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QUANTITATIVE METHODS IN SHIPPING: A SURVEY OF CURRENT USE AND FUTURE TRENDS

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Table of Contents

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1. INTRODUCTION

Ocean shipping is a lucrative and risky business. As pointed out by many of its students, its charter market component is perhaps the purest form of a perfectly competitive market, barriers to entry being smaller than in any other big business and government regulation being extremely difficult to enforce. However, the near perfect market character of chartered shipping coupled with the long lead time required for newbuildings makes it subject to particular violent dynamic effects. As supply of shipping services can only sluggishly adapt to fast changes in demand, the market is plagued by violent fluctuations - long periods of depressions followed by booms.

One would expect that such competitive conditions make shipping a prime target for the application of quantitative managerial methods, which we will in general refer to as Management Science for short, while making explicit mention of other fields such as Economics, Finance or Forecasting as appropriate. Indeed such analyses began in the 30's with Koopmans' (1939) celebrated work and were revitalized in the 60's by several eminent researchers among which the late Zenon Zannetos. Since then, several efforts have been made to adapt to shipping successful quantitative methods from other fields such as Decision Theory, Mathematical Programming or Portfolio Theory, as evidenced in the 1972 Seminaron Shipping Management in Bergen (Lorange and Norman, 1973). The textbooks by Devanney (1971) and Evans-Marlow (1985) are also evident of this trend.

In the 80's computer literacy has greatly increased in the shipping business, providing thus data for more sophisticated analyses. Sophistication was also vastly increased in the analyses performed by banks at the wake of heavy losses in their shipping loans following the depressions of the period. However, there is a strong feeling between those involved in shipping that any sort of formal analysis plays a secondary or even tertiary role compared to other qualities such as the gut feeling for the ups and downs of the market, knowledge of the technical details and quirks of the particular fleet and various other trade secrets. Thus, even highly successful operators claim that they avoid using any but the most rudimentary form of analysis. Of course this is not true for big users of shipping services, and in particular of oil companies who routinely use Management Science to assess their shipping needs and coordinate them with their other activities - refining and finished product deliveries.

The objective of this report is to survey quantitative methods developed in the fields of Management Science and Operations Research with regard to shipping - especially those aimed at the shipping operator; to assess their impact especially in the setting of Piraeus; and finally to point out specific refinements to existing methods or even suggest completely new methods whose development will hopefully serve pressing shipping decision making needs.

In Chapter 2 of the Report we provide a synopsis of the role played by the major participants in the shipping scene with emphasis on the nature of the decisions they have to make. Chapter 3 gives an outline of the well-established Management Science methods in shipping. Chapter 4 surveys the actual use of hese methods in several Greek shipping firms, while Chapter 5 examines possible promising directions for research relevant to shipping needs. A detailed, technical exposition of the methodologies, existing or proposed is given in the Appendix.

2. THE MAJOR SHIPPING ACTIVITIES

This section describes the major shipping activities, with an emphasis on the kinds of decisions facing each of the players in the market.

2. 1 SHIP OWNERS

Supply of marine transportation services is provided by ship owners, therefore decisions by ship owners play a crucial role in the shipping market. The fact that the spectrum of such decisions and the way they are made are very broad and diverse can be understood from the fact that the spectrum of owners in the market and the services they provide are equally broad and diverse: For instance, one may study (a) an independent tramp operator having only one ship, (b) a major oil company operating a fleet of tankers, (c) an owner operating a general cargo ship, (d) a large liner company such as Sea Land, who is owned by CSX, a railroad, and offers intermodal services, and so on. Since the economic scenario behind a particular case may vary dramatically, it would be a mistake to lump all ship owners into a single category and treat all decisions in a uniform way.

A first-level classification that can be made is to divide shipping into two sectors: the **charter (or tramp) market** (where, as mentioned earlier, conditions of almost pure competition prevail), and the **liner market** (which is organized on a more or less cartelized basis). The charter market includes the tanker and drybulk markets as major components, and the liner market includes general cargo as well as unitized cargo ships (containerships and roll on/roll off (ro/ro) ships belong to the latter category).

Ship ownership in the tanker **market** (the most significant component of the charter market) is divided between the so-called independent operators (or simply independents) and oil companies.

An **independent operator** has no transport requirements of his own; he is there simply to offer his ships to the market. Decisions facing him can be classified into three levels: strategic, tactical, and operational.

Strategic decisions involve capital acquisition issues, such as the sale or purchase of a particular ship (or ships), including which shipyard to buy it from, when to do so, whether it is new or second-hand, what form of financing should be used, and so on. The planning horizon for such decisions is on the order of 5-20 years.

Tactical desisions involve the allocation/utilization of ships owned by the operator, including the issue of which charter should be fixed, whether to offer the ship in the spot market or in the term market, whether the ship should be laid up, how the ship should be "positioned" to be best used in future charters, what should be the ship's operating speed, routine maintenance, and so on. Tactical decisions have a shorter planning horizon, on the order of a few months to 2 years.

Finally, operational decisions have a much shorter time horizon (a few days to a few months), and involve issues of the day-to-day operation of the ship, such as management of stores and supplies, bunkering, non-routine maintenance, etc. The line between the tactical and operational decision levels is to some extent arbitrary and depends on the idiosyncrasy of the particular owner.

At first glance, an **oil company** operating a tanker fleet faces similar kinds of decisions. However, the delineation of these decisions among the three levels, as well as the way these decisions are made may be very different from the case of an independent tanker owner. For instance, longer planning horizons are more likely to be used, and strategic issues are likely to be more important. This means that decisions that are operational for an independent owner may be tactical for an oil company, and decisions that are tactical for an independent owner may be strategic for an oil company. As an example, an oil company may decide at the **strategic level** to use its ships only to carry its own oil, and not to offer them in the charter market. The fact that the function of an oil company's tanker division is mainly to satisfy the company's transport requirements (rather than make a profit in the market) means that the behavior of an oil company in the market will generally be quite different from that of an independent owner.

Optimizing the utilization of an oil company's tanker fleet to transport its own oil is an area where important tactical decisions are made. These may include both the matching of vessels to specific shipping requests, and the routing and scheduling of these vessels.

The situation in the **drybulk market** is similar with that in the tanker market. An additional type of decision however is important here, and involves the commodity, which the ship will carry. The drybulk market is less homogeneous than the tanker market in that it involves bulk cargo as diverse as coal, ores, grain, and others. With some exceptions, a ship may be used in many of these diverse trades, and exactly how this should be done becomes an important decision. This decision is more pronounced for OBO carriers (ore/bulk/oil), which can, in addition to the drybulk market, also trade in oil. Since this decision depends on the state of the various markets for the relevant commodities, it is a tactical type of decision and may also involve routing considerations.

The second major component of the shipping market, the liner **market**, is organized along very different lines. It is natural therefore to expect different kinds of decisions. Indeed, one of the prime decisions facing a liner cartel (or conference) is how to set freight rates for the various commodities it carries. Traditional cartelization means that rates are set uniformly (ie are the same for all members of the cartel). The cartel then "charges what the traffic can bear". This means that on a $/ton basis there can be wide disparity among rates for commodities being carried on the same ship for the same trip. Liner market ratemaking is therefore a major type of decision, and a strategic one for that matter. Another strategic decision for each member of a shipping conference is the selection of routes that will be served, of the schedules that will be followed, and of the shipping capacity that will be placed on those routes. Service (as opposed to price) competition in the liner market means that decisions such as frequency of service and operating speed are very important.

The advent of intermodal services (door-to-door or around-the-world) has introduced new kinds of services in the liner market. A detailed description of these services is beyond the scope of this report. However, it is obvious that important types of decisions are involved: these range from marine terminal management to intermodal network design, from intermodal rate-making to control of flow of empty containers, and from intermodal routing to schedule coordination across different modes (ship/rail or ship/road).

As a general rule, in the liner market many more decisions are strategic in nature than in the charter market. This is due to the fact that many more costs in the liner market are fixed costs as opposed to variable. Of course, decisions on maintenance and replacement, management of stores and supplies etc. Are very similar in nature to their counterparts in the charter market.

2. 2 CHARTERERS

In the charter market, the most important decision of a charterer is whether to go spot or buy a time charter. If the latter choice is made, the question is what is the best charter duration. Although this type of decision is tactical in nature (for it depends on expectations largely influenced by the state of the market), some charterers base it on strategic considerations and are not likely to change it significantly in view of charter market fluctuations: as an example, a particular oil company, in addition to being a ship owner, satisfies a large part of its requirements by chartering from independents mainly in the term market, and is not likely to change that philosophy as a result of the state of the market.

Of course, a charterer in the term market can (if he wants) relet the vessel he has chartered, ie. Offer it in the spot market. This type of decision may make sense if the charterer has no actual other use for the ship during the period under consideration.

In the liner market, the spectrum of charterer decisions is usually confined to the selection of the liner company among the members of a cartel that provides better service to the shipper. The possible exception is if the scale of the shipment is large. In this case, it may make sense to "consolidate" freight and turn to the charter market as an alternative (ie. charter a whole ship if quantity warrants it).

2. 3 BROKERS

Ship brokers mediate between supply and demand of shipping services, fixing ships through single trip charters, time charters, contracts of affreightment and the like. They also mediate in the acts of sale and purchase of vessels, new or second hand and even in reorder deals. Such activities rely mainly on an efficient information collection process and ths modern communication media have revolutionized the business. Needless to say personal contacts play an all-important role.

Efficient handling of data is of prime concern to brokers. In the process of fixing a client's ship the broker must present in an extremely short notice all available opportunities and help him select among alternative charters. The reverse process must be carried out for a charterer's demand; the available ships must be identified with all the relevant information concerning the ships' characteristics, location and other specific information, including of course the required fee.

