

Transfer Function Model or Multivariate Model

The model combines some of the characteristics of the univariate ARIMA models and some of the characteristics of multiple regression analysis. This is a method that blends causal model with time series models. Because of the complication of this model the expert recommends the use of computer.[132]

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[132] Makrisdakis/ Wheelwright/ McGee, *Forecasting - Methods and Applications.* Second Edition, John Wiley & Sons, 1983, pp. 479-534.

The above lists of time series forecasting techniques are not exhaustive. There are many other techniques that can be applied in forecasting oil tanker supply such as extrapolation. Fildes, R. (1979)[133] examined the importance of extrapolation and he criticised it. However, the present research has applied the time series forecasting (Box Jenkins ARIMA) the purpose is to compare with econometric forecasting.

3.2.6 *Exponential Smoothing Forecasting*

Exponential smoothing is one of the most consistently used models. Despite the name it is an extremely simple technique to understand and apply. New forecasts are derived by adjudging the subsequent forecast to reflect its forecast error. In this way, the forecast can continually be revised, and use these forecasts on past experience. In addition to this feature, exponential smoothing offers several advantages.

The exponential smoothing model can adapt very easily to computer systems; the data storage requirements are minimal when compared with other forecasting models. The current forecasts of exponential smoothing model are based on all previous historical observation. The model has all the advantages of a weighted

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[133] Fildes, R., "Quantitative Forecasting - The State of the Art: Extrapolative Models" *Journal of operational Society* 30, (8) 1979, pp. 691 - 710.

moving average, thus current observations are assigned larger weight and then the model reacts more quickly to changes in economic conditions.

The exponential model was developed by Holt[134] and Brown.[135] There are three types of methods to compute the model, the single exponential smoothing, double exponential smoothing and adaptive exponential smoothing. The procedures of computation are the same but it is the parameters that are different. The mathematical computation of the model will be found in chapter 8 and appendix E.

The major advantages of these smoothing methods are their simplicity and low cost. There is little doubt that better accuracy can be obtained on the more sophisticated methods. When the data series is stationary, the adaptive-response rate single exponential smoothing is often preferred to single exponential smoothing. The latter method requires specification of *alpha* in such a way as to minimise the MSE (Mean Standard Error). The adaptive response rate exponential smoothing adjusts itself by changing the value of *alpha* to follow basic changes in the data. Although, it may take one or two periods of alpha to catch up with changes in the data pattern, it will eventually do so. Thus even if the forecasts

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134 Holt, C.C., *Forecasting seasonal and trends by exponentially weighted moving averages*, Carnegie Institute of Technology, Pittsburg, Pa., 1957.

135 Brown, R.G., *Statistical Forecasting for inventory Control*, New York, McGraw - Hill Book Company, 1959.

from this method are somehow inferior to the single exponential smoothing with a high alpha it is often preferable because it reduces the risk of serious errors.

3.3 The Existing Literature on Forecasting

There is no specific literature on the forecasting of oil tanker supply. In the area of econometrics, there have been various econometric models (see section 3.4), some of them are dated. However, the thesis will address this area of shipping because there has never been any academic literature on the forecasting of one million barrel oil tankers. To be more precise, the thesis attempts to address two things not yet addressed in the literature, namely:

(1) the econometric forecasting of the supply of million barrel oil tankers.

(2) the analysis, forecasting and comparison of the forecasting results.

There is no proper forecasting of oil tanker supply, as a result the author has emphasised the need for forecasting as the second objective of the thesis. Most of the existing literatures on forecasting are not on tanker shipping, but there is evidence that the method can be very useful to forecast supply of one million barrel tankers.

Amano (1987)[136] the author built the econometric model of the World oil market to forecast for oil prices. The model consists of 32 equations of which 23 are definitional and 9 are estimated. The model was used as a standard forecast exercise that was based on OPEC decisions at the time. The model treated individual areas affecting oil market, the consumption of oil in OECD and Non-OECD. Oil consumption is basically determined by two main variables; the level of economic activity and real oil prices. The supply of oil would be affected by real oil prices. The model simulation was to predict a possible outcome of the OPEC decision reached at the time, in 1986. The applications of single multiple equation to forecast world oil market with a result is somewhat common; he should have used system equation method. He estimated and predicted each of the variables separately; there is evidence of short sightedness and omissions in the model and the forecasts. The forecasting method used for this particular situation was neither tested for accuracy nor checked for forecast errors.

Ma, Cindy W., (1989)[137] examined alternative forecasting models. There is emphasis on the relationship of the variables within a model. In order to obtain a good forecast of dependent variables, it is essential to forecast the explanatory

[136] Amano Akihiro, "A small forecasting model of the World Oil Market". *Journal of Policy Modelling*, 9 (4), 1987, pp. 615-635.

[137] Ma, Cindy W., "Forecasting Efficiency of Energy Future Price". *The Journal of Future Markets*. 9, (5) 1989, pp. 393-419.

variables as well.[138] In this thesis the author uses sets of variables in one model to forecast another dependent variable. Then this can be substituted in the forecast result of one model in the process of forecasting other endogenous variables. As stated by Meese and Rogoff(1983),[139]the structural models have high explanatory power, but they predict badly. This is because the explanatory variables are themselves difficult to predict. In Ma's paper, five time series models were examined; the random walk, univariate autoregressive integrated moving average (UARIMA), Multivariate autoregressive integrated moving average (MARMA), unrestricted vector autoregression (URVAR), and Bayesian vector autoregression (BVAR). The random walk models use the current supply as a predictor of all future supply. This follows the same pattern as univariate time series model. She analysed the random walk model but does not estimate. She introduced the models to compare with other models. This is to know the most cost affective and the one with minimal error among the models. The UARIMA models use only past values and past error of the individual series that are being modelled. These do not use any information from other series in order to forecast other series. MARMA models uses past values and implements other variables to obtain better forecasts.

[138] Ibid.

[139] Meese, R.A. and Rogoff, K., "The Out-of Sample Failure of Empirical Exchange Rate Models of the Seventies: Do They Fit Out-of-Sample?" *Journal of International Economics* 14, 1983, pp. 3-24.

McNees, S.K. (1973)[140] focuses on economic forecasts that are based upon econometric models. "In contrast to purely judgmental or non-econometric forecasts, an econometric model forecast is produced by a specifically defined reproducible principle or methodology."[141] The author has explicitly emphasised on ex-ante (before the fact) forecast and ex-post (after the fact) forecasts. It is the opinion of McNees that the econometric forecasts would make possibly a better assessment of the forecast. Though one of the authorities on forecast evaluation, (Professor Stekler) as reported by McNees[142] has argued that evaluation of the forecasting accuracy of economic models should be based on the model's ex-post predictions. He believed "that the entire rationale behind evaluating the forecasting record of alternative approaches and different models is to select the techniques which is superior. The profession is less interested in knowing which man had the best average".[143]

Cooper, J.P. and Nelson, C.R. (1975)[144] These authors compared the prediction of econometric models of the US economy, using Box-Jenkin's[145] time series models

140 McNees, S. K., "The Predictive Accuracy of Econometric Forecasts". *The New England Economic Review*, Sept./Oct. 1973, pp. 3-27.

141 Ibid.

142 Ibid.

143 Ibid.

144 Cooper, J.P. and Nelson, C. R. (1975) "The Ex Ante Prediction Performance of the St. Louis and FRB-MIT-PENN Econometric Models and Some Results on Composite Predictions". *Journal of Money, Credit and Banking*, 7, 1975, pp. 1-32.

to provide a bench-mark for accuracy. The model tested the correlation between Ex-post, Ex-ante and ARIMA. Another rigorous test of econometric model is their ability to predict post sample data. The accuracy of the model was then tested against ARIMA model by using the Root Mean Square Error (RMSE). This paper has a common factor with Ma (1989)[146] and McNees(1973)[147] testing the accuracy of econometric forecasting with other forecasting methods using post sample period data. The conclusion is that the examination of post sample prediction clearly reinforces the facts and that no single model or predictor can dominate the other. The estimated econometric and ARIMA univariate model was compared and the errors are assessed with (RMSE) Root Mean Square Error.

3.4 A Review of the Literature

The incompleteness of the models of tanker market and the forecasting of one million barrel oil tanker supply creates a need for a specific model to forecast one million barrel oil tanker supply.

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[145] Box and Jenkins (1970), Op cit., p. 78.

[146] Ma (1989), Op cit., p. 87.

[147] McNees (1973), Op. cit., p. 89.

Tinbergen(1934),[148] is one of the earliest econometric applications. He investigated the sensitivity of freight rates to changes in the level of demand and the factors affecting supply. He assumed that freight rates moves to set demand to equal supply although this is not explicit in the estimated equation; it is clearly seen in his theory. He uses data for ton-miles, the size of the fleet, bunker prices and freight rates over the period 1870-1913 to estimate the unknown parameters of the model. There was a demonstration of the importance of the three factors, the demand index, the supply index and the coal price on the calculated freight rates. He has used simple equations to determine freight rates.

Koopmans(1939)[149] investigated the behaviour of tanker freight rates. The main work is a theoretical analysis of the determinants of supply in the freight market, supported by some statistical investigations. He placed emphasis on the behaviour of the freight market and provided an explanation of why there are periods of prosperity. The tanker freight rates become extremely volatile and fluctuates around a very high level. Also, there are longer periods of depression when rates are stable at a low level. He concluded that when demand meets supply at the elastic region, the wide fluctuations in demand would have little impact on rates. On the other hand, there will be a change when the elastic demand crosses the

[148] Tinbergen, J., *Sensitivity of Freight Rates to Changes in the level of Demand and Supply.* Amsterdam: North Holland,press, 1934.

[149] Koopmans, T.C., *Tanker Freight Rates and Tankership Building.* Haarlem, North Holland press, 1939.

supply functions at its inelastic region. Small fluctuations in transportation requirements or the size of the fleet would lead to big changes in rates. He neither models the series nor includes any justification for supply and demand to be equal. In this thesis, there will be an examination of supply and demand. It will take into consideration all the factors affecting both variables which justified by the employment of the appropriate statistical tests.

Zannetos(1966)[150] examined and analysed the factors that affect both the demand and supply of tankership rates. He described the underlying factors that affect supply and demand and hypothesised the expectations of the buyer in the tankership market are price elastic. He emphasised that the short-term rates will affect the long-term rates indirectly through expectations. However, he did not use quantitative material on the subject of forecasting tanker demand and supply. Perhaps because data at the time the work was carried out, it was quite possible that an economic model of this nature could be no better than the alternatives, such as a simple statistical forecasting model based on historical time series. Perhaps one of the reasons could be that because at the time the author could not find a particular model that could withstand a critical examination.

[150] Zannetos, Z.S., *The Theory of Oil Tankship Rates. An economic analysis of tankership operation* . Cambridge: M.I.T. Press, 1966.

Hawdon(1978)[151] developed a model that determines tanker's freight rates in the short and long run. In the short run he assumed that the fleet is fixed and the freight rates can be determined by simply considering the freight market. In the long run the fleet however changes with market conditions, and thus the markets for ships must be critically examined. Basically, the author considered freight rate as endogenous and regressed this on factors effecting rates, such as fuel prices, demand per unit of capacity, fleet prices and other variables. Although this is a reduced form equation, there is no suggestion as to how the price of tankers can influence the supply of freight services in the short run, given the fleet. In his shipbuilding market sector; he assumed that shipowners would order new capacity if the volume of oil trade increases and if the freight rate increases, or if the price of new ships falls.[152] Thus Hawdon estimates a demand for new tankers by regressing orders on prices of new ships, freight rates and the volume of oil trade. The result indicates that demand for orders increases with the volume of trade. However, the estimated coefficient of price turns out to be positive, which is contrary to what was expected, while the coefficient on freight rates is statistically insignificant. The results strongly suggest that he has actually estimated a supply schedule rather than demand.

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[151] Hawdon, D., "Tanker Freight Rate in the Short and Long Run". *Applied Economics* 10, September 1978, pp. 203-217.

[152] Ibid.

According to Hawdon[153], tanker deliveries depend on lagged orders and lagged freight rate; this indicates that current orders have a positive effect on future deliveries. Scrapping was said to be affected by the future stream of profits of old ships. The factors affecting scrapping are assumed to be the long term level of freight rates, fleet and oil seaborne trade. Theoretically, the scrap metal price determines whether or not shipowners are prepared to sell for scrapping. Hawdon did not find it to be significant in his work.[154] This could be because it was theoretically viable but not statistically significant.

Nortank - Norman and Wergeland(1981)[155] developed a theoretical model of the freight market for large tankers of over 200,000 DWT. The model is disaggregated into four different types of tankers. In comparison with other models, the authors have neither estimated the econometric model nor forecast the freight rate for large tankers. It is quite important to test models in order to confirm their suitability. Empirically, the behaviour of each of the markets of tankers (large and medium) is different with special reference to "the million barrel tanker". The demand for freight in the large tanker market is assumed to be completely inelastic. This thus reflects on the assumption that demand for oil is perfectly price inelastic at least in the short run. Freight cost constitutes a small percentage in the final price of oil.

[153] Ibid.
[154] Ibid.
[155] Norman V. and Wergeland T., *A Simulation Model of the Freight Market for Large Tankers*, Report number 4, (Norweigian School of Economics and Business Administration, Bergen), 1981.

The authors further say that the equilibrium freight rates for large tankers can be determined by setting the total supply to equal the demand. However, it is assumed *a priori* that freight rate behaviour in the market affects supply and vice versa. The freight rate has been treated as the main factor determining tanker supply; tanker demand volume depends on crude oil movements. The level of tanker demand is most likely to affect change in tanker supply. These authors use micro data.

Charemza and Gronicki(1981),[156]in an integrated model of the shipping markets, focus on the freight rate market, the shipbuilding market, and the scrap market. The author ignored the commonly used assumption that demand and supply in the shipping markets is observed simultaneously. The authors have estimated the demand for oil freight services as a function of the total world trade in oil. In their quest to prove the theory right, a direct exponential relationship was tested between fleet, proportion of freight and the proportion of trade to fleet. One reason for using the exponential relationship is that there are no other means of testing the validity of the theory. This thesis will consider different types of forecasting methods. This will be compared with other forecast results other than simultaneous-equation econometric model. Time series forecast is one of them.

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[156] Charemza, W. and M. Gronicki, "An Econometric Model of World Shipping and Shipbuilding". *Maritime Policy and Management*, 8, (1) 1981, pp. 21-30.

Rander's(1984)[157] model consists of a tanker freight market, a shipbuilding and a scrapping market. The author has disaggregated the freight market into two components; he models both the spot rate and the time charter rate. In contrast to this approach, most of the other models do not distinguish between the time chartered tankers and spot vessels. The Rander model comprises the shipbuilding and scrapping block. In order to determine scrapping, the fleet is disaggregated into new and old ships. Shipbuilding sector comprises the delivery of new tankers. He assumed that in the freight market, supply is identically equal to the size of the tanker fleet; minus the laid-up ships times the vessel utilisation. Where utilisation rate is the number of transportation services generated by a trading tanker. The fraction of ships in the lay-up is related to profitability of the spot market relative to the costs in lay-up. When the rate increases and profitability is high, only very small proportions of tankers are expected to be laid-up. On the other hand when rates are low and profitability of the spot market becomes negative or low, laying-up would minimise losses. The current laid-up tonnage would depend on the projected freight rates and lagged lay-ups. Rander's paper does not model the economic factors that affect the supply of oil tankers.

[157] Rander, J., Dynamo, An integrated model of the tanker market. Working paper 84/9, Norweigian School of Management, Norway, 1984.

In Glen ((1987),[158] [159] the focus is on the differentiation of the oil tanker market. He uses two key elements in the market, the demand and supply. To detect differentiation, the supply and demand patterns are important. Also, there is a need for information on the crude oil that creates employment for tankers; the loading areas for the tankers. The author's PhD thesis has neither modelled tanker supply nor forecast tanker demand and supply.

Beenstock and Vergottis(1989)[160] strongly develops and estimates a full structural model of the tanker market and dry bulk market. The authors examined the total market with the assumptions that all tankers are one size and operate in the same route and generate the same freight rates. The model incorporates a freight market and a market for tankers. The freight rates and supply of oil tankers were jointly determined. They employed rational expectations modelling to capture the present market behaviour. They assumed that time charter rate affects voyage rates, and that prices of new-built oil tankers will affect the expectations of second-hand tanker prices. The demand for tankers is assumed to affect the expectations of profits and capital gains. The model concluded that equilibrium in the freight market depends on the supply and demand for freight services. What the authors

158 Glen, D., "Differentiation in the oil tanker market". *Journal of Maritime Policy and Management* 17, (4) 1990, pp. 289-312.

159 Glen, D., "Differentiation in the oil tanker market". University of London, Unpublished Ph.D. diss., 1987.

160 Beenstock, M. and Vergottis, A., "An Econometric Model of the World Tanker Market". *Journal of Transport Economics and Policy* 23, (3), September 1989, pp. 263-280.

have not done is to consider the disaggregation of tankers. It is quite expedient that disaggregation of tanker should be considered in order to achieve a reasonable forecasting result.

3.5 Criticism of the Existing Tanker Models

The past attempts to model the behaviour and interactions of the tanker markets have been reviewed. These models beginning with Tinbergen and Koopmans to the present have very similar freight market structures.

When Tinbergen and Koopmans is compared with more recent freight market studies, there is an indication that the estimate based on the observation of the elasticity of supply is stable over a very long time.

There are vast differences between various estimated tanker market models; these are not due to theoretical differences. They rather reflect on the level of aggregation chosen and other practical differences in modelling the effect on supply of the freight rate. Other less significant factors such as the waiting time in port and port costs are included. These factors are of minor importance since they are much less volatile over the cycle, so that at one extreme their effects on freight rate supply can be treated as a constant. One of the common assumptions on this is predetermined factors that are external to shipping, and in most cases is assumed to be completely inelastic with respect to freight rates. The other common assumption made is that the freight market at all precise time. The only model that is not having the same view is Charemza and Gronicki (1981)[161].

Many of the models are aggregated, hence the results have not revealed enough understanding of the supply of specific class of tankers. The only exemption is Glen (1990),[162] who has treated individual classes of tankers. He also disaggregated the market by differentiating the market by size, routes and the quasi rent. However, the general aim of the thesis was to examine the issue of tanker market segmentation, rather than to model and forecast the oil tanker market.

Beenstock and Vergottis are the only authors that have employed rational expectations in these modelling. This is assumed to be generated by an extrapolative mechanism of current and recent trends in various variables (including past rates). Thus it helps to predict the future level of freight rates. Any models that extrapolate recent trend or use some other ad hoc backward looking forecasting rule are capable of simulating shipping cycle. The argument is that increase in demand would lead to increase in freight rates and increase in tanker

[161] Charemza and Gronicki; Op cit., p. 95.

supply in the long run. It is assumed that there will be reduction in lay-up, this in the long run will lead to an increase in investment in tankers.

Clearly, none of these models was tested for the presence of unit roots in the variables to determine their stationarity. The reasons are quite understandable; at the time the importance of the stationarity of variables for regression analysis was not properly recognised. In order to improve on this aspect, the stationarity and the long run equilibrium of the variables will be examined in this thesis. It will reveal the existence of any unit roots and reveal the possibilities of the presence of long-run or equilibrium relationship between the target variables. Many of these models are single equation models. It is argued that many of these are inappropriate for forecasting tanker supply. The reason is that most factors affecting tanker supply are interrelated, hence the application of simultaneous equation econometric model is needed.

3.6 New Model for a Million Barrel Tanker Market

A proposed model for tanker supply will be presented in chapter 4. This will be with some features that are new to the modelling of oil tanker market. Most of the

[162] Glen; Op cit., p.97.

models that were examined are aggregated; they only address freight rates as an endogenous variable. The new model is designed to forecast both the supply and demand of one million barrel oil tankers.

In the model, the two most important routes for million barrel tanker will be considered. The oil imports will be examined by using some economic variables to determine the effect on demand for tankers. Growth in demand is assumed to cause changes in supply. Demand and supply for tankers are likely to be influenced by the oil consumption rate through imports. There is theoretical application of market expectation by all oil tanker market players.

The assumption of market expectation and forward-looking behaviour generates a better prediction of behaviour of the market that does not appear in the conventional models[163]. The system does not only respond to current and past movements in the exogenous variables, but also perceived changes in the future level of the external factors. The intention is to imply the behaviour of the market in the model.

This model will be capable of simulating the effect of oil imports as dictated by the economy and other relevant factors. The model is disaggregated and will

[163] Binkley, J.K. and Bessler, D.A., "Expectations of Ocean Bulk Shipping: An Application of Autoregressive Modelling" *The Review of Economic Statistics*, November 1982 , pp. 516-519.

concentrate on one million barrel tanker segment. The supply of this size of tanker has never been examined in this context before.

3.7 Conclusion

The chapter has reviewed the literature on modelling and forecasting and analysed different types of forecasting methods. The existing models of the oil tanker markets have certain limitations. Many of these models are aggregated at all sizes and do not look at the effect of individual segments in the market. Glen (1987),[164] is an exception, he has differentiated tankers by looking at the three different categories. Many of the recognised contributions are single equation models. The majority of the authors have assessed the market by modelling a specific area.

Basically, many of the models focus on freight rate determination and neglect the analysis of tanker supply. Many of these models were built when there were limitations in technology and the use of computers.

It is clear from the review of the literature that there is a potential for applying recently developed econometric techniques to the modelling of tanker markets.
Different forecast methods were also briefly reviewed. It is argued that the econometric model building method will enable a successful analysis of the one

million barrel tanker market, allowing for base freight rates, tanker demand and tanker supply factors.

[164] Glen (1987); Op cit., p. 97.

Chapter 4

MODELLING THE ONE MILLION BARREL TANKER MARKET

4.1 Introduction

Chapter three reviewed past attempts to model the behaviour of the tanker markets. Almost all these papers focussed on modelling freight rate behaviour. In contrast the modelling of markets in vessels has been more subjective. This is particularly true in the areas of the demand for new tankers and the alternative used tankers; and in modelling expectations of growth in the market. Many of the existing models are aggregated models of the demand for freight services rather than focussing on tanker supply.

This chapter presents a model of tanker supply and its determinants. The supply of tankers is explicitly modelled together with the drivers of tanker demand. Changes in deliveries and scrapping rates also affect the tanker stock. The key driver is the demand for crude oil; and the two most important routes of the one million barrel tanker will be analysed. These routes are driven by the demand for crude oil in Western Europe and the United States of America. The demand for oil is itself affected by the rate of economic growth. The magnitude of the trade through West Africa - Western Europe and West Africa - USES is the key to the success of the one million barrel tanker segment.

The model developed here consists of ten equations; nine are estimated, one is an identity. Here the variables that control supply of tankers are being revealed. The explanation of choice of variables will be given; this will improve the ultimate decision that will be made as result of the model.

The increase in the demand for oil in Western Europe and U.S.A increases the employment opportunities for tankers, thus it affects the potential supply of oil tankers in one million barrel tankers. The trends in oil consumption, the demand for tankers and the supply of tankers suggests a long run relationship between them. Moreover, through the critical examination there is confirmation as regards the slope coefficients of demand and supply, in relation to oil consumption and oil imports.

4.2 Methodology

The model presented in the following sections is a representation of demand and supply relationships in the market for one million barrel tankers.

The model has ten equations. These are oil imports Western Europe, oil imports U.S.A., tanker demand, freight rates index, time charter index, newbuilding price, New orders, delivery, scrapping and the supply of tankers. These variables would have impact in the determination of demand and supply of tanker, especially the tanker supply. How influential these factors are can be found out in section 4.3.

The predetermined variables have been chosen with the assumption that the past will reflect on the future. In order to know the effect of the past on the present and to be able to determine the future, the lagged effect of the variables will be considered. The effect of some of these factors on demand and supply of tanker are not instantaneous; e.g. the effect of new orders on deliveries. Also the pattern of oil trade in the past is assumed to influence both the present and the future tanker stock. The predetermined variables are: the oil consumption Western Europe, oil production Western Europe, oil consumption U.S.A, oil production U.S.A, oil seaborne trade, bunker price, shipbuilding cost index, and the lagged dependent variables, including the exogenous variables.

The methodology of the theoretical approach is the following: it will focus on each of the dependent variables. Also, the independent variables in the equations will be specified. One of the assumptions is that the shipowner's aim is to maximise profits, taking into consideration the market situation with all other variables. In order to maximise profit in a competitive world, shipowners will have to consider the demand for oil in Western Europe and U.S.A and the stability of market freight rates.

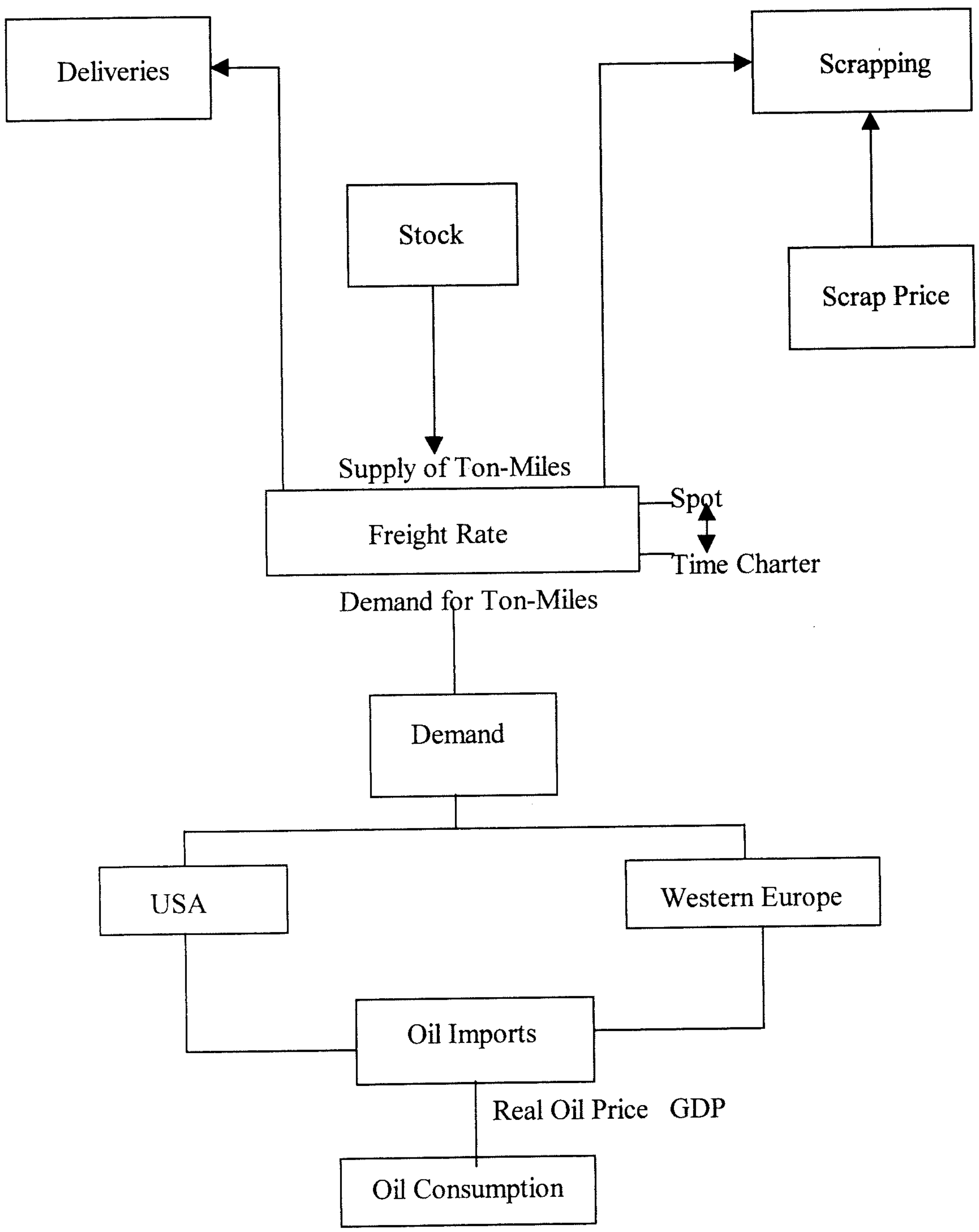
Simultaneous-equation Method

The equations of the model have been estimated jointly, using the simultaneous equation method. The following are the main reasons for using these techniques:

1. It is the only method that can calculate jointly and severally the ten equations using all the variables in the model.
2. It eliminates the bias of individual equation methods.
3. It eliminates bias in the simulation and forecast results since the equations are determined jointly.

The method of two stage least squares (2SLS) will be used in estimating the equations and the model. This is a single-equation method, being applied to one equation of the system at a time. This is argued to provide a satisfactory result for the estimates of the structural parameters. It is also accepted as the most important of the single-equation techniques for the estimation of overidentified models.

Figure 4.1 Oil Tanker Flow Chart
(Million barrel tankers)



Source: Author of this thesis

4.2.1 Summary of the Model Structure

A proper model of tanker supply should at least focus more on the markets for crude oil. In this case, the focus should not only be on the market, but the sources of oil production and consumption. It is then important to begin the theoretical analysis by considering a simple model; the thesis is based on the one million barrel tanker. The market for oil tanker supply would be influenced the freight rate, ship prices, shipbuilding and scrapping market. The analysis of the variables was by computing the simultaneous equations of an econometric model; this is a system approach.

One million barrel tankers are assumed to rely on the demand on main routes, West Africa - Western Europe and West Africa - USEC. Oil consumption and imports from these areas have grown over the years (see chapter 2), thus increasing the demand of oil tankers services. By examining other routes and other areas that have increased their oil imports, the observation of the movement of oil shows an upward trend. However, the author examined the areas that are considered to be the major employer of one million barrel tankers.

Furthermore, crude oil prices and the oil production level of these countries would affect tanker supply. All other things being equal, when the demand for oil increases tanker employment improves. In the short run laid up tankers will be brought into service and in the long run the increase in the demand for tankers would be satisfied. The level of demand and supply are assumed to regulate the freight rate in the market. When there is a reduction in tanker surplus, that is a reduction in the gap between demand and supply, freight rates are likely to improve. When there is a tanker surplus the freight rate may become low depending on factors such as the future prospects. The supply of tankers satisfies the demand.

In the newbuilding market the investors decides whether the level of freight and the number of vessels available in the market justify building new vessels. The assumption is that all vessels are not obsolete. They take into consideration whether there is sufficient trade for the tankers. Newbuildings are tankers for future delivery, and their prices are assumed to be determined in the same way as prices in the futures markets. This is a market where producers and buyers of the products are willing to hedge the risk of an unexpected change in the prices. Also, there are speculators who speculate on prices in order to earn a return if the current and future prices deviate from the expected prices.

Ordering a new ship can only be implemented when the investors envisage that it can justify a reasonable return on investment (ROI); when there is evidence of enough trade to earn sufficient profit. The increase in deliveries of tankers would increase the number of tankers in the market; the effect could be a surplus tonnage; this could be larger if scrapping is low.

A tanker will be scrapped when it is worth very little other than scrap. The scrap value is determined by the given amount of metal in the ship times the scrap prices. The oil prices influences the amount of oil imports at a particular time, having taking into consideration the level of oil stock. Speculation on oil prices in the past had an effect on the consumers; the importers acted when necessary, thus in the long run it affected oil tankers' market, especially the freight rate.

4.3 Tanker Supply Model: An Overview

The number of one million barrel tankers that will be employed in a particular period would depend on oil consumption and oil imports Western Europe and USA. Also, the number of oil tankers that will be employed will depend on the amount of oil transported at a particular period.

Oil Imports and Consumption Western Europe

The quantity of oil that will be consumed will affect Western Europe oil imports. The demand for oil is likely to influence oil tanker supply. The West Africa - Western Europe route in particular is crucial to the million barrel tankers. Thus the quantity of oil imported from West Africa and the million barrel tankers using the route are high, hence the increase in tanker's supply. Therefore, the conclusion is that oil import and oil consumption Western Europe will affect tanker demand and supply.

There are other sources of employment that are considered to be equally significant in this context, such as North Sea oil production. Other sources that would affect tanker supply are the Middle East routes and oil transported to Japan. The percentage of employment for these tankers in the West Africa - Western Europe route is far greater than other sources.

Oil Imports and Consumption USA

As has already been said, the demand for oil tankers of this category depends mostly on the demand for crude oil. It is therefore important to assess the amount of oil consumption in the future before embarking on importation of oil. The West Africa - USES route is one of the largest loading areas for the one million barrel tankers. When the history of USA oil imports and consumption is examined, it will be clear that the loading area is important to million barrel tankers. One advantage is that large tankers are not allowed in US waters as result of draft and shallow waters; it makes one million barrel tankers to be favourite in the area. However, there are other minor routes, but in this analysis the two largest routes from West Africa have been examined.

It was confirmed in the LSE[165] that one million barrel oil tankers in West Africa sailing have increased by 10 percent within three months. It was reported that earnings derived from the West African-US Atlantic coast route is by far the most important trade for Suezmax owners. Equally that the export from West Africa is high, promising continued trade for one million barrel tankers.[166]

The transportation of imports affects the freight rate. When the demand for oil goes up, demand for its transportation will increase. There is a report in the LSE that an increase in trade volume has improved the freight rate.[167] The assumption is that when there is tanker surplus (supply less demand), the freight rate is likely to become depressed in the long run. The assumption is that the increase in the amount of oil imported would cause new orders and deliveries of tankers to increase in the long run.

Crude Oil Prices

Oil prices will affect the quantity of oil consumed per period of time, thus when the prices are high the decision to cut down on the use of oil will be inevitable. The prices

[165]Lloyds Shipping Economist "Suezmax Highs Continue Despite More VLCCs. November 1996, p16.
[166]Ibid., p.112.
[167] Ibid., p.112.

of oil over the time also affect supply of tankers through the quantity of oil and tanker demanded. There is a possibility that in the long term the increase in oil prices will spur consumers to cut down on consumption. The government emphasis on energy saving policy will indirectly affect supply.

It is estimated that the cost of transportation is a very small proportion of the final price of oil. Each tanker carries a large quantity (100,000 tonnes) of oil, and if price is to be charged to each barrel the cost of this becomes very low, compared with the price of oil. They could as well re-schedule tanker deliveries as direct result of lack of employment. When there is less activity in the shipbuilding yards, there would be a reduction in the prices of newbuilding, to encourage tanker owners to sign new contract. The price pattern of secondhand tankers in most cases would follow new building.

Tanker Demand

The demand for one million barrel tankers is attributed to the geographical location of the sources of oil and the location of the main consumer. The movements of crude oil to the refineries would generate employment to tankers. As a result of growth in the economy, when there is increase in the demand for crude oil, the demand for tankers is assumed to increase, thus the supply. When the demand is low the number of tankers' employment will be low and it will reflect on the total tankers, creating a tanker surplus. The importance of tanker demand in the analysis is quite clear, it is a priori that demand will influence supply and that the freight rate would control the size of change.

Freight Rates and Time charter rate

The freight market comprises of the spot rates, voyage rates and the time charter rates. Freight rates are affected by the amount of oil available for transportation. If the demand for transport in the life of a tanker is high, the freight rate will increase. Increase in the freight rate would cause the tanker supply to increase. Reduction in the crude oil imports will reduce tanker demand, thus the tanker surplus and idleness. The freight rates are likely to become low as a result of tanker surplus.

The total tonnage of oil tankers supplied to the market will affect freight rate. High freight rates would encourage shipowners to supply tankers and in the long run surplus tankers would cause the freight rates to decline. There is always a cyclical movement when an increase in one period leads to decrease within the same cycle. This is explained in Zannetos.[168] The freight rate also affects newbuilding prices. When there is a tanker surplus in the market or the freight rate is very low, there would be fewer orders. The shipbuilding market will be affected as a result of reductions new orders. In the long run, if the rate remains low, newbuilding prices are likely to be reduced in order to encourage investors. As a result, the size of new order will be affected, and the deliveries would be delayed. The surplus tonnage would spell an end to some tankers, many would be laid-up and in the long run the uneconomic tankers will be scrapped.

New Orders

This is the number of new tankers in deadweight tonnes ordered at a particular period. Shipowners will order new vessels when the market condition demands it. Sometimes

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[168] Zannetos, Z; (1966) Op cit p. 4.

shipowner order new tankers to replace the ageing vessels or technically obsolete tankers. It is assumed that old age would not greatly influence new order. All things being equal, tanker owners would not hesitate to order tanker if there is justification for it in the freight rate. Furthermore, if owners envisaged future short supply they may place orders. Nevertheless, if the freight market is very low as a result of tanker surplus, there may be a reduction in the number of new orders.

Shipbuilding is not instantaneous; it takes a minimum of one year before a new order becomes a delivery and is launched. Approximately, it will take an average of two years after the initial newbuilding contract has been signed for orders to become deliveries. This is evidence that there is a need for forecasting; tanker owners should know the turning point, and forecast the future in order to avoid making wrong decisions.

Newbuilding Prices

The price of tankers is assumed to affect the total tonnage ordered. Then the law of demand and supply regulates prices. When the demand and supply move toward balance or equilibrium; the assumption is that tanker's price would increase. However, the time taken to build a ship could be a telling factor and there is a need to look at it.

The newbuilding prices are directly related to second-hand prices. The needs and the urgencies to which a tanker is needed would influence the decision of tanker owner. The question is whether to purchase a secondhand vessel or order a new tanker. The availability of finance is likely to play a major role in the decision process. The freight rate will affect newbuilding price in the short and long run. Shipbuilders anticipate the tanker market and set the price of vessels to reflect the anticipated prices. High freight rate is assumed to cause the price of tanker to increase.

Deliveries

This is an addition to present total of one million barrel class tankers. Deliveries of tankers are assumed to depend on lagged new orders. At a certain point in time the new order will become deliveries. Increases in oil tanker demand will in the short and long run cause the supply of tanker to increase, through the reactivation of laid up tankers, new orders and deliveries.

Oil prices, oil imports and consumption in Western Europe and USA are assumed to affect deliveries. The reason could be that increase in the latter would increase tanker supply and increase in new order will affect future deliveries. When newbuilding becomes deliveries, there is a possibility that the uneconomic aged vessel will be scrapped.

Lay-ups

Lay-ups are tankers temporarily not trading due to unfavourable trading conditions. It arises when the freight rate is very low and cannot sustain the cost of operating the vessel. This often happens when there is a period of low freight rates. The freight rate becomes low when supply exceeds demand. In order to improve the situation or more strongly for the shipowner to cut their losses, the best decision perhaps will be to lay-up tanker in the short term. Lay-up is highly possible in the short term, but in the long term it could become a problem and uneconomic.

There is the cost of keeping the tanker in the lay-up position; if the cost is very high and the prospect of trading is low, the shipowner may decide to scrap the vessel. However, the decision to scrap may depend on the scrap prices at the time. There is a possibility that the rate will increase when the demand and supply balances improve. It is a priori that improvement in demand and supply balance will encourage shipowners.

Scrapping

Tankers are likely to be scrapped when there is a long-term depression in freight rates. Also, there will be scrapping if the prospect of trading with profit cannot be guaranteed in the long term. It is *a priori* that if the supply of tanker exceeds demand, the result would be a tanker surplus and rates would decrease. Long-term low freight rates are likely to force the shipowner to scrap vessel, while they avoid the costs of keeping the tanker in the laid-up position.

Tanker scrapping may be due to number of factors, such as old age and technical obsolescence. A reduction in total deadweight is achieved when tonnage scrapped is subtracted from the total tankers. If the scrapped tonnage is greater than the delivery tonnage, the freight rate market would react to the reduction in the tonnage supply. However, it will much depend on the magnitude of the reduction and improvement in tanker demand.

Tanker supply

The total supply reflects on all the variables specified in the model. The supply of tankers would depend on the tonnage delivered and the tonnage scrapped. In order for shipowners to assess the situation of the market they will need a good forecast. They will need to forecast the individual variables that are likely to affect their decisions. Tanker delivery and scrapping level will influence the behaviour of tanker supply.

4.4 Analysis of Tanker Supply Model

In this section, the variables will be examined and analysed, with special attention to the empirical relationship of the series. The behaviour of the market participants in a simple hypothetical tanker shipping industry has been examined. However, in order to increase our understanding of the model, there will be a number of simplifying assumptions.

4.4.1 Basic Foundation of the Model

The basis of the model is as follows. There is assumed to be only one ship type (**MBT**) in the hypothetical tanker shipping industry. In reality there are other types besides oil tankers such as dry bulk carriers, combined carriers, general cargo ships, containers, liquidified gas carriers, car carriers, passenger ships, etc. (See chapter 2, pp.33-38.) Furthermore, each category of ship can be distinguished according to their size, age, propulsion, technology, cargo handling technology, etc. This chapter shall ignore all these differences, the assumption will be that only one tanker type and size exists. It is assumed that there is easy passage in the market; there is free entry into the market.

It is envisaged that the above assumptions and other numerous simplifications that will be made later will not hinder the theoretical insight that will be developed. The aim of constructing this theoretical model of oil tanker supply is to strip away the detail and to develop a simple framework. This is in order to allow people to obtain an understanding of the general principles, and the forces at work.

The exclusion of detail does not affect in any way the fundamental conclusions of this chapter regarding the key interactions among the various markets. Instead, they facilitate a quick understanding of the main results. In the same frame of mind the theory will be computed with simultaneous-equation model method for better result.

The equations that are listed explain and analyse the endogenous and exogenous variables. The analysis will take into consideration all the assumed factors and test their validity. It is assumed that African oil will still maintain the same market share. These variables are believed to be significant to the modelling of tanker supply; viable economic theory and statistically significant.

The theory presented below can be seen in the flow chart above figure 4.1.

4.4.1.1 Western Europe Oil Imports

The variable WEOI is one of the most important sources of demand for one million barrel tankers (see figure 4.1). Therefore, it is necessary to consider and use it as a dependent variable. The tanker demand is assumed to depend on the imports of oil.

This in turn helps determine the supply of the million barrel tankers. Western Europe received an average discharge of oil that creates employment of about 11 per cent for this class of ship. This represents the percentage share of the world total into this category of tanker and 31 per cent of the route. It should be noted that the series for oil imports Western Europe also includes movement to both Northern and Southern Europe, but these element are relatively very unimportant. To get an accurate forecast of oil imports of Western Europe, it is important to explain as much of its exogenous variance using predetermined variables.

The inclusion of lagged data for Western Europe oil imports allows both the short and long run impacts of the exogenaity variables to be modelled. The $WEOI_{t-i}$ is assumed to be positively related to the current and future imports.

Oil Consumption W. Europe (OCWE): The assumption is that the demand for oil would generate employment for one million barrel tankers. The refineries or the consumers are located away from the sources of production; the result is that tankers will benefit. Energy consumption is reckoned to be a prime-factor in economic growth, and tanker demand is driven by oil movements. Increased energy demand reflects both the growth in manufacturing output and industrial production, as well as transportation services. However, it is more logical to rely on an economic forecast to produce energy forecast. Vaughan (1968) argued that "some economists are tempted to use the statistics relating to overall energy consumption as a rough criterion of the material well being and progress of the individual countries with which they are concerned".[169] It is expected that lagged oil consumption (CWE_{t-i}) would affect oil imports Western Europe. The reason being that the importation of oil is planned in

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169 Vaughan. R., "Long Range Planning and oil tanker supply and demand in the 1970's"; North East Coast Institution of Engineers and Shipbuilders, vol 85, 1968. p. 106.

advance and the trend of oil consumption in the past is assumed to affect future oil imports decision.

Crude Oil Prices (COP) (US $/bl): This is a nominal crude oil price. Whenever any of the tanker categories is being examined crude oil prices are most likely to feature. Crude oil prices can affect the tanker market in various ways. If there is an increase in the oil prices, the demand for tanker would decrease. The assumption is that many of these consumers may have to rely on the oil stock within the economy, taking the advantage of low oil prices.

Oil Production W. Europe (PWE): This variable is assumed to be negatively related to oil imports volumes in Western Europe. When oil production increases in Europe there would be a reduction in the volume of oil imports. If the demand for oil can be met with the domestic production level, there is a possibility that there would be no need for imports. In real cases balancing imports with consumption is not as simple as it sounds; one possibility is to build some assumptions into the future, and forecast future oil consumption.

However, the strategy could be that the oil needs of the nation are to be met with both oil imports and the nationally produced oil. It is assumed that most countries would prefer to balance the oil consumption from the national oil production and the oil imports from other countries. A good example is the production of North Sea oil and the European oil consumption rate. The United Kingdom and other members of European Union do import oil from other sources such as Nigeria and the Middle East countries. This is either because the level of oil production does not satisfy oil consumption or for political reasons. However, there is a need to maintain national oil reserve level.

The PWE is inversely related to oil imports Western Europe. Increase in oil production Western Europe is likely to generate reduction in oil imports. The conclusion is that these factors, $WEOI_{t-i}$, CWE_{t-i}, COP and PWE, will affect oil imports; thus the equation has been derived. When there is reduction in PWE it is assumed that the imports of oil would increase. This could be as a result of nation's policies to control national oil production and instead increase oil imports. It could also be as a result of cost of production compared with the cost of imported oil. The proposed equation is presented below.

$$WEOI = f_1(\overset{+}{WEOI_{t-i}}, \overset{+}{CWE_{t-i}}, \overset{-}{COP}, \overset{-}{PWE}, \varepsilon) \qquad (1)$$

4.4.1.2 Oil Imports USA

The oil imports U.S.A (**USI**) is another major source of demand for tanker services. The United State of America is a major consumer of crude oil and thus a major source of employment for the million barrel tankers. Tanker deployment and the route West Africa - USES accounted for more than 30 per cent of the total in 1996. United States of America Eastern Seaboard has witnessed more employment of one million barrel tankers in the past. It is assumed that the past will reflect on the future because of draught limitations and the oil pollution policies in USA.

Oil imports USA (USI) lagged oil imports is considered to be inversely related to current and future oil imports USA. The assumption is that the level of oil imported in the lagged time compared with oil consumption at the same time will affect future decisions on imports. The reduction in the level of oil imports in the previous year is likely to increase the future imports so that stock can be maintained. Looking at the historical data, oil consumption shows a steady increase. In order to cater for the increase, oil imports will have to increase. It is important to understand that there is a limitation to the quantity of oil stock that each nation can hold, however from time to time they need to reach a decision on oil imports, taking into consideration the level of consumption.

Oil Consumption USA(CUS): Oil consumption U.S.A$_{t-i}$ is a determinant of US oil imports. As already been mentioned in the oil imports Western Europe, the government policy could be to curtail imports, which means they have to find way of discouraging wastage to reduce oil consumption. Thus this means an efficient control of oil imports. Once the amount of oil that will be needed is predicted and known, then the implementation of oil policies would follow. This is a simple hypothesis, however the real situation is far from that simple. A careful analysis through forecasting will lead to a better decision. Thus lagged oil consumption USA is argued to be positively related to both current and future USA oil consumption.

Oil Production USA (PUS): The variable is hypothesised to have a negative effect on the oil imports of the United States of America. When USA oil production increases the assumption is that there will be a reduction in the volume of oil imports, Ceteris paribus, if the demand for oil can be satisfied by the domestic oil production level, the possible scenario is that they may not need to import. It can be said that there is a possibility crude oil is imported from other sources because of its different characteristics. The same analogies that apply to Western Europe oil imports apply to USA oil imports. Oil imports in these areas are assumed to have a considerable effect on one million barrel tankers.

As was mentioned above, oil prices are inversely related to USA oil imports. The reduction in the crude oil prices is likely to increase the oil imports. Thus the function of USA oil imports is derived.

$$USI_t = f_2(\overset{-}{USI_{t-i}}, \overset{-}{PUS_{t-i}}, \overset{-}{COP}, \overset{+}{CUS_{t-i}}, \varepsilon) \tag{2}$$

Figure 4.1 shows the relationship of the rest of the model with the oil market.

4.4.1.3 Tanker Demand (DD)

This is the amount for tankers required at a particular period for the transportation of crude oil. Tanker employment is approximated to be equivalent to tanker demand. The difference between demand and employment is the extent to which the fleet could operate more efficiently. Increase in the demand for tankers would lead to increase in tanker supply; this will depend on the size of increase. It is an assumption that the tanker demand forecast will help with the projection of tanker supply. Demand would be affected by oil consumption and oil producton in both Western Europe and USA. The arrows from the bottom half of the flow chart point to demand. See the flow chart figure 4.1.

The demand for tankers would be affected by lagged Western Europe oil consumption, the lagged value of USA oil consumption, crude oil prices, oil production Western Europe and oil production USA.

Oil consumption Western Europe (CWE): As mentioned above, any increase in oil consumption would cause oil imports to increase; however there is a strong indication that CWE_{t-i} is positively related to tanker demand in this model. This is in accordance with the assumption that CWE_{t-i} and DD move in the same direction. The flow chart, figure 4.1 indicates the assumption that increases in CWE_{t-i} would cause DD to increase. In view of this CWE can be confirmed to be important when determining oil tanker demand. The CUS_{t-i} is positively related to oil imports; increase in CUS_{t-1} would cause tanker demand to increase. This would mean that an increase in the level of oil imports USA at lag **i** would cause demand to increase. However, it is assumed that in the long run the sign is likely to remain unchanged. The assumption is that the past behaviour will continue into the future.

Crude oil prices (COP): crude oil prices as already indicated have an effect on tanker demand both in the short and long term. Increase in the nominal oil price is likely to reduce the quantity of oil that will be imported. This would mean reductions in the tonnage of tankers demanded. In most cases OPEC decisions (most especially when oil quotas are being set) have led to increase in oil prices; in many occasions it has led to a surge in oil demand depending on oil prices.

In a similar way as in equation (3) crude oil prices alter the total demand for (MBT) tankers. The lagged crude oil prices affect consumption; and ultimately affect tanker supply. The effort of nations to keep the level of stock and to satisfy energy demand would cause DD to appreciate; in the short run the situation is likely to remain the same.

Oil Production W. Europe (PWE): This variable is inversely related to tanker demand. When there is a reduction in Western Europe oil production there would be an increase in the demand for tonnage. As mentioned above, if the demand for oil can be met from domestic oil production, there may be no need for Western Europe oil imports. However, it is possible to increase oil imports even if oil production can satisfy oil consumption. This could happen as a result of national demand for different types of crude oil. In reality, the reliance on the gap between oil consumption and production in order to determine tanker demand will not necessarily be sufficient. What is needed is to build some assumptions into the future, and forecast future demand as a result of projected oil production and consumption.

Oil Production USA (PUS): The variable is argued to have a negative effect on the demand for oil tankers. When USA oil production increases the assumption is that there will be a reduction in the volume of oil imports, and a reduction in tanker demand. If the demand for oil can be satisfied from domestic production, there might not be any need to import. The same arguments that apply to the effect of Western Europe oil production on demand apply to USA oil production. Oil production in these areas is assumed to considerably affect one million barrel tankers demand.

Empirically, the demand for one million barrel tanker function is derived:

$$DDt = f_3\,(\overset{+}{CWE_{t-i}},\ \overset{+}{CUS_{t-i}},\ \overset{-}{COP_{t-i}},\ \overset{-}{PWE},\ \overset{-}{PUS},\ \varepsilon) \qquad (3)$$

4.4.1.4 Freight rate index (FR)

The freight rate index is very important to tanker shipping; (the freight rate index will simply be referred to as the freight rate) Low freight rates in the market would have a negative effect on supply, thus the reduction in the number of tankers that will be supplied to the market. Increases in tanker demand in the short and long run will make the freight rates appreciate as the demand and supply move towards balance. On the other hand, if there is a tanker surplus in the market the freight rate will become low; sometimes it could turn to depression. The freight rate is assumed to have a considerable effect on tanker supply; there is thus a need to model and forecast the level of future freight rates.

Oil tankers produce output that is measured in ton-miles and sold for a price; that is the freight rate. In reality one major factor that is required for the production of transportation services is fuel. In this model port services are ignored, the only industry input being bunker fuel.

The Million barrel Tanker stock (MBT): The lagged million barrel tanker is assumed to have an effect on the level of freight rates (see figure 4.1). This variable has been lagged because the author is using annual data. When there is a tanker surplus (the difference between demand and supply) the possibility is that freight rates will decrease. On the other hand, a reduction of MBT_{t-i} would increase the freight rate. This is a matter of balancing the demand and supply of tanker. The demand for these tankers (the current level of MBT) has been omitted because oil seaborne trade significantly and better explains the freight rates of one million barrel tankers. Thus demand for these tankers feature in oil seaborne trade.

Oil Seaborne Trade (OST): The volume of total oil tanker trading would affect the price paid for the voyage. The Oil seaborne trade is in tonne-miles, and the calculations of rates also make use of tonne-miles. Oil seaborne trade is considered to positively affect freight rate. Oil seaborne trade OST depends on oil demand as a result of the location of the refineries and the consumer. (See figure 4.1.)

Bunker price (BP): Bunker price is positively related to the freight rates. The assumption is that oil prices impact on the oil tanker, market the bunker price directly affecting freight rates. (See figure 4.1.) Increases in the price of bunkers would cause increases in the freight rate. This is because bunker prices are a significant determinant of the spot freight rate. The coefficient sign conforms to the expectation that an increase in one will spore increase in the other.

Therefore, the freight rate index (FR_t) equation has been derived. The above relationships can be seen in the flow chart, figure 4.1.

$$FR_t = f_4\,(\overset{-}{MBT_{t-i}}, \overset{+}{OST}, \overset{+}{BP}, \varepsilon) \qquad (4)$$

4.4.1.5 Time Charter Freight index (TCI)

Time charter is a period rate ranging from one month to years. The time charter is available for the charterer who is interested in long term contract other than demise contract. The market for time charters has many similarities with futures markets. These markets reflects on the market expectations regarding future spot freight prices. Some charterer employ vessels on a period basis in order to secure carriage for their oil at a predetermined and relatively static cost. This is to overcome the freight rate vagaries that could strongly affect international shipping. On the other hand, the charterer may time charter tankers instead of voyage charter as a result of speculative response, judging that freight rate will increase in the future. The flow chart, figure 4.1 shows the relationship of these variables.

Time Charter Rates **(TCI):** the lagged time charter rate is inversely related to time charter rate. The assumption is that the time charter rate is cyclical and that the future would reflect on the past rate. It is assumed that low TCI follows high TCI. When the lagged time charter is low the current and future time charters are likely to increase. The shipowner may decide to charter their vessels in the spot market; in that case they expose themselves to risks of future movements of freight rates. This will depend on the level of freight rate at the time of the contract. They may prefer to charter their vessels over a period of time at a fixed time charter rate; one of the means by which they can avoid the risk of accepting low freight rate. This will also depend on their anticipation of future spot freight rates.

Million barrel tanker stock: MBT_{t-i} is considered to affect the time charter rate. The assumption here is that when MBT increases spot rate would become low. Since time charter is a future market, the tanker owner in anticipation that the spot rate will be high would prefer to time charter their vessel now and benefit in the future. In this case, the assumption that MBT_{t-i} is inversely related to time charter rate does hold. When the freight rate is low the tanker owners will be reluctant to charter out their vessels on a long-term contract. When they chartered a vessel out on a period basis, they will be chartered on a minimum fixed period. Changes in the difference between tanker supply and demand are likely to increase the volume of time charters.

In order to increase the time charter rate through the reduction in the gap of supply and demand, a number of things will happen. The tanker supply will have to be reduced by increasing scrapping and reduction in the newbuilding programme. Alternatively, a substantial increase in the demand for oil tankers would be needed to absorb the increase in supply.

The ratio of the freight index to the time charter index lagged one: **$(FR/TCI)_{t-i}$** is positively related to the time charter index. An increase in one would cause the other to increase. An increase in the freight rate would cause the time charter to increase. More tanker owners would be prepared to charter their vessels now in order to be in a good position if freight rates decreased. The assumption is that the ratio of freight rates to time charter rates would invariably cause time charter rates to increase. Changes in the one variable would cause the other to appreciate. As a result the effect of the one in relation to the other would affect time charter rate.

The lagged variable has been used with the assumption that the past influences the future. However, it has to be said that the annual index data is the closest available for the disaggregated model. Also what is being considered here is the changes in variables and not the level; so lagged changes are assumed to affect the future behaviour of changes, not levels.

The same argument given above for the freight rate equation would apply to the future expectation of freight rates; despite the time lag. The expectation of the freight rates would affect time charter rate; if the future freight rate is anticipated to increase, the time charter is likely to increase. Lower rates perhaps would discourage the tanker owner to accept time charter for their vessels. In the absence of alternatives, tanker owners may time charter on a short term basis; thus the present and the expectation of future spot rate positively affects time charter rate.

It is assumed that time charter rate would affect the spot rates. If spot market is expected to be more profitable in the future, owners will demand a higher time charter rate. This will enable him to make profitability of the time charter to be equally competitive with that of the spot rate.

Newbuilding price (NBP): The assumption is that the new building price is positively and directly related to the time charter index. Increases in the newbuilding prices of tanker would cause the time charter index to increase. The higher level of newbuilding prices would mean that tanker owners would be prepared to take risk by accepting time charter agreement in a volatile tanker market. The assumption is that the cost of these risks would be reduced considering the low ship prices. The coefficient sign is in accordance with the assumption that increase in newbuilding price are likely to cause freight rate to increase. The assumption is that freight rate and newbuilding prices have causative relationship. The relationship of this is represented in the flow chart, figure 4.1.

Thus the time charter equation is derived:

$$TCI_t = f_5\,(\overset{-}{TCI_{t-i}},\ \overset{-}{MBT_{t-i}},\ \overset{+}{[FR/TCI]_{t-i}},\ \overset{+}{NBP},\ \varepsilon\,) \qquad (5)$$

4.4.1.6 New Orders (NOR)

Orders are placed to replace aged tankers (scrapped) and obsolescent vessels or as a result of the anticipation of an increase in demand and freight rates. The expectation of future demand would warrant a decision to order a new ship. Evidence of scarcity and the number of vessels that will be coming to the end of their trading life are assumed to influence new orders. Ship owners would order new capacity if there are increase in lagged orders, if the stock of million barrel tankers reduces and the freight rate increases.

Shipowners would place orders for new tankers after assessing the likely future market, looking at the present gross surplus (the difference between tanker demand and supply) and new vessel prices. The number of tanker new orders is assumed to be high during times of high freight level and decrease during times of low freight. The vessels ordered may be expected to be mainly of the type and size earning the largest profits at the time of ordering. The assumption is that large tanker will be ordered during the boom time and medium tanker (one million barrel sizes) will be ordered both in the boom and depressed trade periods. The reason being that when there is a reduction in the quantity of oil being carried or if the tankers are unable to trade with full load, the economic vessel such as the one million barrel size are likely to be employed.

Lagged new orders (NOR): All things being equal, increase in the new orders lagged ***i*** (NOR_{t-i}) would increase future orders. This is by taking into consideration high freight rate and low tanker stock. If the trend in the freight rate market is still upward the tendency is that tanker owners are likely to make a decision to order. Lagged orders are positively related to present and future orders. If there is a large stream of orders, the market player should take serious precaution, so that when the orders become deliveries, the freight rate market would be moved into a depression.

Million barrel tanker stock (MBT): The level of MBT_{t-i} would encourage new order contracts. Reductions or a low level in the tanker stock at lagged ***i*** would cause new orders to increase. The minimum number of years to produce and deliver a tanker will have to be taken into consideration. The assumption is that shipowners estimate the present and future tanker surplus (supply less demand) and the age of the vessels before committing themselves to a new order. Shipowners are assumed not to order new tankers or to minimise tanker orders when they envisage a large surplus. The result of wrong decisions could mean a depression to the freight market.

Freight index (FR): It is assumed that orders for vessels and freight level are related to each other. High freight rates coincide with many orders for new ship, and low freight rates with fewer orders. The lagged freight rate is positively related to new orders. As has already been mentioned, when the freight rate increases new orders are likely to increase. The assumption in this case is that the growth at lagged ***i*** will continue into the future. As a result of this, the assumption is that the tanker owner would place new order for ships. However, the increase in the freight rates must justify the cost of the new order. If the price cannot be justified it could become a problem for speculative owners.

Therefore the determinants of the new order equation for one million barrel tanker have been derived. The relationships discussed are shown in the flow chart, figure 4.1

$$NOR_t = f_6(\overset{+}{NOR_{t-i}}, \overset{-}{MBT_{t-i}}, \overset{+}{FR_{t-i}}, \varepsilon) \qquad (6)$$

4.4.1.7 Newbuilding Price (NBP)

It is important to know how the newbuilding prices are determined. There are differences between the quoted newbuilding price and the final new building prices.

The assumption is that it is the final price that actually affects the market and not the quoted price. Here the final price data has been used. One of the qualitative and determinant factors is the competition between the shipyards. In view of this, the price of new tankers fluctuates depending on the number of shipyards chasing the volume of orders. The freight rate is one of the basic determining factors of the new building price. Increase in the ship prices would cause freight rate to increase. When the demand for tanker increases both the freight rate and newbuilding prices increase. This is shown in the flow chart, figure 4.1.

It is a priori that there is a correlation between newbuilding and secondhand prices. This is not surprising since newbuilding and the existing tankers are similar assets once allowance is made for the age.

The newbuilding price is an important factor that has a bearing on the supply of tanker. The tanker owner considers, as an alternative to a newbuilding is the purchase of a second-hand tanker. This means that their prices must be related.

Freight rate (FR): It is an assumption that the freight rate will affect the newbuilding price. The freight rate is positively related to the new building price. The hypothesis is that low freight rates will hinder or reduce tanker order and invariably cause a reduction in tanker prices. There is a tendency that increases in shipbuilding costs will be followed by increases in freight rate. In the shipbuilding industry the cost of building ships can be very high while the freight rate is low.

Demand (DD): It is assumed that increases in the tanker demand will cause the price of tankers to increase. The DD is positively related to NBP. If there is a considerable growth in the level of tanker demand there is a likelihood that tanker prices will increase. The assumption is that the shipowner is likely to order vessels as a result of increases in trade.

Oil seaborne trade (OST): OST_{t-i} is positively related to NBP. The difference between this and the demand is that oil seaborne trade includes other tanker classes other than one million barrel tankers. Increase in OST_{t-i} will cause the endogenous new building price to increase; growth in the economy of the nations would cause the oil seaborne trade to increase. The assumption is that increase in oil seaborne trade will cause the newbuilding price to increase as well. The lagged increase in the ton-miles of seaborne trade would cause NBP to increase.

Shipbuilding Cost Index (SBC): This variable is included in the equation for relationship of the newbuilding prices, because it is assumed that the newbuilding price will take into account the cost of building the vessels. This means that shipbuilding cost is positively related to newbuilding price. Increase in the cost would reflect on the price, and thus the effect on the subsidies. The shipowner will have to justify the price of a new order with the prevailing freight rates and the return on capital employed before committing money to building new ships. It is envisaged that freight rates would affect newbuilding prices; thus the ultimate influence on the capacity of tanker supply.

The cost of ship building (SBC) is positively related to newbuilding prices. This has been estimated as follows: price of metal index PMI times 2 plus the ratio of industrial countries wholesales price index ICWP to exchange rate of dollar DER; [170]

SBC is 2 PMI + [ICWP/ DER]

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[170] Beenstock, M and A. Vergottis, (1989) "An Econometric model of the tanker market" Journal of Transport Economics and Policy, September , Vol. xxiii, Number 3, pp. 263-280.

Therefore the new building price function is derived. The relationship is expressed in the flow chart, figure 4.1.

$$NBPt = f_7 (\overset{-}{FR}, \overset{+}{DD}, \overset{+}{OST_{t-i}}, \overset{+}{SBC}, \varepsilon) \qquad (7)$$

4.4.1.8 Tanker Delivery (DEL)

Tanker deliveries are being examined in order to assess the effect of additional tankers in the market. The effect of this variable on tanker supply is sometimes severe. The reason is because surplus tanker in most cases depresses the freight market. It reduces the shipowner's incentive to trade with their tankers, this is as a result of low freight rates. In a situation like this, there will be a reduction in hire prices. However, the deliveries are hypothesised to depend on lagged deliveries, lagged orders and the expectation of the freight rates. These relationships can be seen vividly in figure 4.1.

Lagged delivery (DEL): It is assumed that lagged tanker deliveries would affect the present and future deliveries. In a situation where the market is in depression due to the number of vessels that were delivered in the previous years, the shipowners are likely to put back deliveries. The cost of cancelling orders is high, but it may not be as costly as when the vessels are allowed to reach a delivery stage. The present contract for a new order takes a minimum of one year to deliver. As a result, there is tendency that deliveries in the past years will cause an increase in the deliveries at present time. The DEL_{t-i} is inversely related to the current and future deliveries. If the deliveries in the past years are low compared with the increasing order, it is assumed that the order would becomes delivery sometime in the future. So low deliveries would mean increase in future deliveries.

Hypothetically, delivery depends on lagged orders, but *ceteris paribus*, other factors such as the level of expectation of freight rate will influence new order in the first place. In the past as a result of excess tonnage due to large tonnage deliveries into depressed market, a number of new order contracts were cancelled. The typical example was the situation of the market in 1979/80. At the time too many vessels were ordered during the boom period, and the result of this was depression in the freight rate market. During that time many of these tankers were sold for scrap and many went straight into lay-up. It was not until 1986 that a significant improvement occured in the tanker freight market.

Therefore, deliveries at lagged **i** are likely to have a considerable effect on supply. The increases in tanker supply due to deliveries are assumed to create a surplus and have an adverse effect on the freight rate. The assumption is that the depressed freight rate market is most likely to lead to a rescheduling of deliveries. The lagged deliveries are inversely related to the present deliveries.

New orders (NOR): The stock of new orders at lagged **i** will cause the present and future deliveries to increase. The NOR_{t-i} is positively related to current and future deliveries. The assumption is that because of the time lag between orders and deliveries the impact of new orders signed now will not be felt in the market until after a minimum of one year. Orders of new tankers is assumed to be initiated by expectations during the period of rising rates and will only stop when rates start declining. Before the deliveries start appearing in the market, the deliveries would shift the supply, thus depressing the freight rate.

Lagged freight rate (FR): As explained above the freight rate plays a significant role in placing orders for tankers and the deliveries of tankers. If the additional tonnage will not be trading as a result of low freight rate, owners may have to cancel the order or convert the ship to other uses. The expectation is that the trend in the freight rate will continue. Increase in freight rates is likely to encourage more orders and in the long run deliveries.

Therefore the function of tanker deliveries is derived. (See figure 4.1)

$$DELt = f_8(\overset{-}{DEL_{t-i}}, \overset{+}{\Sigma NOR_{t-i}}, \overset{+}{FR_{t-i}}, \varepsilon) \tag{8}$$

4.4.1.9 Tanker Scrapping (SC)

Scrapping is defined as the tonnage of tankers that are removed from the total tanker stock in a given time. Also the tonnage of tanker that are to be scrapped when there is a long-term depression in the market. The aged tankers would be scrapped when they pass their trading age. It is assumed that a tanker's trading life is between twenty and twenty-five years. However, it is possible that good maintenance will increase the trading life of vessels.

The belief is that oil tankers are built to last for many years, though the number of years each tanker remains trading will depend on maintenance levels. It can be said that physical deterioration may not be the only factor in deciding whether to send a tanker for demolition.

As there is so much fluctuation and uncertainty in rates in the long run, it is quite probable that the owners of tanker will base their expectations on the only solid evidence, which is the spot rate. Therefore, the expectation is that the number of tankers that will be scrapped is inversely related to freight rate, and laid-up is positively related to scrapping. Therefore, the scrapping rate is hypothesised to be influenced by lay-ups, the freight rate, and oil seaborne trade.

Tanker Lay-ups (LU): The laid up tonnage takes into account the short-term effect on trading tankers. This is a temporary supply contraction; thus the number of tankers laid-up reflects tanker utilisation. When the freight rates are very low or depressed, trading may become impossible as a result of the low revenue that fail to cover the trading cost. The level of freight rates would force the tanker owner to lay-up vessels. In the long run, if the situation does not change, the tanker will become a candidate for scrapping. Laid-up tonnage lagged one is assumed to cause the scrapping level to increase. The shipowner can only endure a limited amount of loss, and the out-of-pocket cost of operation for a short period. In the long run the tanker may be sold for scrap if owners cannot see a future recovery in the market. However, this could also depend on the age and the bankers. The positive sign of the coefficients reflects the expectation that increases in lay-ups will cause scrapping to increase.

Freight Rate (FR): The payment or the hire price for the use of tanker has to be high enough to justify keeping the ship trading. The freight rate level must be at least at a break-even point or profitable level. In the short run, the shipowner would trade at a loss with the expectation of future profit. In the long run depression in the freight rate would strengthen their decision. They will have to decide whether to scrap or to delay scrapping. The freight rate is inversely related to scrapping.

Oil seaborne trade (OST): OST_{t-i} is inversely related to tanker scrapping. The difference between this and the demand is that oil seaborne trade comprises of tanker classes other than one million barrel sizes. Increases in the OST will cause a reduction in the scrapping level. The assumption is that increase in oil seaborne trade would continue into the future and this would probably cause the shipowners to delay scrapping.

The scapping equation has now been derived. See the flow chart, p.108, figure 4.1.

$$SCt = f_9\,(\overset{+}{LU_{t-i}},\ \overset{-}{FR},\ \overset{-}{OST_{t-i}},\ \varepsilon) \qquad (9)$$

4.4.2 Tanker Supply

The thesis is based on the forecasting of the oil tanker stock. All dependent variables enumerated above in the equations will determine tanker supply, either directly or indirectly. The ten equations are very important if the turning points of any of the vital links in the one million barrel tanker sizes are to be tracked. The model is completed by the identity equation of tanker supply. The change in the fleet is simply the difference between deliveries and scrapping.

Therefore, the tanker identity equation is written as:

$$SSt = SS_{t-1} + DEL_t - SC_t \qquad (10)$$

Where SS is tanker supply, DEL is deliveries and SC is scrapping

4.5 Variables Notation and Units of Measurement

DD - Quantity of One million barrel oil tanker demanded per time period. Unit of measurement: Million deadweight tonnes.

SS - Quantity of One million barrel tanker supplied per time period.(excluding laid-up) Unit of measurement: Million deadweight tonnes.

FR - Freight index

NOR - Tanker new orders. Unit of measurement: Million deadweight tonnes.

NBP - Newbuilding price per time period. Unit of measurement: U.S Dollars.

DEL - One million barrel tanker deliveries per time period. Million deadweight tonnes.

LU - Lay-ups per period of time. Measured in million deadweight tonnes.

SC - Scrapping per period of time. Measured in million deadweight tonnes.

MBT - One million barrel tankers per period of time (including lay-ups); million deadweight tonnes.

TCI - Time Charter index

CUS - Oil consumption U.S.A per period of time. Measured in million tonnes.

CWE - Oil Consumption Western Europe per period of time; million tonnes.

USI - United States Oil Imports per period of time; million barrels per day.

WEOI - Western Europe Oil Imports per time period; million barrels per day.

COP - Nominal crude oil prices per time period. Unit of measurement: $US per barrel.

OST - Oil Seaborne Trade per period of time. Measured in Million Tonne Miles.

BP - Nominal Bunker prices . Measured in $US/bl.

ICWP - Industrial Countries Wholesales Price Index per period of time. Index units.

DER - Dollar Exchange rate against SDR.

PMT - Metal price index.

SBC - Shipbuilding cost index, estimated as 2PMT + ICWP/DER

4.6 Identification of the Variables in the Equation

Endogenous variables

WEOI - Western Europe oil imports (mb/d)
USI - U.S.A. oil imports (mb/d)
DD - One million barrel tanker demand (mdwt)
FR - Freight rate index
TCI - Time charter index
NOR - Tanker new order (mdwt)
NBP - Newbuilding price ($)
DEL - Tanker deliveries (mdwt)
SC - Tanker scrapping (mdwt)
SS - Tanker supply (mdwt) [identity]

Exogenous and predetermined variables

CWE - Oil consumption Western Europe (mt)
PWE - Oil production Western Europe (mb/d)
COP- Crude oil prices (Spot $/bl)
CUS - U.S.A. oil consumption (mt)
PUS - U.S.A. oil production (mb/d)
MBT_{t-i} - Million barrel tanker total stock (mdwt)
OST - Oil seaborne trade (mtm)
BP - Bunker price ($/bl)
FRTC - (FR/TCI) ratio of freight rate to time charter
SBC - Ship building cost
LU_{t-i} - Laid-up lagged one

The purpose of this exercise is to examine whether the equations (1-9) are under-identified, exactly identified and over-identified. The table below tells us how it is done for clarity. In these tables; ***1*** will denote the presence of the variable and ***0*** will denote that the variable is excluded. The identity equation (10) was eliminated because the parameters were not estimated.

The determinant of identification or overidentification depend on, two conditions; (i) the order condition for identification and (ii) the rank condition for identification. The first one is based on a counting rule of the variables excluded from the particular equation. For an equation to be identified, the total number of variables (endogenous and exogenous) excluded from it must be equal to or greater than the number of endogenous variables minus one.

This section will be using the same formulae and notation for all the equations.

Let g = total number of equations (endogenous)

k = number of total variables in the model (endogenous and predetermined)

m= number of variables, endogenous and exogenous included in a particular equation

Where (k-m) >= (g-1)

Equations

If k= g = 1, the equation is exactly identified.

If k= g > 1, the equation is over-identified

If k= g < 1, the equation is under-identified.

1. k = 32 m = 5 g = 10

Therefore (k-m) > (g-1)

have (32 - 5) > (10 - 1)

$= 27 > 9$

2. $k = 32$ $m = 5$ $g = 10$

Therefore $(k-m) > (g-1)$

$(32 - 5) > (10 - 1)$

$= 27 > 9$

3. $k = 32$ $m = 6$ $g = 10$

Therefore $(k-m) > (g-1)$

$(32 - 6) > (10 - 1)$

$= 26 > 9$

4. $k = 32$ $m = 4$ $g = 10$

Therefore $(k-m) > (g-1)$

$(32 - 4) > (10 - 1)$

$= 28 > 9$

5. $k = 32$ $m = 5$ $g = 10$

Therefore $(k-m) > (g-1)$

$(32 - 5) > (10 - 1)$

$= 27 > 9$

6. $k = 32 \quad m = 4 \quad g = 10$

Therefore $(k\text{-}m) > (g\text{-}1)$

$(32 - 4) > (10 - 1)$

$= 28 > 9$

7. $k = 32 \quad m = 4 \quad g = 10$

Therefore $(k\text{-}m) > (g\text{-}1)$

$(32 - 4) > (10 - 1)$

$= 28 > 9$

8. $k = 32 \quad m = 5 \quad g = 10$

Therefore $(k\text{-}m) > (g\text{-}1)$

$(32 - 4) > (10 - 1)$

$= 27 > 9$

9. $k = 32 \quad m = 4 \quad g = 10$

Therefore $(k\text{-}m) > (g\text{-}1)$

$(32 - 4) > (10 - 1)$

$= 28 > 9$

All the equations are overidentified and the order condition is satisfied.

The order condition for identification is also necessary for a relation to be identified; but it is not sufficient. The order condition may be fulfilled in any particular equation and yet the relation may not be identified. It is also important to satisfy the rank condition.

"The rank condition for identification states that in a system of **g** equations, any particular equation is identified if and only if it is possible to construct at least one none-zero determinant of order **(g-1)** from the coefficients of the variables excluded from that particular equation, but contained in the other equations of the model".[171] It is known as the rank condition because it refers to the rank of the matrix of parameters of excluded variables. The rank of a matrix is the order of the largest non-zero determinant that can be formed from the matrix.[172]

Tables 4.1 - 4.9 below is to demonstrate that the equations are overidentified. In the rank condition after deleting the relevant row and column all that is left is the coefficients of variables not included in the particular equation. However, these are contained in the other equations of the model. In all the equations at least one of the determinants is non-zero. The equation is now identified. In this case the equations are

[171] Koutsoyiannis, A. (1977) Theory of Econometrics, Second Edition. Macmillan Press. p. 353.
[172] Ibid.,

overidentified; however suppose all the determinants are zero; the equation will be considered to be under-identified.

Table 4.1 Rank condition for identification (Total Equation and Total Variables- WEOI)

Equ	weoi	USI	DD	FR	TCI	NOR	NBP	DEL	SC	SS	PWE	COP	OST	BP	SBC	cwe-
~~1~~	~~1~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~1~~	~~1~~	~~0~~	~~0~~	~~0~~	~~1~~
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0
5	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0
9	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0

Equ	Ost-	Cop-	cus-	pus-	mbt-	frtc-	weoi-	usi-	fr-	Nor1	Nor3	Del1	Del2	tci-	Lu1	Ss1
~~1~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~1~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~
2	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0
3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0
6	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4.2 Rank condition for identification (Total Equation and Total Variables- USI)

Equ	weoi	USI	DD	FR	TCI	NOR	NBP	DEL	SC	SS	PWE	COP	OST	BP	SBC	cwe-
1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1
~~2~~	~~0~~	~~1~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0	[illegible]	0	0	0	0	0	0	0	0	1	1	0	0
5	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0
9	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0

Equ	Ost-	Cop-	cus-	pus-	mbt-	frtc-	weoi-	usi-	fr-	Nor1	Nor3	Del1	Del2	tci-	Lu1	Ss1
1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
~~2~~	~~0~~	~~0~~	~~1~~	~~1~~	~~0~~	~~0~~	~~0~~	~~1~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~
3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0
6	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4.3 Rank condition for identification (Total Equation and Total Variables- DD)

Equ	weoi	USI	DD	FR	TCI	NOR	NBP	DEL	SC	SS	PWE	COP	OST	BP	SBC	cwe-
1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0
5	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0
9	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0

Equ	Ost-	Cop-	cus-	pus-	mbt-	frtc-	weoi-	usi-	fr-	Nor1	Nor3	Del1	Del2	tci-	Lu1	Ss1
1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0
3	0	[illegible]	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0
6	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4.4 Rank condition for identification (Total Equation and Total Variables- FR)

Equ	weoi	USI	DD	FR	TCI	NOR	NBP	DEL	SC	SS	PWE	COP	OST	BP	SBC	cwe-
1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0	1	0	0	0	0	0	0	0	0	[illegible]	[illegible]	0	0
5	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0
9	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0

Equ	Ost-	Cop-	cus-	pus-	mbt-	frtc-	weoi-	usi-	fr-	Nor1	Nor3	Del1	Del2	tci-	Lu1	Ss1
1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0
3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	[illegible]	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	[illegible]	1	0	0	0	0	0	0	0	1	0	0
6	0	0	0	0	[illegible]	0	0	0	1	1	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4.5 Rank condition for identification (Total Equation and Total Variables- TCI)

Equ	weoi	USI	DD	FR	TCI	NOR	NBP	DEL	SC	SS	PWE	COP	OST	BP	SBC	cwe-
1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0
~~5~~	~~0~~	~~0~~	~~0~~	~~0~~	~~1~~	~~0~~	~~1~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~
6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0
9	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0

Equ	Ost-	Cop-	cus-	pus-	mbt-	frtc-	weoi-	usi-	fr-	Nor1	Nor3	Del1	Del2	tci-	Lu1	Ss1
1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0
3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
~~5~~	~~0~~	~~0~~	~~0~~	~~0~~	~~1~~	~~1~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~1~~	~~0~~	~~0~~
6	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4.6 Rank condition for identification (Total Equation and Total Variables- NOR)

Equ	weoi	USI	DD	FR	TCI	NOR	NBP	DEL	SC	SS	PWE	COP	OST	BP	SBC	cwe-
1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0
5	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
~~6~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~1~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~
7	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0
9	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0

Equ	Ost-	Cop-	cus-	pus-	mbt-	frtc-	weoi-	usi-	fr-	Nor1	Nor3	Del1	Del2	tci-	Lu1	Ss1
1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0
3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0
~~6~~	~~0~~	~~0~~	~~0~~	~~0~~	~~1~~	~~0~~	~~0~~	~~0~~	~~1~~	~~1~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4.7 Rank condition for identification (Total Equation and Total Variables- NBP)

Equ	weoi	USI	DD	FR	TCI	NOR	NBP	DEL	SC	SS	PWE	COP	OST	BP	SBC	cwe-
1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0
5	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0
9	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0

Equ	Ost-	Cop-	cus-	pus-	mbt-	frtc-	weoi-	usi-	fr-	Nor1	Nor3	Del1	Del2	tci-	Lu1	Ss1
1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0
3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0
6	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4.8 Rank condition for identification (Total Equation and Total Variables- DEL)

Equ	weoi	USI	DD	FR	TCI	NOR	NBP	DEL	SC	SS	PWE	COP	OST	BP	SBC	cwe-
1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0
5	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0
9	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0

Equ	Ost-	Cop-	cus-	pus-	mbt-	frtc-	weoi-	usi-	fr-	Nor1	Nor3	Del1	Del2	tci-	Lu1	Ss1
1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0
3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0
6	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4.9 Rank condition for identification (Total Equation and Total Variables- SC)

Equ	weoi	USI	DD	FR	TCI	NOR	NBP	DEL	SC	SS	PWE	COP	OST	BP	SBC	cwe-
1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0
5	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0
9	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0

Equ	Ost-	Cop-	cus-	pus-	mbt-	frtc-	weoi-	usi-	fr-	Nor1	Nor3	Del1	Del2	tci-	Lu1	Ss1
1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0
3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0
6	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

From table 4.1 to 4.9 created the table of determinants of order (g-1) has been created.

The results are in table 4.10 to 4.18.

Table 4.10 Determinant for equation 1 (WEOI)

USI	DD	FR	TCI	NOR	NBP	DEL	SC	SS-1
1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0
0	0	0	1	0	1	0	0	0
0	0	0	0	1	0	0	0	0
0	1	1	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0
0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	1	0	1

Table 4.11 Determinant for equation 2 (USI)

WEOI	DD	FR	TCI	NOR	NBP	DEL	SC	SS-1
1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0
0	0	0	1	0	1	0	0	0
0	0	0	0	1	0	0	0	0
0	1	1	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0
0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	1	0	1

Table 4.12 Determinant for equation 3 (DD)

WEOI	USI	FR	TCI	NOR	NBP	DEL	SC	SS-1
1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0
0	0	0	1	0	1	0	0	0
0	0	0	0	1	0	0	0	0
0	1	1	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0
0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	1	0	1

Table 4.13 Determinant for equation 4 (FR)

WEOI	USI	DD	TCI	NOR	NBP	DEL	SC	SS-1
1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0
0	0	0	1	0	1	0	0	0
0	0	0	0	1	0	0	0	0
0	1	1	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0
0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	1	0	1

Table 4.14 Determinant for equation 5 (TCI)

WEOI	USI	DD	FR	NOR	NBP	DEL	SC	SS-1
1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0
0	0	0	0	1	0	0	0	0
0	1	1	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0
0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	1	0	1

Table 4.15 Determinant for equation 6 (NOR)

WEOI	USI	DD	FRI	TCI	NBP	DEL	SC	SS-1
1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0
0	0	0	1	0	1	0	0	0
0	0	0	0	1	0	0	0	0
0	1	1	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0
0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	1	0	1

Table 4.16 Determinant for equation 7 (NBP)

WEOI	USI	DD	FR	TCI	NOR	DEL	SC	SS-1
1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0
0	0	0	1	0	1	0	0	0
0	0	0	0	1	0	0	0	0
0	1	1	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0
0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	1	0	1

Table 4.17 Determinant for equation 8 (DEL)

WEOI	USI	DD	FR	TCI	NOR	NBP	SC	SS-1
1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0
0	0	0	1	0	1	0	0	0
0	0	0	0	1	0	0	0	0
0	1	1	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0
0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	1	0	1

Table 4.18 Determinant for equation 9 (SC)

WEOI	USI	DD	FR	TCI	NOR	NBP	DEL	SS
1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0
0	0	0	1	0	1	0	0	0
0	0	0	0	1	0	0	0	0
0	1	1	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0
0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	1	0	1

The identification of a relation is achieved by assuming that some variables of the model have a zero coefficient in the equation. That implies that some variables do not directly affect the dependent variables in the equation.

The rank condition is satisfied since it is possible to construct a non-zero determinant of order 9 = (g-1) where g = 10. All equations are overidentified; this was the conclusion after the computation of order and rank condition for the equations.

However, according to Greene, W. H.[173] There is a rule of thumb, that is sometimes useful in dealing with the rank and order conditions of a model. The rule says, "If every equation has its own predetermined variable, the entire model is identified."

4.7 Conclusion

In this chapter a simultaneous-equation econometric model of the one million barrel tanker market was developed. The behaviour of the market interactions was also analysed. All the variables including demand and supply were linked to show their relationships.

The model looked at how oil imports Western Europe and USA, tanker demand, the freight rate index, the time charter index, new orders, newbuilding prices, deliveries, scrapping and tanker supply are determined in terms of a set of external factors. The variables include the level of lagged lay-ups, crude oil prices, shipbuilding cost, the lagged value of million barrel tankers, etc.

In the theoretical models, shipowner expectations are assumed to be rational. That is the shipowner makes use of the existing information and take into consideration the likely future changes. Thus shipowner can speculate about future deliveries and this invariably affects the current state of supply. Speculative changes in prices will then force the fleet to respond through changes in the supply of new ships and scrapping. The demand for vessels and supply of tankers will be influenced by oil consumption in Western Europe and USA. The size of the fleet will be influenced by deliveries and

[173] Greene, W. H. (1993), Econometrics Analysis , p.594.

scrapping. However, these are mainly driven by oscillations in demand and supply with freight rates regulating the degree of oscillation.

The simultaneous-equation model was developed and compared. The supply of one million barrel tankers is assumed to be driven by the equations of the model. This follows the assumptions that all the equations of the model would determine any justification for supplying tankers into the existing market. Tanker surpluses are believed to have an effect on the freight rates', and will lead to higher lay-ups and increases in scrapping. The tanker supply is defined as the addition of supply lagged one period to deliveries, less scrapping.

Chapter 5

UNIT ROOTS, COINTEGRATION ANALYSIS AND ERROR CORRECTION MODELS OF THE OIL TANKER MARKET (one million barrel)

5.1 Introduction

Time series analysis is a very important factor in analysing economic and shipping data, most especially oil tanker shipping. Econometric analysis of time series might reveal an important and useful insight about real world behaviour. Because of this, applied econometrics is considered to be a fundamental tool of the economic analyst. Good applied economics requires up to date statistical and economic knowledge.

There has been a considerable development in this area; this has been dealt with in chapter 3. This chapter will review recent developments in the econometric analysis of time series, and its application to the oil tanker market.

Time series data are in most cases not stationary and non stationary data can be a problem to the regression equation result. In order to avoid this, it is important to difference the data for stationarity. The standard means of checking for stationarity of data is through the use of unit root tests. The explanation of this process and the associate statistical methods employed in the analysis form the substance of this chapter.

Econometricians have devised ways of testing data for stationarity, and for testing the data to determine whether or not there is a long run relationship between time series. The modern technique for testing for causality and the long run equilibrium of the variables is called cointegration analysis. If cointegrated series exist, then a valid error correction relationship (ECM) might be present; the Engle-Granger representation theorem states that cointegrated variables are required for an ECM to be meaningful. If it is established that key variables are cointegrated, it would validate the development of a jointly estimated econometric model. This is considered to be more appropriate for the purpose of forecasting tanker supply. Thus this chapter explores cointegration, but does not develop formal error correction models.

The rest of the chapter is structured as follows: Section 2 looks at the classical time series models, which are based on the hypothesis of stationarity data. The effect of non-stationary data in a model will be discussed. After explaining the concept of integrated series in the model, unit root tests and the relevant asymptotic theory will then be analysed. Section 3 reviews cointegration theory and its application to the one million barrel oil tanker. Section 4 will present the empirical result of the unit root tests, and finally, section 5 will present the empirical results of cointegration tests.

5.2 Stationarity

Unit root tests examine the stationarity of series that are employed in regression modelling. Since stationarity is a key assumption of the analysis of time series and cointegration, it is important to understand it.

A series Xt is covariance stationary if its mean, variance and auto-covariance are independent of time. In other words, Xt is stationary if the following conditions are satisfied for all values of **t.**

$$\text{Mean:} \quad E(X)=\mu \qquad 5.2.1$$

$$\text{Variance:} \quad Var.(X_t) = E[(Xt - \mu)^2] = X^{(0)} \qquad 5.2.2$$

$$\text{Covariance:} \quad E[(X_t - \mu)(X_t + k - \mu)] = \gamma_k \qquad 5.2.3$$

Where γ_k , the covariance (or autocovariance). Lag k is the covariance between the values of X_t and X_{t+k}, that is between two X values k periods apart. If k=0, we obtain γ_0 which is simply the variance of $X(=\sigma^2)$, E( ) represents the standard expectation generator.

The properties of a stationary series and a non-stationary series are different. A stationary series will have a well-determined mean that will not vary greatly with the sampling period. Moreover, it will tend to constantly return to its mean value and fluctuations around this mean will have a broadly constant amplitude. On the other hand, the mean of a non-stationary series will vary with time and the term 'mean' cannot in general be used without referring to some particular time period.

The random walk is an example of a non-stationary process

$$X_t = X_{t-1} + \varepsilon_t \qquad \varepsilon t \approx \varepsilon(0, \sigma^2) \qquad 5.2.3a$$

and if X(0) = 0

$$X_t = \sum_{i=1}^{t} \varepsilon_t \qquad 5.2.3b$$

The variance of X_t is $t\,\sigma^2$ and this becomes indefinitely large as **t** approaches infinity. The concept of mean value of X_t has no meaning. In fact, if at some point $X_t = C$, then the expected time until X_t returns to C is infinite.

5.2.1 *The Unit Root Test for Stationarity*

Examining the autoregressive model AR(1)

$$X_t = \beta X_{t-1} + \varepsilon_t \qquad t = 1,2,..... \qquad 5.2.4$$

where β is a real number and ε_t is a sequence of independent normal zero mean random variable with variance σ^2. The series X_t is stationary if $|\beta| < 1$. But if $|\beta| = 1$ the series is not stationary. Equation 5.2.4 is a restrictive model of a more general model that will be discussed when the Dickey-Fuller test is being treated. The variance of the non-stationarity series X_t grows exponentially over time.

The link between stationarity and unit root test can be linked with equation 5.2.4.

If $\beta = 1$, then the equation is said to have a unit root and the first difference ΔX_t, will be stationary under the null (i.e. X_t is a random walk).