The sale of a particular ship also requires the compilation of technical data on the ship. More crucial is the identification of potential buyers. In the case of a client interested in purchasing a used ship of certain characteristics the data collection process is even more difficult. Advances in data processing allow reasonably sized brokerage houses to keep almost complete records of existing ships in CD stored databases that are compiled by specialized firms.

Brokers are additionally called on to play a consultant's role for their clients. They might advise against a deal of sale, purchase or charter although this is against their short run interests, i.e. there is a loss of commission. This consulting activity is traditionally supported by the brokers' individual feel of the market, partly shaped by following the specialized literature, journals and reports. It is not often though that a shipping enconomist is employed in a brokerage house solely in a consulting capacity. As in every brokerage business, executives are valued for the business they bring - and any consulting role that will only indirectly generate profits is secondary to the main profit generating function, fixing deals.

Brokers mediate between their clients and shipping banks. This is an imporant task, especially in the sale and purchase activity. The broker's consulting role is again of importance here, as he must help make the intended transaction look sound from the bank's point of view. He must help in the preparation of the feasibility study that might be submitted to the bank, and also help bolster his client's profile Vis a Vis the bank. The relation of brokers and shipping banks also extends to the services experienced brokers provide by participating in evaluation boards of specific banks.

The decisions faced by a broker are of lesser economic consequence than those of a shipowner or a bank, as much smaller risks are involved for him. It is thus natural to expect a smaller reliance on methodology. On the other hand, to be a successful broker, one must act with as deep an understanding of the market as those responsible for actually making these decisions. Therefore, if banks, owners or big charterers practice sophisticated decision-making methodologies, the broker must follow suit.

An important internal decision faced in brokerage houses is the degree of information technology to be adopted. Although no self-respecting broker can do without the standard communication equipment, there are other mainly computer related technologies that are not obviously cost effective. For instance, investment in sophisticated data bases, intelligent message transmission through computer networks and the like, might or might not be justified, depending on the business size, the philosophy of operation and other factors. Other investments, relating to improving client relations might prove immensely more profitable.

2. 4 BANKS

Shipping banks risk huge losses in times of market downturns. These risks are balanced by comparable profit expectations during normal states of the market or during booms. Overall, the operation of a maritime bank reflects to a great extent the high-risk environment of shipping.

The major decision faced by the banks' shipping branches is to screen bad loans and, naturally, attract shipowners with good prospects. Intangible factors play an important role in these decisions, much more so than in other areas of banking. Loan securities are of significance here since the main form of collateral (the ship) will probably have sunk to a small fraction of its value in case the debtor is in financial difficulty in a market downturn.

The unpredictability of shipping makes formal feasibility studies of particular loan proposals extremely unreliable, much more than in other economic activities. Therefore the objective assessment of the shipowner's managerial potential (proven or manifest) and integrity are of prime importance.

The amount to be lent is of particular importance in most banking deals. Usually owners seek a large amount of leverage, saving their own money for the hard times. A lender is of course not eager to do this and thus increase the risk of the undertaking. However, pressure from owners is such that competition among banks leads sometimes to overfinancing, with the expected catastrophic effects during market downturns.

Loan management and auditing is a crucial aspect of everyday banking practice. Banks must guard against bad loans by keeping a close eye on their debtors' operation and intervene if possible at the first signs of difficulty. If the difficulties persist a bank might even consider selling the high risk loan (a rather difficult proposition) or even precede to more drastic measures. Timing is all-important, since being forced into financial difficulties when they still have a chance to recover should not lose good clients.

An internal decision by commercial banks relates to the funds to be allocated to their shipping branches, as well as the required return on those funds committed to shipping in view of the risk-returns involved. This is a decision banks are particularly concerned with, and such portfolio management issues abound in banking. Naturally, this important strategic decision depends on the relative position of shipping with respect to the other economic activities the bank is involved in.

As with brokers, bank executives are increasingly asked to play the role of an informal consultant to their clients. Thus a bank's image is to a great extent influenced by the success or failure of these informal activities. It is clear therefore that a certain degree of feedback exists here, as observed about brokers' activities: the use of sophisticated decision methodologies by one actor in the shipping market will quickly filter to the others. Therefore, if the use of quantitative methodologies becomes more widespread among owners or charterers t will find its place in banking circles and vice versa.

2. 5 INSURANCE

Insurance policies have traditionally played an important role in shipping due to the great risks involved. The maritime lore is full of stories about shipowners who have been destroyed or saved by calculated or inadvertent insurance decisions. Many stories are in the gray area between the legal and the illegal activities of shipping. A vast amount of experience exists in the field compiled by insurance and underwriting companies.

From the point of view of a shipping manager the obvious decision is how to select the proper amount of insurance coverage, taking nto account the reliability of the insurance company and the costs involved. Insurance agents often complain that shipping managers usually overlook the quality of the services they offer, and concentrate instead on the (cheaper) premia offered by other (competing) companies. It is obvious however that shipowners and their financing banks pay attention to both of these aspects.

The shipowner needs insurance to be covered from physical loss or damage (hull and marine), liability to third parties (protection and indemnity) and loss or interruption of earnings. Some insurance is dictated by govenmental insurance regulations, mortgagees or other contractual requirements. Beyond this, the owner can decide on the additional cover that is proper. Usually the negotiations are carried out through insurance brokers who specialize in various types of insurance (P&I, hull and machinery, loss of earnings, strikes, war or legal risks).

The knowledge of the legal clauses in the contracts is of paramount importance in negotiating, perhaps even more so than the negotiation about the premium or the coverage itself. Personal relations with brokers are also of great importance as nsurance is eventually a matter of utmost good faith. Selecting the appropriate insurance organization (insurance company, underwriting syndicate or club) is also of some importance.

Among the several negotiation points in an insurance contract, of relative importance are (a) the value placed on the ship and (b) the deductible amount (the amount paid by the owner over which nsurance payments are made). The value placed on the ship is negotiated betweeen the owner and the underwriters, and (in principle) reflects the ship's actual value in the (fluctuating) market. Setting a high deductible is a way of reducing premia at the expense of extra risk - which is however guaranteed not to be of catastrophic proportions.

Dealing with insurance claims is an important operational concern. Often cases of dispute arise and legal action is necessary. Usually matters are settled out of court and skillful analyses are required to decide on what amount to settle on and when to press for a court decision.

Proper accounting must be done to deal with the type of insurance carried. Including losses up to perhaps the deductible might be a sound policy when preparing a budget estimate .

From the insurer's point of view interesting questions arise as to the determination of the profitability of investing in underwriting: Some typical questions concern the participation or not in a specific underwriting syndicate, and of course the relevant cash management questions. These topics have been widely analyzed in the insurance literature.

2. 6 SHIPYARDS

A detailed analysis of desisions facing a shipyard is beyond the scope of this report. However, since shipping and shipbuilding are so interrelated, we give a flavor of these decisions.

Shipyard decisions fall into two main categories: decisions related to the **competitive strategy** of the yard vis-a-vis others, and decisions related to **yard management** and operation.

The first category of decisions attempts to answer the following types of questions: what types of vessels should the yard produce? are the designs for these ships developed in-house, or imported? should the yard have also a ship repair facility? what marketing strategy should be used to attract customers? what financing packages should be offered? and so on. Among the above decisions the question on whether to concentrate on repair or in newbuildings is of prime importance among Greek yards.

Once the above questions have been answered, issues to be resolved center on yard design and layout, inventory control, production scheduling, parts and supplies logistics, robots and other technologies, and so on.

It is clear that the two categories of decisions are nterrelated, for the yard cannot formulate a coherent strategy f decisions on yard operation are left open.

2. 7 THE SHIPPING SECTOR IN THE GREEK ECONOMY

The shipping sector has always been one of the most important pillars of the economic activity in Greece. Periods in which shipping industry was thriving were considered as golden years for the economy as a whole. Whenever the former was in decline, recession was inescapable in the latter as well. Three areas are more prominently affected by the shipping industry with repercussions felt widely in the economy:

(i) **The labour market** : The shipping sector absorbed large numbers of unskilled and skilled labour force, thus easing the threat of unemployment in other sectors of the economy. Pressure started to be understood in the national labour market, whenever shipping activity was shrinking or deregulation in the international shipping labour market allowed recruitement of low-waged foreign workers in the fleet under Greek flag.

Decision oriented research is needed to examine the institutional idiosyncrasies of the shipping labour market, how it is affected by international factors, how the skilled workers can be absorbed in the domestic economy in periods of recession in shipping, and to which extent deregulation threatens employment of Greek workers in the shipping industry.

(ii) **Shipping and National Income From Abroad** : Remittances from sailors and foreign currency savings deposits by Greek people working in the shipping industry has always been a help to the persistent Current Account Deficits of the Greek economy. Income From Abroad, mainly generated by shipping, by far exceeded Income To Abroad until 1985. Net Income From Abroad (NIFA) contributed more than 5% to GNP in good times, giving further rise to economic growth of the country. The recession that is observed after 1985 in Greece is partly due to the fact that NIFA has become negative ever since.

As several factors change in the international scene, from local wars to the General Agreement of Trade and Tarrifs, the volume and competitiveness of Greek shipping cannot be taken as granted. Apart from the sectoral consequences, there going to be serious repercussions to the Greek economy as a whole, and in the Current Account in particular.

A more specific source of change will be the completion of the 1992 Project for a Single European Market. Services, like transport, are likely to be completely deregulated, and this will create serious problems in countries specialising to particular forms of services. In a recent publication Tzoannos (1991) thoroughly examines the consequences of the 1992 liberalisation, and concludes that a lot more policy-oriented studies should follow in order to determine the optimal country response in the new conditions.