In order to test for stationarity in general model since equation 5.2.4 does not include a time trend or an intercept, the following models are considered.

$$\text{(i)}\quad X_t = \rho X_{t-1} + \varepsilon_t \qquad \text{5.2.5a}$$

$$\text{(ii)}\quad X_t = \alpha + \rho X_{t-1} + \varepsilon_t \qquad \text{5.2.5b}$$

$$\text{(iii)}\quad X_t = \alpha + \beta_t + \rho X_{t-1} + \varepsilon_t \qquad \text{5.2.5c}$$

where t is a time trend.

Model 5.2.5 test structure can be set as follows:

In (i), the null hypothesis is $\rho=1$ or $\Delta X_t = \varepsilon_t$ and the alternative would be $-1<\rho<1$ or $\Delta X_t = (1-\rho)X_{t-1} + \varepsilon_t$ where $1-\rho \neq 0$. After regressing $\Delta X_t = \beta X_{t-1} + \varepsilon t$ the test to know whether $\beta=0$ is taken using the critical values of Fuller(1976), if the static value exceeds the critical value, we accept the null.

In (ii), the alternative would differ from that of (i), since it is assumed that the mean of X_t in (i) to be zero under the alternative and not so in (ii). Let μ be the mean in such a way that the model would be written as

$$X_t = A + \rho X_{t-1} + \varepsilon_t \qquad \text{5.2.6}$$

where $A=\mu(1-\rho)$, when the alternative is

$$X_t = \mu(1-\rho) + \rho X_{t-1} + \varepsilon_t \qquad \text{5.2.7}$$

(that is, $-1 < \rho < 1$) against null $\rho=1$ which implies $\mu(1-\rho)=0$. So the first difference of X_t is a random walk with no drift. Once the estimation is obtained ($\hat{\rho}$) then we test the hypothesis $\rho = 0$ is conducted by comparing the static with the critical values of $\hat{\tau}\mu$, in Fuller(1976). Then the null is accepted if the absolute value of the t-statistics exceeds the critical values.

5.2.2 *Integrated Variables and Cointegration*

A series X_t is said to be integrated of order (b) if it becomes stationary after differencing (b) times. This can be written as

$$X_t \sim I(b)$$

If X_t is considered as the tanker supply series and not stationary, but X_t-X_{t-1} is stationary, X_t is said to be stationary of order 1 or $\Delta X_t \sim I(0)$.

Assuming that ΔX_t does not yet attain stationarity, in that case one more difference will be taken, such that $\Delta\Delta X_t = \Delta^2 X_t \sim I(2)$. Then X_t is I(2). This is the process of the order of integration.

It is now important to examine the case of two time series X,Y both of which are integrated of the same order, (d) such that a linear combination of X_t and Y_t is integrated of order b< d , then the two series are said to be cointegrated of order d,b.

If $y_t \sim I\ (0)$ and $x_t \sim I\ (1)$, then $\mu_t \sim I(1)$ and the variables x_t, y_t are not cointegrated. In a long run relationship between two variables both must be integrated of the same order if the error term is to be I (0).

$$\begin{vmatrix} X_t \\ \\ Y_t \end{vmatrix} \sim CI\ (d,b)$$

This combination of X_t,Y_t is a restricted version of a more general combination of (N>2) which is known as "multivariate cointegration".

If $y_t \sim I\ (1)$ and $x_t \sim I\ (0)$, then $\mu_t \sim I(1)$ and the variables x_t, y_t are not cointegrated. If $y_t \sim I\ (1)$ and $x_t \sim I\ (1)$, then it may be that $\mu_t \sim I(0)$ and the variables x_t, y_t are cointegrated, only if $[\ \beta, -1\ ]$ constitutes a cointegrating vector If $y_t \sim I\ (0)$ and $x_t \sim I\ (0)$, then $\mu_t \sim I(0)$.

5.3 Cointegration Theory

Cointegration theory is fairly new but an established method of applied econometric research. The idea of cointegration allows specification of the model that captures part of the belief about long-run relationship between pairs of economic variables. The usual problem in applied econometric time series is the existence of non-stationarity; as indicated by the high serial correlation between successive observations, this may distort the conventional statistical test that have been developed for stationary stochastic progress. One consequence for the statistical properties of estimators and tests may be spurious inferences as shown in Granger and Newbold(1974),[174] where they noted the low values of the Durbin-Watson statistic associated with spurious regression. This leads to the rejection of the null hypotheses of no relation, even when it is true. It is important to know the theory; this will be later applied to oil tanker data.

The specification of a single equation with only two random variables (for example X_t and Y_t, then X_t and Y_t) are cointegrated if

(a) the two series are integrated of the same order and

(b) a linear combination of the two series exists and is integrated of a lower order than the individual series

The importance of (a) is that equation such as [$X_\tau = aY_t$] do not make sense if the variables have different orders of integration.

$$X_t = aY_t + \varepsilon_t$$

where

$$\varepsilon_t \sim IN(0,\sigma)$$

Which implies that

$$\varepsilon_t \sim I(0)$$

Then if X_t and Y_t are integrated of different order there will not be any parameter (a) that satisfies the regression above. So a meaningful long-run relationship implies that X_t and Y_t should be integrated of the same order.

[174] Granger, C.W.J. and P. Newbold (1974), "Spurious regressions in Econometrics", Journal of Econometrics, 35, pp. 143-159.

To clarify this result, let us propose a relationship between two series (0, 1). The I(0) series would have a constant mean while the mean of I(1) goes to infinity. Then the error between them (ε_t) would be expected to become infinitely large. It is possible to have a mixture of different order series when N ≥ 3 (number of series under consideration).

The importance of the second requirement comes from the property of ε_t. If the components of X_t and Y_t were I(1) and (X_t - aY_t) is I(0), the movements in one are matched by the movement in the order in the long run. However, if X_t and Y_t are not cointegrated, then ε_t can wander widely and zero crossing would be very rare, suggesting that equilibrium cannot hold (Engle and Granger 1987, p.253).[175]

Generally, cointegration can be explained as follows: The components of the vector SS_t are said to be cointegrated of order b,d (i.e. $SS_t \sim$ CI (b,d)) if all components of or SS_t are I(b) and there exist a vector α ($\neq 0$) such that

$$Z_t = \alpha' \, SS_t \sim I(d) \qquad\qquad d > 0$$

A subset of higher order series must cointegrate to the order of the low order series. Take for example the following series

$$SS \sim I(1)$$

$$SC \sim I(2)$$

$$DEL \sim I(2)$$

where SS = tanker supply, SC= tanker scrapping and DEL = tanker deliveries

if

$$V_t = aSC + cDEL_t \sim I(2 -1) \qquad 5.3$$

and

$$Z_t - eV_t + fSS_t \sim I(1 -1) \qquad 5.4$$

then SC_t and $DEL_t \sim (CI(2,1))$ and V_t and $SS_t \sim (CI(0))$ and $Z_t \sim I(0)$. There can be many combinations.

5.3.1 Characteristics of Cointegration

Two important reasons for the interest in cointegration are the superconsistency property of least squares estimates of the cointegrating vector and the statistical foundation for the use of error correction mechanism(ECM) models. The superconsistency property of cointegration has been proven by Stock et al(1988)[176] and Engle and Granger(1987)[177] who rely on the former two theorems.

Also the statistical foundation for the ECM models means that if SSt and DELt are cointegrated, then there exists an error correction mechanism for the two cointegrating variables. Conversely if an ECM model provides an adequate

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[175] Engle, R. F. and Granger, C.W. J. (1987) "Cointegration and Error Correction Representations, Estiamtion and Testing", Econometrica vol. 55, pp.251-276.
[176] Stock, J.H. and M.W. Watson (1988) " Testing for Common Trends", Journal of the American Statistical Association, pp.1097-1107.
[177] Engle, et al., Op. Cit., p. 167

representation of the variables under considerations, then they must be cointegrated.

5.3.2 Engle and Granger Two-steps Procedure

Let us consider an equilibrium relationship between X_t and Y_t in the form

$$X_t = \alpha\, Y_t \qquad 5.4.1$$

this can be written in form of regression model

$$X_t = \alpha Y_t + \varepsilon_t \qquad 5.4.2$$

$$\varepsilon_t \sim \varepsilon\,(0,\sigma^2)$$

In the first instance model 5.4.2 will be estimated. The fitted residuals from this regression ($\hat{\varepsilon}$) can be used to test the null hypothesis $\rho=1$ in

$$\varepsilon t = \rho\varepsilon_{t-1} + e_t \qquad 5.4.3$$

where e_t is white noise. Now X_t and Y_t should be cointegrated if ε_t is I(0). Then OLS is a consistent estimator of α in the long-run relationship. The α is not unique since one can run the cointegrating regression in either direction, depending upon which of the two series is chosen to normalise on. As it was discussed above, α has the consistency property.

Secondly, the estimate of α from the first stage can be improved upon in an error correction model of the form

$$\Delta X_t = \beta \Delta Y_t + \lambda(X-\alpha Y)_{t-1} + \sum_{i=1}^{k} \pi i_1 \Delta X_t$$

$$+ \sum_{i=1}^{k} \pi i_2 \Delta Y_t + \sum_{i=1}^{k} \pi i_3 \Delta(Xt - aYt) + V_t \qquad 5.4.4$$

as long as cointegration is found in the first stage. The remaining parameters are being consistently estimated by least square since all terms are stationary. The estimate of α is inserted in the error correction term (X_t-αY_t) in (5.4.4). In another way one can substitute the estimated residuals in place of the error correction form.

5.3.3 Procedure of Preparing the Variable for Estimation

The Dickey-Fuller test model for unit roots has been discussed in section 5.2. The reasons for using the Dickey-Fuller and augmented Dickey-Fuller test will be discussed later in this section.

The purpose of this section is to find out if the variables share the same integration and the degree of integration that is common among the series. In fact, one of the main difficulties with the simple Dickey-Fuller test of the form

$$\Delta \ln X_t = \alpha_0 + \alpha_1 X_{t-1} + \varepsilon_t \qquad 5.5.1$$

is that it does not allow for possible presence of a deterministic trend in the process for X_t. Thus in practice it may be more appropriate to model $\ln X_t$ as follows

$$\Delta \ln X_t = \alpha_0 + \alpha_{1t} + \alpha_2 X_{t-1} + \varepsilon_t \qquad 5.5.2$$

Choosing whether equation (5.5.1) or (5.5.2) is more appropriate to test for the order of integration of $\ln X_t$ will depend on the checks on the t-statistics on the α_1 parameter (see Muscatelli and Hurn, 1992, p.6).[178] An alternative sequential testing procedure which is based on the results reported by West(1988)[179] and Durlauf and Phillips(1988)[180] has been suggested by Dolado and Jenkinson(1987)[181] and Dolado et al(1990).[182] These authors show that in models where there is no time trend and a drift term is present the t-statistics of the model will have limiting normal distributions and it is no longer necessary to refer to the Dickey-Fuller tables. However, Hyllberg and Mizon (1989)[183] have shown that this only hold in certain circumstances; thus it is not clear whether one should rely on this result in practice. Having said that, time trend will be included in the test regression, and the result will rely on the Dickey-Fuller tables.

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178 Muscatelli, V. A. and S. Hurn (1992) " Cointegration and Dynamic Time Series Models" , Journal of Economic Surveys, vol. 6, No. 1-43.

179 West, K. (1988) " Asymtotic Normality When Regressors Have a Unit Root", Econometrica 56, pp.1397-1417

180 Durlauf, S. N. and P.C.B. Phillips (1988) " Trends versus Random Walk in Time SeriesAnalysis", Econometrica 56 pp. 1933-1954.

181 Dolado, J.J. and T. Jenkinson (1987) "Cointegration: A Survey of Recent Developments", Applied Economics Discussion Paper, Institute of Economics and Statistics, Oxford.

182 Dolado, J.J. , J. Jenkinson and S. Sos Villa-Rivera (1990) " Cointegration and Unit Root: A Survey", Journal of Economic Survey, vol. 4, No 3.

183 Hylleberg, S. and G.E. Mizon (1989) " Cointegration and Error Correction Mechanism", Economic Journal, (Supplement) 99, pp. 113-125

Another difficulty associated with the simple Dickey-Fuller test is that they are based on the alternative hypothesis that the disturbance term is independently and identically distributed (iid). This is the reason why the modified DF or what is well known as Augmented Dickey-Fuller(ADF) is being included, it takes into account any serial correlation present by entering lagged values of the dependent variable in the regression.

$$\Delta \ln X_t = \alpha 0 + \alpha 1 t + \alpha 2 \ln Xt\text{-}1 + \sum_{i=1}^{n} \gamma ij\, \Delta \ln Xt\text{-}_j \qquad 5.5.3$$

To account for the serial correlation in the model Phillips and Perron (1988)[184] and Perron (1988)[185] have suggested a non-parametric procedure. However, the main problem in computing the modified DF-type statistics, 'Z-statistics' is that one should decide *a priori* on the number of residual autocovariances which are to be used in implementing the corrections suggested by Phillip and Perron. Also Schwert[186] shows there may be problems with the size of this test.[187]

The procedure of unit roots testing is first to test for stationarity of the variables. The test structure will be a one-tail test.

H0: $\alpha 2 = 0$

H1: $\alpha 2 < 1$

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[184] Phillips, P.C.B. and P. Perron (1988) "Testing for Unit Roots in Time Series Regressions", Biometrica, vol. 75, pp. 335-346

[185] Perron, P. (1988) " Trend and Random Walks in Microeconomics Time Series Models," Journal of Economic Dynamics and Control" vol. 12, pp. 333-346

[186] Schwert, G. W. (1989); "Tests for Unit Roots: A Monte Carlo Investigation", Journal of Business and Economics Statistics, vol. 7, pp.147-159.

If the null hypothesis is rejected, that means the variable does not have unit roots. In such case it can be agreed that the variable is stationary and is therefore I(0).

In cases where it is discovered that the level variable does have unit roots, then the next task is to know how many roots are involved in the series, that is to say that another test will be carried out to see whether the series is I(1) or I(2). At this point if stationarity is achieved at the first difference; then it will be accepted that the data is suitable for modelling and forecasting purposes. In this case the regression equation will be different from 5.5.3; the degree of difference will change. It will look like this

$$\Delta^2 \ln X_t = \beta_0 + \beta_1 \Delta \ln X_{t-1} + \sum_{i=1}^{n} \delta ij \, \Delta^2 \ln X_{t-j} \qquad 5.5.4$$

Where j is 1,2,3,4

and the null and alternative hypothesis becomes

H_0: $\beta_1 = 0$

H_1: $\beta_1 < 1$

If it is found that more roots still persist in the process of the series, Then it will be necessary to continue the test by increasing the power of differences in equation (5.5.4) by one.

[187] Schwert, G. W. (1987); "Effects of model Specification on Tests fo Unit Roots in Macroeconomic data." Journal of Moneytary Economics, vol. 20, pp. 73-103.

However, there is a need to eliminate serial correlation in the equation when testing for unit roots. If serial correlation is present in the unit roots equation with lagged one, lagged two will be included. This will be followed until the serial correlation is eliminated. Econometricians recommend ADF in empirical study that involves testing for unit roots.

It has to be said that in order to have a significant result, the sample size must be over 50 (N > 50) data point. However, the sample size used in this analysis is 24, but this does not make the result useless

5.4 Results of the Test of Unit Roots

The author begins the test by looking at each of the variables selected for the model.

$$\Delta \ln X_t = \alpha_0 + \alpha_1 T + \alpha_2 \ln X_{t-1} + \sum_{i=1}^{n} \delta j \Delta \ln X_{t-j} \qquad 5.5.5$$

Table 5.4.1 A: Western Europe Oil Imports

Series # of Lags	lnWEOI	lnCWE	lnCOP	lnPWE
DF(0)	-1.65	-2.00	-3.38	-0.26
ADF(1)	-1.18	-2.22	-2.50	-2.23
ADF(2)	-1.19	-1.51	-2.42	-1.68
ADF(3)	-0.99	-0.93	-1.75	-1.71
ADF(4)	-0.69	-1.22	-0.90	-3.26

The Dickey-Fuller t-statistics of the level series are very low. This indicates that there exist unit root(s). In this case another regression was carried out taking into consideration the first difference.

$$\Delta^2 \ln X_t = \beta_0 + \beta_1 \ln\Delta X_{t-1} + \sum_{i=1}^{n} \gamma j \Delta^2 \ln X_{t-j} \qquad 5.5.6$$

Tests for [I(1) against I(2)]

Table 5.4.2 B: Western Europe Oil Imports

Series Lags	ΔlnWEOI	ΔlnCWE	ΔlnCOP	ΔlnPWE
DF(0)	-5.29*	-3.70*	-5.04*	-2.28
ADF(1)	-2.96	-3.32	-3.81*	-3.68
ADF(2)	-2.21	-3.45	-3.09	-3.21
ADF(3)	-2.37	-2.05	-3.10	-5.79*
ADF(4)	-2.79	-1.32	-3.25	-3.00

* Indicates that the test statistics is significant at the 5% level. Unit root tests reported are tests performed in a regression that includes a constant. MacKinnon critical values for the unit root tests without a trend are -4.49, -3.67 and -3.18 for the 1%, 5% and 10% level respectively.

This test proved that all the variables are stationary at the 5% level and all at I(1)

Table 5.4.3 U.S.A. Oil Imports Series

Series # of Lags	lnUSOI	lnPUS	lnCOP	lnCUS
DF(0)	-2.20	-1.16	-1.60	-1.74
ADF(1)	-2.51	-2.00	-1.74	-2.81
ADF(2)	-2.64	-1.14	-2.40	-1.74
ADF(3)	-2.14	-1.65	-3.19	-1.56
ADF(4)	-2.57	-0.75	-1.19	-2.12
	lnΔUSOI	ΔlnPUS	ΔlnCOP	ΔlnCUS
DF(0)	-3.69*	-3.11	-5.04*	-2.80
ADF(1)	-2.29	-3.07	-3.81*	-3.68*
ADF(2)	-1.99	-2.33	-3.09	-2.68
ADF(3)	-2.27	-3.02	-3.10	-2.39
ADF(4)	-1.71	-3.87*	-3.25	-1.49

* indicates that the test statistics is significant at the 5% level. Unit root tests reported are tests performed in a which includes a constant. MacKinnon critical values for the unit root tests without a trend are -4.49, -3.67 and -3.18 for the 1%, 5% and 10% level respectively.

In order to avoid repetition, the same procedure of table 5.4.1 and 5.4.2 has been applied to the rest of the series and the tables below. The level of the series was first tested, followed by the first difference of the series.

The Dickey-Fuller t-statistics of the level are very low; thus this indicates that there exist unit root(s), as a result a test on the first difference was carried out. The series at first difference signifies a stationarity at various lag levels. The Dickey-Fuller statistics are significant at 5% level, thus ΔlnUSOI, ΔlnPUS, ΔlnCOP and ΔlnCUS become stationary at first difference I(1).

As already being mentioned all other series of the model were tested with the same method. The Dickey-Fuller and Augmented Dickey Fuller statistics were used in determining the stationarity. Each of the variables tested has one unit root.

So far, the procedure of tests for series in equation one and two has been discussed. The same steps are followed when the tests of the remaining variables were carried out. To avoid repetition of the discussion, the results will be summarised in tables.(5.4.4 - 5.4.10)

Table 5.4.4 Tanker Demand

Series # of Lags	lnDD	lnCWE	lnCUS	lnPWE	lnPUS	lnCOP
DF(0)	-2.02	-2.00	-1.74	-0.26	-1.16	-1.60
ADF(1)	-2.17	-2.22	-2.81	-2.23	-2.00	-1.74
ADF(2)	-2.65	-1.51	-1.74	-1.68	-1.14	-2.40
ADF(3)	-4.24*	-0.93	-1.56	-1.71	-1.65	-3.19
ADF(4)	-18.08*	-1.22	-2.12	-3.26	-0.75	-1.19
	ΔlnDD	ΔlnCWE	ΔlnCUS	ΔlnPWE	ΔlnPUS	ΔlnCOP
DF(0)	-4.13*	-3.70*	-2.80	-2.28	-3.11	-5.04*
ADF(1)	-3.05	-3.32	-3.68*	-3.68	-3.07	-3.81*
ADF(2)	-2.47	-3.45	-2.68	-3.21	-2.33	-3.09
ADF(3)	-1.91	-2.05	-2.39	-5.79*	-3..02	-3.10
ADF(4)	-1.68	-1.32	-1.49	-3.00	-3.87*	-3.25

* the test statistics is significant at the 5% level. Unit root tests reported are tests performed in a regression which includes a constant. MacKinnon critical values for the unit root tests without a trend are - 4.49, -3.67 and -3.18 for the 1%, 5% and 10% level respectively.

Tanker demand series are stationary at I(1), though the demand for tanker itself is I(0).

Table 5.4.5 Freight Rate

Series # of Lags	lnFR	lnMBT	lnOST	lnBP
DF(0)	-2.10	-1.88	-1.42	-1.45
ADF(1)	-2.68	-1.97	-1.65	-1.41
ADF(2)	-1.93	-2.36	-2.15	-1.86
ADF(3)	-2.78	-3.42	-2.48	-2.17
ADF(4)	-1.10	-3.57	-2.26	-0.89
	ΔlnFR	ΔlnMBT	ΔlnOST	ΔlnBP
DF(0)	-4.37*	-4.29*	-7.26*	-5.04*
ADF(1)	-4.49*	-2.73	-4.79*	-4.07*
ADFregression (2)	-2.75	-2.15	-2.51	-3.11
ADF(3)	-4.18*	-1.48	-2.00	-3.43
ADF(4)	-2.58	-1.59	-0.90	-2.15

5.4.6 Time Charter Index

Series	lnTCI	lnMBT	lnFR/TCI	lnNBP
# of Lags				
DF(0)	-1.69	-1.88	-1.57	-1.96
ADF(1)	-1.78	-1.97	-1.90	-2.17
ADF(2)	-1.94	-2.36	-2.08	-1.89
ADF(3)	- 2.55	-3.42	-3.10	-2.64
ADF(4)	-11.47*	-3.57	-1.76	-2.79
	ΔlnTCI	ΔlnMBT	ΔlnFR/TCI	ΔlnNBP
DF(0)	-4.78*	-4.29*	-4.71*	-4.39*
ADF(1)	-3.52	-2.73	-3.59	-3.21
ADF(2)	-3.03	-2.15	-3.20	-2.46
ADF(3)	-2.53	-1.48	-3.56	-1.80
ADF(4)	-2.38	-1.59	-3.91*	-1.62

* indicates that the test statistics is significant at 5% level. Unit root tests reported are tests performed in a regression which includes a constant. MacKinnon critical values for the unit root tests without a trend are -4.49, -3.67 and -3.18 for the 1%, 5% and 10% level respectively.

5.4.7 New Order

Series / # of Lags	lnNOR	lnMBT	lnFR
DF(0)	-1.04	-1.88	-2.10
ADF(1)	-2.23	-1.97	-2.68
ADF(2)	-1.98	-.36	-1.93
ADF(3)	-2.77	-3.42	-2.78
ADF(4)	-2.57	-3.57	-1.10
	ΔlnNOR	ΔlnMBT	ΔlnFR
DF(0)	-2.51	-4.29*	-4.37*
ADF(1)	-2.58	-2.73	-4.49*
ADF(2)	-2.72	-2.15	-2.75
ADF(3)	-3.80*	-1.48	-4.18*
ADF(4)	-3.22	-1.59	-2.58

5.4.8 New Building Price

Series / # of Lags	lnNBP	lnOST	lnSBC	lnDD
DF(0)	-1.96	-1.42	-2.66	-2.02
ADF(1)	-2.17	-1.65	-2.70	-2.17
ADF(2)	-1.89	-2.15	-3.25	-2.65
ADF(3)	-2.64	-2.48	-2.76	-4.24*
ADF(4)	-2.79	-2.26	-2.34	-18.08*
	ΔlnNBP	ΔlnOST	ΔlnSBC	lnΔDD
DF(0)	-4.39*	-7.26*	-5.13*	-4.13*
ADF(1)	-3.21	-4.79*	-3.44	-3.05
ADF(2)	-2.46	-2.51	-3.30	-2.47
ADF(3)	-1.80	-2.00	-2.76	-1.91
ADF(4)	-1.62	-0.90	-2.60	-1.68

* indicates that the test statistics is significant at the 5% level. Unit root tests reported are tests performed in a regression which includes a constant. MacKinnon critical values for the unit root tests without a trend are -4.49, -3.67 and -3.18 for the 1%, 5% and 10% level respectively.

5.4.9 Tanker Delivery

Series	lnDEL	lnNOR	lnFR
# of Lags			
DF(0)	-2.63	-1.04	-2.10
ADF(1)	-1.73	-2.27	-2.68
ADF(2)	-1.03	-1.89	-1.93
ADF(3)	-1.26	-3.13	-2.78
ADF(4)	-0.90	-2.50	-1.10
	ΔlnDEL	ΔlnNOR	ΔlnFR
DF(0)	-5.88*	-2.48	-4.37*
ADF(1)	-4.24*	-2.69	-4.49*
ADF(2)	-3.00	-2.70	-2.75
ADF(3)	-2.52	-3.82*	-4.18*
ADF(4)	-1.74	-3.07	-2.58

5.4.10 Tanker Scrapping

Series # of Lags	lnSC	lnLU	lnOST	lnFR
DF(0)	-2.19	-2.70	-1.42	-2.10
ADF(1)	-1.93	-2.06	-1.65	-2.68
ADF(2)	-2.05	-2.92	-2.15	-1.93
ADF(3)	-1.77	-2.18	-2.48	-2.78
ADF(4)	-1.63	-1.58	-2.26	-1.10
	ΔlnSC	ΔlnLU	ΔlnOST	ΔlnFR
DF(0)	-4.56*	-5.95*	-7.26*	-4.36*
ADF(1)	-2.63	-2.69	-4.79*	-4.49*
ADF(2)	-2.08	-3.09	-2.51	-2.75
ADF(3)	-1.61	-2.89	-2.00	-4.18*
ADF(4)	-1.22	-1.43	-0.90	-2.58

* indicates that the test statistics is significant at the 5% level. Unit root tests reported are tests performed in a regression which includes a constant. MacKinnon critical values for the unit root tests without a trend are -4.49, -3.67 and -3.18 for the 1%, 5% and 10% level respectively.

However, where the series are in the border of I(1), it is assumed that the series is I(1) rather than I(0). Banerjee and Hendry (1992)[188] argue that a stationary process with a root near unity may be better treated as if it were I(1) in samples of the size common in economics. This point has also been studied extensively by Campbell and Perron (1991)[189]

5.5 Cointegration: The Application

In section 5.4 above the unit root of the series were examined and the series were confirmed to be stationary at first difference I(1). The results have prompted an investigation of the long term relationship of the variables, which required computation of the cointegration of the series. The cointegration test of these series was carried out before using them in the model.

It is very important to understand the processes by which cointegration of variables can be tested. In this thesis though the multivariate cointegration method is what is actually needed, but in order to understand the stages of cointegration test the pairwise methods have been examined as well.

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[188] Banerjee, A., J.J. Dolado, J.W. Galbraith and D.F. Hendry (1992), " Co-integration, Error Correction and the Econometric Analysis of Non-Stationary Data", Oxford University Press
[189] Campbell, J.Y. and P.Perron (1991) " Pitfalls and Opportunities: "What Macroeconomics Should Know About Unit Roots", in Blanchard, O. J. and Fisher, S. (eds) nber Macroeconomics Annual 1991, MIT Press, Cambridge, MA.

Firstly the Engle-Granger bivariate cointegration method was examined. It was found that most of the paired variables were cointegrated. The Johansen bivariate test method was applied where it was difficult to get a long run equilibrium result. The result of Johansen test confirmed that the series are cointegrated. The tables of Engle-Granger bivariate cointegration of the series will be presented later.

$$\ln Yt = \alpha_0 + \alpha_1 \ln X_t + \alpha_2 Z_t + \varepsilon_t \qquad 5.7.1$$

The cointegration test has used equation 5.7.1 to compute the rest of the series and these are summarised in the tables below. The cointegration results are based on the critical statistics of Dickey-Fuller and the cointegration regression of Durbin Watson (CRDW). The CRDW is considered to be significant the further it moves away from zero.

The power of CRDW depends positively on the goodness of fit of the OLS estimate of the long run relationship. Thus Banerjee et al., (1986) proposed a simple 'rule of thumb' for a quick evaluation of the cointegration hypothesis. If CRDW computed for V_t of an equation is smaller than the coefficient of determination R^2 for this equation, the cointegration hypothesis is likely to be false, otherwise when CRDW > R^2 cointegration may occur. It can then be stated that if the conventional DW statistics computed for the residuals of a static model representing a long run relationship is close to 2, there is no danger of the lack of cointegration of the variables.

Table 5.5.1 Equation One Series (WEOI)[190]

# of Lags	WEOI & CWE	WEOI & COP	WEOI & PWE	CWE & COP	CWE & PWE	COP & PWE
DF(0)	-7.67*	-5.57*	-5.76*	-3.47	-3.68*	-4.05*
ADF(1)	-5.93*	-3.08	-3.32	-2.88	-3.50	-2.61
ADF(2)	-3.82	-2.49	-2.61	-3.19	-3.20	-1.70
ADF(3)	-2.51	-2.42	-2.33	-1.98	-2.10	-2.37
ADF(4)	-1.75	-1.40	-1.95	-1.16	-1.58	-1.87
ADF(5)	-0.88	-0.93	-1.31	-1.80	-1.67	-1.06
ADF(6)	-0.71	-0.95	-1.26	-0.99	-1.10	-0.63
R^2	.47	.02	.07	.14	.01	.01
D. W.	2.94	2.34	2.44	1.29	1.48	1.75

* Significant at 5% level. The CRDW is high, we accept that the variables are cointegrated

As can be noticed, the Dickey-Fuller t-statistics are significant at 5% level. The asterisk indicates 5% level. Some of the variables are very difficult to determine with this method, hence the application of the Johansen method, discussed later. In order to avoid repetition, the summary of the remaining Engle-Granger bivariate cointegrating results will be given in the tables below (5.5.2 - 5.5.9).

[190] All series are in natural logrithm and first difference

Table 5.5.2 Equation Two Series (USI)

# of Lags	USI & PUS	USI & COP	USI & CUS	PUS & COP	PUS & CUS	COP & CUS
DF(0)	-3.41	-2.95	-3.69	-3.35	-3.27	-4.01*
ADF(1)	-2.55	-2.27	-2.56	-3.21	-3.14	-2.45
ADF(2)	-2.85	-2.48	-3.25	-2.13	-2.23	-1.70
ADF(3)	-1.98	-1.97	-3.05	-2.62	-2.67	-3.05
ADF(4)	-1.52	-1.53	-2.89	-2.04	-2.13	-1.97
ADF(5)	-2.18	-2.24	-1.98	-1.54	-1.59	-1.58
ADF(6)	-3.06	-2.81	-1.12	-1.01	-1.01	-0.97
R^2	.01	.06	.57	.003	.65	.19
D. W.	1.36	1.09	1.98	1.38	1.34	1.69

* Significant at 5% level. The CRDW is high, we accept that the variables are cointegrated

Table 5.5.3 Equation Three Series (DD)

# of Lags	DD & CWE	DD & CUS	DD & COP	CWE & CUS	CWE & COP	COP & CUS	PUS & DD	PWE & DD
DF(0)	-3.29	-3.47	-4.03*	-5.00*	-3.47	-4.01*	-0.86	-1.98
ADF(1)	-2.22	-2.39	-2.61	-3.80*	-2.88	-2.45	-1.55	-2.38
ADF(2)	-1.69	-1.78	-1.90	-3.81*	-3.19	-1.70	-1.30	-2.09
ADF(3)	-1.43	-1.00	-1.44	-2.93	-1.98	-3.05	-1.65	-2.60
ADF(4)	-4.50*	-4.82*	-4.97*	-2.87	-1.16	-1.97	-1.19	-1.78
ADF(5)	-1.78	-1.48	-1.87	-2.68	-1.80	-1.58	-1.10	-1.34
ADF(6)	-1.51	-1.15	-1.30	-1.86	-0.99	-0.97	-1.56	-2.17
R^2	.02	.15	.03	.67	.14	.19	0.10	0.03
D. W.	1.26	1.40	1.68	2.07	1.29	1.69	.33	.46

* Significant at 5% level.
The CRDW is high, we accept that the variables are cointegrated

Table 5.5.4 Equation Four Series (FR)

# of Lags	FR & MBT	FR & OST	FR & BP	MBT & OST	MBT & BP	OST & BP
DF(0)	-4.39*	-4.46*	-4.75*	-3.16	-3.25	-3.08
ADF(1)	-3.87*	-4.26*	-4.21*	-2.17	-2.48	-2.07
ADF(2)	-2.51	-2.53	-2.76	-1.73	-1.86	-1.86
ADF(3)	-3.47	-3.58	-3.58	-1.20	-1.31	-1.87
ADF(4)	-2.04	-2.21	-2.18	-1.35	-1.76	-1.42
ADF(5)	-2.66	-3.07	-2.88	-2.88	-4.31*	-2.65
ADF(6)	-1.70	-2.75	-2.17	-1.56	-1.96	-1.72
R^2	.004	.05	.01	.12	.07	.004
D. W.	1.85	1.91	1.99	1.27	1.28	1.11

Table 5.5.5 Equation Five Series (TCI)

# of Lags	TCI & MBT	TCI & FR/TCI	TCI & NBP	MBT & FR/TCI	MBT & NBP	FR/TCI & NBP
DF(0)	-6.61*	-3.88*	-4.74*	-4.20*	-3.32	-3.85*
ADF(1)	-4.46*	-3.26	-2.84	-2.37	-2.15	-2.65
ADF(2)	-3.53	-3.36	-2.78	-1.53	-1.56	-2.69
ADF(3)	-3.30	-2.63	-2.25	-1.36	-1.37	-2.46
ADF(4)	-5.63*	-3.19	-1.95	-1.19	-1.40	-2.62
ADF(5)	-1.64	-3.91*	-1.68	-3.85*	-3.86*	-1.77
ADF(6)	2.54	-3.32	-1.09	-2.06	1.65	-0.91
R^2	.008	.02	.04	.08	.10	.38
D. W.	2.67	1.57	2.06	1.71	1.30	1.63

Table 5.5.6 Equation Six Series (NOR) [191]

# of Lags	NOR & MBT	NOR & FR	MBP & FR
DF(0)	-3.71*	-2.52	-2.86
ADF(1)	-3.06	-2.73	-2.08
ADF(2)	-3.01	-3.76	-1.59
ADF(3)	-2.55	-2.33	-1.35
ADF(4)	-2.55	-2.32	-1.56
ADF(5)	-1.46	-1.58	-3.81*
ADF(6)	-1.71	-1.61	-1.77
R^2	0.08	0.03	0.004
D.W.	1.15	0.89	1.06

[191] * Significant at 5% level.
The CRDW is high, we accept that the variables are cointegrated

Table 5.5.7 Equation Seven Series (NBP)[192]

# of Lags	NBP & FR	NBP & OST	NBP & SBC	NBP & DD	FR & OST	FR & SBC
DF(0)	-4.60*	-4.66*	-5.04*	-3.75	-4.46*	-4.57*
ADF(1)	-3.42	-3.44	-3.72*	-2.67	-4.26*	-3.91*
ADF(2)	-2.42	-2.43	-2.48	-2.56	-2.53	-2.60
ADF(3)	-2.19	-2.23	-2.13	-2.40	-3.58	-3.70*
ADF(4)	-2.39	-2.41	-2.30	-1.71	-2.21	-2.37
ADF(5)	-1.69	-1.66	-1.67	-1.60	-3.07	-2.41
ADF(6)	-2.04	-1.99	-1.75	-1.97	-2.75	-2.23
R^2	.05	.39	.04	.39	.01	.04
D. W.	2.00	2.02	2.18	1.50	1.93	1.90

Table 5.5.7 cont..

# of Lags	FR & DD	OST & SBC	OST & DD	SBC & DD
DF(0)	-4.70*	-2.75	-3.05	-5.52*
ADF(1)	-4.47*	-2.43	-2.09	-4.05*
ADF(2)	-2.85	-1.89	-1.87	-2.68
ADF(3)	-3.31	-1.44	-1.82	-2.88
ADF(4)	-2.08	-1.14	-1.38	-2.71
ADF(5)	-3.20	-2.04	-2.64	-2.50
ADF(6)	-1.61	-1.60	-1.75	-1.73
R^2	.03	.16	.01	.001
D. W.	1.94	.87	1.12	2.34

Table 5.5.8 Equation Eight Series (DEL)

# of Lags	DEL & NOR	DEL & FR	NOR & FR
DF(0)	-6.86*	-6.83*	-2.52
ADF(1)	-4.89*	-4.89*	-2.73
ADF(2)	-2.63	-2.56	-3.16
ADF(3)	-2.59	-2.26	-2.33
ADF(4)	-1.64	-1.38	-2.32
ADF(5)	-1.57	-1.40	-1.58
ADF(6)	-1.44	-1.32	-1.61
R^2	.06	.005	.03
D. W.	2.76	2.75	.89

192 Ibid. p. 184

Table 5.5.9 Equation Nine Series (SC)

# of Lags	SC & LU	SC & FR	LU & FR	OST & SC
DF(0)	-4.58*	-5.33*	-6.32*	-3.06
ADF(1)	-3.36	-3.09	-2.89	-2.03
ADF(2)	-2.88	-3.20	-3.33	-1.86
ADF(3)	-2.41	-3.12	-3.29	-1.90
ADF(4)	-1.83	-2.11	-1.68	-1.45
ADF(5)	-1.82	-2.06	-2.44	-2.89
ADF(6)	-1.65	-1.53	-1.80	-1.68
R^2	0.06	0.05	0.002	0.01
D.W.	2.00	2.30	2.60	1.13

The CRDW of some of the pairs series in Engle-Granger are fairly low, hence it is necessary to look at the Johansen method.

5.5.1 Johansen Bivariate and Multivariate Cointegration Tests

After checking the long run relationship of the series through Engle-Granger bivariate method it is found to be important to test further to confirm that the series are cointegrated. Since some of the variables are signifcant but on the border line, the Johansen bivariate and multivariate cointegration methods were examined. The reason for applying multivariate is to determine jointly the long-run relationship of variables in each of the equations.

The results of the bivariate and multivariate cointegration methods are given below. The t-statistics critical levels are checked against the Johansen critical level at 95%; these are marked with asterisks. In most of the series the null hypothesis of no cointegration is rejected.

Table 5.5.10 : Johansen Bivariate[193] -WEOI Series[194]

Maximum Eigenvalue Tests

	WEOI	CWE	COP	PWE
WEOI		13.70*	16.06*	10.23
CWE			29.46*	13.53
COP				12.26
PWE				
Trace Tests				
WEOI		17.12*	23.72*	15.96*
CWE			36.48*	22.45*
COP				19.44*
PWE				

Table 5.5.11: Johansen Multivariate Cointegration Tests for WEOI

Variables: WEOI, CWE, COP, PWE

Hypothesis		Eigenvalue Tests	Trace Tests
H0	H1	K=1	K=1
r=0	r=1	42.33**	84.03**
r≤1	r=2	24.64**	41.70**
r≤2	r=3	14.74**	17.05**
r≤3	r=4	2.31	2.31

Note: (a) k is maximum lag in VAR
(b) r is number of cointegrating vectors
(c) One and two astericks indicate significance at the 90% and 95% level respectively

The result indicates that there exist at least one cointegration vector in the WEOI equation. There are three cointegrated vectors, that is r is equal to 3. The null hypothesis of eigenvalue and trace tests is rejected. In other to make the argument that the variables are cointegrated, the system has been estimated by using maximum likelihood, following Johansen (1988) and Johansen and Juselius (1990).[195]

[193] Maximum Eigenvalue tests and Trace tests, the hypothesis test is Ho: r=0 against H1: r=1
[194] All variables are in logrithmn

The tests for cointegration by the Johansen approach are very encouraging, it means that there is no need to worry about the slightly insignificant result of Granger and Engle test. The summary of the results of other series and equations will be given in the tables below.

Table 5.5.12: Johansen Cointegrating Vectors (k=1) for WEOI

Variables	Vector 1*	Vector 2	Vector 3
WEOI	3.28	1.33	-0.29
	(-1.00)	(-1.00)	(-1.00)
CWE	-4.41	-2.42	6.04
	(1.33)	(1.81)	(20.4)
COP	0.13	-0.55	0.17
	(-0.04)	(0.41)	(0.59)
PWE	0.26	0.45	0.05
	(-0.07)	(-0.34)	(0.20)

The tables 5.5.10, 5.5.11 and 5.5.12 have looked at the cointegration of WEOI series.

The Johansen co-integrating vector was examined to reveal the relationship of the variables. In this case where there are more than one vector it becomes important to look at the relationship of variables in the vectors for economic explanation. In order to determine this vector that is very close to our theory in terms of signs and economic argument will be examined. At this point the vector that has the variables with correct signs and good economic reasoning was selected.

[195]Johansen, S. and Juselius, K. (1990) Maximum Likelihood Estimattion and Inference on Cointegration: With Application to the Demand for Money", Oxford Bulletin of Economics and Statistics , Vol 52, pp. 169-210.

Table 5.5.13 : Johansen Bivariate[196] -USOI Series[197]
Maximum Eigenvalue Tests

	USOI	PUS	COP	CUS
USOI		11.87	15.28*	9.45
PUS			10.79	21.85*
COP				15.70*
CUS				
Trace Tests				
USOI		15.47*	18.75*	16.05*
PUS			12.63*	24.68*
COP				23.65*
CUS				

Table 5.5.14: Johansen Multivariate Cointegration Tests for USOI

Variables: USOI, PUS, COP, CUS

Hypothesis		Eigenvalue Tests	Trace Tests
H0	H1	k=1	k=1
r=0	r=1	29.64**	67.07**
r≤1	r=2	22.72**	37.42**
r≤2	r=3	7.81	14.71
r≤3	r=4	6.88	6.88

Note: (a) k is maximum lag in VAR
(b) r is number of cointegrating vectors
(c) One and two astericks indicate significance at the 90% and 95% level respectively

Johansen bivariate shows cointegration in most of the pairs. The multivariate cointegration shows more than one vector; at least there is one cointegrated vector. The eigenvalue and trace tests both at k=1 shows that r = 1 and r = 2 respectively.

196 Maximum Eigenvalue tests and Trace tests, the hypothesis test is Ho: r=0 against H1: r=1
197 All variables are in logrithmn

Table 5.5.15: Johansen Cointegrating Vectors (k=3) for USOI

Variables	Vector1	Vector 2*
USOI	-1.32 (-1.00)	-2.17 (-1.00)
PUS	1.15 (-0.86)	-3.12 (1.43)
COP	0.52 (-0.39)	0.10 (-0.04)
CUS	3.27 (2.46)	5.65 (2.59)

The same explanation of tables 5.5.10-5.5.15 applies to table 5.5.16 to 5.5.36. The interpretations of the tables are the same, however the variables vary. In order to avoid repetition the summaries of the tables are presented below. (5.5.16 - 5.5.36)

Table 5.5.16 : Johansen Bivariate[198] -Demand Series[199]
Maximum Eigenvalue Tests

	DD	CWE	CUS	COP	PWE	PUS
DD		13.90	12.76	10.36	12.98*	9.84
CWE			8.41	29.46*	13.53	6.70
CUS				19.30*	12.71	21.86*
COP					12.26	10.79*
PWE						9.70
Trace Tests						
DD		22.66*	20.17*	14.84	22.60*	14.32*
CWE			9.54	36.48*	22.45*	9.24
CUS				23.46*	20.11*	24.68*
COP					19.44*	12.63*
PWE						10.96

198 Maximum Eigenvalue tests and Trace tests, the hypothesis test is Ho: r=0 against H1: r=1
199 All variables are in logrithmn

Table 5.5.17: Johansen Multivariate Cointegration Tests for DD

Variables: CWE, CUS, COP , PWE & DD

Hypothesis		Eigenvalue Tests	Trace Tests
H0	H1	k=3	k=3
r=0	r=1	32.16**	70.78**
r≤1	r=2	23.39**	38.62**
r≤2	r=3	12.99*	15.22**
r≤3	r=4	2.23	2.23

Note: (a) k is maximum lag in VAR
(b) r is number of cointegrating vectors
(c) One and two astericks indicate significance at the 90% and 95% level respectively

Table 5.5.18: Johansen Cointegrating Vectors (k=2) for DD

Variables	Vector 1*	Vector 2	Vector 3
CWE	-13.46	5.66	-8.22
	(-1.00)	(-1.00)	(-1.00)
CUS	4.85	1.10	-3.98
	(0.36)	(-0.19)	(-0.48)
COP	-0.98	-0.89	-1.23
	(-0.07)	(0.15)	(-0.14)
PWE	-2.98	-0.31	0.86
	(-0.22)	(0.05)	(0.10)

* The vector that meet the criteria of the equation relationship

Table 5.7.19 : Johansen Bivariate[200] -FR Series[201]
Maximum Eigenvalue Tests

	FR	MBT	OST	BP
FR		9.30	4.71	9.92
MBT			14.22*	12.59
OST				14.81*
BP				
Trace Tests				
FR		14.99*	7.25	5.77
MBT			20.16*	15.91*
OST				19.92*
BP				

[200] Maximum Eigenvalue tests and Trace tests, the hypothesis test is Ho: r=0 against H1: r=1
[201] All variables are in logrithmn

Table 5.5.20: Johansen Multivariate Cointegration Tests for FR

Variables: FR, MBT, OST, BP

Hypothesis		Eigenvalue Tests	Trace Tests
H0	H1	k=3	k=3
r=0	r=1	32.44**	75.17**
r≤1	r=2	19.76**	42.72**
r≤2	r=3	15.96**	22.95**
r≤3	r=4	6.99	6.99

Note: (a) k is maximum lag in VAR
(b) r is number of cointegrating vectors
(c) One and two astericks indicate significance at the 90% and 95% level respectively

Table 5.5.21: Johansen Cointegrating Vectors (k=3) for FR

Variables	Vector 1	Vector 2*	Vector 3	Vector 4
FR	1.17	1.53	-1.10	-0.23
	(-1.00)	(-1.00)	(-1.00)	(-1.00)
MBT	-1.62	0.26	-2.12	0.55
	(1.38)	(-0.17)	(-1.92)	(2.38)
OST	0.18	0.73	3.75	-1.98
	(-0.16)	(-0.47)	(3.40)	(-8.50)
BP	1.44	1.34	1.87	0.62
	(-1.23)	(-0.87)	(1.69)	(2.68)

* The vector that meet the criteria of the equation relationship

Table 5.5.22 : Johansen Bivariate[202] -TCI Series[203] Maximum Eigenvalue Tests

	TCI	MBT	FR/TCI	NBP
TCI		26.16*	11.01	4.88
MBT			18.66*	8.82*
FR/TCI				6.26
NBP				
Trace Tests				
TCI		42.41*	15.30*	6.28
MBT			30.88*	10.66
FR/TCI				8.23
NBP				

202 Maximum Eigenvalue tests and Trace tests, the hypothesis test is Ho: r=0 against H1: r=1
203 All variables are in logrithmn

Table 5.5.23: Johansen Multivariate Cointegration Tests for TCI

Variables: TCI, MBT FR/TCI, NBP

Hypothesis		Eigenvalue Tests	Trace Tests
H0	H1	K=3	K=3
r=0	r=1	42.54**	73.26**
r≤1	r=2	18.39	30.72**
r≤2	r=3	8.99	12.32
r≤3	r=4	3.32	3.32

Note: (a) k is maximum lag in VAR
(b) r is number of cointegrating vectors
(c) One and two astericks indicate significance at the 90% and 95% level respectively

Table 5.5.24: Johansen Cointegrating Vectors (k=1) for TCI

Variables	Vector 1
TCI	0.58
	(-1.00)
MBT	-2.54
	(4.35)
FR/TCI	-0.43
	(0.74)
NBP	-0.15
	(0.25)

Table 5.5.25 : Johansen Bivariate[204] -NOR Series[205] Maximum Eigenvalue Tests

	NOR	MBT	FR
NOR		13.16*	6.57
MBT			12.11
FR			
Trace Tests			
NOR		18.63*	8.86
MBT			15.23*
FR			

[204] Maximum Eigenvalue tests and Trace tests, the hypothesis test is Ho: r=0 against H1: r=1
[205] All variables are in logrithmn

Table 5.5.26: Johansen Multivariate Cointegration Tests for NOR

Variables: NOR, MBT, FR

Hypothesis		Eigenvalue Tests	Trace Tests
H0	H1	K=1	K=1
r=0	r=1	30.95**	53.62**
r≤1	r=2	17.29**	22.66**
r≤2	r=3	5.37*	5.37*

Note: (a) k is maximum lag in VAR
(b) r is number of cointegrating vectors
(c) One and two astericks indicate significance at the 90% and 95% level respectively

Table 5.5.27: Johansen Cointegrating Vectors (k=1) for NOR

Variables	Vector 1	Vector 2	Vector 3*
NOR	0.18	-0.62	-0.06
	(-1.00)	(-1.00)	(-1.00)
MBT	0.42	0.69	-0.66
	(-0.65)	(1.11)	(-10.59)
FR	-0.64	0.30	0.24
	(-0.28)	(0.48)	(3.89)

* The vector that meets the criteria of the equation relationship

Table 5.5.28 : Johansen Bivariate[206] -NBP Series[207]
Maximum Eigenvalue Tests

	NBP	OST	SBC	DD
NBP		5.88	15.58*	13.02
OST			6.47	16.21*
SBC				12.71
DD				
Trace Tests				
NBP		7.48	17.74*	14.44
OST			9.65	19.28*
SBC				20.33*
DD				

[206] Maximum Eigenvalue tests and Trace tests, the hypothesis test is Ho: r=0 against H1: r=1
[207] All variables are in logrithmn

Table 5.5.29: Johansen Multivariate Cointegration Tests for NBP

Variables: NBP, FR, OST, SBC DD

Hypothesis		Eigenvalue Tests	Trace Tests
H0	H1	K=3	K=3
r=0	r=1	83.32**	189.93**
r≤1	r=2	47.71**	106.60**
r≤2	r=3	28.22**	58.89**
r≤3	r=4	18.99**	30.67**
r≤4	r=5	11.67**	11.67**

Note: (a) k is maximum lag in VAR
(b) r is number of cointegrating vectors
(c) One and two astericks indicate significance at the 90% and 95% level respectively

Table 5.5.30: Johansen Cointegrating Vectors (k=2) for NBP

Variables	Vector 1*	Vector 2	Vector 3	Vector 4	Vector 5
NBP	-5.50	0.77	-0.61	3.32	1.84
	(-1.00)	(-1.00)	(-1.00)	(-1.00)	(-1.00)
FR	-0.88	0.15	1.74	-1.05	0.25
	(-0.16)	(0.19)	(2.84)	(0.31)	(-0.13)
OST	0.54	1.39	-0.06	-0.39	0.19
	(0.09)	(1.79)	(-0.10)	(0.11)	(-0.10)
SBC	6.44	-0.62	1.18	-2.47	-0.89
	(1.17)	(-0.80)	(-1.93)	(0.74)	(0.48)
DD	0.09	0.42	1.16	-0.15	-0.26
	(0.01)	(0.54)	(1.89)	(0.04)	(0.14)

* The vector that meets the criteria of the equation relationship

Table 5.5.31: Johansen Bivariate[208] -DEL Series[209]
Maximum Eigenvalue Tests

	DEL	NOR	FR
DEL		9.54	11.35
NOR			9.73
FR			
Trace Tests			
DEL		11.47*	12.35*
NOR			12.17
FR			

[208] Maximum Eigenvalue tests and Trace tests, the hypothesis test is Ho: r=0 against H1: r=1
[209] All variables are in logrithmn

Table 5.5.32: Johansen Multivariate Cointegration Tests for DEL

Variables: DEL, NOR, FR

Hypothesis		Eigenvalue Tests	Trace Tests
H0	H1	k=3	k=3
r=0	r=1	28.67**	46.51**
r≤1	r=2	14.23**	17.83**
r≤2	r=3	3.59*	3.59*

Note: (a) k is maximum lag in VAR
(b) r is number of cointegrating vectors
(c) One and two astericks indicate significance at the 90% and 95% level respectively

Table 5.5.33: Johansen Cointegrating Vectors (k=3) for DEL

Variables	Vector 1*	Vector 2
DEL	-1.35	-0.45
	(-1.00)	(-1.00)
NOR	0.372	-0.40
	(0.27)	(-0.88)
FR	1.15	1.77
	(0.85)	(3.88)

* The vector that meets the criteria of the equation relationship

Table 5.5.34 : Johansen Bivariate[210] -SC Series[211] Maximum Eigenvalue Tests

	SC	LU	FR	OST
SC		9.11	5.27	19.91*
LU			10.36	6.78
FR				7.65
OST				
Trace Tests				
SC		12.41*	9.51	23.67*
LU			13.45*	10.64
FR				9.79
OST				

[210] Maximum Eigenvalue tests and Trace tests, the hypothesis test is Ho: r=0 against H1: r=1
[211] All variables are in logrithmn

Table 5.5.35: Johansen Multivariate Cointegration Tests for SC

Variables: SC, LU, FR, OST

Hypothesis		Eigenvalue Tests	Trace Tests
H0	H1	k=2	k=2
r=0	r=1	38.55**	86.02**
r≤1	r=2	26.91**	47.47**
r≤2	r=3	11.26	20.55**
r≤3	r=4	9.29	9.29

Note: (a) k is maximum lag in VAR
(b) r is number of cointegrating vectors
(c) One and two astericks indicate significance at the 90% and 95% level respectively

Table 5.5.36: Johansen Cointegrating Vectors (k=2) for SC

Variables	Vector 1	Vector 2*
SC	-0.20	-0.02
	(-1.00)	(-1.00)
LU	0.21	0.15
	(1.06)	(7.17)
FR	0.14	-0.58
	(0.69)	(-26.29)
OST	0.42	0.18
	(2.07)	(8.24)

* The vector that meets the criteria of the equation relationship

The tests for cointegration by the Johansen approach are a little better, therefore it is not necessary to be worried about Engle-Granger tests critical value. The null hypothesis of cointegration in both eigenvalue and trace tests is rejected. With the same critical values used in the last table obtained from Johansen and Juselius(1990)[212] table A2, p.102; the test for the series reveals that one cointegrating vector is assured by both maximum eigenvalue and trace tests.

[212] Johansen, S. and Juselius, K. (1990) Maximum Likelihood Estimattion and Inference on Cointegration: With Application to the Demand for Money", Oxford Bulletin of Economics and Statistics , Vol 52, pp. 169-210.

The static model represented by the estimation of cointegration equations does have a plausible outcome. The null hypothesis of no cointegration is rejected by all criteria of the tests. With the confirmation that the series are cointegrated then it is possible to apply the Engle-Granger (1987)[213] theorem that cointegrated series are suitable for the error correction model.

5.5.2 The Error Correction Model

The general idea is (from Engle-Granger 1987) to estimate the long run relationship and then insert the deviations from the long run path; this will be lagged as the error correction mechanism in the short run equation.[214] As a result the error correction corrects for disequilibrium.

The error correction model is another new modelling technique of econometrics. It is important to mention ECM; however it is not extensively used in this thesis. The reason is that single equation model would have caused the forecast results to be biased. However, this has not stopped the implementation of unit roots and cointegration in the thesis; variables have to be stationary for unbiased result. The existence of long-run relationship confirms the Engle-Granger(1987)[215] theorem that links the long-run equilibrium to the short run dis-equilibrium. In other word, what this proves is

[213]Engle, et al. (1987) Op. c i t., p. 167.
[214] Ibid

that if there is a long-run relationship between variables, there exists an error correction mechanism (ECM) that explains the short-run adjustment to the long-run.

As mentioned above, the awareness of the joint relationship of the series in the model and the forecasting of individual equation model such as that of ECM will undermine forecast results.

Using unit root tests and cointegration analysis, the data series used in the econometric model have been analysed. The first difference of the variable is found suitable for tanker supply model and simultaneous-equation econometric method can be implemented. The significance of unit roots and cointegration in justify the development of the oil tanker model can be seen from the analysis.

5.6 Conclusion

The chapter has examined the unit roots and cointegration methods and these have been applied to determine the stationarity of oil tanker data and the long-run relationship of the variables. In the analysis the Granger and Engle technique for unit roots and bivariate cointegration was examined; also the Johansen technique for testing the bivariate and multiple cointegration was implemented. The pairwise cointegration method was examined to show and

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[215] Ibid.,

complete the procedures of cointegration tests. Further more, to indicate the relationship of the dependent variable to the individual independent variables in the equation. The cointegration technique is essential to ensure that a long run relationship exists between the series in the econometric model. The cointegrated series have an error correction representation, but this aspect has not been developed in the thesis.

Chapter 6

ESTIMATION AND SIMULATION OF THE MODEL

6.1 Introduction

In chapter four a proposed econometric model of oil supply of one million barrel tanker was analysed. The theory developed in chapter four is going to be used in estimation and simulation of the oil tanker model. There are ten equations in the model, which explain existing USA and Western Europe oil imports, the demand for tankers, freight rate, time charter rate,new order, newbuilding price, deliveries, scrapping and tanker supply. These endogenous equations will be estimated to determine the supply of one million barrel tanker. The estimated market will then be used in the simulation exercise.

The statistical evidence suggests that all the measurement of the key variables of the model is reliable. Oil imports in Western Europe and USA are assumed to jointly determine the level of tanker employment. This is a disaggregated oil tanker model, thus avoiding the handling of medium and large tankers. The future demands for oil in the two major areas are computed to show the effect of oil demand on tanker supply and demand. The freight rate determines the level of profit; this is important to the tanker owner and indeed every player in the market. The stock of existing tankers will influence both lay-up and scrapping rates of the vessels and indeed the supply of one million barrel tankers.

The theoretical specification of the model and the econometric methodology that was used in order to estimate its structure in chapter four is also discussed here. For simplicity reasons section 6.2 will review the theoretical specification and will briefly review the estimated equations. Section 6.3 will explain the econometric methodology; thus it presents and discusses the empirical estimation of the model. Section 6.4 simulates the model with responses to various unanticipated and anticipated factors. (Extrapolation and ex-post forecast results were generated from RATS.)

The simultaneous equation model determines the values of one set of variable, (the endogenous variables) in terms of another set of variables, the exogenous and predetermined variables. As a result of two-way causation being found in the functions, it simply implies that the function cannot be treated in isolation. It has to be set within a system of equations that describe the relationships among all the relevant variables.

Furthermore, since the endogenous variables also serve as predetermined variables, it becomes impossible to estimate individual equations separately; instead they need to be computed jointly within the system. The multi-equation model includes separate equations in which the endogenous variables also appear in other equations of the model.

Two Stage Least Squares (2SLS) has been applied. This helps to avoid the correlation problem between endogenous explanatory variables and the error term in the equation. Theil was one of the advocates of the technique.[216]

The objective of the two stage least squares technique is to make the explanatory endogenous variable uncorrelated with the error term, such that the direct application of least squares will result in consistent estimates.

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[216]Theil H., Introduction to Econometrics, Prentice-Hall, Englewood Cliffs, N.J., 1978, pp. 341-342.

6.2 Overview

This section presents the theoretical specification of the oil tanker model. The theoretical analysis is based on the theory that was presented in chapter four. The complete specification of the model is given through equation (1) - (10) listed below.

5.2.1 *Model Listing*

$$1.\ \Delta \ln WEOI_t = \alpha_o - \beta 1 \Delta \ln WEOI_{t-1} + \delta \Delta 1 \ln CWE_{t-1} - \lambda 1 \Delta \ln COP_t - \varphi \Delta \ln PWE_t + \varepsilon_t \qquad 1$$

Where
$WEOI_{t-1}$: Western Europe oil imports lagged one period (mb/d)
CWE_{t-1} : Oil consumption Western Europe lagged one period (mt)
COP : Crude oil prices ($/bl)
PWE: Oil production Western Europe (mt)
ε: random error term

$$2.\ \Delta \ln USI_t = \alpha_o + \beta 1 \Delta \ln USI_{t-1} - \theta 1 \Delta \ln PUS_{t-1} - \varphi 1 \Delta \ln COP_t + \gamma 1 \Delta \ln CUS_{t-1} + \varepsilon_t \qquad 2$$

Where
USI_{t-1}: Oil imports USA lagged one period (mb/d)
PUS_{t-1}: Oil production USA lagged one period (mt)
COP: Crude oil prices ($/bl)
CUS_{t-1}: Oil consumption USA lagged one period (mt)
ε: Random error term

$$3.\ \Delta \ln DD_t = -\alpha_o + \beta 1 \Delta^2 \ln CWE_{t-1} + \varphi 1 \Delta \ln CUSI_{t-1} - \delta 1 \Delta^2 \ln COP_t - \gamma 1 \Delta^2 \ln PWE_{t-1} + \varepsilon_t \qquad 3$$

Where
DD : Tanker demand (mdwt)

CWE_{t-1} : Western Europe oil consumption lagged one (mt)
CUS_{t-1} : U.S.A. oil consumption lagged one (mt)
COP: Crude oil prices ($/bl)
PWE_{t-1} : Western Europe oil production
ε: random error term

$$4.\ \Delta lnFR_t = \alpha_\circ - \beta 1 \Delta lnMBT_{t-1} + \varphi 1 \Delta lnOST_t + \delta 1 \Delta lnBP_t + \varepsilon_t \qquad 4$$

Where
FR: Freight rate index
MBT_{t-1}: Million Barrel Tanker lagged one period (mdwt)
OST: Oil Seaborne Trade (mtm)
BP: Bunker price ($)
ε: random error term

$$5.\ \Delta lnTCI_t = \alpha_\circ - \beta 1 \Delta lnTCI_{t-1} + \phi 1 \Delta lnMBT_{t-1} + \varphi 1 \Delta ln(FR/TCI)_{t-1} + \gamma 1 \Delta lnNBP_t + \varepsilon_t \qquad 5$$

Where
TCI: Time charter index
MBT_{t-1}: Million barrel tanker total stock (mdwt)
$[FR/TCI]_{t-1}$: Ratio of freight rate to time charter rate(index)
NBP: Newbuilding price ($)
ε: random error term

$$6.\ \Delta lnNOR_t = \alpha_\circ + \beta 1 \Delta lnNOR_{t-1} - \phi 1 \Delta lnMBT_{t-1} + \varphi 1 \Delta lnFR_{t-1} + \varepsilon_t \qquad 6$$

Where
NOR_{t-1}: tanker new order lagged one period (mdwt)
MBT_{t-1} : million barrel tanker total stock lagged one (mdwt)
FR_{t-1}: freight rate index lagged one period
ε: random error term

$$7.\ \Delta lnNBP_t = \alpha 0 + \phi 1 \Delta lnDD_t + \varphi 1 \Delta lnOST_{t-1} + \delta 1 \Delta lnSBC_t + \varepsilon_t \qquad 7$$

Where
NBP: new building price ($)
DD : tanker demand (mdwt)

OST_{t-1}: oil seaborne trade lagged one period (mtm)
SBC: Shipbuilding cost (index)
ε: random error term

$$8.\ \Delta \ln DEL_t = \alpha_0 \ - \beta 1 \Delta \ln DEL_{t-1} - \beta 2 \Delta \ln DEL_{t-2} + \phi 2 \Delta \ln NOR_{t-3} - \varphi 1 \Delta^2 \ln FR + \varepsilon t \qquad 8$$

Where
DEL: tanker deliveries (mdwt)
DEL_{t-1}: tanker deliveries lagged one period (mdwt)
DEL_{t-2}: tanker deliveries lagged two period (mdwt)
NOR_{t-3}: tanker new order lagged three period (mdwt)
FR: freight rates index
ε: random error term

$$9.\ \Delta \ln SC_t = \alpha_0 \ + \beta 1 \Delta \ln LU_{t-1} - \phi 1 \Delta \ln FR_t \ - \delta 1 \Delta^2 \ln OST \ + \varepsilon t \qquad 9$$

Where
SC: tanker scrapping (mdwt)
LU: laid up lagged one (mdwt)
FR : freight rate index
OST: Oil seaborne trade (mtm)
ε: random error term

$$10.\ SS_t = SS_{t-1} \ + \ DEL_t \ - \ SC_t \qquad 10$$

Where
SS_{t-1}: tanker supply lagged one period (mdwt)
DEL : deliveries (mdwt)
SC: scrapping (mdwt)

All these equations (1-9) were estimated from the data. The notation is the same as the one used in chapter four.

Equation (1) and (2) models oil imports into Western Europe and USA. These equations capture the positive effect of oil imports on tanker supply. It is assumed that the demand for oil would create demand for tankers and the supply of tankers. The importance of the price of crude oil is evident in the equation, changes in the crude oil prices and oil production of the examined countries are hypothesised to be inversely related to oil imports. It shows that when there is changes in prices of oil especially when it is low more crude oil would be imported. Generally, the effect of changes in oil prices on tanker market is very important. Whether the prices increased or decreased the effect can sometimes be drastic depending on the magnitude of changes. It is evident that changes in lagged oil consumption and lagged oil imports have a positive response to the future oil imports; most especially in Western Europe and USA. The assumption is that the quantity of oil that will be consumed reflects on imports.

Equation (3) relates changes in oil consumption Western Europe and USA and crude oil prices to the demand for tankers. The coefficient of lagged oil consumption USA is hypothesised to have a positive sign, it thus indicates that growth in CUS lagged one would in future mean growth in demand for tanker. This would happen in the short run; in the long run the assumption is that there will be steady growth. The negative sign of oil prices is consistent with the view that reductions in oil prices are likely to increase demand for crude oil. The expected positive coefficient on oil consumption Western Europe lagged one is also true, it is likely to generate extra demand. The expected effect of these variables is as follows: a reduction in COP will cause DD to grow and growth in oil consumption raises the growth in DD tonnage. Oil production Western Europe is inversely related to tanker demand. It means that less oil production in Europe will also cause growth in tanker demand.

Equation (4 and 5) represents the freight rate component of the market, it considers the freight rate and time charter rate. FR is assumed to be affected by the lagged total stock of fleet (MBTt-1) a reduction in the growth of the stock will cause a growth in freight rate. Both oil seaborne trade and bunker price are positively related to the freight rate. What this means is that growth in bunker price (BP) and oil seaborne trade (OST) will cause freight rate to grow. Time charter can be regarded to be a proxy for the futures market. The assumption is that the lagged value of TCI would cause growth in the future rate, this could be due to speculation. When there is increasing change in tanker stock (MBT_{t-1}) the change in time charter rate will also increase. The coefficient of the ratio of freight rate to time charter is assumed to be positive and would cause growth in the time charter rate. The new building price (NBP) indicates a positive effect; it means high growth in tanker price would create growth in the time charter rate in the long run. The assumption is that the two would move in the same direction. This can be assumed to be in the short and long run. However, there is a possibility that other factors such as growth in the tonnage supplied would have an effect on the price of tanker in the long run.

Equation (6) - (9) represents the ship market model. Equation (6) models a variable of key factors in the decision to order new tankers; one seeing the level of tanker orders lagged one. Other things being equal, high rate values of orders will be positively correlated with future values of orders; this in anticipation that there will be growth in trade. This is in relation to the assumptions made in chapter 4. The reduction in tanker stock (MBT) would be a signal to tanker owners to re-assess the market; this may lead to a decision to order a new ship. In order to do this the time has to be right since the order would not become a delivery until after at least one year. Furthermore, growth in freight rates at lagged one is expected to be a long-term growth that would cause the order to increase.

Equation (7) models the theoretical supply price of tankers. The newbuilding price will be affected by the shipbuilding cost; the cost of producing each tanker reflected on prices, and the relationship is positive; thus growth in one causes the other to improve. The tanker demand and oil seaborne trade is positively related to NBP, thus changes in the growth of these factors causes growth in NBP.

Equation (8) assumes that lagged deliveries, lagged orders and the lagged freight rate all jointly determine deliveries. In accordance with the assumption made in chapter 4 and with all things being equal, deliveries at lag one and two are expected to be inversely related to the present and future deliveries. Reduction in growth in lagged one and two of tanker deliveries thus mean growth in the future, as a result of increasing order. Growth in the order book lagged three periods could only mean future growth in deliveries. It is envisaged that growth in freight rates would mean growth in the new order if shipowners anticipates growth in the future. In this case deliveries will increase in the long run. The FR is positively related to the deliveries at the base year. The planned delivery rate is the amount of ships intends to be delivered per period.

Equation (9) is the theoretical supply of tanker scrap generated by changes in lagged lay-ups, changes in the freight rate, and the rate of change of oil seaborne trade. As demonstrated in chapter 4 the laid-up tonnage lagged one period is positively related to scrapping. It is assumed that in poor market conditions, tankers will be laid-up, but because of the cost of laying up, in the long run the tankers are more likely to be scrapped. The freight rate is assumed to have a negative effect on scrapping. In the short run the coefficient sign describes the effect of low freight rate on scrapping tonnage as temporary. In the long run the vessel would become a demolition candidate. Oil seaborne trade is inversely related to scrapping levels. What is simply being said here is that reduction in oil movements would cause growth in tanker scrapping in the long run. In the short run surplus tankers would be laid-up.

All things being equal, not all lay-ups would result in scrapping. However, if the growth in the freight rates cannot justify keeping the vessels the vessels may be sold for scrap.

Equation (10), the final identity equation simply says that the total supply of tanker is equal to the lagged supply plus the difference between deliveries and scrapping. The change in the fleet is equal to the difference between deliveries and scrapping.

6.3 Estimation

The econometric estimation methods used here can be related to the equations that were listed and discussed in chapter four. The specification as presented in section 6.2 above, is derived from the theory analysed in chapters 4 and 5. All the equations are considered to be important in order to predict supply of tankers. The model of the tanker supply market listed in section 6.1 is a simultaneous-equation model and is jointly estimated to avoid single-equation biases. Equation (1) - (9) are jointly estimated and their relationships were specified to understand tanker supply.

The series have already been tested for the presence of unit root and cointegration.

6.3.1 *Econometric Methodology*

Oil imports and oil consumption Western Europe and USA

The models for these have made use of economic factors that are assumed influence both imports and the consumption of oil. The model implies that imports and consumption in the two areas can be efficiently estimated independently of the rest of the system, but to avoid bias and inaccurate forecast the series have to be estimated within the system. The equations made use of predetermined variables that can also be found in equation 1 and 2. The parameters of equation (1) and (2) can be estimated individually by (ILS), but for forecasting purposes, the result could be biased, making the forecast unreliable. As has already been said, the reason is that there are variables that are present in more than one equation.

Equation (3) defines the demand for tankers that is generated from the growth in the economy; growth in oil imports and oil consumption. Here the economic factors of oil consumption Western Europe and U.S.A were used; these are the two major areas that employ one million barrel tankers. In order to assess demand at a particular period of time the nominal crude oil prices was included in the explanatory variable as an exogenous factor. The equation was estimated using simultaneous-equations; two stage least squares was applied because the model is over-identified.

Equation (4) models freight rates. The equation includes the expectation of the stock of tankers, the oil seaborne trade and bunker prices. It is reckoned that the lagged MBT would extend into the future. Equation (5) is jointly estimated within the system. The lagged value of time charter rate has been used to understand the past and using the knowledge to forecast the future. The equation (6) relates to the order level and involved three variables; this was jointly estimated.

Equations (7-9) were jointly estimated with simultaneous equation method. Freight rates feature in all the three equations, thus it was applied for forecasting purposes.

All the unknown parameters of these equations were estimated jointly. Instrumental variables have been used; many of the variables are predetermined. Two Stage Least Squares (2SLS) was used as the best method of simultaneous-equation suitable for over-identified models. The list of endogenous, exogenous and the predetermined variables can be found in chapter 4, section 4.6.

6.3.2 *The Results*

The econometric estimates are shown below. Figures in parentheses are t-statistics, which test the null hypothesis that the coefficients are equal to zero in the demand, freight rate index, new order and newbuilding price equations. The R^2 and the adjusted R^2 is reported for each of the equations. It simply shows the fit of each individual equation. The serial correlation of the equations were tested, by use of the Durbin Watson statistic. The Box-Ljung statistic that tests for residual autocorrelation is found to be significant for most of these equations. The standard errors of the equation within the system are assumed to be reasonable.

The t-statistics of PWE in equation one, CUS in equation two, PWE in equation three, lagged freight rate in equation eight, freight rate and OST in equation nine are included because these variables are on the borderline and theoretically they are significant in each of the equations. In theory the assumption is that the level of oil production in Western Europe cannot be excluded when taking decisions on the stock of fleet (MBTt-1) a reduction in the growth of the stock will cause a growth in freight rate. Both oil seaborne trade and bunker price are positively related to the freight rate. What this means is that growth in bunker price (BP) and oil seaborne trade (OST) will cause freight rate to grow. Time charter can be regarded to be a proxy for the futures market. The assumption is that the lagged value of TCI would cause growth in the future rate, this could be due to speculation. When there is increasing change in tanker stock (MBT_{t-1}) the change in time charter rate will also increase. The coefficient of the ratio of freight rate to time charter is assumed to be positive and would cause growth in the time charter rate. The new building price (NBP) indicates a positive effect; it means high growth in tanker price would create growth in the time charter rate in the long run. The assumption is that the two would move in the same direction. This can be assumed to be in the short and long run. However, there is a possibility that other factors such as growth in the tonnage supplied would have an effect on the price of tanker in the long run.

Equation (6) - (9) represents the ship market model. Equation (6) models a variable of key factors in the decision to order new tankers; one seeing the level of tanker orders lagged one. Other things being equal, high rate values of orders will be positively correlated with future values of orders; this in anticipation that there will be growth in trade. This is in relation to the assumptions made in chapter 4. The reduction in tanker stock (MBT) would be a signal to tanker owners to re-assess the market; this may lead to a decision to order a new ship. In order to do this the time has to be right since the order would not become a delivery until after at least one year. Furthermore, growth in freight rates at lagged one is expected to be a long-term growth that would cause the order to increase.

Econometric estimates[217]

Western Europe Oil Imports

1970 - 1993

$$\Delta \ln WEOI_t = \alpha_0 + \beta 1 \Delta \ln WEOI_{t-1} + \delta \Delta 1 \ln CWE_{t-1} - \lambda 1 \Delta \ln COP_t - \varphi \Delta \ln PWE_t + \varepsilon t \qquad \hat{1}$$

$$\underset{}{\Delta \ln WEOI_t} = \underset{(0.10)}{0.002} - \underset{(-2.29)}{0.59 \Delta \ln WEOI_{t-1}} + \underset{(2.83)}{1.77 \Delta 1 \ln CWE_{t-1}} - \underset{(-3.34)}{0.16 \Delta \ln COP_t} - \underset{(-1.42)}{0.19 \Delta \ln PWE_t}$$

$R^2 = 0.63$, $\overline{R}^2 = 0.51$, D.W. = 2.18, BL = 0.57, S.E. = 0.05

Where

$WEOI_{t-1}$: Western Europe oil imports lagged one period (mb/d)
CWE_{t-1} : Oil consumption Western Europe lagged one period (mt)
COP_t : Crude oil prices ($/bl)
PWE: Oil production Western Europe (mt)
ε: random error term

Oil imports USA

1970 - 1993

$$2.\ \Delta \ln USI_t = \alpha_0 - \beta 1 \Delta \ln USI_{t-1} - \theta 1 \Delta \ln PUS_{t-1} - \varphi 1 \Delta \ln COP_t + \gamma 1 \Delta \ln CUS_{t-1} + \varepsilon t \qquad \hat{2}$$

217 Figures in parenthesis are t-statistics for testing the null hypothesis that the true value of the coefficient equals to zero. BL is the Box-Ljung statistic that takes account of the residual autocorrelation.

$$\Delta \ln USI_t = \underset{(0.17)}{0.003} + \underset{(0.87)}{0.19\Delta \ln USI_{t-1}} - \underset{(-2.37)}{0.93\Delta \ln PUS_{t-1}} - \underset{(-4.13)}{0.27\Delta \ln COP_t}$$

$$+ \underset{(1.29)}{0.73\Delta \ln CUS_{t-1}} + \varepsilon_t$$

$R^2 = 0.72$, $\bar{R}^2 = 0.62$, D.W. = 2.15, BL = 0.93, S.E. = 0.06

Where
USI_{t-1}: Oil imports USA lagged one period (mb/d)
PUS_{t-1}: Oil production USA lagged one period (mt)
COP: Crude oil prices ($/bl)
CUS_{t-1}: Oil consumption USA lagged one period (mt)
ε: random error term

Tanker demand

1970 - 1993

3. $\Delta \ln DD_t = -\alpha_o + \beta 1\Delta^2 \ln CWE_{t-1} + \varphi 1\Delta \ln CUSI_{t-1} - \delta 1\Delta^2 \ln COP_t$
$- \gamma_1 \Delta^2 \ln PWE_{t-1} + \varepsilon t$ $\hat{3}$

$$\Delta \ln DD_t = \underset{(-0.38)}{-0.003} + \underset{(2.14)}{1.21\Delta^2 \ln CWE_{t-1}} + \underset{(3.55)}{0.70\Delta \ln CUSI_{t-1}} - \underset{(1.89)}{0.05\Delta^2 \ln COP_t}$$

$$- \underset{(1.26)}{0.37\,\Delta^2 \ln PWE_{t-1}}$$

$R^2 = 0.67$, $\bar{R}^2 = 0.66$, D.W. = 1.9, BL = 0.45, S.E. =0.04

Where
DD : Tanker demand (mdwt)
CWE_{t-1} : Western Europe oil consumption lagged one (mt)
CUS_{t-1} : USA oil consumption lagged one (mt)
COP_{t-1} : Crude oil prices lagged one ($/bl)
PWE_{t-1} : Oil production Western Europe
ε: random error term

Freight rates index

1970 - 1993

4. $\Delta lnFR_t = \alpha_o - \beta 1 \Delta lnMBT_{t-1} + \varphi 1 \Delta lnOST_t + \delta 1 \Delta lnBP_t + \varepsilon t$ $\hat{4}$

$$\Delta lnFR_t = \underset{(1.06)}{0.07} - \underset{(-5.29)}{1.71}\Delta lnMBT_{t-1} + \underset{(3.54)}{1.39}\Delta lnOST_t + \underset{(2.64)}{0.35}\Delta lnBP_t$$

$R^2 = 0.66$, $\overline{R}^2 = 0.62$, D.W. = 2.9, BL = 0.05, S.E. = 0.05

Where
FR: Freight rate index
MBT_{t-1}: Million Barrel Tanker lagged one period (mdwt)
OST: Oil Seaborne Trade (mtm)
BP: Bunker price ($)
ε: random error term

Time charter index

1970 - 1993

5. $\Delta lnTCI_t = \alpha_o - \beta 1 \Delta lnTCI_{t-1} + \phi 1 \Delta lnMBT_{t-1} + \varphi 1 \Delta ln(FR/TCI)_{t-1} + \gamma 1 \Delta\ lnNBP_t + \varepsilon t$ $\hat{5}$

$$\Delta lnTCI_t = \underset{(0.52)}{0.02} - \underset{(-2.44)}{0.23}\Delta lnTCI_{t-1} + \underset{(2.25)}{1.03}\Delta lnMBT_{t-1} + \underset{(2.17)}{1.98}\Delta ln(FR/TCI)_{t-1}$$

$$+ \underset{(2.28)}{0.58}\Delta lnNBP_t$$

$R^2 = 0.61$, $\overline{R}^2 = 0.48$, D.W. = 1.70, BL = 0.70, S.E. = 0.21

Where
TCI: Time charter index
MBT_{t-1}: Million barrel tanker total stock (mdwt)
$[FR/TCI]_{t-1}$: Ratio of freight rate to time charter rate(index)
NBP: Newbuilding price ($)
ε: random error term

New order

1970 - 1993

$$\Delta \ln NOR_t = \alpha_o + \beta 1 \Delta \ln NOR_{t-1} - \phi 1 \Delta \ln MBT_{t-1} + \varphi 1 \Delta \ln FR_{t-1} + \varepsilon_t \qquad \hat{6}$$

$$\underset{(1.67)}{\Delta \ln NOR_t = 0.09} + \underset{(1.73)}{0.24 \Delta \ln NOR_{t-1}} - \underset{(-2.98)}{1.86 \Delta \ln MBT_{t-1}} + \underset{(3.17)}{0.92 \Delta \ln FR_{t-1}}$$

$R^2 = 0.57$, $\overline{R}^2 = 0.42$, D.W. = 2.18, BL = 0.24, S.E. = 0.28

Where
NOR_{t-1}: tanker new order lagged one period (mdwt)
MBT_{t-1} : million barrel tanker total stock lagged one (mdwt)
FR_{t-1}: freight rate index lagged one period
ε: random error term

Newbuilding prices

1970 - 1993

$$7.\ \Delta \ln NBP_t = \alpha 0 + \beta 1 \Delta \ln DD_t + \varphi 1 \Delta \ln OST_{t-1} + \delta 1 \Delta \ln SBC_t + \varepsilon_t \qquad \hat{7}$$

$$\Delta \ln NBP_t = \underset{(1.37)}{0.04} + \underset{(2.03)}{0.96 \Delta \ln DD_t} + \underset{(2.36)}{0.65 \Delta \ln OST_{t-1}} + \underset{(2.28)}{0.24 \Delta \ln SBC_t}$$

$R^2 = 0.60$, $\overline{R}^2 = 0.45$, D.W. = 2.11, BL = 0.04, S.E = 0.12

Where
NBP: new building price ($)
DD : tanker demand (mdwt)
OST_{t-1}: oil seaborne trade lagged one period (mtm)
SBC: Shipbuilding cost (index)
ε: random error term

Deliveries

1970 - 1993

8. $\Delta\ln DEL_t = \alpha 0 \ - \beta 1 \Delta \ln DEL_{t-1} - \beta 2 \Delta \ln DEL_{t-2} + \phi 2 \Delta \ln NOR_{t-3} + \varphi 1 \Delta^2 \ln FR_{t-1} + \varepsilon t$ $\hat{8}$

$$\ln DEL_t = \underset{(0.94)}{0.14} - \underset{(-3.24)}{0.76\Delta\ln DEL_{t-1}} - \underset{(-2.22)}{0.49\Delta\ln DEL_{t-2}} + \underset{(2.46)}{0.78\Delta\ln NOR_{t-3}} - \underset{(-1.54)}{0.72\Delta^2\ln FR_{t-1}} + \varepsilon t$$

$R^2 = 0.52$, $\overline{R}^2 = 0.36$, D. W. = 2.3, BL = 0.86, S.E. = 0.6

Where
DEL: tanker deliveries (mdwt)
DEL_{t-1}: tanker deliveries lagged one period (mdwt)
DEL_{t-2}: tanker deliveries lagged two period (mdwt)
NOR_{t-3}: tanker new order lagged three period (mdwt)
FR_{t-1}: ratio of new order to deliveries lagged one period
ε: random error term

Scrapping

1970 - 1993

9. $\Delta\ln SC_t = \alpha 0 + \beta 1 \Delta \ln LU_{t-1} - \phi 1 \Delta \ln FR_t - \delta 1 \Delta^2 \ln OST_t + \varepsilon t$ $\hat{9}$

$$\Delta\ln SC_t = \underset{(0.04)}{0.005} + \underset{(4.13)}{0.70\Delta\ln LU_{t-1}} - \underset{(-0.51)}{0.23\Delta\ln FR_t} - \underset{(1.61)}{1.45\Delta^2\ln OST_t}$$

$R^2 = 0.59$, $\overline{R}^2 = 0.50$, D. W. = 1.21, BL = 0.96, S.E. = 0.4

Where
SC: tanker scrapping (mdwt)
LU_{t-1}: laid up lagged one (mdwt)
FR : freight rate index
OST_t : Oil seaborne trade
ε: random error term

In order to assist understanding, the estimated equations have been numbered in the same way as the corresponding theoretical ones. Thus equation $(\hat{1})$ is the econometric estimate of equation (1).

Equations (1 - 9) have been jointly estimated because of the interrelationship of the variables. Equation (1) coefficients support the claim that growth in oil consumption Western Europe causes the imports of oil to grow. Growth of the CWE at lagged-one would cause growth in WEOI. The model also demonstrates that growth in $WEOI_{t-1}$ would raise growth rate of present and future oil imports. The assumption is that growth would continue into the future, as in the historical data. The estimated coefficient indicates positive response, while the other variables COP and PWE are inversely related to WEOI. Equation $(\hat{2})$ relates lagged oil imports, lagged USA oil production, crude oil prices and lagged consumption to the present and future USA oil imports. Increasing growth in demand for oil in these two areas would continue to cause growth in tanker supply. The reasons being that in most cases substantial growth in the changes in oil imports would mean growth in demand for transportation; thus inevitably causing the supply to appreciate. Reduction in crude oil prices would cause growth in oil consumption; the growth would come as a result of consumers who are ready to take advantage of prices and use more energy in the form of oil.

Changes in tanker demand equation $(\hat{3})$ are assumed to be affected by changes in CWE lagged one, USI lagged one, COP lagged one and PWE. The slope coefficient of the rate of change in Western Europe oil consumption lagged one with respect to changes in tanker demand is estimated to be -0.82 while changes in oil imports USA lagged one to changes in DD is estimated to be 0.70. Growth in the rate of change in CWE_{t-1} will have a positive effect on the changes in tanker demand, thus the growth in tanker supply. Growth in USI lagged one year in this estimation cause the changes in demand improve. The slope coefficient of rate of changes in crude oil prices to changes in tanker demand is estimated to be -0.07. Reduction in the rate of change in crude oil prices are assumed to cause growth in tanker demand in the short and long run, thus the growth in tanker supply. Reduction in the rate of change in oil production Western Europe with the coefficient of -0.37 would cause growth in tanker demand.

Equation ($\hat{4}$) indicates that changes in the freight rate are affected by changes in lagged stock of tankers, this invariably is assumed to influence tanker supply. Changes in the freight rate will increase when there is negative change in MBT at lag one. It is estimated that reduction in the tanker stock will cause the freight rate to appreciate in value. Further more, growth in oil seaborne trade and or in bunker prices would cause growth in freight rates. The important point is the belief that changes in the freight rate in the long run depends on existing fleet. Growth in the bunker price will cause growth in the freight rate. The estimated coefficients are of the right sign.

Changes in time charter equation ($\hat{5}$) is estimated using changes in TCI lagged one, MBT lagged one, newbuilding price and the ratio of time freight rate to time charter lagged one. The equation specifies that reduction in growth of TCI lagged one will cause change in the immediate future time charter to decrease; this in relation to the cyclical behaviour of freight rates, will affect the supply of tankers. The growth in MBT and the growth in the ratio of freight rate to time charter lagged one are positively related to the growth in TCI. Changes in the time charter rate influenced by the changes in the growth of tanker prices. Changes in the growth of tanker prices caused growth in time charter. The assumption is that growth in the changes to freight rate is likely to cause the future tanker supply to grow. Changes in the tanker price are positively related to changes in TCI. The estimation reveals growth in time charter rate; this implies that there would be further growth in tanker supply.

Equation ($\hat{6}$) states the estimated change in the value of new order equation. It relates changes in NOR lagged one year to changes in the future new order, that is the difference in dead-weight tonnes between the present order and the past orders. When tankers owner order vessels at lagged one, unless there is a great change in the increase or anticipated growth in the freight rates, the change in orders would not increase because of the cautious approach to additional orders. The effect of this would mean less growth in oil tanker supply in the future; thus growth reduction in MBT lagged one will cause growth in tanker order. Changes in the lagged freight rate coefficient indicates a direct relationship to changes in NOR. The level of changes in freight rate can in many cases influence the tanker owner to order thus causing changes in tanker orders.

Equation ($\hat{7}$) is the estimated changes in price for newbuilding. It is estimated that changes in tanker demand, oil seaborne trade lagged one and the cost of producing oil tankers, would affect changes in NBP. The fact is that the shipbuilders would at least want to cover the shipbuilding cost when pricing vessels, *all things being equal.* When the market is booming it will reflect on tanker prices. Growth in the oil seaborne trade (OST) would cause growth in tanker demand, thus this would cause changes in freight rate to rise in the short and long run. Booming markets are likely to attract more tanker supply and in the long run creating surplus and low freight rate.

Equation ($\hat{8}$) implies the estimated changes in tanker deliveries. It relates changes in deliveries lagged one and two years, new orders lagged three and freight rates lagged one to changes in tanker deliveries. As demonstrated in chapter 4, the model has shown that reduction in growth of deliveries at lagged one and two would cause growth to the present tanker deliveries. This may be due to order cancellations as a result of the depressed freight rate. The estimated coefficients of these variables are statistically significant. The coefficient of changes in new order is positive; growth in the tanker new order will mean growth in the present and future deliveries. Growth in new order at lagged three and growth in freight rates are positively related to growth in deliveries. Sometime it becomes very expensive to cancel deliveries, thus the reduced growth in the freight rate may still mean growth in tanker deliveries.

Equation ($\hat{9}$) is the estimated changes in scrapping equation for one million barrel tanker size. It is assumed that a reduction in the changes to freight rates will cause changes in scrapping to grow. Decreases in the rate of change in oil seaborne trade will also influence tanker scrapping. Changes in lagged lay-ups coupled with changes in freight rates and the rate of change in oil seaborne trade will cause changes in tanker scrapping to grow. The estimated coefficients and signs of the variables are in line with expectations. Changes in scrapping are expected to increase during the depression and to decrease in the boom time. When the gap between demand and supply is reduced. Growth in tanker scrapping will reduce tanker supply; the magnitude will depend on the size of changes in scrapping.

Equation (10) is an identity equation that relates lagged supply to deliveries and scrapping.

6.4 Tanker Simulations

In this section the response of one million barrel tankers to various changes in the exogenous variables is simulated. The structure of the theoretical model is the same with the econometric model of one million barrel tanker supply estimated above. Thus similar qualitative results are expected. However, there are also some peculiar features in the results presented here. These reflect some structural differences between the theoretical and empirical model.

The model is simulated over 20 years, however the results of the first 10 years have been reported. This is because there was a convergence in the simulated results after 9 years. The changes in the endogenous variables grow at a constant rate after 9 years and invariably tailed off to a constant growth rate.

In this section certain words were used in order to create an understanding on how the system responds to various shocks. The term Unanticipated and anticipated shocks have been used here to mean the effect of extrapolation and the ex-post forecast compared with the base forecast.