(iii) **Ship-building industry** : This is one of the most technologically advanced sectors of the construction industry in Greece. The level of activity, the competitive structure of the industry, the externalities with other manufacturing sectors are important aspects to be investigated. Some case studies are occasionally published by the Centre of Economic Planning (KEPE), but there is still a lot to be looked at, especially in the light of privatisation and deregulation. As ship-building is the main determinant of supply, prices and other market variables are also going to be affected.

Another interesting externality of ship-building is generated by the significance of the role that naval armed forces play in national security. This link may impose quite different considerations on looking at the future of ship-building in Greece, than would be the case under mere economic arguments.

3. A SURVEY OF EXISTING METHODS AND TOOLS

3. 1 FORECASTING

Forecasting charter market fluctuations is a particularly difficult task. There are mainly two categories of difficulties: First, it is difficult to forecast demand for (marine) transport. Second, even if future demand is assumed to be known with certainty, it is difficult to link fluctuations in that demand (and equivalent fluctuations in transport supply) with fluctuations in freight rates, or in other market parameters such as ship prices.

Demand for (marine) transport is a derived demand, depending on factors such as demand for the commodity to be shipped, and existence of alternative means of transport (e.g., an oil pipeline). As such, it not only depends on a variety of macroeconomic factors that are not trivial to predict (oil prices, industrial growth, etc), but is also heavily dependent on political developments, which are even more difficult to predict. The recent war in the Gulf is a prime example: pipeline closures and bombing of oil terminals drastically shifted the demand pattern for oil. It then follows that accurately forecasting both the aggregate demand for ocean transport of a specific commodity, and, a fortiori, the detailed demand on a specific trade route is an almost formidable task.

Some models predicting charter market fluctuations bypass this difficulty altogether, by assuming demand an exogenous parameter, supplied by the user. The user then runs a model that takes transport demand and transport supply (which is easy to predict) as inputs , and produces the freight rate as output, for various scenarios based on different assumptions about demand. The work of Devanney (see Section 3.2) is one example of such an approach.

Alternatively, and for all the difficulties mentioned above, other models explicitly use forecasting/econometric techniques to predict not only transport demand, but also all other parameters of interest (freight rates, ship prices, etc). An example of such an approach is the BDSS software package marketed by Marsoft, Inc., USA. BDSS (for Bulk Decision Support System) is a package to assist operators in the tanker and dry bulk shipping markets. It produces forecasts of all relevant market variables, including freight rates, and newbuilding and secondhand vessel prices, for several standard ship categories. A demand forecasting model is part of BDSS, and the basic parameter in the econometric equations estimating rates and prices is the expected utilization rate (expected demand/expected supply).

Since BDSS is proprietary commercial software, little is known about its methodology. As is usual, the coded product is delivered to the user as a "black box", i.e. in "exec" form. This prevents the user from seeing the structure of the model's algorithms. It is known however that the model is based on forecasting / econometric techniques similar to those widely used in the prediction of other world macroeconomic variables.

Models like BDSS are validated by hindcast runs, i.e. having the model "forecast" the market for a certain period in the past, based only on information available at the beginning of that period. Hindcast runs also serve to fine-tune the model, i.e. adjust the model's parameters or coefficients so that a good fit is observed a posteriori. Of course, the implicit assumption is that the underlying processes that drove the market in the past will remain the same in the future. Since this assumption is not necessarily true, there is a continual need for fine-tuning such models as new market data become available.

By contrast to demand, it is relatively easy to forecast marine transport supply: there is excellent information on both the current world shipping fleet and on the orderbook of ships that will join the supply in the future. This can be exploited in models that calculate freight rates in the charter market as functions of supply and demand, the latter assumed exogenous. Such models will be described in section 3.2.

An alternative approach to forecasting is through time-series analysis. Time-series analysis deals with the situation where a variable or a group of variables is explained exclusively in terms of past observations of itself and purely random factors. The great advantage of this approach is that it does not pre- suppose any causal relationship with other variables, hence not requiring ad hoc modelling assumptions that often are to be blamed for the cautious reception that quantitative methods enjoy among 'real-life' decision-makers. The guiding principle of time-series methods is that all information regarding particular economic variables is captured in its own history and the particular pattern of chance, which are assumed to continue when forecasting is to be undertaken.

An interesting application of time-series techniques is the analysis of models with many economic variables in order to capture cross-correlations between them. In this way several important characteristics of the behaviour of one variable vis-a- vis others have been studied: For example, if cyclical fluctuations are observed one can find out which variable leads and which lags the cycle relative to another variable, whether it is procyclical or countercyclical and so forth. The intensity and the frequency of fluctuations can also be investigated.

The importance of such analysis in understanding the interrelations of various activities in the shipping economy is beyond doubt. Is ship-building a leading indicator for a rise in the supply of charters, or it simply follows a previous peak? Are world-trade fluctuations affected by the capacity of the shipping industry, or the other way around? How does a recession in a national economy affects the schedule in the liner operation, and the location of charters? Questions like these are best studied by employing time series methods, rather than using other models of less than unequivocal validity. A more detailed presentation of the time series method as well as some promising recent developments in forecasting techniques is given in Appendix 7.9.

3. 2 FREIGHT RATE AS FUNCTION OF SUPPLY AND DEMAND

Determining the level of the charter market freight rate as a function of supply and demand dates as back as 1939, with the seminal work of Koopmans (1939) on the tanker market, the most important component of the charter market. The work of Zannetos (1966) further expanded on the same topic.

The basic idea behind these efforts is the demonstration that the tanker market is perfectly competitive. This means that one can consider marginal costs in order to produce the short-term supply curve for tanker capacity. Once demand is known, the intersection with the supply curve yields the spot rate for a particular route. This idea was used later by Devanney (1970), to construct a spot rate model in which demand is exogenous and perfectly inelastic. All tankers are rank-ordered according to marginal cost, and various assumptions on future newbuildings and scrappings are made.

Zannetos did considerable analysis to correlate term rates to the spot rate, as well as other market parameters to one another. He also examined extensively the existence of price-elastic expectations in the behavior of buyers and sellers in the market, a factor claimed to be one of the prime determinants of market behavior.

Devanney also incorporated his spot rate model within a linear programming "transportation problem" formulation to optimize petroleum flows and predict freight rates on a worldwide network basis. This model (which is proprietary and marketed by Devanney's consulting company, Martingale, Inc.) also produces "optimal" oil price differentials at the various oil production or consumption points. Determining optimal price differentials is tantamount to optimizing the dual of the transportation problem defined on the network, with oil prices corresponding to the dual variables on the constraints defined by flow conservation at the corresponding supply or demand points. Establishing "acceptable" oil price differentials on a worldwide geographical basis is considered to be a major type of decision by oil producing entities such as OPEC (see also Appendix 7.7).

The tanker market is so far the only component of the charter market examined so extensively for its rate fluctuations. No comparable models exist for the dry bulk market, lack of market homogeneity being the main reason.

It is also interesting to note that for all the considerable degree of uncertainty in the charter market, none of the methods mentioned so far considers uncertainty in an explicit sense.

3. 3 CHARTER MARKET DECISIONS UNDER UNCERTAINTY

In the Seminar on shipping Management in Bergen (Lorange and Norman (1973)), Devanney presented a dynamic programming formulation for the problem faced by an independent owner operating a single ship in the charter market. The owner is assumed to be risk neutral and, depending on the status of his ship, has the alternatives to spot charter, term charter, lay up, recommission, or scrap the ship. He has to make such decisions at regular time intervals.

This formulation assumes a state space that includes the status of the ship at the moment of decision (available for charter, laid up, in the middle of charter, etc). It also assumes that the spot rate at the next review period depends on the spot rate now and on its time derivative, and evolves according to a Markov process whose transition probabilities are known for all combinations of freight rate values (see also Appendix 7.2).

This last assumption (knowledge of all probabilities), together with the risk neutrality assumption, may be rather strong hypotheses, and as such constitute the model's main limitations. An investigation of the risk neutrality assumption (and, by extension, of ship owners' risk preference structure) was examined by Lorange in the volume by Lorange and Norman(1973).

3. 4 INVESTMENT AND PORTFOLIO ANALYSIS

The reduction of an operator's risk is of prime concern in shipping management. Within this framework one can list the following problems:(a) What is the proper amount of leverage in ship acquisitions? (b) What is the proper liquidity of a shipowning firm (c) What is the appropriate types of ships a shipowner should build or acquire? (d) What percentage of a fleet should be in long term time charters vs tramp operation?

The question of the proper fleet structure can be dealt with portfolio type techniques, as suggested by Lorange and Norman (1973). In portfolio analysis one is interested in asset combinations that are efficient, in the sense that there exists no other asset combination with higher expected return and smaller risk. If one measures the tradeoffs between risk and return through a utility function, the determination of the efficient asset combinations (portfolio) can be found through mathematical programming , provided there is adequate statistical data about the relative performances of the various assets.

An obvious application of these ideas to shipping is to examine the various types of ships from the point of view of risk versus return. One must include in the description of the type mentioned above the various technical characteristics, the condition, age, and other features of the ship. Selecting an horizon of say a year, one can easily determine the return on a unit investment of a ship of a given type, based on its operating profit plus its estimated resale value at the end of the year. Statistical analysis can in principle be carried out to determine such relations.

For portfolio analysis to be useful in practice, the statistical analysis must prove the existence of diversification opportunities, i.e. types of ships whose return are not heavily and positively correlated. Thus if one establishes that there is a correlation close to +1 among the returns on all types of ships, then not much risk reduction is possible. If however there are ship types with small or negative return correlations, the opportunity exists for diversification. To our knowledge no such analysis has been undertaken so far, as for instance Lorange and Norman restrict themselves to theoretical analysis and do not go into shipping data analysis.