Unanticipated shocks - The assumption here is that the factors would follow extrapolative growth. It is an assumption that there will be continuity in the historical trend. That is to say that the underlying economic pattern in the historical data must continue into the future. This does not imply that the economic activity is static or unchanging, but it does assume that the pattern or structure of institutional relationships that exists in the historical data continues into the future. The endogenous estimates are produced from the estimates based on X value falling outside the actual database.

X_{n+h}, where **n** denotes now and **h** denote time units ahead to time.

Therefore, X_{n-j}, j = 0, 1,.....,N

Thus it is assumed that all factors such as oil consumption of Western Europe and USA, crude oil prices, shipbuilding cost and bunker prices follows the historical trend.

The result of the result of these assumptions is then compared with the base forecast. The percentage change of the unanticipated results are reported and analysed.

Anticipated shocks - In this case it is reckoned that the system's reacts to shocks that are anticipated by the players before they actually occur. The assumption is that at time **t** there is a change in the factors, as in the unanticipated version, but the changes over time are constant. What has been used here is the ex-post forecast that was generated from RATS; these used historical variables to determine the future growth. These results are considered known for number of years. The difference here is that the shock is not unexpected but the market players had a foresight of it at time zero. The assumption relies on the fact that all other things are equal. The forecast assumed that the dependent and independent variables are known with certainty.

The percentage difference in the simulation and the base run forecast will be reported in the tables below. The simulation assumption is that there is an increase of 15% in oil consumption Western Europe and 20% in USA oil consumption, 10% increase in crude oil prices, 35% increase in shipbuilding cost and 50% increase in bunker price.

6.4.1 Western Europe oil consumption shocks

Table 6.1 shows the response of the system to an oil consumption shock that permanently raises the changes in oil consumption by 15%. The table distinguishes the effect on various exogenous variables and examines cases when it is anticipated and unanticipated. All figures in the table are percentage changes of simulation and the base forecast.

Unanticipated increase in Western Europe oil consumption

An unanticipated increase in oil consumption leads to a change of 1.2% in tanker demand. It immediately shows an increasing change of 21.7% in freight rate. This invariably implies a change in time charter rate of 2.6%. This increases the revenue and thus improves the profit, thus the increase and changes in tanker prices by 14.6%.

Changes in freight rates will probably bring out laid up tankers, thus creating increase in the tanker supply, which inevitably alter the changes in freight rates. Initially, there is increasing changes to freight rate, but in the long run it slowed down. In the year 0 changes in scrapping increase was reduced to 2.8%. The change in deliveries however increased by 38.8% at year 0; in the following years shipbuilding begins to respond to the higher values, and in year one changes in deliveries was up by 36.8% slightly up from year 0. By year 3, changes in deliveries only increase by 40.0%. Change in scrapping at year 1 increase by 2.3% a little lower than previous year 0. The increase in changes to tanker scrapping for the whole period never exceeds 3.5% in a year, this occurred in year 9. The small changes of scrapping and increase in changes in deliveries helps to raise the changes in the size of the fleet and thus the market balances, rates and revenue became unstable. However, this does not immediately reduce changes in the fleet size.

Table 6.1 SIMULATED EFFECTS OF A 15% INCREASE IN OIL CONSUMPTION WESTERN EUROPE[218] (Percentage Changes)

Year	Tanker Demand A	Tanker Demand U	Freight Rate Index A	Freight Rate Index U	Time Charter Index A	Time Charter Index U	New Order A	New Order U
0	18.2	1.2	0.9	21.7	2.2	2.6	30.9	41.1
1	20.7	5.9	0.0	24.7	1.5	0.4	44.2	53.0
2	18.4	13.0	14.7	24.4	1.8	- 1.1	33.3	56.5
3	18.2	18.9	23.1	24.2	- 6.2	- 3.1	14.0	47.7
4	15.8	25.5	15.4	23.9	-11.9	- 4.8	- 4.9	38.1
5	19.6	31.5	11.8	23.7	-12.3	- 6.7	-14.5	35.8
6	16.7	37.4	7.8	23.4	- 5.9	- 8.2	-18.0	35.1
7	16.8	44.1	5.5	23.2	- 5.1	- 9.6	-25.0	37.1
8	13.4	50.8	2.6	23.0	- 4.8	-11.0	-32.8	36.3
9	12.8	58.3	0.0	22.8	0.9	-12.6	-41.6	40.0

Year	Newbuilding Price A	Newbuilding Price U	Tanker Deliveries A	Tanker Deliveries U	Tanker Scrapping (%) A	Tanker Scrapping (%) U	Fleet A	Fleet U
0	-1.9	14.6	25.0	38.8	0.09	2.8	0.6	15.0
1	0.2	17.5	36.8	36.8	0.04	2.3	0.9	14.0
2	0.6	19.0	42.1	42.1	0.05	2.4	2.5	11.6
3	0.9	21.7	45.8	40.0	0.05	2.5	5.7	10.0
4	2.9	24.7	50.2	38.0	0.05	2.7	7.4	7.6
5	5.2	27.8	70.9	42.8	0.05	2.8	8.4	5.9
6	7.7	30.8	63.1	40.9	0.04	3.0	10.7	3.1
7	10.2	33.9	39.1	45.4	0.05	3.1	11.8	1.0
8	12.8	37.3	43.4	43.4	0.02	3.3	13.1	1.5
9	15.6	40.9	52.4	41.6	0.02	3.5	14.2	4.0

A - Anticipated
U - Unanticipated

[218] Percentage Changes.
Scrapping: Changes in percentage points.

It is presumed that the backlog orders are still being delivered and the occasional small changes in the freight rate increase are assumed to have been caused by speculators.

Anticipated increase in oil consumption Western Europe

When the shock is anticipated there is a 18.2% speculative increase in the changes of tanker demand in year 0 when the news regarding the future higher level of consumption come out. This causes an immediate growth of the fleet supply by 0.6%. The changes in scrapping remain small, this believed to exclude the percentage of the obsolete tankers. Changes of supply continue to have steady increase in the period, up till year 5, the increase in year 7 is 1.0%. The changes in demand continue to grow, at year 1 it increased by 20.7%, and by 16.8% in year 7; this is down on the growth at year 2. This increase is assumed to take most of the lay-up tanker into trading, however, changes in percentage scrapped are still increasing; with very small margin. Changes in the growth of the fleet are accumulated so that in year 2 and year 4 there is a considerable reduction in the percentage growth. The growth in new orders increases by 30.9% in year 0 and in year 4 the growth in order is reduced by -4.9%. The growth in deliveries of tankers steadily increased; in year 0 the growth is 25.0% and in year 2 it is 36.8%. The growth in newbuilding price is decreased by -1.9% in year 0 and in year 3 it grows by 0.9%. The general effect of this is the initial small percentage growth in freight rates. It implies a reduction in the growth of tanker supply, as a result of reduction in the growth in freight rates. The growth in time charter reduces from year 3 after a small increase in year 0 up to year 2. The growth in the size of the fleet permanently rises by an amount, which is nearly the same as demand. This causes the growth in the freight rate at the later stage of the simulation to improve.

6.4.2 USA oil consumption shocks

This section considers the impact of changes in oil consumption USA on the tanker demand and supply. The results are shown in table 6.2. It can be seen that growth in oil consumption does cause growth in tanker demand, it also causes growth to the fleet. The oil consumption in this area caused the demand to grow thus other factors such as the freight rate, new order etc.

Unanticipated increase in USA oil consumption

When the shock is unanticipated there is growth in most factors. In year 0 the change in tanker demand increase by 3.7% and the changes in freight rates index increase by 22.8%. This implies a growth in the time charter rates of around 2.6%. The expected profit profile improves due to the growth in prices. Indeed in year 0 the growth in scrapping remain very low at 0.6%. However, growth in deliveries increases immediately by 38.8%. The growth in deliveries is assumed to be due to the improved expectation in the lagged periods. It could also have been due to changes in the lagged order that was delayed as a result of low freight rate in the lagged period. At year 1 the new order grow by 41.2% and by year 4, the growth is 30.9% and at year 9 the growth is 36.7%.

Growth in scrapping decrease in year 1 by -1.0% and in year 4 it is 0.03%, the highest growth for the whole period is recorded in year 0. However, there is a steady growth in the fleet, this helps to raise the size by 15% in year 0 and by 14% in year 1, this caused the market situation to change. As the growth in the freight rates reduces, the profits lose some of their initial gains. However, despite the slowing down of growth in freight rate, the fleet growth is not dampened but increases in year 5 to

Table 6.2 SIMULATED EFFECTS OF A 20% INCREASE IN OIL CONSUMPTION U. S. A.[219]
(Percentage Changes)

Year	Tanker Demand		Freight Rate Index		Time Charter Index		New Order	
	A	U	A	U	A	U	A	U
0	24.0	3.7	20.0	22.8	15.7	2.6	30.9	41.2
1	26.5	3.3	19.8	24.7	4.6	0.3	23.1	30.6
2	23.9	3.2	18.5	25.5	4.9	-1.4	14.8	34.7
3	23.6	2.9	16.5	27.3	-3.3	-3.2	8.8	40.9
4	21.0	2.9	9.2	29.1	-9.2	-4.8	- 9.8	30.9
5	24.8	2.6	8.1	28.9	-9.7	-6.7	-17.7	30.7
6	21.6	2.3	2.8	28.5	-3.1	-7.9	-21.3	29.7
7	21.7	2.2	0.0	28.2	-2.3	-9.3	-29.6	28.5
8	18.0	2.0	- 2.7	28.0	4.2	-11.0	-35.8	30.3
9	17.6	1.9	- 5.1	28.7	3.9	-12.4	-43.0	36.7

Year	Newbuilding Price		Tanker Deliveries		Tanker Scrapping (%)		Fleet	
	A	U	A	U	A	U	A	U
0	-1.9	14.7	25.0	38.8	1.85	0.6	0.6	15.0
1	-0.1	17.6	21.0	21.0	1.26	-1.0	0.9	14.0
2	-0.3	18.0	25.9	26.3	1.56	0.0	1.3	12.7
3	0.9	21.2	30.2	25.0	1.30	0.13	4.0	11.5
4	2.6	24.4	34.7	23.8	1.31	0.03	5.2	9.9
5	5.2	27.8	45.0	33.3	1.34	0.04	5.7	8.4
6	6.9	29.9	57.8	36.3	1.34	0.06	6.9	6.4
7	8.5	31.9	39.1	45.4	1.22	0.03	7.9	4.4
8	10.5	34.4	52.2	52.1	1.20	0.03	9.2	2.0
9	12.5	36.9	60.8	54.2	1.22	0.03	10.8	0.5

A - Anticipated

U - Unanticipated

[219] Percentage changes.
Scrapping : changes in the percentage points.

12.1% and reduces to 9.9% in the final year of the simulation. In the long run the unrestrained growth in fleet size cause the freight rates growth to decline.

Anticipated increase in USA oil consumption

When the shocks are anticipated there is a 24.0% growth in demand in year 0 and -1.9% speculative reduction in the growth of newbuilding price in year 0 as the news regarding the future higher level of demand became known. The percentage growth in scrapping remains unchanged. The growth in scrapping in year 1 is 1.26% whereas in the year 0 it was 1.85%. Changes in the size of the fleet increases with the growth in deliveries. In year 1 the growth in deliveries increase by 21%, in year 2 the percentage growth is 25.9%, however in year 7 changes in deliveries increase by 45.4% and in the final year of the simulation the percentage growth is 54.2%. In the meantime growth in the prices of new tanker increases and this continuously reduces new orders, thus in year 6 growth in new order decreases by 21.3%. The growth in the fleet is accumulated so that the growth in the freight rate decreases by -2.7% and 5.1% in year 8 and 9 respectively. However, the rest of the simulated period shows growth. As far as the growths in the freight rate remain improving, the fleet will continue to grow until the freight rate start to decline and no justification for additional tanker.

6.4.3 Oil price shocks

This section considers the impact of changes in oil prices on demand and supply. The oil price will influence crude oil movements. It will also affect freight rates. The results are shown in table 6.3. It can be seen that growth in oil prices leads to a strengthening of growth in tanker prices. On the contrary, the oil prices increases of the 70's were followed by a significant depression.

Speculations and OPEC decisions are two of the major factors affecting the crude oil prices. These invariably increased and reduce prices; negative or positive changes to oil prices will affect tanker demand and freight rate. Low prices may generate more demand for tanker and supply and higher price may cause a reduction that invariably reduces tanker demand. The effect on freight rate could be more stringent; less demand, low freight rates and increase in demand could mean higher freight rate. The crisis in the early seventies is a vivid example, when crude oil prices increased as a result of cutbacks in long haul OPEC exports.

At the time the big drop in the demand cancelled out the higher price and thus the market became depressed. The simulation in this case look at the effect of changes in crude oil prices on the market for tankers. The assumption is that the level of demand would change both in the short and long run after the increase in oil prices.

Unanticipated increase in crude oil prices

Table 6.3 shows the response of the markets to an increase of 10% in oil prices. In year 0 freight rates grow by 22.8% and the growth in time charter rates is 2.2%, this could have been due to the expectation of the stabilisation of the freight rate market.

The freight rate grows by 23.6% in year 1, this is regarded as an increase in the percentage growth. There is no change and no growth in the time charter rate in year 2 is 0%. However, from that point there is a decline in the percentage change. It declined from -1.4% in year 2 to -13% in year 9 of the simulated period. In year 3 the growth in the freight rate increase by 25.2% and in year 5 it increase by 26.8% this happen as a result of growth in prices. The improvement of the changes in freight rates is expected to last for some time, since the small growth in oil prices is permanent while the response of the fleet to the profit is not instantaneous. There is an initial 14.5% growth in the newbuilding price; it is caused by the increase in the profitability and the expectation of improvement in the future. The growth in prices cause immediate reduction in the growth of scrapping, the percentage rate is 0.14% from year 0. In year 0 growth in deliveries increase by 38.8% and in year 3 it increase by 31.5%, however this causes growth in the fleet to increase by 15.7% in year 0 and the fleet grow continuously, and there is no change to the freight rates. The changes in the demand for tanker is not sustainable for long and the growth in the fleet is as a result of growth in deliveries from the backlog orders.

Anticipated increase in oil prices

When the shock is anticipated the market foresees its impact on revenue and so prices increase before the shock. In year 1 deliveries grow by 25%, in year 2 it grows by 26.3% and 47.3% in year 3. On the other hand, there was an immediate reduction in

Table 6.3 SIMULATED EFFECTS OF A 10% INCREASE IN CRUDE OIL PRICES[220] (Percentage Changes)

Year	Tanker Demand A	Tanker Demand U	Freight Rate Index A	Freight Rate Index U	Time Charter Index A	Time Charter Index U	New Order A	New Order U
0	0.3	-16.2	-1.7	22.8	-7.5	2.2	29.0	-19.3
1	2.9	-15.9	-0.8	23.6	-16.3	0.0	40.3	-15.1
2	1.4	-15.5	-1.0	23.4	-15.6	-1.4	27.8	-16.8
3	0.8	-16.0	-1.6	25.2	-22.3	- 3.5	15.8	-18.5
4	-0.8	-15.6	-7.7	25.0	-26.9	- 5.1	-1.6	-24.0
5	2.9	-15.4	-8.9	26.8	-27.2	- 7.0	-11.2	-28.0
6	0.3	-15.7	-11.4	26.5	-21.9	- 8.5	-14.7	-30.0
7	0.7	-15.3	-13.8	26.2	-21.9	-10.0	-23.4	-31.9
8	-1.8	-15.1	-16.0	26.0	-15.9	-11.6	-31.3	-33.3
9	-6.3	-14.7	-18.0	25.7	16.1	-13.0	-40.2	-35.8

Year	Newbuilding Price A	Newbuilding Price U	Tanker Deliveries A	Tanker Deliveries U	Tanker Scrapping (%) A	Tanker Scrapping (%) U	Tanker Fleet A	Tanker Fleet U
0	2.0	14.5	25.0	38.8	0.05	0.14	0.7	15.7
1	2.9	14.3	26.3	26.3	0.02	0.14	1.0	13.8
2	3.7	13.9	31.5	31.5	0.02	0.16	1.5	12.5
3	5.4	13.6	47.3	40.0	0.00	0.16	4.4	11.1
4	7.9	11.6	57.8	42.8	-0.02	0.17	5.4	10.0
5	8.2	11.3	68.4	42.8	-0.02	0.18	6.5	6.3
6	9.9	9.4	84.2	59.0	-0.02	0.19	7.7	5.7
7	10.2	9.1	60.8	60.8	-0.02	0.20	8.9	2.2
8	10.8	8.4	73.9	73.9	-0.04	0.21	10.1	1.1
9	11.1	8.2	95.4	79.1	-0.04	0.22	11.7	1.3

A - Anticipated
U - Unanticipated

[220] Percentage changes.
Scrapping: changes in percentage points.

the growth of tanker scrapping by 0.02% in year 1, it remains the same in year 2 and in the year 3 it is 0%. The growth of fleet in this case has a steady increase; the growth in year 1 is 1.0%, in year 2 it increase by 1.5% and in year 3 the increase is 4.4%. In view of this the growth in tanker newbuilding prices decreases by -2.9% in year 1, however the downward trend continues as a result of instablility in the demand for oil. In 3 year changes in tanker demand decrease by -5.4% and in the 4th year, it decrease by -7.9%. The fleet in this case continues to grow as the ship value decreases. As a response, growth in the fleet in the long run causes changes in freight rate to become unstable. The change is -0.8% in year 2 and -18.0% in year 9 of the simulation period.

There are similarities in the behaviour of freight rates when the growth in oil prices are anticipated and unanticipated. In the short and long run the percentage increase in the variables improved, especially freight rates. The changes in deliveries are permanently increasing in order to maintain a higher fleet at a given scrapping rate, while there is little change in the long run level of scrapping. There is also a permanent growth in the size of the fleet of around 1.5%. This implies that a bigger fleet in the long run satisfies change in tanker demand.

6.4.4 Shipbuilding Cost Shocks

This section considers the effect of changes in shipbuilding costs on the tanker market. The results are shown in table 6.4. The direct effect of the shock is to reduce the supply of new tankers at a given level of ship prices. An increase in the growth of shipbuilding cost is assumed to affect the price of vessel.

Unanticipated increase in shipbuilding costs

When the shock is unanticipated the percentage growth of deliveries exhibits cyclical behaviour, it is more of drop in percentage than increase in the growth rate. In anticipation of this, the changes in the price value of tanker increase in year 0 and the effect of this is that the scrappage rate does not change. The negative change in deliveries is however bigger compared with the unchanged rate of scrapping. As a result the percentage growth of the fleet remain small. In year 0 where changes in deliveries are predetermined, the growth in the fleet actually reduces because the rate of scrapping remains unchanged at low percentage; thus there is fall in the freight rates. The magnitude of the short-term change is very small, however, because of the steady decrease in the percentage growth of fleet, the freight rates increases at a steady rate.

Table 6.4 SIMULATED EFFECTS OF A 35% INCREASE IN SHIPBUILDING COSTS[221] (Percentage Changes)

Year	Tanker Demand		Freight Rate Index		Time Charter Index		New Order	
	A	U	A	U	A	U	A	U
0	1.1	-15.4	39.1	23.2	17.0	2.6	34.5	45.0
1	3.8	-15.2	38.7	23.0	5.8	0.4	34.6	42.8
2	2.8	-14.8	25.5	22.3	6.1	-1.8	27.7	50.0
3	2.4	-14.6	34.7	22.1	-2.2	-4.2	5.2	36.3
4	0.8	-14.6	25.3	21.8	-8.2	-5.2	-13.1	26.1
5	4.4	-14.1	21.4	20.6	-8.7	-7.0	-22.5	23.0
6	2.2	-14.0	17.8	20.4	-1.9	-8.5	-27.8	18.9
7	2.7	-13.7	14.4	21.2	-1.1	-10.0	-34.3	16.7
8	-0.2	-13.5	12.0	21.0	5.4	-11.7	-41.9	18.1
9	0.0	-13.2	9.0	20.7	5.1	-13.0	-48.6	23.3

Year	Newbuilding Price		Tanker Deliveries		Tanker Scrapping (%)		Tanker Fleet	
	A	U	A	U	A	U	A	U
0	29.7	51.6	1.10	1.3	2.38	0.89	0.7	-15.0
1	27.2	49.8	0.89	0.9	1.16	0.05	0.6	-14.2
2	25.0	48	0.94	1.0	1.32	0.0	0.8	-13.3
3	21.8	46.3	1.00	1.0	1.30	0.99	3.6	-11.8
4	19.4	44.7	1.10	1.1	1.27	0.03	4.3	-10.3
5	18.0	43.2	1.20	1.3	1.27	0.05	5.2	-8.7
6	16.6	41.8	1.40	1.4	1.30	0.03	6.5	-6.7
7	15.3	40.1	1.30	1.4	1.20	0.03	7.5	-4.7
8	14.1	38.8	1.40	1.3	1.22	0.02	8.6	-2.5
9	12.9	37.5	1.60	1.5	1.25	0.02	10.0	-0.2

A - Anticipated
U - Unanticipated

[221] Percentage changes.
Scrapping : changes in percentage points.

The value in terms of changes in newbuilding prices increases in year 0 by 51.6% but the percentage growth reduces to 49.8% in year 1 and 37.5% in year 9. However, from year 2 onwards the percentage growth of newbuilding prices increase. In the long run the decrease in the fleet growth cause the growth in freight rate to remain stable, as well as the growth in the percentage growth rate of scrapping.

Anticipated increase in shipbuilding costs

When the shock is anticipated the growth in the fleet does increase steadily, it increased at low rate for the first five years, even when there is growth in cost of shipbuilding. The percentage change in newbuilding prices witness a steady growth; in year 1 it increase by 27.2%, in year 2 the percentage growth is reduced by 25%. There is growth in deliveries of tankers and there is a decline in the growth of freight rates as a result of steady growth in the fleet. Initially when the shock occurs, the percentage growth of deliveries begins to decrease significantly; thus it considerably curtailed the growth of the fleet. Eventually, the growth in the fleet increase in year 7 by 6.5% and freight rates by 14.4%. The growth in newbuilding prices increases by 15.3%; thus it implies that growth in trade and growth in demand are in a steady state or do not change.

6.4.5 Bunker Price Shocks

This section considers the impact of a 50% increase in bunker prices on freight rates, ship prices, fleet size etc. to a foreseen and an unforeseen situation. The results are shown in table 6.5. As in the prices of oil, it can be seen that a growth in fuel prices leads to a growth in newbuilding prices and changes in freight rate. Fuel costs represents the biggest component of operating costs since the early 70's, thus the importance of fuel prices on tanker shipping. The aim of the simulation performed here is to show purely the effects of the bunker oil price change itself. Thus, as with other independent variables, growth in tanker demand is assumed to be unchanged after the growth of fuel prices.

Changes in the bunker price affects freights and the profitability. However, the theoretical effects on tanker profitability of a growth in freight cost depend on how quickly the market can react to the changes or the elasticity of the freight rate market. Growth in the bunker price will imply a growth in freight rates, unless demand is completely elastic in which case rates do not change.

Unanticipated increase in bunker prices

Table 6.5 shows the response of the markets to a 50% change in the prices of fuel. In year 0 freight rate grow by 23.9%, but the growth in the time charter is 2.6%. The growth rate of freight rate is expected to last for a while since the changes in bunker prices is permanent and the response of fleet cannot be instantaneous. There is a speculative growth in prices, this has happened as a result of increase in profitability.

Table 6.5 SIMULATED EFFECTS OF A 50% INCREASE IN BUNKER PRICES[222] (Percentage Changes)

Year	Tanker demand		Freight Rate Index		Time Charter Index		New Order	
	A	U	A	U	A	U	A	U
0	-0.2	-16.6	60.0	23.9	14.6	2.6	38.1	49.0
1	2.6	-16.2	59.4	23.6	3.6	0.4	51.9	61.2
2	1.1	-15.7	44.1	23.4	4.0	1.0	48.1	73.4
3	1.3	-15.5	54.5	23.1	-4.2	-3.1	21.0	56.8
4	-0.3	-15.1	44.6	22.9	-10.0	-4.5	3.2	40.4
5	3.4	- 5.0	40.0	22.6	-10.4	-6.3	16.1	33.3
6	1.2	-14.8	35.7	22.4	-3.9	-7.9	21.3	29.7
7	1.7	-14.5	31.7	22.2	-3.1	-9.3	28.1	31.4
8	-0.9	-14.3	28.0	22.0	3.3	-11.0	35.8	30.3
9	-0.9	-14.0	24.5	21.7	2.9	-12.4	44.4	33.3

Year	Newbuilding Price		Tanker Deliveries		Tanker Scrapping (%)		Tanker Fleet	
	A	U	A	U	A	U	A	U
0	-1.1	15.6	1.3	1.5	2.92	1.20	0.7	15.0
1	0.5	18.2	2.0	2.0	1.09	-0.08	0.6	14.0
2	-3.1	14.6	2.1	2.1	1.42	0.0	0.6	13.3
3	-3.0	16.5	2.3	2.2	1.33	0.03	3.3	12.0
4	-1.3	15.5	2.4	2.1	1.27	0.03	3.9	10.6
5	1.2	22.8	2.6	2.4	1.27	0.06	4.6	9.2
6	2.7	24.9	3.2	2.5	1.27	0.03	5.7	6.9
7	4.5	27.0	2.6	2.8	1.25	0.03	6.5	5.6
8	6.3	29.3	2.9	2.9	1.20	0.02	7.7	3.3
9	8.1	31.7	3.1	3.0	1.20	0.02	9.0	1.1

A - Anticipated
U - Unanticipated

[222] Percentage changes.
Scrapping : changes in percentage points.

Particularly between years 1 and 2 there is anticipated improvement over the long-term future. There is a reduction in the growth rate of scrapping by -0.08% in year 1. In the following years there is no change, so the growth rate of scrapping remain 0%. Delivery responds and it grow by 2.0% in year 1, in year 3 the growth is 2.2%. Shipbuilding peaks at year 9 of the simulated period, thus deliveries grow by 3%.

The fleet continuously grows and this implies that rates become unstable. The growth in time charter rate continuously decrease in value. In the long run, there is a need to regulate the costs and prices, so that growth in deliveries and fleet remain stable. This is required to close the gaps of demand and supply balance.

Anticipated increase in bunker prices

If the shock is anticipated the market is expected to experience considerable growth in the freight market. This will cause immediate speculative growth in newbuilding prices. These reduce the percentage growth in the rate of scrapping and encourage shipbuilding after a while. Because there is plenty of time for shipbuilding to respond to the anticipated shortage, there is a significant growth in deliveries without changes in prices rising more than 8.1%. The rates grow by 54.5% in year 3 whereas when the shock is unanticipated the fleets do not respond, thus the maximum rate of growth is 23.1%. Price changes reach an all time high at the end of year 9 of the simulated period and this is lower than the 31.7% peak in the case of unanticipated shock. The growth in freight rates and changes in the fleet follows the same pattern. When the growth in the fleet reduces, the changes in freight rate increase and vice versa. There are similar long run changes as in the unanticipated assumptions, thus growth in freight rate is stable on 24.5% in the long run.

6.5 Conclusion

The estimation and simulation of the model shows the way forward in tanker supply forecast. The anticipated increase of the exogenous variable indicates that the factors are feasible to determine changes in supply, having taken into consideration the effect of changes in freight rates. Simulation with the model gives a clearer view of the effect of changes of exogenous variables shocks, (oil consumption in Western Europe and USA, crude oil prices, shipbuilding costs and bunker price). Exogenous effects on the changes of endogenous variables (demand, freight rate indices, time charter index, new order, newbuilding prices, deliveries, scrapping and fleet).

The unanticipated and anticipated scenarios allow the assessment of the future, just by employing different assumptions. The responses in these scenarios are different from each other; it allows meaning to be read into the simulated series. What this implies is that, the model can be used to predict different situations of the future.

Chapter 7

ONE MILLION BARREL TANKER FORECAST 1994 - 2005

7.1 Introduction

This chapter illustrates how the model developed in chapter 4 for forecasting purposes and scenario planning is implemented. The model will be applied to generate forecasts of one million barrel tankers supply. The forecasts will be presented later in this chapter.

The model estimates Western Europe and USA oil imports; also tanker supply, demand, freight rate index, time charter index, new orders, newbuilding prices, deliveries, and scrapping. One of the crucial assumptions of the model is that tanker owners' expectations are rational.

The assumption is that there is a practical usefulness in the predictions generated by these models. In fact, if such an assumption is not operative, the analysis of the fundamentals is still useful for the practical purposes of analysis.

7.2 Forecast Assumptions

A base run set of assumptions regarding future growth in supply and demand for tankers, oil prices, oil imports, shipbuilding cost and other external or exogenous variable was used in order to generate a base case forecast. The main base run assumptions were that tanker demand grows steadily at around 1.5% in the short run, (2 years) but settles at 2.8% in the long run (5 years) while oil prices remain at about $17.5 per barrel. This implies that the forecast of the exogenous variables will follow the growth in the historical data.

The base run analysis indicates that freight rates would for a while decrease by 6.6%, thereafter they start to increase by about 6.9% per year. It also shows that the newbuilding prices will have a steady average increase of 2%. The rise in freight rates has probably been caused by the increased demand for transportation generated by the temporary increase in long haul imports. The increased demand was operating against an inelastic short term supply, (due to leads, lags and costs in breaking out of lay-up) leading to significant temporary increases in freight rates. The fluctuation in tanker prices reflects the general view concerning the longer-term future.

The assumption is that oil imports will grow steadily as a result of low oil stock; therefore demand for tanker will rise in relation to the increase in the demand for crude oil. Freight rates would increase from 1996 onwards. All other factors in the model can be said to follow the historical trend.

7.3 The Base Run Forecast

With the assumptions that the historical past would continue into the present and future, it is expected that the model would follow the historical trend. The assumption is that the scrapping rate would increase by about 5% per annum. The effect on the total fleet is probably not going to be that great and the newbuilding replaces aged and obsolete tankers. The magnitude of the tanker's tonnage supplied would reflect on the freight rate. When the tanker supply increases, the freight rate would fall. As indicated earlier, the assumptions on each of the variable factors in the model would cause the supply of tanker to increase. On the other hand, low economic growth is likely to affect the amount of oil imports in the examined areas, hence tanker demand and supply.

It should be pointed out to the reader that all the forecast figures reported in this chapter are in levels. The forecasts of changes in variables have been added to the level of the base year, that is 1994. The year 1994 has been taken as the beginning of forecast because 1993 is the end of the historical data. Therefore, forecast of change of the year 1994 has been added to the actual level of 1993. This then gives the forecast of 1994; this has been repeated for all other forecast figure. (See section 7.4 for further explanation.)

Ex-Post Forecast

The historical data covered 1970-1993; these two years (1994 and 1995) have been considered as the ex-post-forecast period. The tables below (7.2) show the forecast developed for the above assumptions.

Table 7.1: Actual Data for the Exogenous Variables

Year	CWE (mt)	PWE (mt)	CUS (mt)	PUS (mt)	COP ($/bl)
1994	712.7	300.6	966.1	649.2	16.21
1995	725.6	312.8	958.4	644.7	17.35

Year	MBTt-1 (mdwt)	OST Billion Ton-Miles	BP ($US/tons)	SBC (index)	LU (mdwt)
1994	42.1	7469	87	245.2	0.95
1995	44.4	7375	94	278.3	0.74

Year	FRt-1 (index)	TCIt-1 (index)	WEOIt-1 (mb/d)	USIt-1 (mb/d)	NORt-1 (mdwt)
1994	94	279	9.8	8.9	2.2
1995	102	313	9.6	8.8	4.0

Year	DELt-1 (mdwt)	DDt-1 (mdwt)	SSt-1 (mdwt)	SC (mdwt)
1994	1.61	33.9	44.4	0.80
1995	1.40	32.8	43.7	0.90

Sources: BP, Statistics of World Energy.
Jacobs, J. I., Review of World Oil Tanker.
ISL - Shipping Statistics Year book 1996.
ISL - Shipping Statistics and Market Review- various issues.
Lloyds Shipping Economists - various issues.
International Financial Year book 1996.
Fearnleys Review - World Bulk Trades.
Drewry Shipping Consultants, Drewry monthly

It is an assumption (with special reference to the exogenous variables) that all variables would grow in line with the historical data. The actual variables for 1994 and 1995 are given above (See table 7.1) and there will be further discussion in chapter 8. In that chapter the difference between the actual and forecast will be examined, using Root Percentage Error etc. to measure forecast efficiency.

Forecast Estimation

The estimated figures of the ex-post forecast will be shown in this section. The same method will apply in the ex-ante forecast; however this will be discussed in the next section. By comparing the ex-post-forecast results of Western Europe Oil imports, USA oil imports and the tanker demand there is evidence of influence of oil imports on demand. Oil imports in Western Europe appeared to increase by about 11.2%, thus the demand increased by about 2.2%. There was a recorded increase in US oil imports of about 8.1%; this will generate additional demand for tankers. The conclusion is that the two areas of imports will influence the demand and supply of tankers. The oil import has been measured in (mb/d) as this was common with the countries in question. In other words the general and common way of reporting or expressing imports is (mb/d). Oil tankers measurement is quite different; the tankers are measured in tonnes, tonne-miles or dead-weight tonnage. The data sources have reported oil tankers data in dead-weight tonnes, hence the use of DWT.

In this thesis only oil imports and oil consumption were reported in million barrels per day (mb/d). The rest of the data on tankers have been measured in dead-weight tonnes for the reasons given above.

Table 7.2 Forecasts of Oil Imports and Tanker Demand

Year	WEOI (mb/d)	USI (mb/d)	Demand (mdwt)
1993	10.3	7.9	33.0
1994	11.6	8.6	34.1
1995	11.7	8.9	34.3

Source: Forecasts from this thesis

However, the demand in 1995 increased and WEOI and USI increased by 0.9% and 1.1%. The assumption is that market players have used more of other modes of transport and larger tankers; one million barrel tanker demand are not likely to claim 100% share of the increase in imports.

The trend of tanker demand and supply is considered to follow the economic cycle. A booming economy can be said to favour increase oil consumption, thus the increase in oil imports. Another factor that affects oil imports and tanker demand is the oil prices. Increase in oil prices is noted to have effect on the imports at a particular time. Whether there is an oil price increase or decrease, the effect on the tanker market can sometimes be serious. It can be said that low oil prices would increase oil consumption, thus the increase in oil imports.

Table 7.3 Forecasts of Tanker Supply, Demand and Freight rates

Source: Forecasts from this thesis

Year	Demand (mdwt)	Supply (mdwt)	Freight rates (index)
1993	33.0	44.0	112
1994	34.1	45	115
1995	34.3	46.1	116

Table 7.3 relates the effects of tanker demand to supply and the effect of freight rate on the supply. The forecast indicates that increase in demand by 3.2% does have immediate response of 0.3 in tanker supply . However, the assumption is that there is a lag between the time the increase occurred in demand and when supply actually increases. The freight rate and tanker supply has responded to the expectation that demand would increase. The freight rates were up by 10.1% and supply by 2.3%. There was increase of 4.5% in demand. This can be attributed to the improvement in the economy. It is a priori that freight rate is very important to tanker supply. The expectation of increase of the freight rate would influence tanker owner to bring vessels out of lay-up or delaying scrapping.

Table 7.4 Forecasts of Supply, Freight, Newbuilding and New order

Year	Supply (mdwt)	Freight indices (index)	Newbuilding Prices ($m)	New order (mdwt)
1993	44.0	112	60.5	6.0
1994	45	115	62.9	5.5
1995	46.1	116	65.0	5.2

Table 7.4 examines the relationship and the effect of the freight, newbuilding price and second-hand price. From the point of view of the newbuilding price, other than the cost of building, the supply level would influence the newbuilding price. When the tanker supply increases by 2.3% it causes the newbuilding price to increase by 3.2%. New orders responded to tanker supply; thus the new orders increase of 7.6% justifies the assumption. Increase in the freight rate indicates a market speculation that can sometimes be short term or completely incorrect.

Table 7.5 Forecasts of Supply, Demand, Delivery and Scrapping

Year	Supply (mdwt)	Demand (mdwt)	Deliveries (mdwt)	Scrapping (mdwt)
1993	44.0	33.0	2.4	0.40
1994	45.0	34.1	2.0	0.42
1995	46.1	34.3	1.9	0..42

Source: Forecasts from this thesis

Table 7.5 indicates what the level of scrapping would be at this level of supply. There is an indication that an increase in the demand would increase deliveries both in the short and long run. However, there is always a lag effect between the order and when the tanker becomes a delivery, as a result it may not be appropriate to consider any addition to supply until the vessel begins to trade. It is assumed that scrapping becomes steady mostly as a result of long term improvement of the freight rate. The age of the vessel is another factor that could affect scrapping, however vessel life can be prolonged if the freight rate market is high or expected to increase. The model forecasts growth of the freight rate from 1994 onwards. Tanker supply shows a steady growth, likewise the freight rates. The increase in deliveries is an evident in the size of the fleet (supply). The supply of one million barrel tankers increases faster than scrapping; hence scrapping does not have strong effect on supply.

Table 7.6 Forecasts of Supply, Demand, Freight rate index and Time charter rate

Year	Supply (mdwt)	Demand (mdwt)	Freight indices (index)	Time charter index
1993	44.0	33.0	112	270
1994	45.0	34.1	115	293
1995	46.1	34.3	116	325

Source: Forecasts from this thesis

Table 7.6 examines the freight rates market and the demand and supply. Indirectly, increases in the price of oil are likely to cause increase in bunker price, and the supply of tankers. This coupled with low demand will cause vessel to slow steaming in order to minimise on the consumption of fuel. Also when there is no trade to which to attribute the increasing cost of fuel, the strategy will be to cut down on fuel by slow steaming. Directly, increase in oil price causes the freight rate to increase and supply of tanker would increase as a result.

In summary, the increase in the oil price caused the freight rate to increase. There are two reasons for these: firstly, because of the effect of crude oil prices on bunker oil prices. Secondly, because fluctuations in oil prices effect the demand for oil and this invariably feeds into tanker demand. The freight and time charter rate shows a steady increase from 1994 onwards. The increase in the freight rate activates a response from tanker owners. They increase tanker supply in order to generate income through employment. For the forecast figure, see table 7.3.

7.4 Base Run Forecast

Ex-ante forecast

The assumption of the base-run is that there will be permanent increase in oil imports. The demand for oil in the major nations would have an average growth of 1% per annum. This slow increase has been due to the increase in oil prices. However, lower prices are likely to contribute to growth rates in world economic activity and therefore in the demand for tankers.

Tanker supply is likely to cause future increase of freight rates. However, it is envisaged that the increase in tanker freight rate would decline; just as the tanker supply increase in the base forecast; see table 7.7 below. Therefore, there will be a long-term average growth of 0.8% in the demand for time charter rate. Demand for oil is predicted to have a steady growth of 8.7%. This would continue to increase towards the middle of the next decade. Growth in tanker demand will encourage an increased tanker supply. The supply is assumed to grow by 2.2% towards the end of the forecasting year 2005. Shipbuilding cost would increase slowly at an average of 2% up to the end of the decade as a result of inflation, but from then on it should increase in line with the total demand and the freight markets.

The assumption is that there will be speculative behaviour in the second-hand markets. There will be a short run development in prices; which triggers the longer run influence on scrapping, newbuilding price and also freight rates. The prices will increase immediately to reflect these assumptions. However, there will be a limitation in the size of the increase. Thus the higher price stimulates fleet growth (reduction in scrapping and increased in the supply of newbuilding); hence there is negative effect on future freight rates.

It is expected that the supply of new tankers as measured by the order book would increase. Further more, the increase in new order would cause tanker deliveries to increase; and generate an increase in tanker supply. The difference between deliveries and scrapping dictates the level of changes in the fleet size, after allowing for losses.

In line with the increase in values there is tendency that the supply of new tankers will increase. The forecast is that the order book will increase to 7.3 million dead-weight tons by the end of the forecasting period, the expectation is that deliveries will increase to 2.2 million dead-weight tonnes. This implies that one million barrel tankers will continue to increase for some time after the forecast period. The freight rate is expected to rise towards the end of the forecast period by about 3% in anticipation of increase in trade, despite the marginal increase in the fleet size. Lower oil prices will reflect on bunker prices; thus the time charter rate will remain at 2%, the same as in the second year of forecast. It will then increase by about 0.6% towards the end of the forecasting period.

With the assumption that demand would have a steady growth, it would probably affect the rates and prices will rise considerably. This will happen when the balance of tanker supply and demand improves. Eventually the fleet will move in line with demand; in the long run the fleet will grow by about 6%. The deliveries and scrapping will determine the total fleet. Recent double hull legislation is possibly going to affect the supply as the ageing tanker withdraws from trading. The reduction in the fleet would reinforce freight rates. The increase in rates and prices will reduce scrapping and advance the supply of newbuilding. The supply-demand position moves closer to balance.

As indicated in section 7.3, the forecasts presented in the tables below are the level of the variables. Changes that occurred in the endogenous variables were forecasted and were added to the base forecast, starting from year 0. The last year of the historical data 1993 is regarded, as 0 and tanker supply was 44.0mdwt. The forecast of the change in supply for 1994 was 1.0mdwt. Therefore, the tanker supply level for 1994 will be 44.0 + 1.0 = 45.0.

Table 7.7 The Base Forecast for SS, WEOI, USI and DD - One Million Barrel Tanker[223]

Year	Tanker supply (mdwt)	W. Europe Oil import (mb/d)	USA Oil imports (mb/d)	Tanker demand (mdwt)
1985	49.1	8.7	5.1	32.4
1986	47.8	9.7	6.1	32.4
1987	47.2	8.2	6.3	32.0
1988	47.3	9.4	7.2	32.6
1989	46.9	9.7	8.0	33.3
1990	45.7	9.8	8.0	35.2
1991	43.9	9.8	8.2	30.1
1992	44.0	10.1	7.8	33.2
1993	44.0	10.3	7.9	33.0
1994	45.0	11.6	8.6	34.1
1995	46.1	11.7	8.9	34.3
1996	47.2	11.8	9.0	35.9
1997	47.3	11.9	9.0	36.9
1998	48.4	12.1	9.2	38.6
1999	49.5	12.3	9.1	38.3
2000	50.6	12.4	9.2	40.2
2001	51.9	12.6	9.1	41.1
2002	53.2	12.8	9.2	43.3
2003	54.5	13.0	9.3	44.4
2004	55.8	13.2	9.4	47.2
2005	57.0	13.4	9.5	48.6

Source: Forecasts from the thesis (All forecast figures are in levels form)

[223] All forecast figures are in levels form
1985 - 1993 Actual historical figures, 1994 - 1995 Ex-Post Forecast figures,
1996 - 2005 Ex-Ante Forecast figures

Table 7.8 The Base Forecast[224]: Supply, Freight index, Time charter index and Demand

Year	Tanker supply (mdwt)	Freight rates index	Time charter index	Tanker demand (mdwt)
1985	49.1	57	151	32.4
1986	47.8	65	142	32.4
1987	47.2	75	178	32.0
1988	47.3	80	251	32.6
1989	46.9	102	274	33.3
1990	45.7	108	241	35.2
1991	43.9	110	271	30.1
1992	44.0	112	270	33.2
1993	44.0	112	270	33.0
1994	45.0	115	293	34.1
1995	46.1	116	325	34.3
1996	47.2	129	325	35.9
1997	47.3	121	354	36.9
1998	48.4	130	378	38.6
1999	49.5	135	381	38.3
2000	50.6	140	356	40.2
2001	51.9	145	354	41.1
2002	53.2	150	333	43.3
2003	54.5	155	335	44.4
2004	55.8	160	355	47.2
2005	57.0	165	355	48.6

Source: Forecasts from this thesis

[224] Ibid., All forecast figures are in levels form

Table 7.9: The Base Forecast[225]: Supply, Order, Newbuilding price and Demand

Year	Tanker supply (mdwt)	New order (mdwt)	Newbuilding Price ($m)	Tanker Demand (mdwt)
1985	49.1	1.6	25.0	32.4
1986	47.8	3.5	26.5	32.4
1987	47.2	4.2	34.0	32.0
1988	47.3	4.4	46.0	32.6
1989	46.9	6.5	54.0	33.3
1990	45.7	9.7	55.0	35.2
1991	43.9	6.7	44.5	30.1
1992	44.0	6.0	61.5	33.2
1993	44.0	6.0	60.5	330
1994	45.0	5.5	62.9	34.1
1995	46.1	5.2	65.0	34.3
1996	47.2	5.4	67.0	35.9
1997	47.3	5.7	69.7	36.9
1998	48.4	6.1	72.0	38.6
1999	49.5	6.2	73.8	38.3
2000	50.6	6.1	75.6	40.2
2001	51.9	6.4	77.4	41.1
2002	53.2	6.7	79.2	43.3
2003	54.5	7.2	81.0	44.4
2004	55.8	6.8	82.9	47.2
2005	57.0	7.3	84.8	48.6

Source: Forecasts from this thesis

225 Ibid; All forecast figures are in levels form

Table 7.10 The base Forecast[226]: Supply, Delivery, Scrapping and Demand

Year	Tanker supply (mdwt)	Deliveries (mdwt)	Scrapping (mdwt)	Tanker demand (mdwt)
1985	49.1	0.2	0.40	32.4
1986	47.8	0.9	0.30	32.4
1987	47.2	0.9	0.50	32.0
1988	47.3	1.3	0.10	32.6
1989	46.9	1.7	0.10	33.3
1990	45.7	0.7	0.10	35.2
1991	43.9	3.5	0.40	30.1
1992	44.0	2.4	0.40	33.2
1993	44.0	2.4	0.40	33.0
1994	45.0	2.0	0.42	34.1
1995	46.1	1.9	0.42	34.3
1996	47.2	1.9	0.43	35.9
1997	47.3	1.9	0.43	36.9
1998	48.4	1.9	0.44	38.6
1999	49.5	1.9	0.44	38.3
2000	50.6	1.9	0.44	40.2
2001	51.9	2.3	0.44	41.1
2002	53.2	2.3	0.45	43.3
2003	54.5	2.2	0.45	44.4
2004	55.8	2.2	0.46	47.2
2005	57.0	2.2	0.46	48.6

Source: Forecasts from this thesis

226 Ibid., All forecast figures are in levels form.

7.5 Market Prospects

The main factors that will determine the market for the million-barrel tankers and forecast up to the year 2005 have been examined. It has to be noted that though it is impossible to guarantee that the predictions are one hundred percent correct, however it is important to the future of one million barrel tankers supply. The possibility of human judgement error in relation to assumptions and anticipation was dealt with in chapter 6.