Portfolio analysis can also give guidelines on how to allocate the ships of a particular existing fleet between long term time charter versus tramp operation. This can be done in a simple one-period framework or by extending the multi-period dynamic programming approach of Devanney (cited in the previous section) to risk averse decision makers owning a fleet rather than a single vessel. We give a detailed formulation of these ideas in the appendix.

3. 5 ACQUISITION STRATEGY - NEW BUILDINGS AND SECOND HAND

A potentially lucrative but extremely risky shipping decision is that of newbuildings as well as sale and purchase of used vessels. Although these decisions are identical in principle to those in standard investment analysis, shipping investments deserve special attention because of the volatility in the resale price of used ships. In view of this increased uncertainty, standard investment criteria as NPV, IRR are not prominent in shipowners' analyses and even shipping banks do not place too much emphasis on them. In fact, not even risk adjusted NPV methods seem to be in much use, let alone more sophisticated simulation analysis of particular investments.

What seems to be a common strategy in shipping acquisitions is to examine a worst case scenario for a particular ship(s). If the ship can break even (including debt service) at a realistically low charter rate, the shipowner looks favourably upon its purchase. The shipowners seem eager to get the highest possible loan and try to keep their own capital as liquid reserves.

The above strategy would make little sense in a less risky activity, but it seems justifiable in the context of shipping. Given that charter rates are characterised by huge (usually short lived) peaks, a ship that can survive until a peak occurs will definitely be a worthwhile investment by any criterion. The question is whether the shipowner has enough liquidity to stay in the market through the market downturns that will probably precede the peak.

These ideas can be the basis for a much more sophisticated simulation of a particular ship acquisition, where the market prospects will be expressed in probabilistic terms in conjuction with cost factors that are bound to vary. The link between forecasting methods and investment analysis seems particularly important, as one would require a more detailed probabilistic forecast as an input to the simulation than the one available in commercial forecasting software such as Marsoft's.

A different approach to the problem reminiscent of stock market analyses was recently presented by Marcus, Glucksman, Ziogas and Meyer (1991). It should be noted that two of the authors, K. Meyer and B. Ziogas, are actively involved in shipping and thus the observations in that paper have added weight. The methodology proposed is to estimate a value index for a particular class of ships and to compare it with actual prices. The strategy is then to buy undervalued vessels and sell overvalued ones (Buy Low - Sell High). In a recent issue of *Seatrade Review*, Lyons (1992) gives a non-technical description of this methodology under the impressive heading "The making of Meyer's millions".

The sale/purchase activity could also be modelled in a dynamic programming setup again in the spirit of Devanney's dynamic programming model, where an extra decision - the sale of the vessel - is also available to the shipowner at every review period. The sale price could be described by some statistical method and should be coupled to some extent with the spot price. Alternatively, one can write down simpler models that reflect the actual shipowner's decision process that focuses on the decision either to immediately sell the ship or to operate it for one extra period. The decision will be made by simply comparing the current revenue that will arise from selling at the prevailing price versus the net income from chartering the ship plus the expected sale price at the next review period. We provide a technical description of such a model in the appendix.

3. 6 THE OPTIMUM SPEED OF SHIPS

A common practice in shipping is slow steaming in periods of low rates, within of course the contractual limits of the particular charter. Of course, the design speed of a ship is a feature of its constructionn but it is likely that speed can be varied within limits. One can then analyse the speed parameter in order to maximize profits. Evans and Marlow (1985) provide a comprehensive exposition, while Ronen (1980) gives a more sophisticated analysis. Mar Molinero and Mitsis (1984) examine the actual fuel consumption of a ship as a function of several parameters using regression techniques.

The main assumptions in the analysis are (a) Fuel consumption depends on speed in a known way (b) economic parameters remain constant. For a bunker consumption that increases as the cube of the speed it can be easily shown that the speed that maximizes profits is directly proportional to the square root of the freight rate and inversely proportional to the square root of the bunker price. This result is applicable if the optimal speed thus derived is above the minimal speed of the charter agreement. More complicated formulae can be developed to take into account time in port and disbursements, cargo handling costs, canal dues as well as the difference in the speed characteristic of a fully laden ship vs one in ballast. One could also take into account the fact that when slow steaming, less fuel is required and hence more cargo can be loaded. This consideration amplifies to some extent the benefits from slow steaming.

A similar problem arises when a ship is owned by an industrial firm whose goal is to transport its goods at the lowest cost, subject to various constraints on timing, location of the sources of supply and demand, scheduling etc. Here speed of ships could be just one of the parameters that enter the optimization procedure (see Ronen (1986), Brown et al (1987) and the references therein). However, in most such models speed is not specifically taken into account, as it introduces a strong nonlinearity.

3. 7 WEATHER ROUTING

In weather routing, one wishes to determine a path linking the ship's port of origin to its destination port, so that a known measure is optimized. Measures may include transit time (minimum time routing) or a general voyage cost function (minimum cost routing). The problem is due to the fact that weather conditions along the course of the voyage may vary in both time and space, so that the great-circle route (optimal under uniform and constant weather and equivalent to a straight line on the Euclidean plane) is not necessarily the best one. The weather routing problem is complicated by the fact that weather conditions are uncertain. This means that one cannot obtain the entire path from origin to destination as the solution to the problem, but rather a "policy", prescribing vessel direction and speed as a function of vessel location, weather, and time (see also Appendix 7.8).

Although the literature on weather routing is rich, few works view the problem from an Management Science perspective, most of the studies concentrating on the ship/sea/weather interaction. For instance the ESPRIT project KBS-SHIP developed an "Expert Voyage Pilot", which is an expert system that incorporates a knowledge base for many aspects of the ship's operation, including weather routing. Among weather routing studies with an explicit O.R. orientation, we may cite the work of Chen (1978) and of Perakis and Papadakis (1989).

Chen developed a dynamic programming algorithm for the minimum voyage cost problem under uncertainty. The cost function included penalties for arrival after a prescibed date (this makes his approach very relevant for the liner market, in which arrival on time is very important). His approach considered the seakeeping features of the ship as a function of weather, and consisted of an open-loop approach that solved for the minimum expected cost using best available weather estimates, and reoptimizing whenever these estimates changed. Perakis and Papadakis assume a minimum time problem, which they solve using calculus of variations in a discretized setting.

Weather routing packages are commercially available from companies specializing in providing meteorological and voyage information to deep-sea vessels. Oceanroutes, Inc. (USA) is perhaps the best known such company, although its software is proprietary and therefore its methodology is not public. Chen also heads another company providing similar support services.

3. 8 OPTIMAL LOADING PROBLEMS

There are a variety of loading problems in shipping, and a variety of considerations are relevant in loading a ship. For instance, the ship must be loaded in such a way, so that at no time during the ship's journey or during the loading process itself should the structural integrity or the stability of the ship be jeopardized. There are specific commercial software packages that deal with such problems, mainly for tankers, product carriers, and dry bulk ships. No "optimization", in the strict sense of the word, is performed, all of these packages aiming at producing loading plans that are within the acceptable range.

In the loading of a containership, and in addition to the above considerations, an important factor is the ability to minimize port delays that are due to "overstowage". Overstowage occurs whenever a container to be delivered at a certain port is stowed directly on top of another container to be delivered at an earlier port. Stowing some of the containers in such a way causes delays, but may be necessary for stability reasons.

The work of Aslidis (1982,1989) is relevant for this problem. Aslidis developed a variety of methods (dynamic programming, local search, and network-based heuristics), to solve the overstowage minimization problem.

As in the previous cases, there exists some proprietary software for this problem too. Such software is developed in-house by major container shipping companies, and is not publicly or commercially available. It is speculated that this software is based on simple heuristic rules.

A related problem arises when an operator (usually running a liner) wants to select cargoes in order to maximize his revenue for a particular trip. Each type of cargo has different volume - weight characteristic and different freight rate, which is assumed to be given exogenously. The cargo selection should be done without violating the volume and weight constraints of the ship. If there is no possibility to bargain about the freight rates and te operator can refuse cargoes, then the cargo mix that optimizes the revenue can be easily determined by linear and integer programming techniques. Evans and Marlow (1985) also present some empirical solutions for the problem that do not require programming techniques, and thus were useful before the computers made these particular techniques easily accessible. Another interesting problem is the determination of the rates to be set for each cargo type by a line, assuming that in its subsequent operation the line will not refuse any cargo at these rates. In this rate setting problem, the volume - weight chatacteristics of the different cargoes should be taken into account in addition to other operating and demand related factors. Again mathematical programming techniques can prove useful.

3. 9 MAINTENANCE AND REPLACEMENT

Preventive maintenance and replacement of marine hardware is an area that seems well-suited for the application of Management Science techniques. However, to our knowledge, the published literature on this topic is not very rich. Devanney (1971) examines some problems in which the probability of failure of a particular component is not precisely known. That probability is thus treated a random variable that has a known prior distribution. This distribution is then updated in a Bayesian fashion, taking into account information received continually on the operational status of the component. Depending on the problem, Beta or Gamma distributions are used for the priors, and it is shown that the posterior distribution is also Beta or Gamma (with different parameters).

Devanney also presents an "automatic replacement" dynamic programming algorithm, for minimizing the expected total (failure and replacement) cost of a component on board the ship.