6.5.1 *Base Forecast Result Analysis*

Oil imports and consumption Western Europe and USA

The volume of oil that will be needed by the two major areas and route of this category of tanker has been forecasted to increase as the years go by. Western Europe highest imports would come in 2005; the forecast figure shows 13.4 mb/d, increase of 11.4% compared with 1996 figure of 11.8 (mb/d). Also towards the end of the forecasting period the figure shows a steady increase in oil imports which can be attributed generally to the upward turning of the economy. From the year 1997 there is a steady improvement in the imports figure with an average increase of 1.6%. USA oil imports is also considered to move with the trend of the economy. The forecast of oil imports for 1996 is 89.0mb/d and the highest prediction for the forecast period is in year 2005 that is 9.5mb/d. The lowest for the forecast period is 9.0 mb/d in 1996 and 1997. Generally the trend shows that the situation would improve, thus demand and supply of one million barrel tankers. The oil consumption volume is assumed to reflect on imports, hence the forecast figure for the oil consumption in the two major routes follow the same trend as the imports. The evidence gathered from the forecast of these imports shows some optimism for the demand and supply of one million barrel tankers. For the forecast figure, see table 7.7 and figures 7.1 and 7.2. Figure 7.10 compares the movements of the four series DD, WEOI, USI and SS.

Tanker demand

The demand for one million-barrel tankers according to the forecast figures would steadily increase. *All things being equal* an increase in tanker demand would cause the supply to increase as demand. The lowest demand according to the forecast is in the year 1996; the forecast figure is 35.9 mdwt compared with the previous year which was 34.1 mdwt. The prediction for the rest of the forecast period shows some optimism, which can be regarded as a good prospect for supply. Demand in this case follows the trend pattern in oil imports; it increases throughout the forecast period; and is expected to remain high as the oil imports increases. See tanker demand figure 7.3.

Freight Rate

The freight rate follows the forecast figure of tanker demand. It shows a steady increase, the highest freight rate recorded is in the year 2005, a peak figure of 165. The index from the year 1996 witnesses a continuous increase to 129, but decrease to 121 in 1997; 6.6 per cent. The lowest index forecast is 1996. The demand forecast may be low in 1997, but supply forecast increases by 2.3%. The indication is that freight rate index would always track the movement in demand and supply. The freight rate increase towards the end of forecast period.

The forecast figures for the freight rate (1996-2005) are given in table 7.8 and figure 7.4.

Time charter is predicted to have a steady growth pattern. The time charter index forecast in 1996 is 325 it shows an increase of 9.8% from 1994 and same as in 1995; the final year of the ex-post forecast. It shows an upward movement, however the movement is in steady state. This is the same pattern shown in freight rate index and the demand for tankers, however the tanker supply shows more of upward trend in the forecast period than time charter. The actual forecast figures can be seen in table 7.8 and figure 7.5.

New order

The volume of new orders that will be placed in the future will depend on current freight market conditions. It will also depend on the perception of future profitability, as well as on shipbuilding capacity and the availability of finance. New orders are considered from the forecast figure to be moderate between 1995 and 1997, however the forecast shows an ever-increasing trend. The lowest level is predicted to be 5.4 mdwt in 1996. The forecast shows an increase of about 6.6% in 1998 compared with the increase in the previous forecast year of 3.7%. The rate of ordering will rise to a peak of 7.3 mdwt in 2005, largely on the expectation of freight market movement. See table 7.9 and figure 7.6.

Newbuilding Price

Newbuilding prices always follow the fortunes of the tanker market. The tanker demand situation reflects in the newbuilding price. When the demand for tankers is low the prices of newbuildings tend to be low as well. The forecast figure of the newbuilding price for example in the year 1997 is $US67 million and the tanker demand for the same year is 36.9 mdwt. The price of newbuilding is predicted to be very high in year 2005, even for the forecast period $US 84.8 million is the highest. The lowest price is predicted for 1996 where the forecast building price is $US 62.9 million. The very high newbuilding price of 2005 can be attributed to other factors such as the high cost of shipbuilding. The forecast for the whole period shows ever-increasing prices. This could also be attributed to speculative increase in demand and freight rates. See table 7.9 and figure 7.6.

Deliveries

Tanker deliveries will depend on previous orders, and late deliveries. Also depending on the market situation, some of the deliveries can be delayed or some orders cancelled. The forecasts have predicted a steady delivery rate. In 1996 the forecast deliveries will be 1.9 mdwt and the highest delivery for the forecast period is 2.3 mdwt in year 2001 and 2002. The general view of these forecast is that deliveries will be steady from year 1996 onwards. The lowest forecast for deliveries is 1.9 mdwt, this would occur in years 1997 to 2000. See table 7.10 for the forecast figures and figure 7.7.

Scrapping

Tanker scrapping is predicted to be steady over the forecast period. The factors that determine the rate of newbuilding ordering levels also affect scrapping, especially current freight market conditions and perceived profitability. The age profile is another important factor. The scrapping rate is forecast to remain stable throughout the period. See table 7.10. The situation would probably change when the deadline for double hull tanker comes into effect. This could mean increase in scrapping as a result of the number of obsolete tankers. The highest scrapping recorded for the forecast period is 0.42 mdwt. It is assumed that from the year 2005 upwards, the situation could change as a result of full return to a rate of scrapping consistent with the age profile of the fleet. As already been said new legislation is likely to send many tankers to scrap yard. The number is likely to be high because it will become impossible to keep very old tankers in the service regardless of the levels of freight rates, newbuilding prices and scrap values; see table 7.10 and figure 7.9.

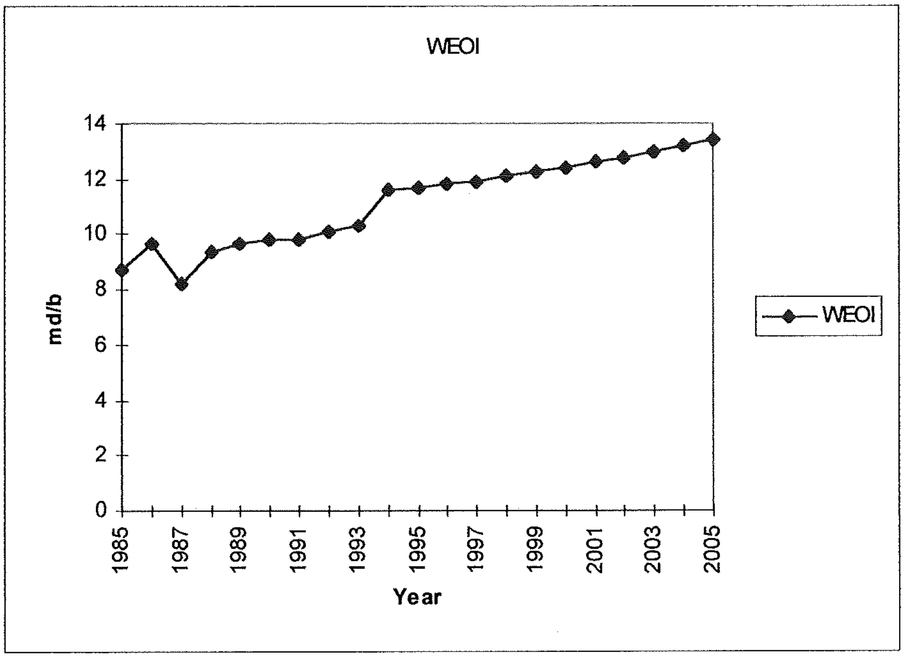
Tanker supply

The discussions of the forecast of the endogenous variables would enable the forecast of the trends of are million barrel tankers to be effectively assessed. Most especially the trend in scrapping and deliveries of newbuilding, they are very important to tanker supply. Low scrapping and high delivery will increase supply and on the other way round it will reduce supply. The forecast indicates a steady growth in tanker supply, these are likely to slow down immediately after the forecast period. However, the whole of the forecast period has shown an increasing trend. The tanker supply will be high in 2005 at 57.0 mdwt, the forecast figures shows an increase for the rest of the forecast period. See the forecast figure in the tables above, tables 7.7 to 7.10.

When the forecast result of demand and supply are compared, the indication can be seen clearly that the predicted rise in size of the fleet will far exceed the likely growth in demand in the whole forecasting period. However, the demand and supply balance increases towards the end of the forecast period. See table 7.10 and figure 7.14.

The figures' below (Fig. 7.1 to 7.14) are constructed from tables 7.7 to 7.10, pp. 247-249. The historical data used for these graphs is from 1985 to 1993, the ex-post forecast is 1994 to 1995 and the ex-ante forecast of the estimated model in chapter 6 is 1996 to 2005.

Figure 7.1: Western Europe oil imports forecast[227]



Source: Forecasts from this thesis

(The source of figures 7.1-7.14 is from the thesis forecasts)

[227]1985-1993 Actual historical figures
1994-1995 Ex-post forecast results
1996-2005 Ex-ante forecast results

Figure 7.2: USA Oil imports forecast

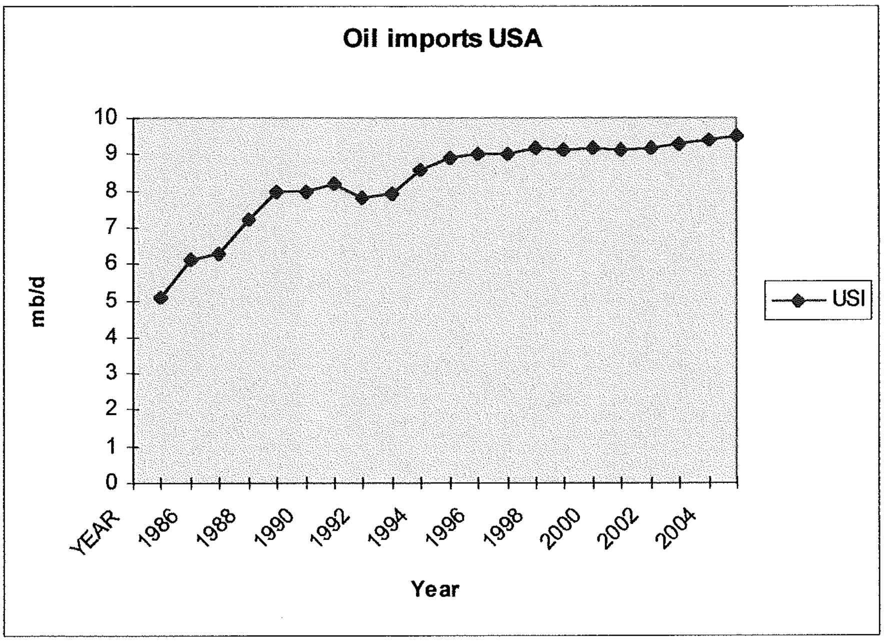


Figure 7.3: Tanker demand forecast

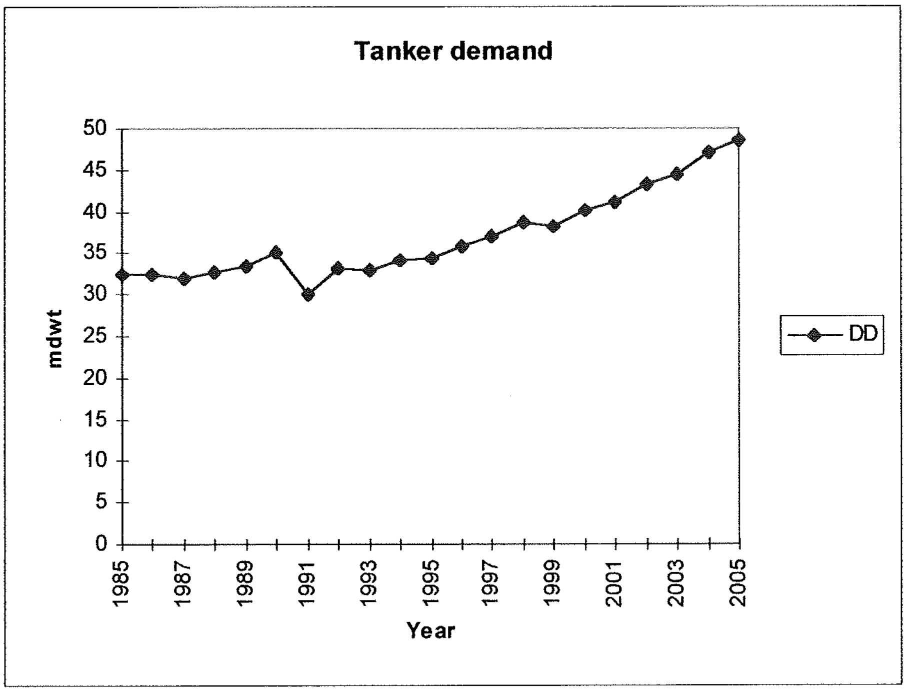


Figure 7.4: Freight rate forecast

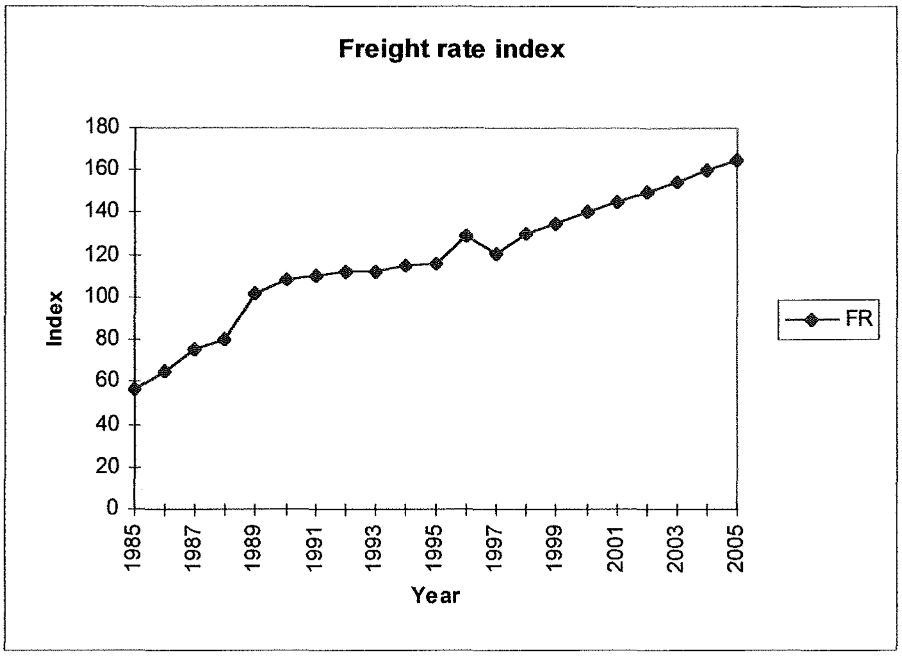


Figure 7.5: Time charter forecast

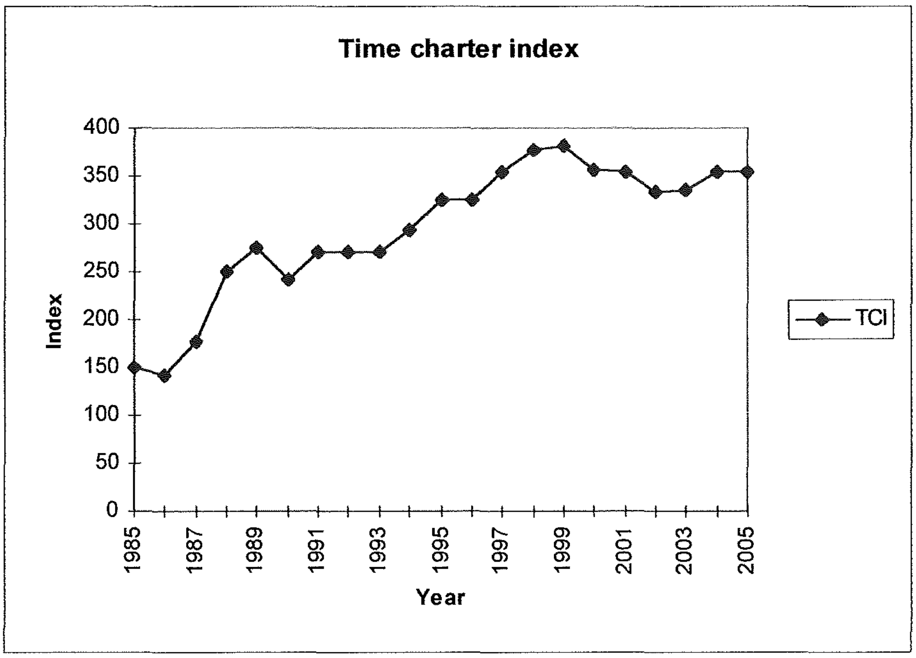


Figure 7.6: New order forecast

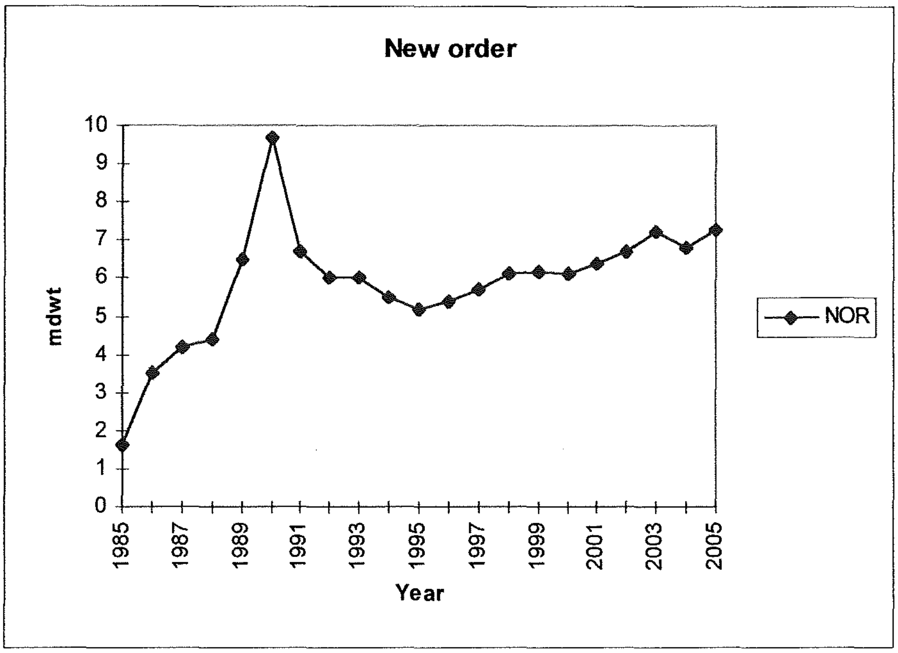


Figure 7.7: Newbuilding price forecast

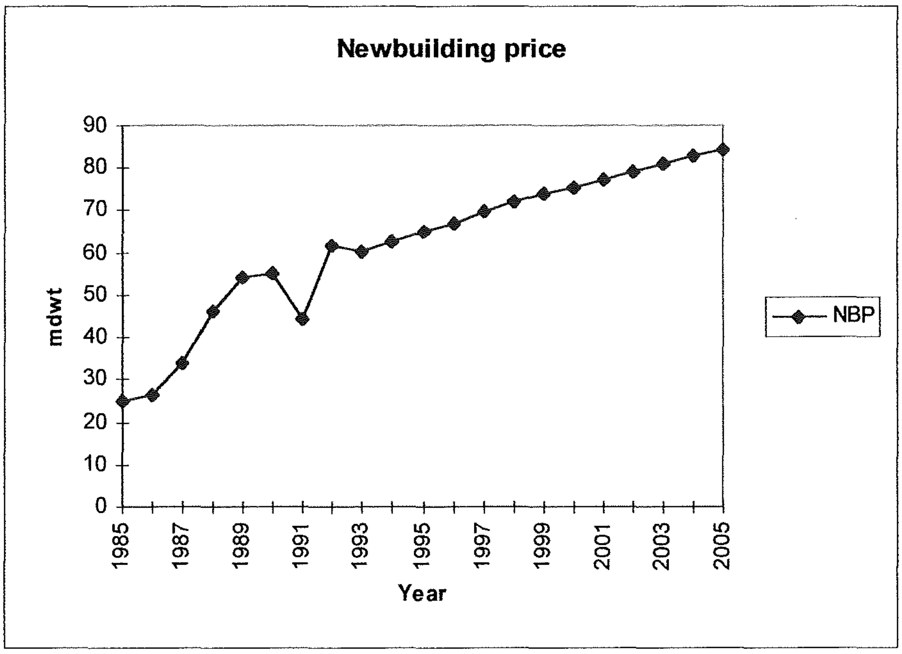


Figure 7.8:Tanker deliveries forecast

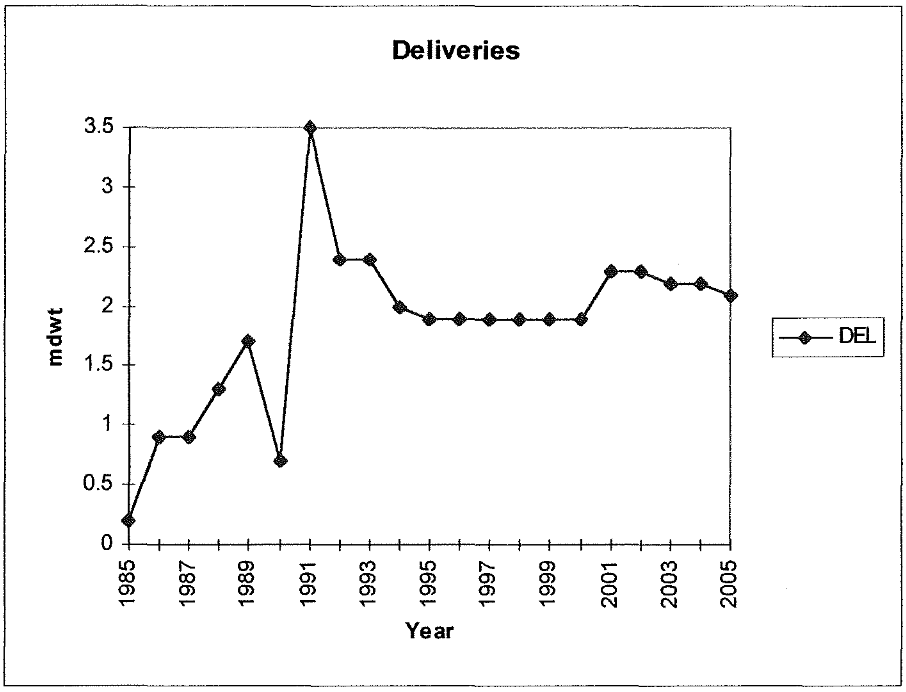


Figure 7.9: Tanker scrapping forecast

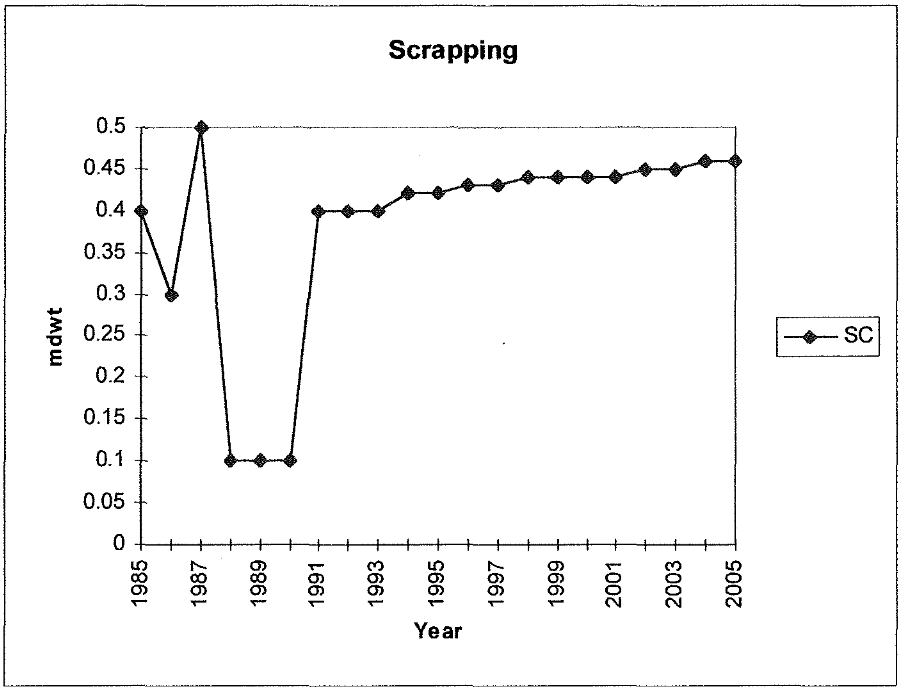


Figure 7.10: Tanker supply forecast

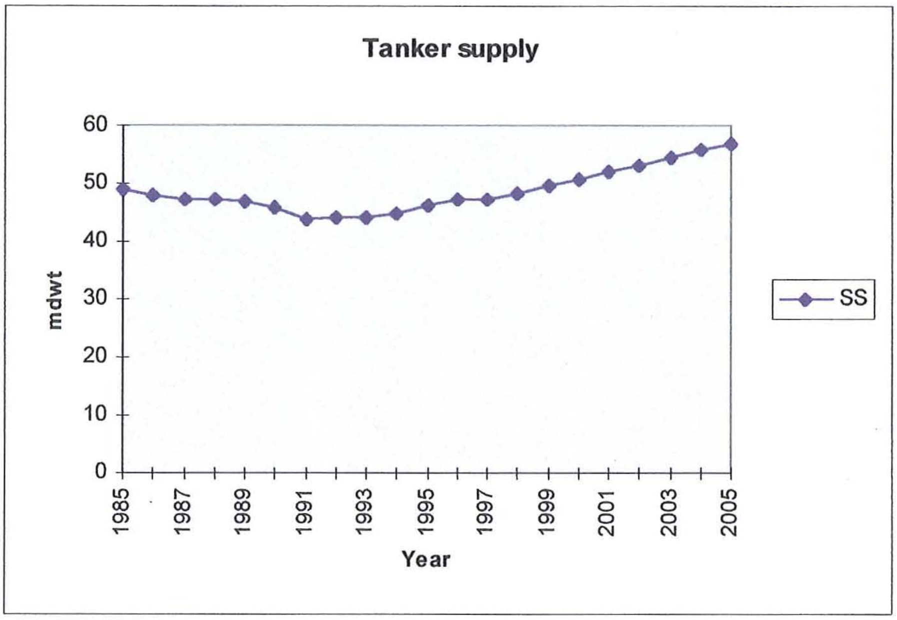


Figure 7.11: The relationship of SS, WEOI, USI and DD forecast

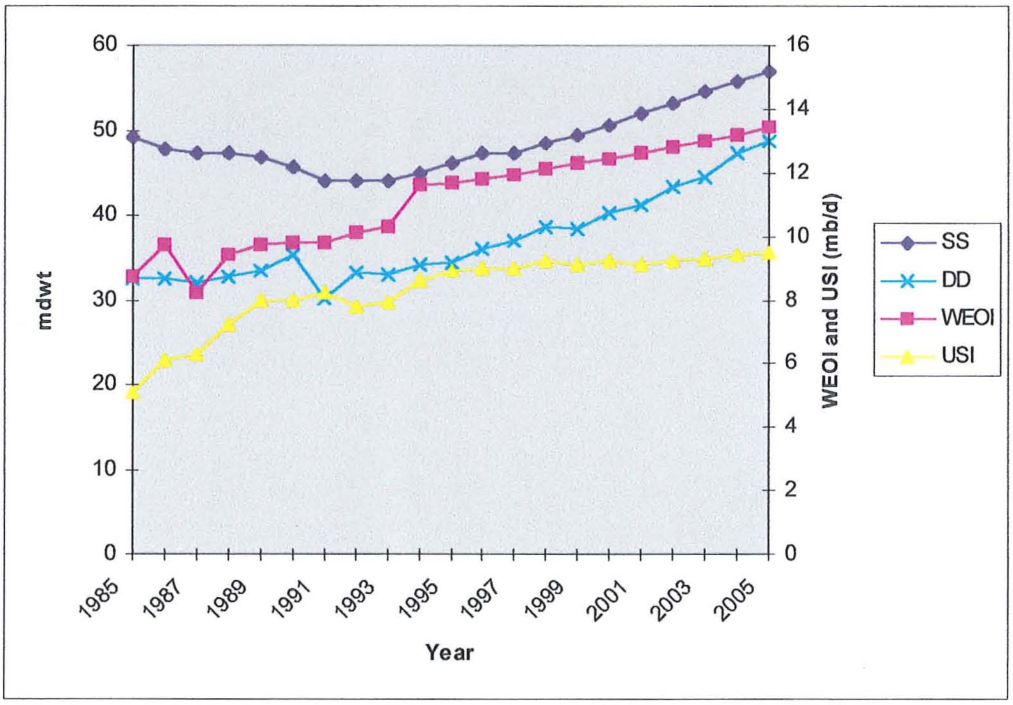


Figure 7.12: The relationship of FR, TCI, DD and SS forecast

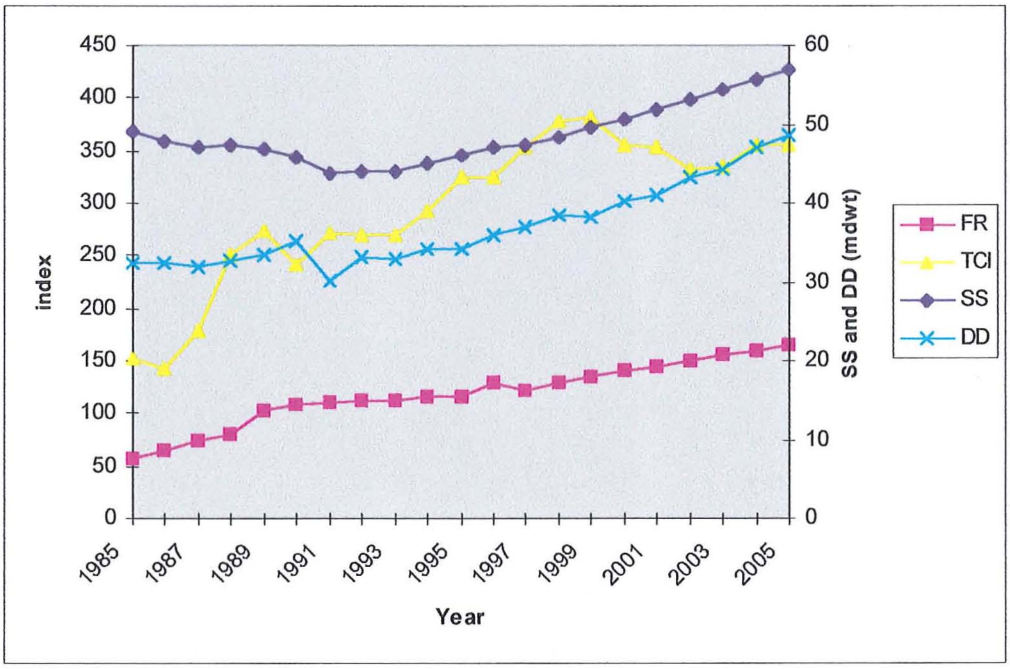


Figure 7.13: Relationship of SS, NOR, NBP, and FR forecast

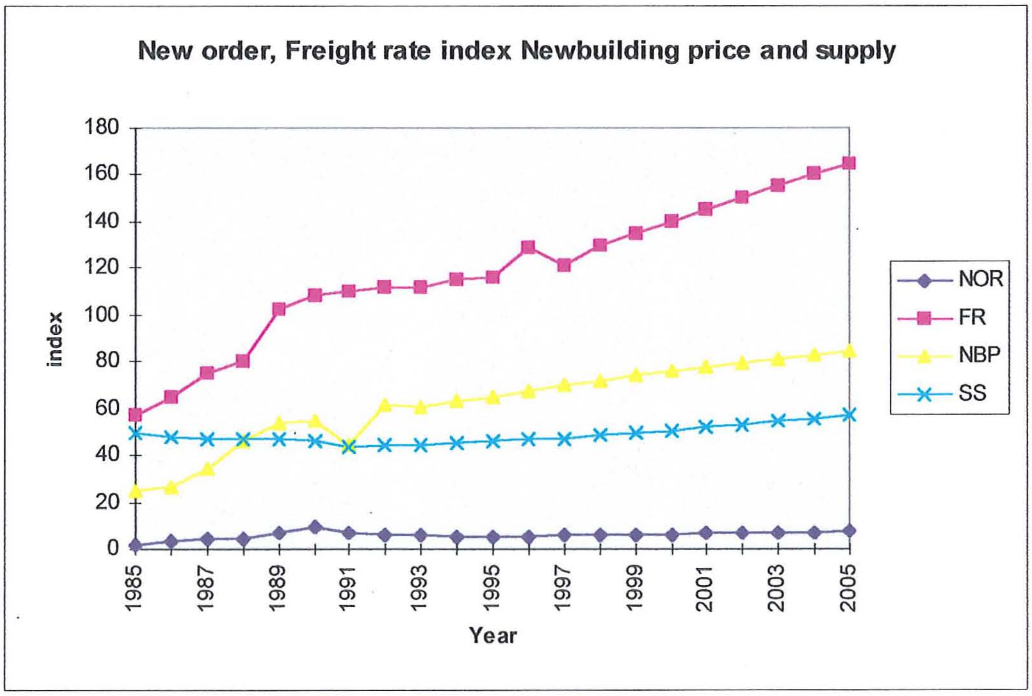
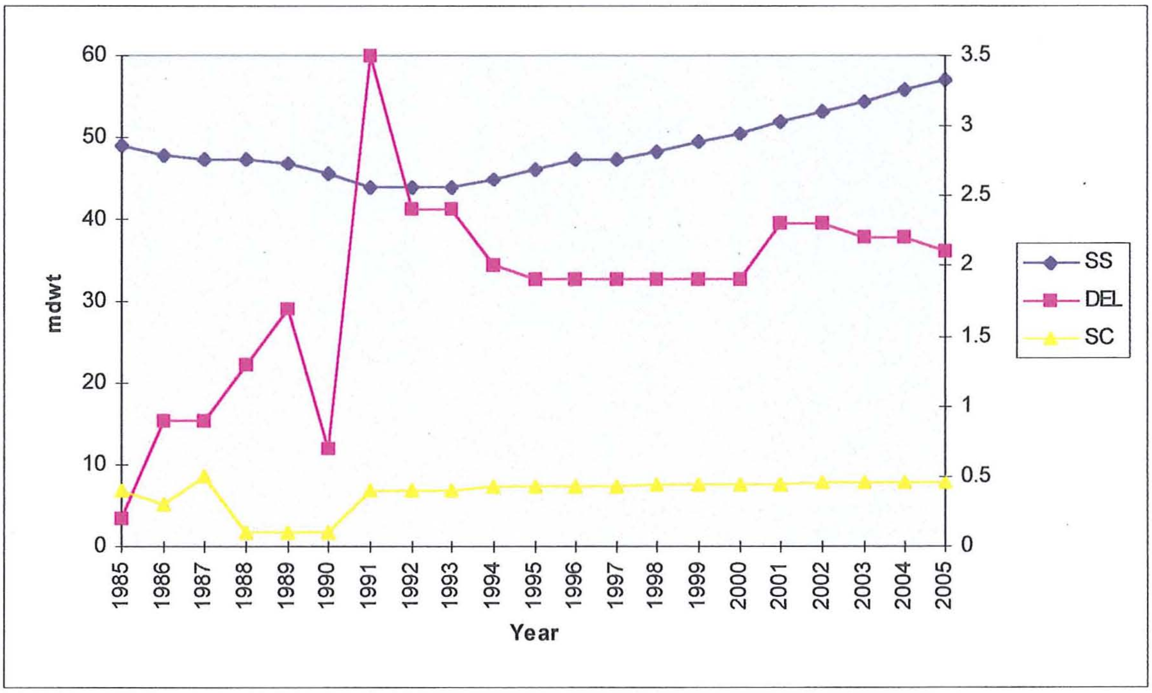


Figure 7.14: The relationship of SS, DEL and SC forecast



Source: (figure 7.1-7.14) Forecasts from this thesis

7.6 A comment on the effect of recent legislation on scrapping rates

It is important to understand that recent legislation such as OPA, (the USA Oil Pollution Act 1990) will affect the future of tanker supply. The legislation is already in place; it is anticipated that it will have a considerable effect on the oil tanker market.

The deadline for all single-hulled tankers trading in US waters is year 2015. (See chapter 2, pp. 44. Perhaps this category of tankers may not feel the effect until the year 2004; however the tendency that the effect will be sooner than later is not known, it can only be assumed.

The pressure to scrap tankers is expected to continue in the years ahead, 1996 and through to year 2000's and will increase further when MARPOL Reg. 13G begins to affect the tanker fleet. The effect of MARPOL 13G and OPA overlap from the outset, as a result many of vessels mandated out by OPA 1990 will also be subject to MARPOL 13G phase-out.

As a result of these changes, it is assumed that as a result of legislation that scrapping will increase significantly towards the end of the decade. More of this scrapping will come as a result of this legislation. The ageing fleet reflects the significant deadweight of tankers delivered in the 70's and 80's. It is speculated in this thesis that scrapping will increase by 10% per annum, that is above the ex-ante forecast of tanker scrapping of this model. (See table 7.9.) This would take effect from the year 2005.

7.7 Conclusion

In general the forecast figures for the period indicates an optimistic future for the one million barrel tanker stock. Scrapping and delivery rates are steady, also tanker supply is projected to grow steadily. However, there is a tendency for further decrease in supply. After examining the factors that affect supply and forecasts the factors, a positive view of the future of tanker supply was obtained. It is clear that the level of freight rates, new orders, deliveries, scrapping, and the level of demand have a significant influence on supply. It is concluded that the demand-supply balance will improve to and beyond 2005.

Chapter 8

APPLICATION OF ALTERNATIVE FORECASTING METHODS, EFFICIENCY AND COMPARISON WITH ECONOMETRIC MODEL

8.1 Introduction

In any situation where forecasts are needed, especially for planners, there is a very wide choice of methods. There are choices ranging from simple intuitive models to highly sophisticated quantitative models. However, they can all be classified in terms of their cost, complexity and accuracy.

Faced with the need to make decisions in an atmosphere of uncertainty, forecasts tend to be the only means to reduce the risk in the volatile market.

Forecasting can be classified as qualitative or quantitative. Qualitative techniques need no input of judgement; they are mechanical procedures that produce qualitative results. Whatever method is applied, it is important to know that all forecasts are basically a projection of past data and experiences into an uncertain future.

The thesis has looked extensively at econometric forecasting in the previous chapters. However, because there has not been any forecasting of one million barrel tanker supply, the decision was made to employ other forecasting methods, such as Exponential Smoothing, Box -Jenkins ARIMA and random walk, in order to compare the results.

In the literature much attention has been given to the selection of a particular forecasting method and a series of comparisons of these methods have been carried out. However, the authors have arrived at different conclusions concerning which models give better results. In view of the previous examination the author of this thesis has opted to use econometric modelling as the main forecasting method. There have been few practical forecasts using this method, especially for tanker supply forecasts. There are none for the one million barrel tanker. Most of the literature, as discussed in chapter three, constructed econometric models without using them for forecasting. It is envisaged that the use of an econometric model will improve forecast accuracy, because it takes into consideration many variables that have been shown to influence tanker supply.

The other techniques that are employed to generate comparative forecast are Exponential Smoothing, and Box-Jenkins. A considerable contribution has been made with these methods as forecasting methodologies

'Simple methods', to be discussed later, include methods such as e.g. random walk models and exponential smoothing, Brown's method, the Holt method and adaptive filtering.

The result of applying alternative forecasting models to the tanker data are presented and discussed in sections 8.4 to 8.6. There is also additional information provided on the computation of these models in appendix E. An explanation of the econometric forecasting model and its analysis has already been discussed in chapters 4 to 6.

The uncertainty and costly information in the tanker shipping market have warranted a thorough search for the best information in terms of forecasting to improve the situation in the tanker market. Better estimates of future tanker supply enhance planning and investment which could lead to more efficiency in supply. It is essential to have forecasting mechanisms that can predict the subsequent supply of one million barrel tankers as accurately as possible.

The question is whether (causal model) econometric forecasting predict the subsequent tanker supply with the same or better accuracy than predictions generated from various time-series models. It has to be said that even if time-series models predict more accurately than the causal model, it does not necessarily imply that the causal models are inferior forecasts. The gain in the incremental accuracy must still be weighed against random walk, exponential smoothing and ARIMA models or against buying ready made forecasts in which the forecast method is not explained. It is however crucial for the forecast to be as close as possible to the actual result, of course the relative cost is also very important to use in the comparison of various forecasting methods.

This chapter will also compare the forecasting performance of the econometric forecast of tanker supply (Western Europe oil imports, USA oil imports, tanker demand, freight rate index, time charter, new order, newbuilding price, delivery, scrapping) with the predictions of various widely used time series forecasting models.

8.2 Analysis and Application

8.2.1 *Exponential Smoothing:*

Single Exponential Smoothing

All mathematical forecasting models try to relate the supply in the next few years (or short term time interval) to recent behaviour. It seems reasonable to give more weight to more recent observations i.e. as we go back in time the past has less and less effect on the future. Simple exponential smoothing uses an exponentially weighted sum of data points.

Double Exponential Smoothing

Single exponential smoothing when applied to a process whose forecast underlying mean is a constant, performs very well but is clearly unstable when the variable is known to be increasing or decreasing. Tanker supply series including those considered in this thesis fall into the category of non-stationary underlying supply. Single exponential smoothing can be adapted to allow for the inclusion of a slope factor and the resulting model is known as double exponential smoothing.

Box-Jenkins Method

This procedure allows an appropriate model to be selected from a range of feasible models and caters for the possibility of multi-parameter models. From this point it is assumed that for some difficult data, a Box-Jenkins model will almost certainly turn out better than a single or a two parameter exponential smoothing model from the sheer number of options available to the forecaster using the Box-Jenkins approach.

If a series can be divided into definite section where the sections are assumed to have different underlying models, it may turn out that exponential smoothing provides as good as or even a better estimate of the same model in each of the cases. Although Box-Jenkins (1979)[228] gives a contrary example, it has been generally accepted that the Box-Jenkins approach required a large number of observations in order to correctly identify the time series model (n=50 or greater than 50). In the shipping industry it is not normal for events to remain unchanged for this length of time.

[228]Box, G.E.P., and G.M. Jenkins, Time Series Analysis, Forecasting and Control, rev. ed. San Francisco: Holden-Day 1976.

However, it is very easy to fit a Holt model to a comparatively small number of data points that will adequately highlight any local trends.

The formulae and the calculations of the alternative models can be found in appendix E.

8.3 Criteria for Forecasting Accuracy

Various statistics are available to measure forecast accuracy. The most commonly used criterion for evaluating the performance of alternative forecasting methods and models is the accuracy which refers to the correctness of the forecast as measured against actual events. Accuracy can be measured in a number of ways, such as the squared error (SE), absolute percentage error (APE) or percentage error or bias (PE). Other accuracy measures will be examined later.

It is very important to have some qualitative measure of how closely individual variables track their corresponding data series. The measure that is most often used is called the root square error.

$$\sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^F - Y_t^a)^2}$$

Where

Y^F = Forecast value of Y_t

Y^a = Actual value

T = number of periods in the forecast

The RMS error is thus a measure of the deviation of the forecast variable from its actual. The magnitude of this error can be evaluated only by comparing it with the average size of the variable in question.

Root Percent Error -

$$\sqrt{\frac{1}{T}\sum_{t=1}^{T}\frac{(Y_t^F - Y_t^a)^2}{Y_t^a}}$$

Error is

$$\frac{1}{T}\sum_{t=1}^{T}(Y_t^F - Y_t^a)$$

Percentage error is

$$\frac{1}{T}\sum_{t=1}^{T}\frac{(Y_t^F - Y_t^a)}{Y_t^F}$$

The last three error statistics are commonly used and are different measures of the deviation of the predicted value from the realised value. There is a possibility that error (E) will be close to zero if large positive errors cancel on large negative errors. The use of mean square errors can avoid the problem of positive and negative error cancelling. However, as mentioned above, root mean square error is used more often in practice, as this measure tends to penalise large individual errors more heavily. For these reasons root square error has been chosen as the principal criteria for comparing the forecast performance of econometric model forecasting from time series model forecast results. Low RSE forecast error are only desirable measure of forecast fit. Another important criterion is how will the model forecast the turning points in the historical data. There will be further discussion in section 8.5, pp. 298-203.