3. 10 ROUTING, SCHEDULING, AND VESSEL POSITIONING

Although research on cargo ship routing and scheduling pales in comparison to work on truck or aircraft routing and scheduling, it still constitutes an important body of work. Ronen (1982) and Alexis (1982) give surveys of work in this area. Generally, the literature deals with problems where a fleet of ships (either bulk, or general cargo) has to distribute (either pick up, or deliver, or both) cargo to or from known ports, possibly within prescribed time windows (see also Psaraftis et al(1985) and Brown et al(1987)).

None of the above models considers the charter market in conjunction with routing, because the specific objectives to be optimized are not related to a fluctuating freight rate. A different kind of routing problem brings that connection into play. This is known in the shipping parlance as the "vessel positioning" problem, the problem of taking advantage of differences in rate fluctuations in different geographical areas to maximize profit.

Garmilla (1989) considers a version of this problem in the case of an OBO carrier, the owner of which has the option to "play" in three different markets (ore, bulk, and oil), and move from one trade area to another (possibly on ballast) according to the revenues expected in each. A heuristic with some "look-ahead" capability is developed. Still, this is not a complete vessel positioning model because freight rates are assumed to be exogenous user inputs, rather than forecast by a model.

4. THE IMPACT OF QUANTITATIVE METHODS: THE PIRAEUS SCENE.

This section attempts to assess the impact of methodologies (such as those described in the previous section) on the shipping industry, with a focus on the Piraeus scene.

For the purposes of this project we have extensively visited with various organizations actively involved with shipping in Piraeus (shipping companies, banks, and management consultants). The purpose of these visits was to find out how decisions are being made, and specifically to ask whether Management Science analytical tools such as those described earlier are being used. Although we cannot claim by any means that our survey has been exhaustive (what is true for Piraeus is not necessarily true for London or Oslo), we feel that we have gotten input from a sample that is representative enough to allow us to reach some conclusions.

As a general rule, and not unexpectedly, the answer to the last question ("do you use Management Science tools to support decisions in your company?") turned out to be "no" most of the time. Some minor exceptions to this rule exist, and some companies appeared interested in such methods, but this interest seemed to be due to courtesy or curiosity most of the time (as opposed to a pressing need for solving a difficult problem).

More specifically, the situation with respect to the various types of players in the Piraeus shipping scene can be described as follows:

4. 1 SHIPPING COMPANIES

Only companies in the charter market were solicited (Greece not being very big in the liner business). Most of them seemed to be doing business the old fashioned way: tradition and "gut feeling" are the main factors affecting decisions at all levels, and if analytical techniques are used at all, they tend to be extremely primitive and concern routine calculation problems (e.g., voyage calculations).

A few of the companies appeared to at least intend to place more emphasis on computerizing the management of their operations (payroll, stores and supplies, etc). However, no sophisticated software tools aimed at managerial decision making were generally found: as an example, in a company which is "advanced" in terms of use of computer technologies, important capital investment calculations are being carried out without using any of the widely available investment analysis software.

Another company (operating a tanker fleet) had purhased BDSS, Marsoft's market prediction model (see Section 2.1). In spite of BDSS's stiff (by Greek standards) annual cost (between $12,000 and 20,000 depending on the configuration selected) such a purchase was justified not so much for changing the way decisions are made, but rather for providing a certification that the intuition behind these decisions is in the right direction. To date, a total of ten (10) Greek companies, of which three (3) are banks, have purchased this package. It is interesting to note that one of these companies has purchased the package on the condition that the company's name be kept secret. It thus seems that in Piraeus competitive advantage comes not only by access to sophisticated information systems, but also by keeping this fact secret from competitors, even though the latter may have access to the same information.

Several companies use (or wish to increase the use of) custom-made software developed and/or marketed by management consulting companies such as Danaos Ltd. These companies provide software packages to support the accounting, technical, operation, and chartering departments of a shipping company, by relieving these departments of tedious and time consuming calculations and procedures. None of the methodologies behind these packages can be considered to fall into the realm of Management Science. However, the sucessful use of such packages, although still at its infancy in Piraeus, will certainly free shipping managers from prejudices and fear of such tools, and will raise the potential for the use of analytical methods.

A factor that will probably lead to some more reliance on analytical methods in shipping is that recent events such as the Gulf War and the breakdown of the USSR have brought into focus the need for extra protection against uncertainty. Coupled with the operation of new hedging mechanisms such as Futures Markets in Bunkers and the BIFFEX market, shipowners have been examining in more detail the financial side of shipping. The Greek press even published a gloating report on the success of computerized hedging models that helped shipowners weather the aforementioned crises, although no details are given about the actual computer models used.

The more acceptable management science techniques are by far those with a strong engineering component, such as optimal speed calculations, optimal loading, and weather routing. Still, not much reliance is placed on optimal speed calculations, most operators citing the unreliability or lack of bunker consumption data. On the other hand, weather routing agencies are being consulted to some extent by ship operators in Pireaus. Optimal loading problems were recognized as important but were not of immediate concern to the tramp operators that were contacted.

4. 2 BROKERS

The attitude of ship brokers towards Management Science techniques is similar to that of operators. Even those brokerage houses that are heavy users of information technology do not employ any decision making software. It is interesting to note that Marsoft's sales of their forecasting software in Pireaus did not include any brokerage house. It is our feeling that this is due to the program's stiff price, and it is likely that competing versions of lower price will find use in the brokerage business. Informal conversations with practitioners have confirmed this feeling. However, we speculate that there might be other factors that make the use of market forecasting unlikely in the brokerage business. One such factor, taking Marsoft's point of view, strong sales to brokers would flood the market with BDSS forecasts, jeopardizing their business. Second, from a broker's viewpoint, it would probably be dangerous to attempt to convince a client that this is a good time to buy a ship while at the same time convince another that it is a good time to sell. BDSS standard forecasts could support only one of these two positions, but not both.

We did not observe the use of any formal quantitative analysis in consulting about sale and purchase decisions or in advising about the proper charter selection. It is the feeling of charterers that the limited time available in fixing those deals is much better spent in looking in more depth the fundamentals of the deal, as for instance the ship' s mechanical condition, its marketability and the overall market prospects when sale-purchases are considered. In chartering, the time element is even more crucial as even minutes count in fixing deals, making thus unthinkable the performance of any but the most rudimentary mental calculations. It was stressed however that people with a strong Management Science background who have a feeling of the analytical aspects of shipping decision making would be highly valuable in the brokerage business.

4. 3 BANKS

Much more attention is placed on analytical techniques in the banking environment, where the time pressures are much less marked than in shipowning and brokerage concerns. Formal investment analysis is routinely carried out to evaluate the amount to be lent -if any- to particular owners. Banks also follow closely the changes in the market and take into account specialists' reports, perhaps to a greater extent than individual shipowners or brokers. It is significant that several bank offices in Piraeus have purchased specialized forecasting software. However, it was stressed to us that little emphasis is placed on formal investment analysis and prediction models and then mainly from a negative point of view, i.e. to eliminate obviously bad deals. It is traditional banking criteria that play a dominant role in key decisions.

It is worth noticing that quantitative investment methodologies, such as the one presented in Marcus et al (1991) are reportedly used in efforts to raise venture capital in the shipping domain. Apparently, these fund raising efforts are to a large extent successful although no specific data is available to the authors. Furthermore, we can not assess the role, if any, that the quantitative methodology played in securing sufficient venture capital.

4. 4 CHARTERERS

A field where Management Science techniques have been reportedly used with success by practitioners is in planning the use of their own fleet and the chartering of extra tramp ships by large companies mainly in the oil and minerals business. The scheduling problem of transporting large quantities of raw materials to processing plants and finished products to demand points has received extensive coverage in the literature. Several actual implementations in big firms have been reported.

Optimization scheduling models have been developed as well as simulation tools. These are detailed in the survey by Ronen (1983). The results of optimization models are used mainly as simple non binding guidelines to schedulers since, due to the uncertainties involved, it has been reported that there is just a 30% probability for a ship running under a computerized scheduling model to actually meet its planned schedule. Thus optimizing scheduling models are to a large extent being used to assess the fleet size required to perform the required transportation task while meeting the scheduling constraints. For actual day to day scheduling it seems that simulation models are of wider use and commercial software has long been available, as apparent from the trade journal articles by Cheshire (1972), Hayman (1972), Datz (1968) and the report by Kydland (1969), which refers to work done within the auspices of the Norwegian Institute of Shipping Research.

Liner scheduling problems have also been solved in practice using quantitative scheduling techniques. However, in the (mainly tramp) Piraeus operations we visited, scheduling problems were not of much concern.

5. PROSPECTIVE DEVELOPMENTS

If one asks the general question "where do we go from here?" in the area of quantitative methods in shipping, the answer is that there are two general major (but quite distinct) directions:

1. try to implement existing methods and tools
2. try to develop new ones.

Direction (1) means the implementation of some of the methods presented in Section 3 for the solution of some real-world problems facing the shipping industry. Direction (2) means improving upon the state of knowledge in quantitative methods by introducing and/or developing new or more advanced methodologies for this class of problems. Of course, a combination of the two directions is also relevant. However, in terms of time of actual implementation such a combination lies further ahead of either one of the two main directions above.

The discussion of Section 4 has revealed that (at least in terms of the Piraeus scene) there isn't currently that much in terms of implementation of "any" non-primitive quantitative tool in the shipping industry, let alone a sophisticated Management Science tool. This may lead to the conclusion that the prospects for direction (1) are not very good, particularly for the Piraeus-based shipping industry. Many reasons can be offered for this state of affairs, including a "modus operandi" that is the product of a very long tradition, and the fact that many of the Management Science tools seem obscure and too theoretical for the industry. The general reluctance of academics to engage in anything lesser than PhD-level research is also to blame for this problem.