The Theil inequality coefficient is another accuracy measurement.

$$U = \frac{\sqrt{\frac{1}{T}\sum_{t}^{T}(Y_F - Y_t^a)^2}}{\sqrt{\frac{1}{T}\sum_{t=}^{T}(Y_t^F)^2} + \sqrt{\frac{1}{T}\sum_{t=}^{T}(Y_t^a)^2}}$$

U will always fall between 0 and 1.

If U = 0, $Y^F{}_t = Y^a{}_t$ for all **t** then there is a perfect fit.

If U = 1, the predictive performance of the model is as bad as it possibly could be.

8.4 The Result of the Alternative Forecasting Models

8.4.1 *ARIMA model*

The results given below are computer generated by feeding into the computer the historical data. The Akaike Information Criterion (AIC) is employed to select the lag length of the time series models. The criterion that is based on an extension of a maximum likelihood principles and produces the minimum mean squared prediction errors of the dependent variable. Actually, AIC maximise the likelihood functions (minimises the sum of squared errors) for each model, takes its logarithm, and then subtracts the number of parameters in the model that has the largest numerical value[229]. The specification of ARIMA (p,d,q) model (1,0,0) was obtained by the examination of the autocorrelation functions (ACF) and the partial autocorrelation functions (PACF) of the historical data.

[229] Harvey, A.C. (1981), Time Series Models. Wiley and Sons, New York. 1981, pp.113-114.

The tables 8.1 to 8.4 below shows the forecast figure of ARIMA(1,0,0).

ARIMA (1,0,0) $Xt = \mu + \phi_1 X_{t-1} + \varepsilon_t$

Table 8.1

ARIMA (1,0,0) forecast - Tanker supply, WEOI, USOI, and tanker demand

Year	Tanker supply (mdwt)	Western Europe oil imports (mb/d)	USA oil imports (mb/d)	Tanker demand (mdwt)
1985	49.1	8.7	5.1	32.4
1986	47.8	9.7	6.1	32.4
1987	47.2	8.2	6.3	32.0
1988	47.3	9.4	7.2	32.6
1989	46.9	9.7	8.0	33.3
1990	45.7	9.8	8.0	35.2
1991	43.9	9.8	8.2	30.1
1992	44.0	10.1	7.8	33.2
1993	44.0	10.3	7.9	33.0
1994	44.2	10.4	7.7	32.4
1995	44.8	10.6	7.5	31.7
1996	45.5	10.7	7.4	31.2
1997	46.2	10.8	7.3	30.6
1998	47.1	10.9	7.2	30.1
1999	48.0	10.9	7.0	29.6
2000	48.9	11.0	6.9	29.2
2001	49.9	11.1	6.8	28.8
2002	50.9	11.1	6.8	28.4
2003	51.9	11.2	6.7	28.0
2004	52.8	11.3	6.5	27.5
2005	54.0	11.5	6.5	27.1

Table 8.2

The ARIMA(1,0,0) forecast - Supply, Freight rate index and time charter index

Year	Tanker supply (mdwt)	Freight rate index	Time charter index	Tanker demand (mdwt)
1985	49.1	57	151	32.4
1986	47.8	65	142	32.4
1987	47.2	75	178	32.0
1988	47.3	80	251	32.6
1989	46.9	102	274	33.3
1990	45.7	108	242	35.2
1991	43.9	110	271	30.1
1992	44.0	112	270	33.2
1993	44.0	112	270	33.0
1994	44.2	113	274	32.4
1995	44.8	114	279	31.7
1996	45.5	115	285	31.2
1997	46.2	117	291	30.6
1998	47.1	118	298	30.1
1999	48.0	119	304	29.6
2000	48.9	120	310	29.2
2001	49.9	121	316	28.8
2002	50.9	122	322	28.4
2003	51.9	123	328	28.0
2004	52.8	124	332	27.5
2005	54.0	125	338	27.1

Table 8.3

The ARIMA (1,0,0) forecast - Supply, New order, Newbuilding and Demand

Year	Tanker supply (mdwt)	New order (mdwt)	Newbuilding price (US$)	Tanker demand (mdwt)
1985	49.1	1.6	25.0	32.4
1986	47.8	3.5	26.5	32.4
1987	47.2	4.2	34.0	32.0
1988	47.3	4.4	46.0	32.6
1989	46.9	6.5	54.0	33.3
1990	45.7	9.7	55.0	35.2
1991	43.9	6.7	44.5	30.1
1992	44.0	6.0	61.5	33.2
1993	44.0	6.0	60.5	33.0
1994	44.2	6.1	62.6	32.4
1995	44.8	6.2	64.5	31.7
1996	45.5	6.3	66.3	31.2
1997	46.2	6.4	68.2	30.6
1998	47.1	6.5	70.1	30.1
1999	48.0	6.6	71.9	29.6
2000	48.9	6.7	73.8	29.2
2001	49.9	6.9	75.7	28.8
2002	50.9	7.0	77.5	28.4
2003	51.9	7.1	79.4	28.0
2004	52.8	7.2	80.2	27.5
2005	54.0	7.3	82.0	27.1

Table 8.4

The ARIMA (1,0,0) forecast - Supply, Delivery, Scrapping and Demand

Year	Tanker supply (mdwt)	Deliveries (mdwt)	Scrapping (mdwt)	Tanker demand (mdwt)
1985	49.1	0.2	0.4	32.4
1986	47.8	0.9	0.3	32.4
1987	47.2	0.9	0.4	32.0
1988	47.3	1.3	0.1	32.6
1989	46.9	1.7	0.1	33.3
1990	45.7	0.7	0.1	35.2
1991	43.9	3.5	0.4	30.1
1992	44.0	2.4	0.4	33.2
1993	44.0	2.4	0.4	33.0
1994	44.2	1.8	0.37	32.4
1995	44.8	1.5	0.37	31.7
1996	45.5	1.3	0.37	31.2
1997	46.2	1.2	0.36	30.6
1998	47.1	1.1	0.36	30.1
1999	48.0	1.1	0.36	29.6
2000	48.9	1.1	0.36	29.2
2001	49.9	1.1	0.36	28.8
2002	50.9	1.1	0.36	28.4
2003	51.9	1.1	0.36	28.0
2004	52.8	1.1	0.36	27.5
2005	54.0	1.1	0.36	27.1

8.4.2 Exponential Smoothing Forecasting Model

As explained earlier, the exponential smoothing figure is generated from the application of computer package (SPSS) which deals with all forms of exponential smoothing forecast. Trends, seasonal and normal linear smoothing can be computed with considerable levels of significance. The results presented in tables 8.5 to 8.8 are the levels of the linear exponential smoothing calculation. The calculation takes into consideration the previous year's data to compute the present and vice versa. The forecast is for ten years. This is done to conform to the other analysis in the thesis. See appendix E for the detail on the method and analysis of exponential smoothing forecasting. The result of the computation will be given in the table below and the comparison of the results will be given in the next section.

The exponential smoothing model used is

$$F_T = AX_T + (1\text{-}A)\, F_{T\text{-}1}$$

Where F_T is the exponential method value in period T; the forecasted value made at time T for the next period. A is the smoothing constant ($0 \leq A \leq 1$); X_T is the actual value of the series in period T. $F_{T\text{-}1}$ is the average experience of the series smoothed to period $_{T\text{-}1}$.

$F_T = AX_T + (1\text{-}A)\, F_T$; $F_T = AX_T + F_{T\text{-}1} - AF_{T\text{-}1}$; $F_T = F_{T\text{-}1} + A(X_T - F_{T\text{-}1})$

Therefore, exponential smoothing is simply the old forecast ($F_{T\text{-}1}$) "plus" A "times" the error ($X_T\text{-}F_{T\text{-}1}$) in the old forecast.

Table 8.5

The Exponential Smoothing Forecast - Tanker supply, WEOI, USOI, and tanker demand

Year	Tanker supply (mdwt)	Western Europe oil imports (mb/d)	USA oil imports (mb/d)	Tanker demand (mdwt)
1985	48.1	8.7	5.0	32.4
1986	48.0	9.5	6.3	32.3
1987	47.1	8.3	6.2	31.9
1988	47.5	9.2	7.3	32.6
1989	46.7	9.6	8.1	33.3
1990	45.5	9.7	7.9	35.3
1991	43.7	9.7	8.2	29.7
1992	44.3	10.0	7.7	33.4
1993	43.9	10.2	7.9	32.9
1994	44.7	10.5	8.0	32.8
1995	45.3	10.7	8.1	32.6
1996	46.0	10.9	8.2	32.4
1997	46.7	11.1	8.3	32.2
1998	47.4	11.4	8.4	32.0
1999	48.1	11.6	8.5	31.8
2000	48.9	11.8	8.6	30.6
2001	49.6	12.1	8.8	31.4
2002	50.4	12.3	8.9	31.2
2003	51.9	12.5	6.7	28.0
2004	52.9	12.7	6.5	28.0
2005	54.1	12.9	6.4	27.8

Table 8.6

The Exponential Smoothing Forecast - Supply, Freight rate index and time charter index

Year	Tanker supply (mdwt)	Freight rate index	Time charter index	Tanker demand (mdwt)
1985	48.1	56	149	32.4
1986	48.0	65	138	32.3
1987	47.1	75	192	31.9
1988	47.5	79	274	32.6
1989	46.7	102	274	33.3
1990	45.5	108	228	35.3
1991	43.7	109	287	29.7
1992	44.3	111	263	33.4
1993	43.9	111	272	32.9
1994	44.7	115	277	32.8
1995	45.3	118	284	32.6
1996	46.0	121	292	32.4
1997	46.7	124	299	32.2
1998	47.4	127	306	32.0
1999	48.1	130	314	31.8
2000	48.9	133	321	31.6
2001	49.6	136	328	31.4
2002	50.4	139	336	31.2
2003	51.1	142	343	31.1
2004	52.9	145	349	30.8
2005	54.1	148	356	30.6

Table 8.7
The Exponential Smoothing forecast - Supply, New order, Newbuilding and Demand

Year	Tanker supply (mdwt)	New order (mdwt)	Newbuilding price (US$)	Tanker demand (mdwt)
1985	48.1	1.6	25.4	32.4
1986	48.0	4.6	26.5	32.3
1987	47.1	4.6	33.6	31.9
1988	47.5	4.9	45.1	32.6
1989	46.7	8.0	53.4	33.3
1990	45.5	11.9	54.8	35.3
1991	43.7	6.2	45.2	29.7
1992	44.3	7.0	60.3	33.4
1993	43.9	6.8	60.4	32.9
1994	44.7	6.1	63.0	32.8
1995	45.3	6.2	65.4	32.6
1996	46.0	6.3	67.8	32.4
1997	46.7	6.4	70.1	32.2
1998	47.4	6.5	72.5	32.0
1999	48.1	6.6	74.8	31.8
2000	48.9	6.8	77.1	31.6
2001	49.6	6.9	79.5	31.4
2002	50.4	7.0	81.9	31.2
2003	51.1	7.0	84.2	31.1
2004	52.9	7.1	86.7	28.0
2005	54.1	7.1	88.5	27.8

Table 8.8
The Exponential Smoothing forecast - Supply, Delivery, Scrapping and Demand

Year	Tanker supply (mdwt)	Deliveries (mdwt)	Scrapping (mdwt)	Tanker demand (mdwt)
1985	48.1	0.6	0.39	32.4
1986	48.0	0.8	0.33	32.3
1987	47.1	1.0	0.44	31.9
1988	47.5	1.2	0.21	32.6
1989	46.7	1.5	0.14	33.3
1990	45.5	1.4	0.11	35.3
1991	43.7	2.3	0.30	29.7
1992	44.3	2.5	0.36	33.4
1993	43.9	2.6	0.38	32.9
1994	44.7	2.5	0.39	32.8
1995	45.3	2.6	0.42	32.6
1996	46.0	2.8	0.44	32.4
1997	46.7	2.9	0.46	32.2
1998	47.4	3.0	0.49	32.0
1999	48.1	3.1	0.52	31.8
2000	48.9	3.3	0.54	31.6
2001	49.6	3.4	0.57	31.4
2002	50.4	3.5	0.60	31.2
2003	51.1	3.7	0.64	31.1
2004	52.9	3.9	0.67	28.0
2005	54.1	4.0	0.69	27.8

8.4.3 RANDOM WALK model

The model employs a single random walk equation. The random walk is an important class of time series, not because there is much to say about it, but because it has characteristics to which it can be compared with other series. A random walk is defined as the cumulative sum of random disturbances. If the mean of the random disturbances is 0, as is often the case, the random walk will show no overall trend; but it can and often does drift far away from its long term mean. Therefore, the successive observations in a random walk are white noise. When the mean of the disturbances is 0, the best forecast for a random walk is simply the most recent observation.

$$X_{T+1} = X_T$$

If trend is present it will be $X_{T+1} = X_T + (X_T - X_{T-1})$

The result of the random walk forecast is given in table 8.9 to 8.12 below.

Table 8.9
The Random walk forecast - Tanker supply, WEOI, USOI, and tanker demand

Year	Tanker supply (mdwt)	Western Europe oil imports (mb/d)	USA oil imports (mb/d)	Tanker demand (mdwt)
1985	49.0	8.7	5.0	33.2
1986	48.5	9.5	6.3	32.3
1987	47.1	8.3	6.2	31.9
1988	47.5	9.2	7.3	31.6
1989	46.9	9.6	8.1	33.3
1990	45.5	9.7	7.9	35.3
1991	43.5	9.7	8.2	32.7
1992	44.3	10.0	7.7	33.4
1993	47.7	13.2	6.9	30.4
1994	45.0	10.2	8.1	34.3
1995	45.9	10.0	8.3	35.6
1996	46.9	9.9	8.5	36.9
1997	47.8	9.8	8.7	38.2
1998	48.8	9.7	8.9	39.5
1999	50.0	9.6	9.1	40.7
2000	50.8	9.5	9.3	42.0
2001	51.7	9.4	9.5	43.3
2002	52.7	9.2	9.6	44.6
2003	53.7	9.2	9.9	45.9
2004	54.8	9.3	10.0	46.7
2005	55.2	9.3	10.1	47.0

Table 8.10
The Random walk forecast - Supply, Freight rate index and time charter index

Year	Tanker supply (mdwt)	Freight rate index	Time charter index	Tanker demand (mdwt)
1985	49.0	56	149	33.2
1986	48.5	65	138	32.3
1987	47.1	75	192	31.9
1988	47.5	79	274	31.6
1989	46.9	102	274	33.3
1990	45.5	108	228	35.3
1991	43.5	109	287	32.7
1992	44.3	111	263	33.4
1993	47.7	86	211	30.4
1994	45.0	113	276	34.3
1995	45.9	114	282	35.6
1996	46.9	115	289	36.9
1997	47.8	117	295	38.2
1998	48.8	118	302	39.5
1999	50.0	119	308	40.7
2000	50.8	120	315	42.0
2001	51.7	121	321	43.3
2002	52.7	122	327	44.6
2003	53.7	123	334	45.9
2004	54.8	123	338	46.7
2005	55.2	124	342	47.0

Table 8.11
The Random walk forecast - Supply, New order, Newbuilding and Demand

Year	Tanker supply (mdwt)	New order (mdwt)	Newbuilding price (US$)	Tanker demand (mdwt)
1985	49.0	1.3	25.4	33.2
1986	48.5	4.6	26.5	32.3
1987	47.1	3.9	33.6	31.9
1988	47.5	4.9	45.1	31.6
1989	46.9	8.0	53.4	33.3
1990	45.5	9.8	54.8	35.3
1991	43.5	6.2	45.2	32.7
1992	44.3	7.0	60.3	33.4
1993	47.7	6.8	60.5	30.4
1994	45.0	6.0	62.3	34.3
1995	45.9	6.2	64.2	35.6
1996	46.9	6.2	66.0	36.9
1997	47.8	6.3	67.9	38.2
1998	48.8	6.4	69.7	39.5
1999	50.0	6.5	71.6	40.7
2000	50.8	6.6	73.4	42.0
2001	51.7	6.6	75.3	43.3
2002	52.7	6.7	77.1	44.6
2003	53.7	6.8	79.0	45.9
2004	54.8	6.9	79.3	46.7
2005	55.2	7.0	79.4	47.0

Table 8.12
The Random walk forecast - Supply, Delivery, Scrapping and Demand

Year	Tanker supply (mdwt)	Deliveries (mdwt)	Scrapping (mdwt)	Tanker demand (mdwt)
1985	49.0	0.6	0.39	33.2
1986	48.5	0.8	0.33	32.3
1987	47.1	1.0	0.44	31.9
1988	47.5	1.2	0.21	31.6
1989	46.9	1.5	0.54	33.3
1990	45.5	1.4	0.31	35.3
1991	43.5	2.3	0.30	32.7
1992	44.3	2.5	0.36	33.4
1993	47.7	2.6	0.21	30.4
1994	45.0	2.5	0.64	34.3
1995	45.9	2.6	0.48	35.6
1996	46.9	2.6	0.60	36.9
1997	47.8	2.7	0.55	38.2
1998	48.8	2.8	0.49	39.5
1999	50.0	2.9	0.34	40.7
2000	50.8	2.9	0.44	42.0
2001	51.7	3.0	0.33	43.3
2002	52.7	3.1	0.40	44.6
2003	53.7	3.2	0.40	45.9
2004	54.8	3.3	0.40	46.7
2005	55.2	3.3	0.40	47.0

8.5 Forecast Accuracy

In the previous section the criteria for accuracy was discussed. There are five statistics for measuring forecast accuracy: Error (E), Percentage error (PE), Root square error (RSE), Root percent error (RPE) and Theil's inequality coefficient.

These five error statistics are different measures of the deviation of the predicted value from the realised value. The problems that can be found in the methods will be explained in the chapter. The reason for selecting the particular error measurement method employed has been mentioned in section 8.3.

8.6 Empirical Evidence

The variables used in the forecast were tested and found to be reliable in predicting the supply of "one million barrel tanker". With this assumption, the accuracy measurement would now be performed to show the difference in each of the forecasting methods.

8.6.1 *Forecast Errors*

The tables below (8.13 - 8.17) lists the forecasting error statistics of the endogenous factors considered in the models. The data are based on the end of the year figure. The supply equations of one million barrel tanker error are considered under the headings econometric, univariate autoregressive integrated moving average, random walk and exponential smoothing. The analysis of the results of the error, percentage error, Square error, root percent error and Theil's inequality are given and explained below.

Table 8.13
Forecast Errors (E)

Endogenous Variables	Time Interval	Econometric Model	ARIMA	Exponental Smoothing	Random Walk
WEOI	1	0.9	0.9	0.6	0.4
	2	1.3	0.9	0.9	0.4
USI	1	-0.6	-1.1	-1.1	-0.8
	2	-0.4	-1.1	-1.1	-0.5
Demand	1	0.5	-0.5	-0.5	1.1
	2	-0.1	-0.9	-0.9	2.4
Freight index	1	2.0	-5.0	4.0	5.0
	2	5.0	-15	1.0	2.0
Time charter	1	3.0	-23	-6.6	-13
Index	2	2.0	-40	-3.8	-20
	1	-0.2	2.8	1.8	2.9
New order	2	0.1	2.9	2.3	3.3
Newbuilding	1	-2.1	-3.5	-3.5	-0.7
Price	2	3.1	-4.9	-3.2	0.7
	1	0.2	0.2	0.3	0.9
Deliveries	2	-0.3	-1.0	-0.3	0.1
	1	-0.2	-0.1	-0.02	0.2
Scrapping	2	-0.1	-0.1	0.1	0.1
	1	0.4	-1.2	-1.2	-0.1
Supply	2	0.1	-3.6	-3.6	-1.3

1 - 1994
2 - 1995

Table 8.14
Root Square Errors (RSE)

Endogenous Variables	Time Interval	Econometric Model	ARIMA	Exponential Smoothing	Random Walk
WEOI	1	0.18	0.94	0.77	0.63
	2	0.27	0.94	0.94	0.63
USI	1	0.12	0.22	0.22	0.16
	2	0.08	0.22	0.22	0.10
Demand	1	0.32	0.32	0.33	1.04
	2	0.06	0.59	0.59	1.57
Freight index	1	1.30	3.27	2.00	2.23
	2	3.20	9.83	1.00	1.41
Time charter	1	1.96	15.0	43.2	8.52
Index	2	1.31	26.2	24.9	13.1
	1	0.13	1.67	1.34	1.90
New order	2	0.06	1.70	1.51	1.81
Newbuilding	1	1.37	0.29	2.29	0.45
Price	2	2.03	0.44	2.09	0.83
	1	0.13	0.65	0.54	0.94
Deliveries	2	0.19	0.06	0.19	0.06
	1	0.09	0.07	0.01	0.12
Scrapping	2	0.04	0.05	0.31	0.05
	1	0.26	0.78	0.79	0.06
Supply	2	0.06	2.36	2.30	0.85

1 - 1994
2 - 1995

Table 8.15 Percentage Errors (PE)

Endogenous Variables	Time Interval	Econometric Model	ARIMA	Exponential Smoothing	Random Walk
WEOI	1	0.39	0.39	0.26	0.17
	2	0.58	0.40	0.40	0.18
USI	1	-0.28	-0.53	-0.53	-0.38
	2	-0.19	-0.53	-0.54	-0.24
Demand	1	0.64	-0.64	-0.64	1.42
	2	-0.12	-1.16	-1.16	3.10
Freight index	1	0.79	-1.99	1.59	1.19
	2	1.91	-5.75	0.38	0.76
Time charter	1	0.44	-3.42	-9.82	-1.93
index	2	0.28	-5.69	-5.41	-2.84
	1	-0.28	3.92	2.52	4.06
New order	2	0.14	43.0	34.1	4.89
Newbuilding	1	-1.43	-2.38	-2.38	-0.47
price	2	2.09	-3.31	-2.16	0.47
	1	5.37	5.37	8.06	24.1
Deliveries	2	-0.51	-1.72	-5.16	1.72
	1	-14.3	-10.5	-1.91	18.1
Scrapping	2	-7.52	-8.60	10.7	8.60
	1	0.38	-1.14	-1.14	-0.09
Supply	2	0.09	-3.27	-3.27	-1.18

1 - 1994
2 - 1995

Table 8.16
Root Percentage Errors (RPE)

Endogenous Variables	Time Interval	Econometric Model	ARIMA	Exponential Smoothing	Random Walk
WEOI	1	0.059	0.049	0.039	0.026
	2	0.087	0.060	0.060	0.026
USI	1	0.041	0.076	0.076	0.055
	2	0.027	0.076	0.077	0.034
Demand	1	0.056	0.811	0.056	0.125
	2	0.113	0.338	0.102	0.273
Freight index	1	0.126	0.315	0.252	0.315
	2	0.309	0.929	0.061	0.123
Time charter	1	0.115	0.887	2.545	0.501
index	2	0.075	0.509	1.433	0.754
	1	0.074	0.042	0.670	1.080
New order	2	0.038	0.116	0.885	1.270
Newbuilding	1	0.173	0.289	0.289	0.057
price	2	0.255	0.403	0.263	0.057
	1	0.103	0.103	0.155	0.466
Deliveries	2	0.124	0.414	0.124	0.041
	1	0.146	0.107	0.019	0.185
Scrapping	2	0.072	0.082	0.103	0.082
	1	0.039	0.056	0.117	0.009
Supply	2	0.009	0.102	0.343	0.124

1 - 1994
2 - 1995

Table 8.17
Theil Inequality Coefficient Measurement (U)

Endogenous Variables	Time Interval	Econometric Model	ARIMA	Exponential Smoothing	Random Walk
WEOI	1	0.084	0.029	0.034	0.020
	2	0.098	0.049	0.054	0.020
USI	1	0.017	0.072	0.053	0.047
	2	0.005	0.079	0.041	0.029
Demand	1	0.002	0.022	0.016	0.005
	2	0.022	0.017	0.003	0.040
Freight index	1	0.026	0.016	0.026	0.018
	2	0.025	0.017	0.025	0.017
Time charter	1	0.024	0.009	0.003	0.005
index	2	0.018	0.039	0.030	0.034
	1	0.157	0.207	0.207	0.020
New order	2	0.072	0.158	0.158	0.158
Newbuilding	1	0.007	0.004	0.006	0.002
price	2	0.022	0.018	0.025	0.016
	1	0.111	0.058	0.219	0.219
Deliveries	2	0.151	0.034	0.030	0.030
	1	0.311	0.367	0.333	0.111
Scrapping	2	0.363	0.417	0.374	0.304
	1	0.006	0.002	0.003	0.006
Supply	2	0.002	0.012	0.017	0.024

1 - 1994
2 - 1995

8.6.2 *Forecast Errors: Comparison*

The Econometric Model Compared With Time Series Models

The forecast from the econometric model uses annual data and the errors are based on the ex-post result. Also the time series forecasts are generated from the same historical data and with the errors computed by comparing the deviation from the ex-post results. The two time series models examined are ARIMA and Random walk. The two seems to be very close though the univariate autoregressive integrated moving average overall performances are more reliable than the random walk model. The result of Random walk is not that convincing; the two are single variable model. One would expect ARIMA to perform far better than random walk.

There is evidence of different effects on the individual variables concerned. The root square error (RSE) generally favours time-series performance, though the difference in performance to the econometric model is not very marked. In some of the variables the performance of the econometric model is superior to that of the time-series. Overall, both models' performance are not significantly different.

Basically, the two years considered (1994 and 1995) thus show mixed results. The majority of the results show that the econometric model of tanker supply is less than 1% in error; this implies that the oil tanker forecasts of the one million barrel tankers are very close and can be accepted. Take for example the performance of tanker supply; the RSE in the first instance for econometric model are 0.26 and 0.06 in the two years. The time series models on the first and second year are 0.78 and 2.36 for ARIMA model and 0.06 and 0.78 for random walk. Table 8.14 shows the detailed results of the Root Square error calculations.

Econometric model versus Exponential Smoothing

The point of comparing the causal model with the time series one is to determine which is the most effective, for forecasting. The root square error of the forecast indicates that the margin of performance is not that different. There is an indication that the forecast performance in each of the years examined is similar and that the forecasts can be considered reasonable for years one and two. The RSE in these two years for the econometric model of tanker supply are 0.26 and 0.06 while exponential smoothing they are 0.79 and 2.30 respectively. This indicates that the exponential smoothing performance in this case is not as accurate as the econometric model. It does not necessarily mean that the exponential smoothing model is bad. The differences in RSE of the models are not that large to suggest that the results are useless. What it simply mean is that it is quite appropriate to accept the econometric model results as a reliable forecasting model, better than the ability of other models in question.

The Theil inequality coefficient measurement shows the evidence that econometric model is feasible and that it can be relied upon in this respect. See table 8.17. The fact is that the calculation has to be less than one, it should be between 0 and 1. When it is 0 the forecast is deemed to be perfect and when it is 1 the forecast is bad and not reliable. In all these models that was examined, tanker supply forecasts is closer to 0 than 1.

Tables 8.13 and 8.15 presents respectively the forecast errors and the percentage errors of the forecasting methods. The forecast errors are quite small in many of these variables, only a couple of the variables have big error (E) results. Almost all the variables have very small PE. These include tanker supply and demand, Western

Europe oil imports and oil imports USA. However, in general term the mean error indicates that there is a tendency for all models to over-predict rather than under-predict the series in the periods ahead. The percentage errors in table 8.15 reveal more about the under prediction and over prediction of these series.

8.6.3 *Explanations of the Forecasting Performance of Econometric Model*

All oil tanker markets are volatile. There is always fluctuation in the supply and the demand for tankers including the one million barrel segment. In view of this, tracking the trend of supply will never be 100% accurate. However, the forecasting of the series gives more advantage to correct decisions; that is, a decision with a minimal margin of error. The econometric model has used some economic variables that are not stable; thus the tracking of the trend of this data can only be done with a limited degree of accuracy. As can be seen from the forecast errors calculated in the tables above, some series are more stable than others. Another assumed reason for the performance can be agreed to be the disparity of the sources of the data. There is a possibility that one source is more accurate than the other. Generally, it is accepted that the addition of explanatory variables to a forecasting equation would improve the degree of accuracy. However, inclusion of too many variables may also increase the standard error of the equation and reduced its statistical efficiency.

The equations examined in this model, as can be seen in (chapter 4) are statistically significant. There is an indication that the model would be very useful for the purpose of forecasting. All the equations are significant at the 5 percent confidence level.

8.7 Conclusion

The application and construction of exponential smoothing, ARIMA, and random walk have been examined. The chapter presented a comparison of the results of these three methods of forecasting with the econometric model that was developed in chapter 4; and shows that the endogenous series' forecasts are very close to the actuals, although a few of these reveal disparities. However, this is not unusual since the methods of computation are different and employ different parameters. The ARIMA, and random walk are univariate models, while exponential smoothing uses a weighted moving average.

The chapter also looked at different forecasting methods. The performances of the methods were analysed and compared. It has been assumed that the forecasts would track the historical data. It has also been assumed that the future would behave in the same way as the past. The econometric forecasting model has been compared with time series models, ARIMA and random walk and exponential smoothing. Further more, in order to examine the error in the forecast the following were calculated for each of the series. They are the error (E), percentage error (PE), Root square error (RSE), root percentage error (RPE) and the Theil's inequality measurement.

The performance result of these models did not show any significant differences. However, the econometric model tended to perform better than the others. There is strong evidence that each of the series performs differently, with some series forecasts being more accurate than others. However, lower accuracy does not necessarily mean that the models are unemployable for forecasting purposes.

There is also evidence that the forecasted years do not in any way make the results untypical. The year 1994 and 1995 have not been drastically affected by the shipping cycle or major events.

As accuracy is important in forecasting of the supply of one million barrel oil tankers, the econometric forecast is useful. There is evidence from the forecast that suggests that tanker supply of one million barrel size will greatly depend on the forecasting of the relevant econometric time series.

Chapter 9

CONCLUSIONS

9.1 Introduction

This chapter provides a brief summary and conclusion to the thesis. The main objective of this thesis has been to build a tanker supply model and explain how the factors are related; also to forecast the one million barrel oil tanker supply. In the second section the contributions to research on the oil tanker market by this work will be discussed. In the third section, the empirical results from the estimation of one million barrel oil tanker supply model and oil tanker forecast will be summarised. Section four will suggest areas for further research on this topic.

9.2 Theory

In order to model and forecast the supply of one million barrel tankers, a theory for demand and supply was developed. Nine dependent variables were modelled in terms of nine structural equations, one identity and a set of independent factors. The oil demand sector, freight rates sector and shipbuilding sector; this is a ten equation model, the tenth is an identity. A theory of the one million barrel oil tankers has been presented. Based on this theory, the econometric model of one million barrel oil tankers was estimated. The demand responses were quantified with respect to the rate of changes in oil consumption, oil production, crude oil prices, and changes in oil imports.

Since there is no experience in model building and forecasting of one million tankers and since there has never been any testing of the relevant variables (unit root tests and cointegration tests) it is very important to understand the implications and application. The work presented here is novel in this respect.

The novel feature of this thesis is the treatment of one million barrel oil tanker as a unique sector. Since the demand for the oil tanker is a derived demand, it stems from the demand for crude oil in specific areas.

The theory is that the oil imports and consumption in the areas mentioned would determine one million barrel tanker demand. Tanker supply is then affected by the increase in demand. It is taken as a self evident that freight rates affect the supply of tankers.

A major problem in this model of one million barrel tankers is that the relevant variables are interrelated. As a result, some of the relationships between the variables will have to be specified and estimated in order to determine the behaviour of the tanker stock. The problem is solved by the use of system equation methods and a simultaneous-equation econometric model.

In particular the selected variables are non-stationary and as a result each of the variables was tested for unit roots. The regression of non-stationary data would have affected the results of this work. Sometimes time series data wander far apart, thus it means that the series in each of the equation are tested for the presence of long run equilibrium relationships. The cointegration method was applied, and it was shown that cointegrating vectors existed for each of the proposed equations is the econometric model.

9.3 The Econometric Model

The theoretical dynamic model has turned into an empirical econometric model, in order to quantify the demand and supply of million barrel oil tankers. Systems of supply equations have been estimated for the million barrel oil tanker market using data over the period 1970-1993. Separate demand and supply functions are specified. Oil imports in Western Europe and USA, the freight rate index, the time charter index, new orders, newbuilding prices, deliveries and scrapping are specified modelled as part of the system.

It can be said that the tanker market changes frequently over time, sometimes very rapidly. As a result of the short cycle period it is considered in this thesis that 20 years will be enough to capture the required events in the oil and tanker markets. Monthly data could have been used for estimation, especially freight rates; but was impossible to collect for all series. As a result of these difficulties, annual data has been used throughout the research. Moreover, disaggregated data for this class of tankers has not been easy to collect and collate. Care was taken in the process to ascertain that the specified models were compatible with the classification problem faced by the market players. The final data used for estimation were scaled down to the ones relating to the one million barrel oil tanker, except where there was uniformity in the data for all tankers, such as for oil imports and consumption, oil production, oil seaborne trade and the shipbuilding cost index. Some of the data was constructed from other series. The unit of measurement is different but the data are unique for the 100-160,000 dwt tankers.

The data employed in this thesis was tested for the presence of unit roots. The level of each of the variables were tested and confirmed to be non-stationary. The first differences of the variables are stationary; thus the changes in the variables were modelled. One other difficulty encountered is that instead of changes in variables, three equations have been estimated using both first and second order differenced series.

Regarding the estimation methods of these systems, they are identified to fall into the class of complete systems of supply equation, which satisfy functional constraints. The constraint that some of these variables should be determined before the other has prompted the decision to examine the equations together in a system. It was recognised that simultaneous-equation methods should be employed for estimation, with the exception of one equation, which was an identity.

The unique features of the estimated models are, the high disaggregation of supply, deliveries, scrapping, generally the one million barrel market and the estimation of the model in growth terms.

The empirical results were consistent with a priori views regarding the signs and magnitude of various relationships. The tanker supply equation is an identity and it shows that deliveries cause supply to increase while scrapping cause it to decrease. The model's coefficients were statistically significant in most cases.

It was found that Western Europe oil imports are affected by lagged European oil imports, lagged oil consumption, crude oil prices and lagged oil production. These variables are themselves affected by the level of economic developments. The demand for tanker was found to move with the changes in oil consumption ratio in Western

Europe and the USA. The USA oil imports effect on demand is more or less the same order of magnitude for WEOI. Growth in oil consumption will cause the imports to grow. Reductions in both oil production and in oil prices also caused USA oil imports to grow. The crude oil price has a negative effect on oil consumption.

In this research the oil imports affect tanker demand; it led to demand growth. The factors affecting tanker demand are oil consumption Europe and USA, the crude oil price, and oil production in Western Europe. Reduction of growth in oil production in Western Europe and in oil prices causes tanker demand to grow. Demand also influenced tanker supply; other factors are tanker deliveries, scrapping and the state of million barrel tankers.

The results are consistent with the findings of other studies. The difference is that they have modelled levels data, but this study has modelled changes using the factors. The growth in demand for tankers has induced supply to grow and increases in the freight rate caused laid-up tankers to be reactivated, thus increasing supply. Reduction in tanker stock has caused growth in the freight rate. Also growth in oil seaborne trade caused the freight rate to respond and changes in bunker price caused changes to freight rate. The effect of all this is that the tanker supply grows.

The growth in tanker orders is mirrored in the delivery series. The estimated coefficient of tanker new orders is 0.78. The delivery grows with the changes in lagged new order. The reasons being that deliveries of tanker order are not instantaneous, thus the lagged time between order and deliveries. Growth in tanker deliveries caused supply to increase. Growth of freight rate index and reduction in the lagged deliveries caused a response from the supply, thus there was growth in deliveries.

The result of the simulated response of the system to various anticipated and unanticipated external shocks is compatible with the priori expectations. The results of these simulations indicate growth in the endogenous variables. The simulation has allowed the assessment of the magnitude of responses of the model. It has also made it possible to look at responses of unexpected increases in oil consumption Western Europe and USA, crude oil price, bunker prices and shipbuilding cost with endogenous factors. Growth in tanker demand caused growth in tanker supply in the short term (activation of the laid-up tankers), and in the long run due to the level of growth in freight rates the tanker supply grows (tanker deliveries). The addition to the total number of tonnage is due to tanker deliveries; the tanker tonnage scrapped is low. The changes in tonnage scrapped caused the changes in fleet size to increase a little, although the improvement in freight rates is hardly noticeable.

The assumption is of a 10% increase in oil prices. See table 6.3, p.221. The impact on supply when unanticipated growth in the freight rate is that there was growth in tanker deliveries as a result of improvement in freight. The growth in time charter rates improves for short time before it decreases, and there was a small growth in tanker scrapping. The result was a decrease in the growth of tanker demand. The shock has a gradual effect on the size of the fleet when anticipated. This caused the freight rates to react.

The simulated response of the market to an unanticipated 50% increase in shipbuilding cost shock is considered. See table 6.4, p. 228. The direct effect was a reduction in the supply at a given level of ship prices and it reduces the growth rate of the total fleet, and caused growth in freight rates.

The simulated responses of an anticipated shock of 20% and 15% increase in oil imports in USA and Europe exhibits growth in tanker demand and supply. See tables 6.1 and 6.2 in p.217 and p.220. These changes also create a further growth in the freight rates. The growth in freight rate improved but in the long run the changes in supply expanded to a level where freight rates decreases. The examined major oil importing areas behave in a similar fashion.

9.3.1 Forecast

The model developed in this thesis has been used to generate forecasts of the million barrel tanker's market up to the end of 2003. These indicate that the improvement in market conditions is largely permanent. The severe depression of the early 1980's was an extreme one of events that were aggravated by the unforeseen nature of the oil shocks that caused it. The lagged stock and scrapping capacity and the size of the fleet that have already occurred caused the future supply to grow. In addition, growth in demand and the freight rate index supports the higher level of supply that is seen in this thesis. Also, the indication is that the recent improvement in the supply conditions would probably be for the long term.

With the assumptions that historical past reflects on present, the model follows the same trend with little adjustment. However, the model seems flexible to accommodate new data to improve forecast. The trend in supply follows a cycle since the economic cycle of the importing area affects demand and supply. There is steady growth in supply; this in the long run caused depression to the freight rate. The base forecast shows that the demand for time charter rate will have a long-term positive growth which averages 1.4%; and demand for oil will have a steady growth of 1%. The tanker demand attracts increase in supply and the supply of tanker in the category grows stronger towards the end of the forecasting period. The scrapping is low as a result of the increase in demand and the freight rate index figure. The tanker owner would have to bear the cost, but in terms of the increase in freight rates it should be a blessing in disguise to them. The supply of new tankers as measured by the order book is expected to increase. Also expected to increase are deliveries, as a result of increase in order of tankers. There is optimism for the supply of tanker, though the growth in scrapping is less than deliveries. The tanker supply-demand balance would improve. The improvements are going to be activated by increase in tanker demand and a modest rise in freight rates.

It has been hypothesised that the legislation will cause tanker scrapping to increase by another 10% per annum. This will be in addition to the base forecast in this thesis. However, this may not happen until after 2003.

The results of the alternative forecasting methods are very close to the econometric forecasts. The supply of tanker increases faster than demand and the other factors of this model behave in the same way. The demand was stronger towards the end of the forecasting period and also the freight rate.

Comparison of these methods and the accuracy test of econometric model were conducted by using Root square error. This is consistent and very small. Generally the results of these forecast methods have a mixed results. In some of the methods it is better in one of the two years used. The econometric forecast of tanker supply is better than those generated by other methods for many of the endogenous variables. The RSE of supply is 0.26 and 0.06 for year 1 and 2. As a result it can be said that econometrics method can be relied upon more than the others can.

This work has demonstrated that it is possible to model a segment of the disaggregated tanker market.

Above all, good information is essential to the smooth functioning of tanker market. Up to date knowledge and expert opinion will be of immense value to both oil and tanker markets. Knowledge of the market will safeguard every action taken in the market. Considering the cost of new tankers, it would be unwise for the people in shipping to act on new projects, such as newbuilding, without a thoughtful review of market conditions, future trends, and a thorough assessment of the benefits and risks.

9.4 Recommendations for Future Research

It would be naive to suggest that every possible facet of modelling the one million barrel oil tanker supply has been covered in this thesis. Space and time limitations have imposed a compromise. However, there are questions left open for further research, and the author suggests some here.

Forecasting through model building provides a critical examination of the factors that affect tanker supply. The results have illustrated the usefulness of econometric modelling and time series forecasting models. The result suggests that future modelling of tanker supply in this category could proceed by using multivariate time series model, such as multivariate autoregressive integrated moving average (MARMA).[229] This uses other factors and may increase the forecast accuracy. Accuracy is very important in tanker supply and extensive analysis of MARMA

[229] Makrisdakis/ Wheelwright/ McGee, (1983) Forecasting - Methods and Applications. Second edition 1983, John Wiley & Sons. p. 526.

model could reduce forecast errors. Whether the forecast will be superior to those from the econometric model is something that could be explored.

Combination carriers and tankers larger than one million barrel,s might affect the supply of one million barrel tankers. It is suggested that the supply of other tankers such as those mentioned above could be modelled in the same way as in this thesis. The simulated results can then be examined against the disaggregated model results based on one million barrel oil tanker. Despite the restrictions of size of vessel that can trade in certain waters, there are areas where one million barrel tankers come against steep competition with larger vessels' size and class.

The theoretical framework used for modelling the supply, freight, delivery and scrapping has produced satisfactory results. These suggest that future research might benefit by using the methods in this thesis. The theoretical framework without major modification can be used for the aggregate shipping market. Whether this is desirable is debatable. The answer to this question depends on an evaluation of the benefits. In theory there are some good reasons for aggregation. At the same time, there are some practical factors that argue against aggregation.

However, examining the total supply in the tanker market would create awareness of the vital statistics for survival. Such awareness as the effect of aggregate tanker supply on the freight rates market and vice versa. It would be of interest to estimate and compare the result of aggregated (supply) model with the disaggregated model. What would the slope of coefficient of the estimates from the aggregate model be like? Would this provide any additional information?

This thesis has been forced to use annual data, especially for freight rates, the reason is that many of the variables examined are annual data. Therefore, the annual data is the closest that can be estimated in the thesis. It is suggested that future research should employ monthly data instead. However, whether monthly data will be available for all the variables of the model and whether the result will be better than annual data is something to be discovered in the future.

It has been shown (in chapter 5) that many of the data series used in constructing the econometric model appeared to be non-stationary. Modern econometric methods now allow the modelling of such data using error correction mechanisms (ECM) and cointegration methods. As more data becomes available, it should be possible to develop models of the one million barrel tanker market which use quarterly data to estimate either single equation ECM models, or multi-equation reduced form vector error correction models (VECM). This would take the research modelling process further from the point achieved in this thesis. As such, the developments of ECM and VECM methods represent an interesting opportunity to develop and extend the model presented, estimated, and discussed in this thesis.