Yet, it is equally plausible that the situation may be changing, albeit extremely slowly. Companies seem eager to at least "show off" that they are supporters of fancy software or hardware, and that may be contagious. Also, many new-generation managers are, by education, more aware of these tools, and know that certain problems just cannot be solved on the "back of the envelope" anymore, particularly if the competition uses sophisticated models for the same purpose. Finally, maybe academics seem to realize that for something to be useful to industry it does not have to be a PhD thesis (and in fact it probably should not be one in many cases).

Perhaps the key to user acceptance of such models is the need for the user to actively participate in all stages of model development, from problem definition, to formulation, to solution, to prototype development, to implementation. The fact that this happens seldom (if at all) can explain the reluctance of the industry to accept such models. If these models are developed with little or no contact with the real world, it is very unlikely that the industry will undertake the effort to master them. We therefore think that whatever models are developed under direction (2), their use will be limited or nonexistent unless the actual end-user is an integral partner of the development team.

Various EEC-sponsored R&D programs (where industrial participation is mandatory) are good vehicles for such cooperation to occur. Other schemes of academia-to-industry cooperation may exist also: for instance, students may be doing their theses on a topic of interest to a shipping company (or a related company), while working or doing an apprenticeship in that company. The thesis of Papaeconomou (1991) at NTUA - management information system for stores and supplies- is an example, although the student left his company upon graduation and the software was not implemented. Given these caveats about direction (1), what can be said about direction (2)?

Several sub-directions for further research can be considered. These improve upon the state-of-the-art, as this was described in Section 3. A non-exhaustive list follows:

1. The development of an advanced decision support system for the charter (most notably tanker) market is still a target for further R&D and a topic that is of interest to some shipping companies, if developed correctly. Such a tool would complement the BDSS package by examining issues such as allocation of ships to available cargoes (multiple cargo fixing), by explicitly introducing uncertainty and risk, and by managing efficiently the multitude of information that is available to a company from brokerage houses. Babilis (1991), a PhD student at NTUA, is currently working on some of these problems, by developing stationary chartering policies for a single ship under a Markov process for the state of the market and a quadratic utility function. We present an alternative (preliminary) model in Appendix 7.3. It should be noted that the simple model was not unfavourably received in conversations we had with shipping executives.

2. Related to the development of a DSS for chartering, it is crucial to develop a DSS for new orders, sale and purchase of vessels, again combining forecasting and decision methodologies. The simple model presented in Appendix 7.4 is a step in that direction. Since it refers to a single vessel it must be extended to fleets in order to be able to incorporate portfolio concepts as well.

3. Portfolio techniques are of proven value in finance and the experience gained from their application there could be easily applied to shipping. There is a host of important problems that could be addressed in this framework including (a) the selection between tramp operation and long term charter in running a particular fleet (b) the selection of the vessel type to be bought or sold. Furthermore, the shipping industry is in need of sophisticated methodologies that incorporate opportunities for hedging in the day to day operation, and again this is hardly possible without recourse to portfolio analysis.

4. A prerequisite for most of the above applications is a thorough statistical analysis of the maritime time series (BIFFEX, spot rates) using the arsenal of stock market price analysis.

5. A host of promising areas exist for coupling engineering - oriented techniques (ie. stability analysis) with optimization. This is related to scheduling and loading analysis which have already seen lots of application in shipping.

6. Time series analysis should be applied to model the statistical properties of the most important variables in shipping activity, their correlation and their cyclical characteristics. A by product of the analysis will be the construction of leading indicators which are of vital importance in predicting the reversal of a cycle in the shipping market. Furthermore, modern econometric modelling using the framework of rational expectations and information processing can be fruitfully applied to analyze the behaviour of the maritime market. This is especially relevant for the analysis of spot and forward rate markets.

7. In state decision making on shipping matters, the standard economic methodology provides adequate tools for policy assessments. However there is a lack of in depth studies of specific topics on the relation of national economies and shipping. An indicative list of such topics especially relevant for Greece follows:

- The analysis of shipping labour market and its relation with the national one. Issues of job searching, deskilling and reskilling, bargaining institutions, insurance, vocational hazard.
- The role of shipping in the National Income. Structure, size and consumption ropensities of the income generated in shipping. The impact on the Current Account and the role of savings.
- The prospects of shipbuilding in the light of privatisation and market deregulation. Investment, technological nnovation, and spillovers with other sectors of manufacturing. Externalities associated with the links between the commercial fleet and the naval defence system of Greece: Economies of scale, strategic aspects and operational interdependencies.

In concluding this report, a note of optimism is in order. One can not but be impressed from the wealth of subsidized research that is being carried out either in maritime research institutes (especially the Maritime Economics Research Center in Rotterdam and the Center for Shipping Research in Bergen) or in universities. Since shipowning concerns help directly or indirectly these efforts, we believe that it is only a matter of time before Management Science techniques start making a marked contribution to maritime management and practice.

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7. APPENDIX

7. 1 OPTIMAL SPEED OF SHIPS

The main assumptions in the analysis are (a) Fuel consumption depends on speed in a known way (b) economic parameters remain constant. Then the daily variable gross profit GS is given as a function of speed s by the expression GS(s) = RWs/d - c_R - pF(s), where R is the Freight Rate per ton, W the deadweight available for cargo, d the distance including the ballast leg, s the speed, c_R the running costs per day, p the price of bunker/ton and F(s) the daily bunker consumption for a particular speed s. For a bunker consumption specified by the function F(s) = ks^3, with k a factor of proportionality, the following expression gives the optimal speed

$$s_{opt} = (RW/3pkd)^{1/2}$$

This result is applicable if the optimal s is above the minimal speed of the charter agreement. More complicated formulae can be developed to take into account time in port and disbursements, cargo handling costs, canal dues as well as the difference in the speed characteristic of a fully laden ship vs one in ballast. One could also take into account the fact that when slow steaming, less fuel is required and hence more cargo can be loaded. This consideration amplifies to some extent the benefits from slow steaming.

A similar problem arises when a ship is owned by an industrial firm whose goal is to transport its goods at the lowest cost, subject to various constraints on timing, location of the sources of supply and demand, scheduling etc. Here speed of ships could be just one of the parameters that enter the optimization procedure (see Ronen (1986), Brown et al (1987) and the references therein). However, in most such models speed is not specifically taken into account, as it introduces a strong nonlinearity.

One can consider several other speed related optimization problems. For instance, if cc is the capital cost/day and c_r is the running cost per day, the total cost for Y days is (c_c +c_r)Y +pF(s)Y, with p and F as before, disregarding days in port, canal and port charges etc. The transported quantity is T = WY/(d/s) assuming a trip of length d and full loading. Then the cost per transported ton is

$c_T = [(c_c+c_r)+pF(s)]Yd/(WYs) = d[(c_c+c_r)/s+pF(s)/s]/W.$

If the fuel consumption obeys the cube law the optimal c_T is attained for s_{opt} = [c_c+c_r/2pk]1/3, which is a cube root law in contrast with the square root law that obtains for a tramp operator.

One could question the rationale of introducing a capital cost which is sunk anyway and argue thet the proper way to handle speed is within the framework of a dynamic model with fixed requirements on the quantity to be transported. A similar model was presented by Artz (referenced in Evans-Marlow) and leads again to a cube root optimal speed law.

Perhaps the best justification for a cube law is when considering a time charter. The time charterer is assumed to pay a fixed cost R per day plus fuel consumption. Then the total cost for Y days is Y(R+pF(s)) while the total transported quantity is YW/(2d/s). The average cost per transported ton is similar to that derived before and the optimal speed that the charterer should dictate is again given by a cube root law sopt = $[R/2pk]^{1/3}$.

7. 2 CHARTER MARKET DECISIONS UNDER UNCERTAINTY

A dynamic programming formulation can be developed for the problem facing an independent owner operating a single vessel in the charter market. According to this model, the owner is called to make a decision about his ship every T months, where T is the duration of a voyage charter (round-trip) for the route in which the ship will operate. Possible decisions depend on the status of the ship at the time and include chartering the ship for a number of consecutive voyages, waiting, laying it up, bringing it out of layup, or scrapping it. The ship is assumed to have a maximum lifetime of N*T, at the end of which it will be scrapped (if it has not been scrapped earlier).

The basic issue in the formulation is to come up with a state representation that makes sense. A generic state representation is by the pair (X,M), where X is a scalar index showing the status of the ship (in the middle of a charter with k voyages left, available for immediate charter, laid up, or scrapped), and M is a vector describing the state of the market.

To obtain a sufficient representation of the state of the market, M should include at least R1, the spot rate, and $DR_1 = R_1(n) - R_1(n-1)$, its rate of change through time (n is the stage variable index, and the time interval between stages n-1 and n is T). More elaborate representations may include R_m, the m-voyage term rate, or other market variables. However, such a more elaborate representation would be very burdensome computationally. A way out of this problem is to assume that R_m is a known function of R_1 and DR_1, and set $M=(R_1, DR_1)$.

This formulation assumes that we know the conditional probabilities Pr[M(n+1)|M(n)] for all feasible combinations of M(n+1) and M(n). If these probabilities are assumed independent of n, then M evolves according to a dicrete-time, stationary Markov process.

The optimal value function is defined as $W_n(X,M)$, the maximum expected total discounted profit from stage n to the end of the lifetime of the ship, given that the status of the ship and the state of the market at stage n are X and M respectively. It is then straightforward to develop a recursive relationship for W_n. The generic form of this recursion is

$$W_n(X(n),M(n))= \mathrm{Max}_y[\mathrm{DPROFIT}(X(n),M(n),y)+ \rho \Pr[M(n+1)|M(n)]W_{n+1}(X(n+1),M(n+1))]$$

where y represents the various options available to the ship owner (these generally depend on X(n)), DPROFIT(X(n),M(n),y) is the incremental profit associated with decision y if state variables are X((n),M(n)), and ρ is the discount factor. Note that generally state variable X(n+1) is a function of both X(n) and y, and that in case X = "ship in the middle of a term charter", the owner has no alternatives and there is no maximization in the recursion (y is null and DPROFIT=0).