APPENDICES

A- Data

B- Tables

C- Graphs

D- Estimation methods and techniques

E- Alternative forecasting methods - Computation processes: ARIMA and Exponential smoothing

DATA

APPENDIX A

A i: One Million Barrel Tanker (100-160,000mdwt)

Year	USI	CUS	COP	PUS	DD	OST	MBT	FR	TCI
1970	3.4	694.6	1.4	501.9	3.3	6487	3.3	86	2.0
1971	3.9	719.3	1.8	506.6	4.5	7454	4.5	107	2.0
1972	4.7	775.8	1.9	489.5	5.6	8649	5.6	84	2.0
1973	6.3	818.0	2.8	457.3	6.6	10216	6.6	86	2.0
1974	6.1	782.6	10.8	436.8	9.9	10620	9.9	61	2.0
1975	6.0	765.9	10.6	415.9	29.0	9727	14.5	50	126.0
1976	7.3	822.4	11.5	404.9	28.9	11179	32.8	63	126.2
1977	8.7	865.9	12.7	466.9	31.8	11820	34.6	47	124.7
1978	8.2	888.8	12.7	488.1	32.3	10678	33.4	64	146.5
1979	8.4	868.0	13.0	480.9	34.3	10497	38.8	118	223.0
1980	6.7	794.1	28.0	484.1	33.1	9239	47.2	85	303.0
1981	6.0	746.0	32.0	482.8	31.9	8193	37.7	56	261.9
1982	5.0	705.5	34.0	484.5	30.1	6282	36.5	49	157.3
1983	5.0	704.9	32.0	486.8	28.3	5558	35.0	53	145.5
1984	5.4	726.9	29.0	496.7	31.8	5648	35.3	57	152.9
1985	5.1	721.7	28.0	499.3	32.4	5157	34.2	57	150.6
1986	6.1	751.3	14.0	482.9	32.4	5905	33.8	65	142.0
1987	6.3	767.3	19.0	467.8	32.0	6016	34.2	75	177.5
1988	7.2	793.4	17.5	459.8	32.6	6510	35.5	80	251.4
1989	8.0	794.9	15.7	429.5	33.3	7276	37.5	102	274.3
1990	8.0	778.9	18.4	417.1	35.2	7720	39.1	108	241.6
1991	8.2	770.8	20.5	423.4	30.1	8990	40.1	110	270.6
1992	7.8	840.4	17.2	413.5	33.2	8590	43.8	112	270.0
1993	7.9	857.4	16.3	397.5	33.0	8990	43.3	112	270.0

A ii: One Million Barrel Tanker (100-160,000mdwt)

Year	BP	NOR	NBP	SS	SBC	DEL	SC	LU
1970	20	4.2	18.0	21.8	126.6	0.5	0.1	1.2
1971	25	6.5	18.0	24.7	112.9	0.5	0.1	1.5
1972	24	11.2	22.0	27.0	113.3	0.5	0.1	1.2
1973	32	25.4	20.0	28.4	161.8	0.5	0.1	1.4
1974	77	19.3	22.0	32.2	211.2	0.5	0.1	1.5
1975	77	8.6	38.0	40.1	185.3	1.6	0.1	0.9
1976	74	3.4	34.0	47.8	182.5	1.4	0.1	1.1
1977	77	1.3	34.0	53.0	190.4	1.3	0.7	1.5
1978	70	0.6	36.0	53.8	195.1	0.6	0.6	1.4
1979	114	0.9	40.5	52.9	254.4	0.4	0.5	1.5
1980	144	1.4	40.5	53.0	278.8	0.8	0.6	0.9
1981	180	1.1	40.0	52.0	236.5	0.3	0.5	1.7
1982	167	1.1	34.0	50.4	208.7	0.3	0.6	1.5
1983	162	1.0	31.5	49.1	218.8	0.6	0.3	2.5
1984	179	1.5	29.0	51.3	211.6	0.4	0.4	2.7
1985	152	1.6	25.0	49.1	100.0	0.2	0.4	2.5
1986	81	3.5	26.5	47.8	190.8	0.9	0.3	1.2
1987	104	4.2	34.0	47.2	212.1	0.9	0.5	0.3
1988	77	4.4	46.0	47.3	232.4	1.3	0.1	0.4
1989	91	6.5	54.0	46.9	330.5	1.7	0.1	0.3
1990	104	9.7	55.0	45.7	301.9	0.7	0.1	1.2
1991	78	6.7	44.5	43.9	269.2	3.5	0.4	0.5
1992	72	6.0	61.5	44.0	233.0	2.4	0.4	0.8
1993	70	6.0	60.5	44.0	233.0	2.4	0.4	0.8

A iii: One Million Barrel Tanker (100-160,000mdwt)

Year	WEOI	CWE	PWE
1970	12.9	627.0	22.8
1971	13.5	656.0	21.9
1972	14.1	701.8	22.3
1973	15.4	748.9	22.5
1974	15.8	699.3	22.6
1975	12.6	664.4	30.8
1976	13.7	710.3	45.2
1977	13.3	697.3	65.7
1978	13.1	715.1	85.5
1979	13.1	714.7	112.4
1980	12.2	681.1	121.4
1981	10.6	633.9	129.6
1982	9.7	603.3	147.5
1983	9.0	585.8	168.4
1984	8.9	590.6	182.7
1985	8.7	580.6	189.9
1986	9.7	602.2	195.1
1987	8.2	599.6	199.9
1988	9.4	608.4	199.3
1989	9.7	611.0	194.5
1990	9.8	617.8	202.1
1991	9.8	622.4	214.6
1992	10.1	637.6	230.9
1993	10.3	646.5	243.2

TABLES

APPENDIX B

Table B1: Coal Consumption (mt) (oil equivalent)

Year	USA	W. Europe	Japan	Others	W. Total
1984	430.2	304.4	69.9	1199.2	2001.2
1985	440.5	322.7	76.4	1241.9	2081.5
1986	435.0	327.0	81.7	1278.8	2122.5
1987	453.8	330.2	88.6	1313.5	2186.1
1988	474.9	324.4	96.2	1330.0	2225.5
1989	477.9	325.9	99.3	1341.2	2244.3
1990	480.9	317.8	102.4	1327.9	2229.0
1991	477.9	301.7	106.0	1276.8	2162.4
1992	476.7	280.2	77.9	1318.5	2153.3
1993	450.5	261.5	79.3	1279.8	2141.1
1994	492.5	391.5	82.0	1219.3	2184.9
1995	494.4	383.0	85.9	1247.4	2210.7

Source: BP Statistics, Statistical Review of World Energy

Table B2 Proved Oil Reserves 1996

	(000mt)	(000mb)	Share of ratio	R/P
USA	3.70	29.60	2.9	9.7
CIS	7.80	57.00	5.5	22.0
S. Arabia	35.07	261.20	25.7	83.8
U.K.	0.60	4.30	0.4	4.4
Nigeria	2.80	20.80	2.1	30.2
China	3.30	24.00	2.4	22.0
N. America	11.70	86.60	8.5	18.8
W. Europe	2.30	17.70	1.7	6.9
CIS & C. Europe	7.80	57.00	5.5	22.0
Middle East	89.20	659.90	64.9	92.3
Africa	9.80	73.30	7.2	29.2
Asia & Australa.	6.10	44.10	4.4	17.0
L. America	11.40	78.90	7.8	39.3
OPEC	105.80	778.20	76.5	79.5
W. Total	138.30	1016.90	100.0	42.8

R/P - Reserve to production rate

Source: BP Statistics, Statistical Review of World Energy

B3: World Proved Reserves As at 1996 (Major reserves(000mb)

Year	USA	L.America	W. Europe	M.East	CIS	Africa	W. Total
1970	46.7	16.3	4.4	330.0	40.0	74.7	635.0
1975	38.9	35.4	25.6	368.3	80.4	65.1	666.1
1980	37.0	80.0	25.0	344.0	116.0	58.9	660.0
1981	36.5	85.0	25.2	362.6	63.0	56.2	678.2
1982	36.9	78.5	23.5	369.0	63.0	57.8	677.4
1983	34.5	81.7	23.7	360.0	65.0	56.9	685.0
1984	34.9	82.9	23.9	400.0	68.0	56.8	710.0
1985	35.9	84.3	28.4	391.0	67.0	56.7	709.0
1986	32.5	88.9	18.2	402.0	70.0	55.2	708.0
1987	33.4	114.3	22.4	570.0	60.0	55.2	895.0
1988	34.6	122.1	17.7	564.8	80.0	56.2	896.5
1989	34.1	125.2	18.4	571.6	58.5	58.8	916.6
1990	33.9	121.0	14.4	660.3	59.9	59.9	1011.8
1991	33.8	119.8	14.5	662.3	58.9	60.4	1009.2
1992	32.1	123.8	15.8	661.8	59.2	61.9	1006.8
1993	31.2	124.9	16.7	662.9	59.2	61.9	1009.0
1994	30.1	78.3	18.8	660.3	57.0	62.2	1009.2
1995	29.6	78.9	17.7	659.5	57.0	73.1	1016.9

Source: BP Statistics, Statistical Review of World Energy

B4: Oil Consumption(mt)

Year	N. America	W.Europe	Asia & Aus.	World T.
1970	767.6	627.0	343.4	1937.4
1971	795.1	656.0	379.2	2040.1
1975	849.0	664.4	458.7	2192.3
1980	881.7	681.1	520.8	3024.0
1981	827.7	633.9	507.0	2918.3
1982	778.4	603.3	486.5	2820.3
1983	773.1	585.8	487.9	2764.9
1984	793.6	590.6	505.4	2812.7
1985	790.2	580.6	498.1	2809.2
1986	819.4	602.2	521.9	2897.7
1987	837.5	599.6	538.1	2449.1
1988	867.1	608.4	581.5	3039.1
1989	871.6	611.0	616.1	3090.1
1990	853.7	617.8	650.2	3140.1
1991	840.4	637.6	681.1	3190.7
1992	857.4	646.5	725.6	3145.6
1993	864.1	647.7	754.9	3121.4
1994	966.1	712.7	808.5	3189.1
1995	958.4	725.6	845.2	3226.9

Source: BP Statistics, Statistical Review of World Energy

B5: Trade Movements - Major Exports(000b/d)

Year	U.S.A	M. East	W. Africa	Asia	Others
1970	260	12930	800	1160	7990
1971	220	15250	930	1270	7510
1975	210	18505	1455	1470	6720
1980	555	17510	1745	2394	7685
1981	605	14605	1700	2573	7860
1982	815	11660	1550	2612	7795
1983	740	10355	1465	2996	7715
1984	720	9845	1655	3208	7995
1985	780	9340	1600	3288	7715
1986	765	10880	1610	3402	8010
1987	745	11315	1410	3243	7330
1988	845	11842	1380	4136	7976
1989	817	13389	1758	3796	8511
1990	889	14212	1582	3259	9251
1991	1000	13829	2500	1699	10892
1992	949	14948	2433	1795	9031
1993	959	16456	2676	1982	12415
1994	943	16513	2675	2517	12879
1995	949	16651	2723	2576	13341

Source: BP Statistical Review of World Energy

B6: Trade Movements - Major Imports(000b/d)

Year	U.S.A	W. Europe	Japan	Others	Total
1970	3420	12940	4280	4960	25600
1971	3930	13520	4720	5970	28140
1975	6025	12610	4945	6755	30335
1980	6735	12214	4985	8390	32324
1981	5950	10623	4460	8000	29033
1982	5040	9717	4155	7020	25932
1983	4990	9006	4145	6555	24696
1984	5380	8739	4305	6470	25093
1985	5065	8733	4045	6645	24488
1986	6045	9242	4140	7220	26647
1987	6245	8238	4125	6315	24923
1988	7240	9438	4412	7111	28201
1989	8019	9702	4549	8320	30590
1990	8026	9747	4802	8866	31441
1991	7791	10118	4925	9504	32338
1992	7845	10237	5291	9216	31441
1993	8527	10333	5307	10321	34488
1994	8929	9840	5612	11146	35527
1995	8831	9567	5581	12261	36240

Source: BP Statistical Review of World Energy

B7: Tanker Demand and Supply Balance

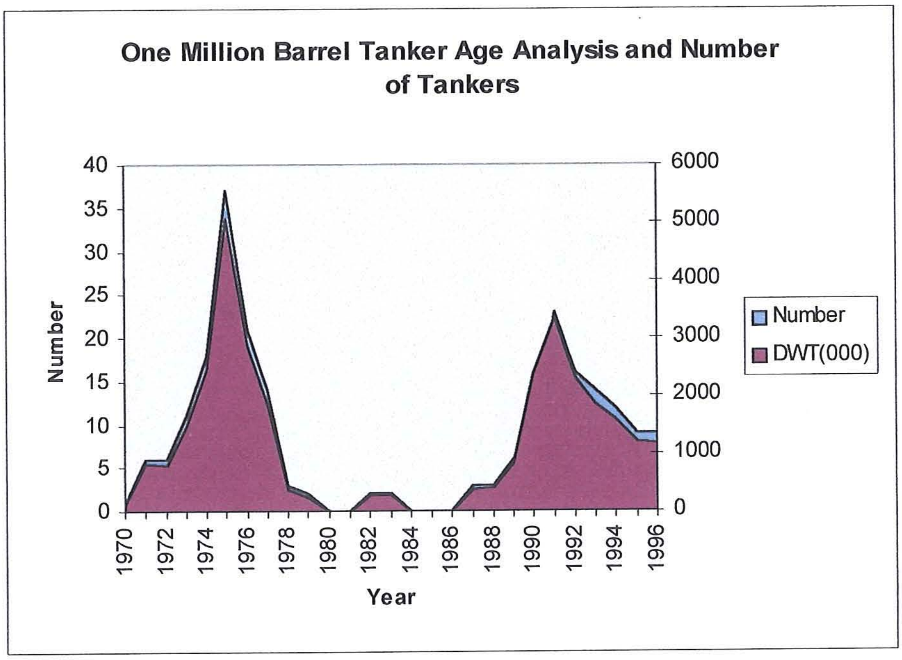
Year	Demand (mdwt)	Supply (mdwt)	Balance (mdwt)	Inactive tanker (mdwt)
1973	193	236	43	3
1974	194	259	65	5
1975	158	258	100	42
1976	240	304	64	48
1977	234	320	86	33
1978	232	322	90	31
1979	232	330	98	16
1980	192	320	131	25

Source: Drewry Shipping Consultants

GRAPH

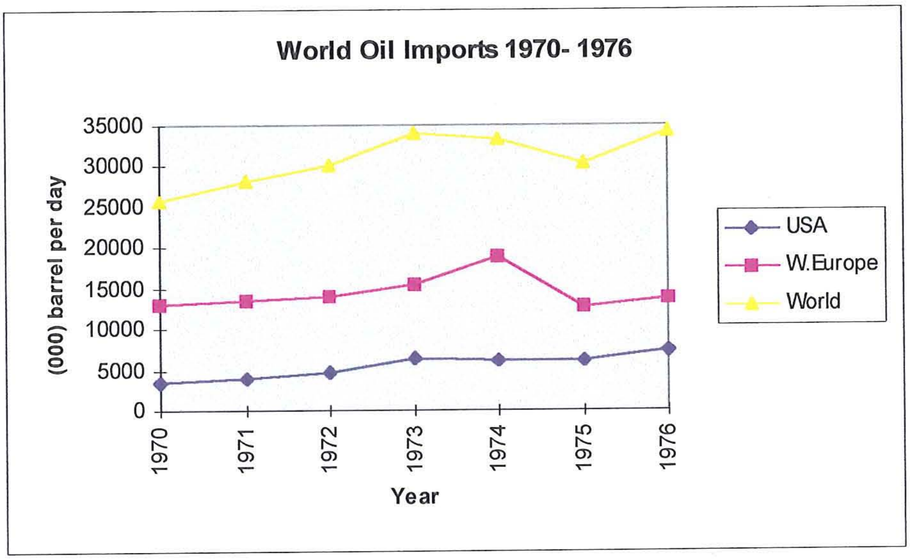
APPENDIX C

C1: One million barrel tanker age analysis 1970-1996



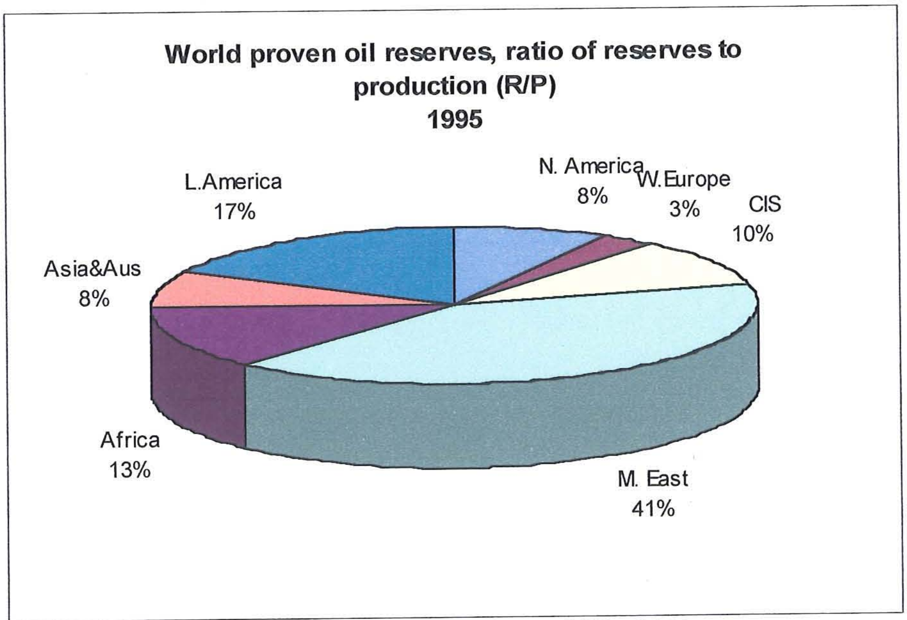
Source: Review of Shipping Statistics and Logistics,
Institute of Shipping Statistics and Logistics, Year Book, 1990-1996

C2: World Oil Imports 1970-1976



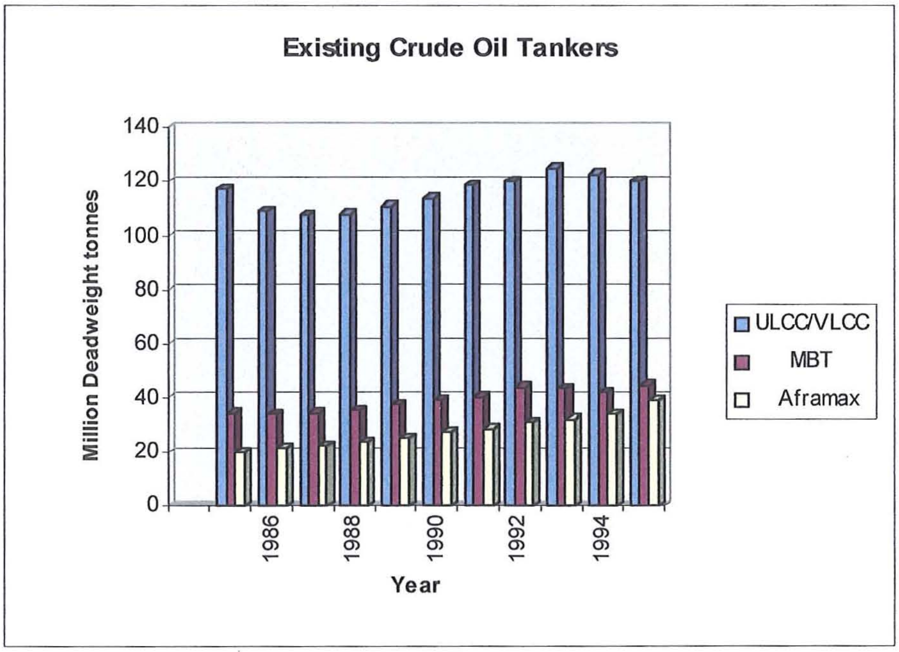
Source: BP Statistics: Review of World Energy

C3: Ratio of Proved Oil Reserves to Production 1995



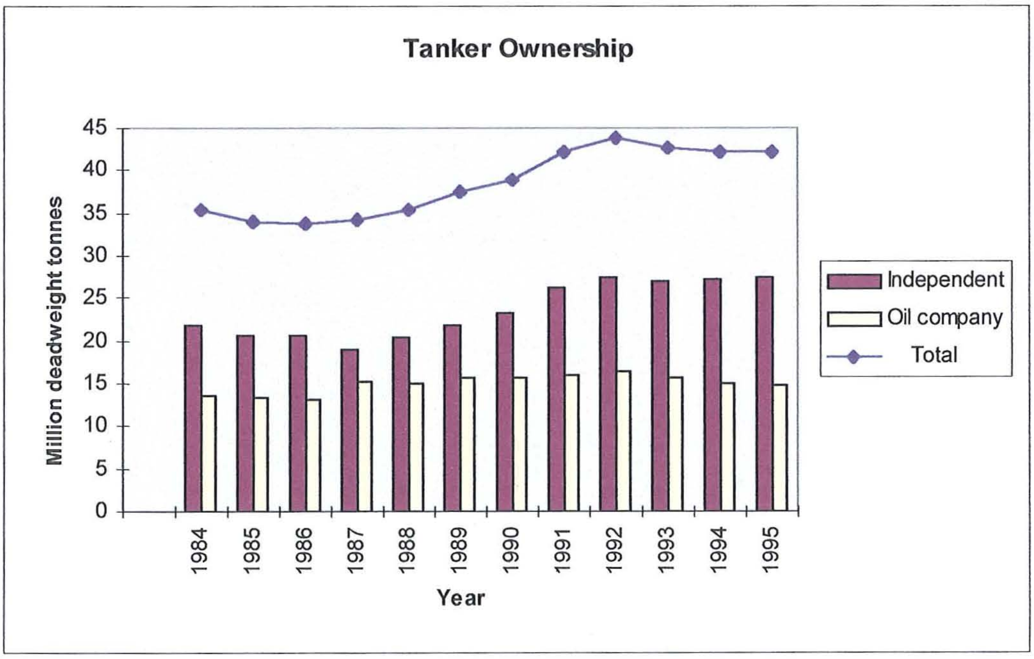
Source: BP Statistics: Review of World Energy

C4: Existing crude oil tankers



Source: Jacobs, J. I. World Tanker Fleet Review

C5: Tankers - Division of Ownership



Source: Jacobs, J. I. World Tanker Fleet Review

APPENDIX D

D.1 Estimation Methods and Techniques

The thesis modelled the supply of one million barrel tankers by the means of simultaneous equation with the regression analysis and econometric model. The aims are to build a tanker supply model and use the result to forecast the future. There has been critical examination of the million barrel tankers as a unique mode of transport for crude oil. The assumption is that the best method to forecast this category of tanker will be regression analysis and simultaneous-equation econometric model.[230] It is therefore expedient to examine the statistics of the equations within the system.

Forecast By Regression: Regression Analysis

Regression analysis is a widely used technique for quantifying the behavioural relationship between two or more economic factors (see chapter 3). The starting point in regression analysis is an equation model.

An advantage of regression analysis is that it is based on a model that can produce a number of statistical measures to check its validity. Also, in particular the advantage of regression method compared with others (such as moving average) is that it takes into account of all the known variables in the equation. The equation explained a great deal about the structure of the supply of tanker category being examined. Not only are individual relationship specified but the model accounts for the interaction of all these

230 Makridakis / Wheelwright / McGee, (1983). Op. cit., p.318.

inter relationships at the same time.[231] See section 3.2.1 in chapter 3, where the regression model was discussed.

D.2 *The Statistical Tests for the Regression and Simultaneous Equations*

The Significance of the Coefficient

This test indicates whether the dependent variable depends on the independent variable. The t-values determined by the ratio of the estimated regression coefficient to its standard error, are used for testing the significance of the coefficients. When the t-value exceed 2 (as the cut-off critical value of t) it is accepted in this case that the coefficient is statistically significant.[232]

$$t = \frac{X_i - \mu}{S^2x}$$

with n-1 degree of freedom

where S^2x = Sample estimate of the population variance

μ = value of the population mean

$S^2x = \sum (X_i - \overline{X})^2 / n-1$

n = sample size

The Explanatory Power of the Regression

It measures the dispersion of observations around the regression line. The higher the R^2

231 Makridakis, et al (1983), op cit., p. 332.

232 Baron, M. and Tagget, D. , The Managers guide to Business Forecasting, Basil Blackwell 1985.

the closer the observations to the line and the better the goodness of fit. This means that the explanation of the variation of the endogenous by the changes in the explanatory variable (exogenous).

$$R^2 = 1 - \frac{\sum_{i=1}^{n} e^2}{\sum_{i=1}^{n} (Y_i - \overline{Y})^2}$$

Where $e_i = Y_i - \hat{Y}$

Econometricians prefer to use a different measure of the overall goodness of fit, the adjusted R^2. Additional variables in the existing equation will cause reduction in the adjusted R squared.

$$\overline{R}^2 = \frac{1 - \sum_{i=1}^{n} e_i^2 / n - k - 1}{\sum_{i=1}^{n} (Y_i - \hat{Y})^2 / (n-1)}$$

In contrast, in the simultaneous equation model the adjusted R-squared is not bounded between 0 and 1. R^2 can be negative.

It indicates the proportion of the total variance that is explained by the regression equation. The F- statistics is also calculated though both tests are virtually for the same thing. It shows percentage of dependent variable explained by the independent variables. This is a test of null hypothesis that the regression equation coefficients are not equal to zero; except the intercept. In the model, the size of F- test is large and significant, so we reject the null hypothesis.

$$F = \frac{R^2/(k-1)}{(1-R^2)/(T-k)}$$

where T is the number of observation, k is the number of coefficients estimated (including the intercept).

When F (k - 1; T - k) exceeds the critical value of F (k - 1; Tk) at a level of significance. The null hypothesis that all the coefficients of the regression (except the intercept) are zero is rejected. This also implies that R^2 is statistically significant.

Serial Correlation or Autocorrelation

This is to test for the presence of first-order serial correlation among the terms. The Durbin Watson (DW) is calculated by[233]

$$\text{D.W.} = \frac{\sum_{i=2}^{n} (e_i - ei - 1)^2}{\sum_{i=1}^{n} e_i^2}$$

Where ei = The error or the difference between the point and the line.

e_{i-1} = error lagged one

By using the lower **(dL)** and upper **(dU)** values for d, which are provided in statistical tables for T and k, for a level of significance (1% and 5%). Where **d** lies between dU

233 Durbin. J. and Watson, G.S., "Testing for serial correlation in Least Square Regression II." Biometrika, Vol. 38 (1951), pp. 159-178.

and 4 - dU, the test indicates the absence of first-order serial correlation. If **d** falls below dL, it indicates the presence of positive serial autocorrelation. If **d** falls above 4 - dL, it indicates the presence of negative serial correlation. In other cases the test is inconclusive.

The presence of serial correlation leads to an incorrect estimation of the regression coefficients. Thus it is important to transform the original functional form by taking into account the value of the first-order serial coefficient (ρ).

The estimation of the value of rho (ρ); there is a suggestion to the use of autoregressive procedure developed by Statistical Analysis System (SAS).

$$\rho = \quad r = \frac{(2.0 - D.W.)}{2}$$

$$e = Y - Y_R$$

$$\rho^* \; e_{t-1} = \text{correction factor}$$

$$Y_t = e_t + e_{t-1}$$

Forecast_t = Residual + correction factor

Where e = error,

Y = Actual

ei = Residual

e_{t-1} = Error in the previous year

The null hypothesis is that the model prior to the rho transformation did not differ significantly from the transformed model. The F- statistics are calculated for testing this hypothesis:

$$F(1;T - k - 1) = (SSR\,(r = 0) - SSR\,(r = r)) \overline{)SSR(r = r)/(T - k - 1)}$$

Where SSR is the sum of square residuals; k is the number of coefficient estimates (including rho); the estimated rho; T is the number of observation. When the F (1; T - k - 1) value exceeds the critical value of F (1; T - k - 1) at a given level of significance. This test and the Durbin Watson test provide a double-checking for testing the presence of first-order serial correlation among the disturbance terms. However, as we would see below, Durbin Watson is not suitable for an analysis of equations with lagged variables, the option open to check these equations is autoregression analysis. The only useful test for autocorrelation of this type is Durbin h statistics.

For testing the presence of first-order serial correlation among the disturbance terms, the Durbin Watson test cannot be used for equations with lagged variables. The result of DW will be biased towards 2; Hence the use of Durbin *h*.

$$D = q\sqrt{\frac{n}{1 - n.V}}$$

where q = 1- (DW/2)

n is the number of observations

n.V is the square of the standard error of the coefficient on the lagged dependent variable. The test can only be used if **n .V < 1**.

This is a normalised test; the absolute value of **D** is less than the normal variate critical value at the chosen level of significance, the hypothesis of no positive autocorrelation is accepted.[234]

The other tests that were carried out are multicollinearity, specification error and heteroscedasticity.

234 Koutsoyiannis. A.(1977). Theory of Econometrics. Second edition. Macmillan Press. pp. 211-217

Multicollinearity

Multicollinearity happens when the explanatory variable is constant or when one variable is simply a multiple of another. Perfect linear dependence occurs if one of the explanatory variables is a linear combination of some of the others. Generally multicollinearity occurs when there are fairly high correlation between pairs of the explanatory variables. The correlation matrix of the variables was considered before using them in the model. The high correlated variables were screened and rejected. Though it is in fact very difficult sometime to reject some of these variables because of their influence on the dependent variable.

The purpose of the estimation of the model is to forecast the value of the dependent variables. In view of this, the intercorrelated variables have been included in the equation and ignoring the problem of multicollinearity. This has also been considered with the assumption that it is certain that the same pattern of intercorrelation of the explanatory variables will continue in the period of prediction. The belief is that it is possible to get a good forecast even without being able to disentangle the separate influence of the explanatory variables; provided the later continue to change in the same way as in the historical period. However, if the relationship between the explanatory variables is expected to change in the period of the forecast, then the accurate forecasting would require accurate knowledge of the separate coefficients; The separate influence of the explanatory variables on the dependent variable.[235]

Specification Error

Specification error occurs when the result from econometric failed to relate to reality. It is deemed important to use all the techniques of statistics and econometrics

235 Christ, H., Econometric Models and Methods, Macmillan 1983, pp. 389-90.

carefully and with considerable judgement; otherwise the results may bear little in relation to the reality. The specification error of including irrelevant explanatory variable and excluding relevant explanatory variable; these thus results in a specification error. The exclusion of relevant variable will bias the estimate of beta and the estimate of coefficient will be different from the time value. The degree of bias will much depend on the covariant between the other explanatory variables and on the value of the coefficient of the beta.

It is important to know that specification error of exclusion of relevant variable would bias the estimate of the remaining coefficients, while the inclusion of an irrelevant variable merely reduces the efficiency of the inference techniques. It is reckoned that there is justification for including all the variables in the equations. For economic and theoretical reasons; they are viable in the model.

Heteroscedasticity

This is a problem mostly associated with studies in which data are collected from units that varies in size. It occurs when the standard deviations of the disturbance terms are not identical for all observations. In order to detect heteroscedasticity the model was first estimated with ILS (Instrumental Least Square) and the presence of heteroscedasticity was checked by computing the relationship between the standard deviation of the errors and the characteristics of the observations. Microfit 3.0 has been use to derive the diagnostic test for all the equations.

It can be said that the best way to deal with heteroscedasticity is to seriously look at the form of the variables before formulating the model. It even be better still to specify the relations of the variables in a log-linear rather than linear form in order to reduce the apparent heteroscedasticity.[236]

236 Mirer, Thad W., Economic Statistics and Econometrics. Macmillan publishing Co. Inc. 1983.

APPENDIX E

The Holt-Winter Forecasting

This method can handle data embedded with seasonality. Since the data here are not seasonal, the calculating process has already been dealt with in chapter 8.

Adaptive Forecasting

Adaptive forecasting is the term use for forecasting methods which 'adapt' themselves to the characteristics of supply. The basis requirement of any such adaptive forecasting method is that as the supply becomes more changeable, the forecast itself responds and becomes more sensitive. Conversely, as the supply becomes more stable the forecast should also become more stable.

Computing Exponential Smoothing

$$Ft+1 = Ft + (\frac{Xt}{N} - \frac{N_{t-N}}{N})$$

When the observation X_{t-N} is not available the possible replacement will be the previous periods forecast F_t, Hence the equation is rewritten.

$$Ft+1 = Ft + (\frac{Xt}{N} - \frac{Ft}{N})$$

$$Ft-1 = (\frac{1}{N})Xt + (1-\frac{1}{N})Ft$$

1/N should be constant between zero (if N were infinite) and one (If N=1)

Therefore substituting alpha for 1/N, the equation becomes:

$$Ft - 1 = \alpha Xt + (1 - \alpha)Ft$$

Where

alpha X_t - Most recent observation

(1-alpha)F_t - Most recent previous forecast

$$F_{t+1} = \alpha X_t + (1 - \alpha)[\alpha X_{t-1} + (1 - \alpha)F_{t_{-1}}]$$

$$\alpha X_t + \alpha(1 - \alpha)X_{t-1} + (1 - \alpha)^2 F_{t-1}$$

Substitute process by replacing F_{t-1} by its component F_{t-2}

However the simplest way to write the equation is:

$$F_{t+1} = F_t + \alpha(X_t - F_t)$$

$$F_{t+1} = F_t + \alpha(e_t)$$

Where $\mathbf{e_t}$ is the forecast error

When alpha is .2 the equation would look like this:-

$$F_{1995} = aX_{1994} + (1\text{-}a)F_{1994}$$

$$= (.2)(X_{1994}) + (.8)(F_{1994})$$

One of the problems of exponential smoothing is how to determine or find the best value for alpha. However, the means is by trial and error. It is more appropriate to choose alpha with the lowest standard error. It is envisaged that the computer package SPSS does this by giving ten different levels of alpha from 0 to 1 with the Sum of squared error (SSE).[237]

The problem of whether to optimise alpha, to minimise MSE, MAPE or some other measure; suppose MSE is minimised. Unlike the mean, where this minimisation occurs any time the average of a set of numbers is calculated, for exponential smoothing the minimum MSE must be determined through trial and error. A value for alpha is chosen, the MSE is computed over a test set, and then another alpha value is tried. The MSE are then compared to find the alpha value that gives the minimum MSE.

An Adaptive Approach[238]

The equation for forecasting with the method of Adaptive response rate single exponential smoothing(ARRSES) is more superior to the SES (Single exponential smoothing) simply by replacing alpha with α_t .

$$F_{t+1} = \alpha_t X_t + (1 - \alpha_t) F_t$$

Where

$$M_t = \beta e / e_t /(1 - \beta) M_{t-1}$$

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237 SPSS/PC + Trend for the IBM PC/XT/AT and PS/2, SPSS - Statistical Data Analysis. 1990

238 Makridakis / Wheelwright / McGee, (1983), Op cit., p. 333.

$$\alpha_{t+1} = // \frac{Et}{Mt} //$$

$$Et = \beta et + (1-\beta)E_{t-1}$$

$$et = Xt - Ft$$

α and β are parameters between 0 and 1 and // denotes absolute values.

Therefore

$$F_{1995} = a_{1994}X_{1994} + (1 - a_{1994})F_{1994}$$

Once the actual value for the year 1995 is known, alpha can be updated and use for the next periods calculations. This will entails computing **e1995** , **E1995** and **M1995** .

e1995 = Actual - Forecast

Where e is the error / residuals

$$E_{1995} = \beta(e_t) + (1-\beta)(E_{t-1})$$

$$M_{1995} = /(e_t)/ + (1-\beta)(M_{t-1})$$

Where

E = Smooth error term

M = Absolute error term

Therefore

$$\alpha_{1996} = / \frac{E_{1995}}{M_{1995}} /$$

$$F_{1996} = \alpha_{1995}X_{1995} + (1 - \alpha_{1995})F_{1995}$$

Double Exponential Smoothing:

Browns One Parameter Linear Method

The approach is preferred to linear moving average, as a method of forecasting in the great majority of cases

$$S' = \alpha Xt + (1-\alpha)S_{t-1}$$
$$S'' = \alpha St + (1-\alpha)S_{t-1}$$

where S'_t is the single exponential smoothed value.

S''_t is the double exponential smoothed.

Therefore

$$a_t = S'_t + (S'_t - S''_t) = 2S'_t - S''_t$$

$$b_t = \frac{\alpha}{1-\alpha}(S'_t - S''_t)$$

$$F_{t+m} = a_t + b_t m$$

Where

m is the number of period ahead to be forecast.

Using alpha is 0.2 and forecast for one period ahead.

$F_{1995} = a_{1994} + b_{1994}(1)$

Where

a_{1994} = .2 S'_{1994} - S''_{1994}

b_{1994} = .2/.8 (S'_{1994} - S''_{1994})

S'_{1994} = .2X_{1994} + .8S_{1993}

S''_{1994} = .2S'_{1994} + .8S''_{1993}

Double Exponential Smoothing:

Holt's Two Parameter Method

Holt's linear exponential smoothing method provides greater flexibility, it allows the trend values to be smoothed with a different parameter than that used on the original series. The forecasts for Holt's make use of two smoothing constants (with value between 0 and 1) and three equations

$$S_t = \alpha X_t + (1-\alpha)(S_{t-1} + b_{t-1})$$
$$b_t = \gamma(S_t - S_{t-1}) + (1-\gamma)b_{t-1}$$

$$F_{t+m} = S_t + b_t m$$

Alpha (α) = .2

Gamma (δ) = .3

F_{1995} = S_{1994} + b_{1994}(1)

Where

S_{1994} = .2X_{1994} + .8(S_{1993} + b_{1993})

b_{1994} = .3(S_{1994} - S_{1993}) + .7b_{1993}

therefore F_{1995} = S_{1994} + b_{1994}

Since S_{1995} = .2X_{1995} + .8 (S_{1995} + b_{1994})

and $b_{1995} = .3(S_{1995} - S_{1994}) + .7b_{1994}$

$F_{1996} = S_{1995} + b_{1995}$

The Holt's linear exponential smoothing requires two estimates, one to get the smoothed value for S_1 and the other to get the trend b_1.

Therefore $S_1 = X_1$

$b_1 = X_2 - X_1$

$b_1 = (X_2 - X_1) + (X_3 - X_2) + (X_4 - X_3)$

Triple Exponential Smoothing

Winter's Three-Parameter Trend and Seasonality Method

This method unlike other methods discussed above can handle data embedded with seasonality. It is based on three smoothing equations, one stationarity, one for trend and one for seasonality. It is quite similar to Holt's method, with one additional equation to deal with seasonality.

(a) Overall Smoothing

$$S_t = \alpha \frac{X_t}{I_{t-L}} + (1-\alpha)(S_{t-1} + b_{t-1})$$

(b) Trend Smoothing

$$b_t = \gamma(S_t - S_{t-1}) + (1-\gamma)b_{t-1}$$

(c) Seasonal Smoothing

$$I_t = \beta \frac{X_t}{S_t} + (1-\beta)I_{t-1}$$

(d) Forecast

$$F_{t+1} = (S_t + b_t m)I_{t-L-m}$$

Where

L is the length of seasonality

b is the trend component

I is the seasonal adjustment factor

F_{t+m} is the forecast for **m** periods ahead.

The parameter values are α (.2), β (.05) and $\gamma = (.1)$

$$F_{1995} = [S_{1994} + b_{1994}(1)]I_{1991}$$

$$S_{1995} = .2\frac{X_{1995}}{I_{1991}} + .8(S_{1994} + b_{1994})$$

$$I_{1995} = .05(\frac{X_{1995}}{S_{1995}}) + 0.95I_{1991}$$

The implication is the determination of the parameter alpha, beta and gamma that can minimise MSE or MAPE. Winter forecasting method need to use at least one complete season data (i.e. L periods) to determine initial estimate of the seasonal indices I_{t-L} and the estimation of the trend factor from the period to the next.

$$b = \frac{1}{L}[\frac{(X_{L+1} - X_1)}{L} + \frac{(X_{L+2} - X_2)}{L} + \ldots + \frac{(X_{L+L} - X_L)}{L}]$$

E2 The Box-Jenkins Approach for the Analysis and Forecast of Time-Series

It is assumed that it is appropriate to familiarise the reader of this to the concept underlying the Box-Jenkins approach to the forecasting of time series, hence a description to increase their understanding of the work. In fact, the term Box-Jenkins is often mis-specified.

In the 1960's a general class of models called Autoregressive -Integrated moving average processes (called ARIMA processes) were developed for the analysis and forecasting of time series. Box-Jenkins (1970) produced an iterated method for the Identification, Estimation and Verification of these models. Since 1970, many authors have contributed further knowledge of the behaviour pattern of ARIMA processes. However, every mentioning of ARIMA model is being associated with Box-Jenkins.

The range of ARIMA models that can be selected is very extensive. Some ARIMA models have equivalent representation for exponential smoothing models.

There is one important criterion for using ARIMA model and that is the need for moderately large number of observation to enable the true model to be established. Some authors have suggested that the number of observation should be greater than fifty. Such as Reid(1970)[239] and Anderson(1976)[240], however they do not give explicit reason for their suggestion.

[239] Reid, D.J. (1972) "A Comparison of Forecasting Techniques on Economic Time Series, Forecasting in Action", London: Operational Research Society.

[240] Anderson, O.D. (1976), Op cit., p.83.

Box-Jenkins (1970) avoided recommending a minimum series sample size; however, Jenkins (1979) managed to fit a 2 parameter univariate ARIMA model to thirteen data points.

There is no dispute as to the usefulness of ARIMA modelling or to the number of realistic alternative ARIMA models that can be produced from the analysis of a time series. This is one reason why ARIMA modelling should not be omitted from any univariate forecasting analysis.

Since this research is only using ARIMA forecasting models to show alternative forecasting method to the econometric method implemented in the thesis. The idea here is to give some useful information to give the reader lea-way when following the steps in building the models. The real aim of the model as specified above is to produce results from applying Box-Jenkins techniques to see how ARIMA processes are capable of adequately modelling tanker supply. In view of this, the presentation of 'standard' theory has been avoided, but relevant references are giving where appropriate so that if wished a complete understanding of ARIMA modelling can be sort.

Stochastic Process and Stochastic Models for Forecasting

An unusual thing that evolves over time with respect to certain laws of probability is called a "stochastic process". A time series is one particular realisation of a stochastic process. An observation $\mathbf{y_t}$ at time $\mathbf{t}$ is a realisation of a random variable $\mathbf{y_t}$ with probability density function $\mathbf{f(y_t)}$.[241] The set of observations $\mathbf{y_{t1}.......y_{tn}}$ that make

[241] Makridakis et al. (1983). Op. cit., p. 333

up the time series may be thought of as a realisation of an n-dimensional random variables $(Y_{t1},\ldots\ldots,Y_{tn})$ with probability density $f(y_{t1},\ldots\ldots y_{tn})$.[242]

A stationary stochastic process is a time series whose statistical properties do not change over time. There are various degree of stationarily. If the statistical properties of a stochastic process are not affected by a change of time origin, the process is said to be strictly stationary.

The principle of Box-Jenkins univariate modelling is that given a stationary time series $y_1, \ldots\ldots y_n$ then it can be represented by either (-A) a moving average(MA) or (-B) an autoregressive (AR) process or (-C) a mixed autoregressive - moving average (ARMA) process.

Moving Average(MA) Stochastic Models

Moving average models are based on the idea that a time series in which successive values are highly dependent can be regarded as generated from a series of independent. A moving average operator of order of **q** can be define as

$$\Theta(B) = 1 - \Theta B - \Theta_2 B^2 - \ldots\ldots - \Theta_q B^q$$

and the moving average model known as a **MA(q)** model can be written as

$$y_t = \Theta(B)a_t$$

[242] Ibid., Makridakis (1983). p. 350.

Autoregressive (AR) Stochastic Models

$\{y_t\}$ is defined as an AR process of order **P** if the current value can be represented as a linear weighted sum of **P** previous values.

An autoregressive operator of order **P** is defined as

$$\phi(B) = 1 - \phi B - \phi B^2 - ..... - \phi_p B^p$$

and the autoregressive model, known as **AR(p)** model can be written as

$$\phi(B)y_t = a_t$$

Mixed Autoregressive - Moving Average (ARMA) Stochastic Models

The inclusion of both autoregressive and moving average terms in a model leads to greater flexibility in the choice of a particular model for an actual time series. An ARMA model containing **p** autoregressive parameters and **q** moving average parameters is known as an ARMA **(p,q)** model.

$$y_t = \phi y_{t-1} + ... + \phi_p y_{t-p} + a_t - \Theta a_{t-1} - ... - \Theta_q a_{t-q}$$

or

$$\phi(B)y_t = \Theta(B)a_t$$

The importance of ARMA process lies in the fact that a stationary time series may often be described by an ARMA model involving fewer parameters than a MA or AR process by itself. Box-Jenkins (1970) states that for actually occurring stationary time series, an adequate representation can be obtained with AR, MA or ARMA models in which **p** and **q** are not greater than **2** and often less than **2**.[243]

In practice, most time series are non-stationary. If this is the case the Box-Jenkins method assumes that the series can be reduced to stationarily by differencing some finite number of times (possible after removing some deterministic trend).

If y_t is a non-stationary time series let $W_t = \nabla^d y_t$ equals the stationary series after **d** differences have been taken. If $\nabla^d y_t$
replaces y_t in the equation i.e.

$$\phi(B)\nabla^d y_t = \Theta(B)a_t$$

or

$$\varphi(B)W_t = \Theta(B)a_t$$

where

$$\varphi(B) = \phi(B)\nabla^d$$

equal to

$$1 - \varphi_1 B - \varphi_2 B^2 - \ldots - \varphi_{p+d} B^{p+d}$$

Such model is called an 'Integrated' model. Therefore,

$$\varphi(B)W_t = \Theta(B)a_t$$

is considered to represent an autoregressive integrated moving average model of order (p,d,q) also called ARIMA(p,d,q).

[243] Box, G.E.P. and Jenkins, G.M. (1970), Op cit, p.79.

As specified above the reason for including time series in this thesis is not to detail Box-Jenkins time series, but to summarise taking into consideration the understanding and the ultimate use of the models in forecasting time series.

The application of a computer has been used to analyse the result from the data. However, the procedures are factually the same. The steps or the process will be listed in order to avoid unnecessary details. The computer package (SPSS) Statistical Package for Social Science.[244]

The Box-Jenkins Methodology Steps of Iteration

In time series the following six points are a step by step guidelines identification procedures:

1. Obtain a plot of the series for visual inspection of its stationarily.
2. If the series is not stationary it should be reduced to stationary by differencing the appropriate number of times.
3. Calculate the autocorrelations and partial autocorrelations of the differenced series for lags.
4. Study the appearance of the autocorrelation function and the partial autocorrelation function in order to look for clues concerning the orders **p** and **q** for the **AR** and **MA** parameters.
5. Estimated autocorrelations can be highly autocorrelated with each other so that detailed difference to the theoretical autocorrelation function cannot be expected.
6. Calculate preliminary estimates of the parameters that are to be tentatively entertained and test whether or not these estimates are within the admissible region for the theoretical parameters of the models.

[244] SPSS/ PC + Trends for the IBM PC/XT /AT and PS/2, SPSS Inc. 1990, op cit., p.343.

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