This formulation can be extended to the case the decision-maker is not risk neutral (as implicitly assumed above) but has a general (nonlinear) utility function u(A), with A being his final asset position. In this case, one would need to add the ship owner's initial asset position to the state space of the DP formulation, for that information would be necessary for his decision. An exception is the case in which $u(A)=-\exp(-\lambda A)$, with λ a positive constant (case of constant risk aversion) in which case it can be proven that such an addition into the state space is not necessary. A further extension would be to include many ships in the problem and thus examine possible portfolio effects, as stated in Chapter 3 of this report.

7. 3 OPTIMAL POSITIONING

The objective in this type of problems is to provide a model to help select among alternative charters for a single ship. We assume there are N locations the ship might be located at any time t, indexed by i=1,2,..,N. The owner considers charter offers with destinations indexed by another location index j= 1,2,..,N. The profit from a trip between i and j is assumed to be a known quantity $c_{ij}(t)$ that depends on time in a known way. The trip from i to j is of known duration T_{ij}. If the owner decides not to accept any charter and to wait instead at the same location he can be considered as accepting a dummy trip from i to i of duration $T_{ii}=1$ and cost $c_{ii}<0$. The selection process repeats when a new port is reached and in particular at location j at time $t + T_{ij.}$

The above problem can be formulated in principle as a dynamic programming one as follows. Let V(i,t) be the discounted profit at time t corresponding to the optimal operation for infinite duration. Then V must satisfy the equation

$$V(i;t) = \max_j [\, c_{ij}(t) + \exp(-\rho Tij)*V(j;t+T_{ij})] \qquad j = 1,2,..,N$$

This equation is of only conceptual value as it is not possible to solve it in practice. It is the starting point though for more tractable versions of the problem. In particular, if one is mainly interested in exploiting seasonalities in the charter rates, the problem can be modified as follows: Consider that there is a yearly periodicity in the profit rates and that things repeat every T time units. This means that we have the relations $c_{ij}(t) = c_{ij}(t+T)$ and hence V(i;t) = V(i;t+T). Then the original dynamic programming equation becomes

$$V(i;t) = \max_j [c_{ij}(t) + \exp(-\rho T_{ij})*V\{j;(t+T_{ij})\mathrm{mod}T\}]$$

and it can be solved with standard computational methods (policy iteration algorithms). The solution will provide an optimal strategy that specifies which charter should be selected (if any) in case the ship is located at any location i and at any time t. A reasonable version of the model can be based on bi-weekly time intervals in which case the periodicity is T = 24 weeks. The possible locations need not be more that 10 if we follow the standard maritime area classification schemes. The difficulty with the model is in the determination of the appropriate profit rates $c_{ij}(t)$.

The model can be easily extended to take into account the possible sale of the ship by specifying a dummy location i = N+1 and appropriate values for $c_{i,N+1}(t)$ to correspond to the sale price at time t and set V(N+1;t)=0 to mark the end of the ship's operation. A weak point of the formulation is that it can not incorporate anticipated spot rate changes while keeping the periodic framework. For this a finite horizon model would be more appropriate provided horizon effects are not overwhelming.

7. 4 SHIP ACQUISITION POLICIES

Assuming that a shipowner reviews his fleet periodically, he will sell a ship if its sale price is greater then the sum of its expected revenue plus the (discounted) expected price in the next review period, keeping in mind that the ship has aged. A simple quantitative expression of these ideas would be as follows: Let c be an index of the prevailing charter rates and S an index of the sale price of a new vessel. Let us assume that a ship aged T has running costs r(T) and sale price Sq(T) with q(T) a known ageing function. The proper value of the ship, V(c,S,T) must satisfy the following dynamic programming equation

$$V(c,S,T) = \max \{Sq(T);[c-r(T)]/(1+\rho/2)+E[V(c_{+1},S_{+1},T_{+1})|c,S]\}$$

with ρ being the interest rate and the +1 subscript denoting the next period value. The equation reflects the fact that the ship should be sold if its present price, Sq(T), exceeds its discounted net revenue plus its expected discounted price in the next time period.

The above formulation assumes that the next period values of c,S depend only on their current values, a Markovian assumption . Of course, more sophisticated probabilistic dependence can be written down. On the other hand, if one assumes time independence of c,S the above equation simplifies considerably and computational results can be readily obtained.

7. 5 PORTFOLIO ANALYSIS OF SHIPPING DECISIONS

The question of how to allocate the ships of a particular fleet between long term time charter versus tramp operation can be dealt in the framework of portfolio analysis. A formulation could be as follows : Let a fleet consist of j = 1,2,.., N vessels and examine for simplicity fixed horizon policies. Let $x_j=1$ if the j-th ship is operated in the tramp market, and $x_j = 0$ if it is time chartered for the entire horizon. Let TC_j be the (riskless) return on the time charter, and TR_j the uncertain return of the tramp market. Then the total return is

$R = \Sigma_j\{x_j*TR_j + (1-xj)*TC_j\} = [TC_j + \Sigma_j x_j(TR_j-TC_j)]$

If U is a utility function then the problem becomes

$\max E\{U(\Sigma_j [TC_j + x_j(TR_j-TC_j)])\}$

with x_j being 0 or 1.

The above formulation is highly static since it does not take into account the effects of changing markets or of the possibility to switch among tramp - long term charter operation. To do that, one could develop a model similar to the dynamic programming model of Devanney which was described earlier in Appendix 7.2. In his model Devanney considers the decisions relating to a single vessel that is to be operated for the rest of its life so as to maximize expected profits. A similar model could be written for a fleet of (identical) ships where the objective would be to maximize the expected utility of the operation rather than the expected monetary value. This will give rise to portfolio effects when a risk averse utility function is chosen. In particular, the ratio of tramp operated vs time chartered ships could in principle be examined as a function of both the fleet size, the risk averseness and other parameters. These results would useful to explain the observed behaviour of operators but also in a positive sense as a guide to operating policy.

7. 6 CARGO SELECTION

There are several technical constraints relative to how a ship should be loaded. The obvious constraints are that cargo weight and volume should not exceed the ship's capacity. More technical constraints refer to the ship's stability, and other safety considerations. The operational objective is to select the loading parameters in order to maximize some profit criterion subject to the mathematical expression of the above weight-volume constraints. In the case of the charterer who wants to transport a homogeneous cargo, the obvious criterion is the total transported quantity. In case however there are several different cargos to be transported, a reasonable criterion might be to maximize a weighted sum of the quantities transported. The relative coefficients for the cargoes could reflect their unit profits. The operator of a liner faces a similar problem.

A more detailed desnription of the formulation is as follows: Assuming that there are j = 1,..,m types of cargo, let FR_j be the freight rate (in \$/ton) that holds for the j-th cargo. Also let SF_j be the stowage factor (inverse density) of the j-th cargo. If the line operator were free to select among the various cargoes in order to maximize revenue, he would maximize the function

$\max\ R = \Sigma_j FR_j*X_j$

such that

$\Sigma_j X_j < W$

and $\Sigma_j SF_j*X_j < SF*W$

with $X_j>0$ for all j. Here X_j is the quantity of cargo j to be loaded, W the deadweight available for cargo and SF the ship's stowage factor so that SF*W is the available stowage volume in the ship. In case limited amounts of each cargo is available, further constraints of the form $X_j < B_j$ should be included in the formulation. It should be noted that the above linear programming formulation can be used to derive several results which were obtained in the shipping literature without the use of linear programming. (eg. Evans and Marlow(1985).

The above linear program can be easily solved for the quantities to be loaded assuming that these can be continuously varied. However, the problem is much more complicated in case there are specific cargoes, each of which can be either accepted at its total quantity or be turned down. In that case the optimization is an integer programming problem (multidimensional knapsack) which, though very difficult to solve if the number of cargoes is large, can be routinely solved for a reasonable number of cargo types.

The above formulations form the beginning for realistic models of the optimal liner operation. The actual problem is a dynamic one where cargoes differ according to origin/ destination and this gives rise to difficult dynamic loading problems which have been examined elsewhere in this report. See the references in Section 3.8.

7. 7 OPTIMAL WORLD PETROLEUM FLOWS

In addition to the question of freight rate formation, a natural question that can be asked in the tanker market is how one can determine the allocation of shipping capacity among the great number of possible oil flow routes on a worldwide basis. This would determine traffic on an individual route as a function of more global information on supply and demand. A related question is what are the flows that minimize the total transportation cost. Yet another question is whether there exists a set of "optimal" petroleum price differentials among various oil producers so that flow equilibrium is maintained, and what is the relationship between oil prices and transportation costs.

Not surprisingly, all of these questions are interrelated. Consider the following very simple "transportation problem" linear programming formulation of the problem of minimizing the total cost of supplying oil from m origins to n destinations:

Minimize $\Sigma_{ji} c_{ij}*x_{ij}$

subject to $\Sigma_j x_{ij} = s_i$ (i=1,..,m)

$$\Sigma_i\, x_{ij} = d_j \quad (j=1,..,n)$$

$$x_{ij} \geq 0 \quad (i=1,..,m,\ j=1,..,n)$$

where c_{ij} is the (known) unit transport cost of supplying oil from origin i to destination j (ie, the freight rate which is assumed to be known), s_i is the (known) supply of oil from origin i, and d_j is the (known) demand for oil at destination j. The decision variable here is x_{ij}, the amount of oil that will flow from i to j (for all i and j). Call this problem (P).

If one introduces dual variables FOB_i and CIF_j to the supply and demand constraints respectively, one can obtain the dual (D) of (P) as follows:

Maximize $\Sigma_j\, CIF_j{}^*d_j - \Sigma_i FOB_i{}^*s_i$

subject to $CIF_j - FOB_i \leq c_{ij}$ $i=1,..,m$ $j=1,..,n$

At the optimum, the Kuhn-Tucker conditions dictate that for all pairs (i,j) the product $x_{ij}{}^*(FOB_i + c_{ij} - CIF_j)$ is always zero. If FOB_i is interpreted as the price of oil at origin i (FOB from Free-On-Board) and CIF_j is interpreted as the price of oil at destination j (CIF for Cost-Insurance-Freight), then it follows that the following conditions must be satisfied for all pairs (i,j):

1. If for a pair (i,j) $x_{ij} > 0$ then $CIF_j = FOB_i + c_{ij}$. This means that if there is some flow of oil from i to j, then the CIF price is equal to the sum of FOB price plus freight rate.
2. If for a pair (i,j) $CIF_j < FOB_i + c_{ij}$, then $x_{ij} = 0$. This means that if CIF is strictly less than the sum of FOB plus freight rate, then there is no flow from i to j.

Note that the constraints of (D) preclude that CIF_j be greater than the sum $FOB_i + c_{ij}$, for any pair (i,j). If this constraint is violated, ie. if $CIF_j > FOB_i + c_{ij}$, (D) is infeasible and the corresponding primal solution sub-optimal. If this is the case, a reconfiguration of flows is in order so that these conditions eventually are satisfied (this would correspond to a sequence of Simplex pivots until the optimum is reached).

Note also that if total supply = total demand ($\Sigma_i s_i = \Sigma_j d_j$), one of the constraints of (P) is redundant, and this means that the solution of (D) is not unique. In this case one can set one of the variables of (D) (an FOB or a CIF) to an arbitrary value, and then determine the relative levels of all other prices (differentials) with respect to that arbitrary value. Thus, (D) cannot determine absolute levels of oil prices, but rather optimal price differentials. These differentials are linked to freight rates in the fashion shown above. Furthermore, the objective function of (D) is the total value of oil at destination minus its total value at origin, a difference which (according to duality theory) is always a lower bound to total transportation cost, equality being achieved only at optimality.

The above model is of course simplistic, for it implicitly assumes that supplies and demands are perfectly inelastic, and that freight rates are fixed. An extension and link to a freight rate model would be more realistic.

7. 8 WEATHER ROUTING

A general dynamic programming formulation of the ship optimal weather routing problem can be obtained if we assume that decisions are made sequentially. If n is the stage variable, we define $U_n(X,W,t)$ as the minimum expected cost from the current position of the ship (2-D location X at time t) to its ultimate destination port, given that weather conditions at (X,t) are described by a vector W of meteorological variables.

Major decision variables for the ship are P, the engine power output, and φ, the vessel's heading. Then X(n+1) and t(n+1) are known functions of X(n), W(n), t(n), P, and φ, and the incremental cost between X(n) and X(n+1) is a known function DCOST of all these variables.

A major issue in weather routing concerns the evolution of W, the weather variable. Thus, W may be deterministic or stochastic. The stochastic case is perhaps the most interesting one, especially the case when W(n+1) depends on W(n). If the conditional probability Pr[W(n+1)|W(n)] is known, the recursive equation for U_n can be written as follows:

$$U_n(X(n),W(n),t(n)) = \mathrm{Min}_{P,\phi}\, [\mathrm{DCOST}(X(n),W(n),t(n),P,\phi) + \Sigma\, \Pr[W(n+1)|W(n)] * \\ * \, U_{n+1}(X(n+1),W(n+1),t(n+1))$$

Boundary conditions at the terminal port will set Un equal to zero (or to a known penalty for possible late arrival).

An important computational issue is how to discretize X,W, P, φ, and t, and how to set the stages n=1,2,... Usually, a 3-D grid is set up for the X and t variables, and the problem is transformed into a stochastic shortest path problem.

7. 9 NEW DEVELOPMENTS IN FORECASTING AND ECONOMETRICS

In Section 3.1 we saw that applications of forecasting and econometric techniques in general is rather limited. This is unfortunate given the enormous progress witnessed in applying econometric developments in more conventional areas of economic analysis. Such developments aimed particularly to resolve a number of shortcomings in previous methodologies, that in the past have made econometrics to be at least cautiously received in markets where information gathering was of paramount importance, such as the ship market.

There are some categories of econometrics that can succesfully be applied to maritime economics and we will briefly examine how each of them can be usefuly exploited.

7. 9.1 Time-series Analysis and Forecasting.

Time-series analysis deals with estimation of Auto-Regressive Integrated Moving-Average models, (ARIMA in short), in which a variable or a group of variables is explained (possibly after differencing) in terms of past observations, and a distributed lag of white noise. The great advantage of this approach is that it does not pre-suppose any causal relationship with other variables, hence not requiring ad hoc modelling assumptions that often are to be blamed for the cautious reception that quantitative methods enjoy among 'real-life' decision-makers. The guiding principle of time-series methods is that all information regarding particular economic variables is captured in its own history and the particular pattern of noise, which are assumed to continue when a forecasting is to be generated. In the meanwhile the statistical properties of the ARIMA model can be fruitfully utilised to establish important properties of the time-series, like seasonality, trends, cycles etc. ARIMA models can be easily built for a single time-series, in which case the above properties are associated with the particular variable.

Another promising application of time-series techniques is the estimation of multivariate ARIMA models in order to capture cross-correlations between different economic variables. In this way several important characteristics of the behaviour of one variable vis-a-vis others can be studied: For example, if cyclical fluctuations are observed one can find out which variable leads and which lags the cycle relative to another variable, whether it is procyclical or countercyclical and so forth. The intensity and the frequency of fluctuations can also be investigated.

The importance of such analysis in understanding the interrelations of various activities in the shipping economy is beyond doubt. Is ship-building a leading indicator for a rise in the supply of charters, or it simply follows a previous peak? Are world-trade fluctuations affected by the capacity of the shipping industry, or the other way around? How does a recession in a national economy affects the schedule in the liner operation, and the location of charters? Questions like these are best studied by employing Vector Auto-Regressive methods, rather than estimating structural models of less than equivocal validity.

In shipping it is often difficult to associate several important variables with other explanatory variables, especially by practitioners lacking detailed knowledge of econometrics. Time-series models dispense with such 'structural' modelling requirements and can be straightforwardly applied for the variable(s) in concern.

Several estimation packages, (like TSP, RATS, micro-FIT, PC-Give, etc) offer very efficient time-series methods and are readily available for use in any type of maritime variables. With little extra programming, they can turn into user-friendly interactive programms designed for a specific range of variables. Estimation methods can also be employed to capture particular characteristics of the decision process in the shipping sector, such as information processing, reaction patterns, speculative behaviour etc.

7. 9.2 Advances in Econometric modelling.

The suspicion that currently surrounds black-box econometric models in the shipping industry is not unlike the criticism surfaced towards the traditional estimation techniques in the second half of the 1970s. Epitomised by the seminal Lucas's Critique (1976), traditional model-building was found unrealistic in assuming that private agents are backward-looking and impotent in timely realising the future effects of changes in policy regimes. The theory of Rational Expectations allowed for a forward-looking modelling of private sector expectations, reflecting a 'strategic' behaviour not only for government, but also for other economic agents. This allows them to react to policy announcements, yielding outcomes that differ substantially from the traditional backward-looking framework of analysis. By now Rational Expectations have been largely incorporated in econometric model-building. New generation models offer more realistic outcomes, and can be used for forecasting under alternative assumptions about policy regimes.

The description fits several situations in shipping decision-making. The reaction of the spot charter market to changes in world-economic activity obviously depends on the ability of agents to correctly assess the impact of these changes over time. Information on trade patterns, government policy, and both the national and international economic climate can, if properly analysed, to give some guidance over the response of maritime markets. It is precisely this framework of information-processing and strategic-reaction that the theory of Rational Expectations helps to build.

In fact, nowadays we are witnessing a relaxation of the strictures of the Rational Expectations Hypothesis. Because it is often argued that full and timely information may be difficult to be possessed by all economic agents, knowledge of fundamentals cannot be realistically assumed. Phenomena like price-bubbles, positive-feedback trading, fads etc are often observed in spot markets to demonstrate persistent deviations from fundamentals. Although they are less likely to occur in shipping, because fundamentals are more closely tied to real (as opposed to speculative) economic activity, they nevertheless pose the problem of markets operating with less than full information. Current research tries to identify patterns of bounded rationality and gradual learning that asymptotically converge to the fundamental solution implied by the full rationality assumption. Applied to shipping, such models could lead to a fruitful combination with the expert systems currently used to obtain guidance under uncertainty or generate 'forecasts' when an exogenous variable changes.

Two types of models can be developed when such a research initiave is undertaen: One describing specific maritime markets, in which variables describing the rest of the economy are taken as exogenous. Then this 'maritime' model can be linked to a model describing the overall economic activity. This becomes all ethe more important when shipping industry plays a substantial role in a national economy, as typically is the case with Greece.

Finally, another area of econometric methods applicable to shipping is that related to causality tests. In shipping, as certainly in other markets, it is useful to know which direction goes the use of one variable to explain the behaviour of another. For example, are charter prices explaining the extent of contracting or vice-versa? Granger's causality test can be used to obtain an interesting insight about the interaction of different variables. In fact, such a test should precede any attempt to formulate equations to be estimated, because the categorisation into dependent and explanatory ones may be completely misplaced.