A Valuation of Options to Extend the Time Charter Period: The Application of Artificial Neural Networks

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Approval Sheet

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인공신경망을 활용한 용선기간연장옵션의 가치평가

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요 약

해운시장의 옵션에는 파생상품으로 거래되는 운임옵션과 용선 또는 신조계약에 수반되는 실물시장의 옵션이 있다. 실물시장의 옵션 중 용선계약에 추가되는 정기용선의 기간연장과 화물수송계약(COA)의 추가 항차 옵션은 실무에서 아주 빈번하게 다루어진다. 파생상품이든 실물이든 운임옵션에 대해서는 이론적인 가치평가가 이루어지지 않고 대체로 운임선도(FFA)시장의 미래물 가격을 기반으로 그 가치가 추정되는 것이 현실이다. 해운의 옵션은 Black-Scholes모델(BSM)과 같은 이론모델이 직접적으로 적용되기 어려운 형태이므로 학문적으로 많은 연구를 필요로 한다.

이 연구는 용선기간연장 옵션을 대상으로 하고 있다. 선물옵션(option on futures)의 성격을 가지고 있는 용선기간연장 옵션을 기대가설과 효율적시장가설을 근거로 Black-Scholes모델을 적용할 수 있는 유럽식 콜 옵션형태로 변환하여 그 가치를 평가한 후 실현가치와 비교함으로써 Black-Scholes모델의 적용타당성을 테스트하

였으며, 최근 경영, 재무 영역에서 활용도가 커지고 있는 인공신경망(ANN)을 적용하여 옵션의 가치를 평가한 후, 그 결과를 Black-Scholes모델과 비교하였다.

이 연구는 용선기간연장 옵션에 대하여 정형화된 계량모델을 적용하여 평가한, 그리고 인공신경망을 적용한 첫 시도라는 점에서 의미가 있다. 특히 인공신경망의 적용은 해운시장의 다양한 분석에 기계학습분야를 적용하는 후속연구를 이끌어 내는 측면에서 중요성이 있다. 이 연구의 결과를 실무에 적용하면 지금까지 정확한 가치평가 없이 주먹구구식으로 이루어지던 용선기간연장 옵션에 대한 가치평가의 가이드라인을 제시함으로써 의사결정의 합리성을 제고하는 데 직접적으로 기여할 것으로 기대된다. 또한 저시황기에 용선연장 옵션이 신용도가 양호한 용선주에게 대가 없이 제공되던 관행에 비추어 신용위험에 대한 계량적 평가의 근거로 활용될 수 있다는 면도 부수적인 성과가 될 것이다.

이 연구는 자료의 제약으로 파나막스형 벌크선 시장에 한정하여 수행되었다. 향후 해운의 다른 영역에 대한 연구는 이 연구의 결과를 일반화하는 데 중요한 역할을 할 것이다. 또한 인공신경망을 적용한 옵션가치의 평가가 이 연구에서 정의된 1년 후의 3개월에 대한 시황예측의 성격이 있어 시황예측 영역으로의 확대도 기대할 수 있다. 이 경우 Black-Scholes모델에서 사용된 입력변수 이외에 운임선도시장의 자료 등 다양한 입력변수를 추가하여 그 성과를 검증할 수 있을 것이다.

핵심어: 용선기간연장옵션; Black-Scholes옵션가치평가모형; 인공신경망

Abstract

Options in the shipping market consist of paper freight options and physical options attached to charterparties or newbuilding contracts. The options most frequently associated with the physical shipping market are options to extend the charter period on time charters and additional shipment options attached to contracts of affreightment. In both the paper market and the physical market, the value of freight options, in practice, is estimated mostly by referring to the forward curves of freight derivatives. The option on freight has different properties from its financial counterparts, and the straightforward adoption of theoretical models like the Black-Sholes option pricing model (BSM) has not produced promising results. So far, academic research in this field has also hardly made a meaningful contribution to practice and is in need of further elaboration.

This research focuses on the period extension options attached to time charter contracts. In this paper, extension options, which have the property of options on futures, were conceptually transformed into regular European call options before the BSM was applied. The efficient market hypothesis (EMH), which justifies the parity of the performance of a long-term charter to that of repetitive short-term charters for the same period, worked as the basis of the conversion.

The option values determined by the BSM were compared with the actual realized values to verify the applicability of the model. Additionally, a robust relationship mapping model, artificial neural networks (ANN), was employed to derive the option values, and then the results were compared with those of the BSM. The ANN is recently expanding its application to business, finance, and

management, and is drawing attention in the areas of discrimination, pattern recognition, and forecasting.

This study is meaningful as the first-time application of both the closed-form solution and the ANN to the valuation of physical freight options. In particular, the application of the ANN is expected to lead the active adoption of machine learning tools in the analysis of shipping market behavior. The result of this research can contribute to enhancing the quality of chartering decisions by providing criteria to determine option values. The decision rationality to be achieved by the model can be contrasted with the fact that, so far, decisions have been made with a 'rule-of-thumb' valuation of options. The extension option, in reality, tends to be granted to charterers with better credit, even free of charge when the market is at its trough. Hence, the results could also be used as a tool to quantify counterparty risk.

This analysis is limited to the Panamax bulk market, which has long-term data consistency. The extension of the study to other segments of bulk shipping such as Cape, Supramax and even to wet bulk markets will help generalize the model's performance. The result also implies the 'forecasting' performance of the ANN because the value of the extension options contains the information required to make freight market forecasts. Therefore, the study can be extended to the area of forecasting. In that case, the performances can be tested with additional input variables, such as forward market features, to the BSM input variables.

Keywords: time charter extension option, Black-Scholes option pricing model, artificial neural networks, ANN

Chapter 1 Introduction

1.1 Background

Freight options consist of options as shipping derivatives and physical options. The main difference is whether the physical delivery of the freight service, which is required in physical options, is necessary.

Paper options on freight were introduced in 1985, when BIFFEX was launched. The lack of hedging effectiveness of the derivatives based on the Baltic Freight Index (BFI), which was a composite of diverse shipping sectors, resulted in the de-listing of freight options in April 2002. Currently, freight options are traded as over-the-counter (OTC) instruments, and the annual trading volume in 2015 was about 300,000 lots.

Freight options in the physical shipping market are as important as their paper counterparts. They stem from several parent contracts: period extension options are attached to the time charters; additional shipment options are added to contracts of affreightment; and newbuilding contracts are often concluded with an optional number of vessels granted to ship-owners.

The common practice of granting charter period extension options without assessing the values causes problems in chartering practice. In particular, when the market is at its trough, owners tend to grant the optional period to relatively more credible charterers. The problem is that the extension option is written mostly free of charge and the owners do not assess how much of the value is transferred to the charterers. Both parties have no theoretical ground to negotiate the hire for the optional period and the valuation relies on the forward curve of freight derivatives as a rough guideline.

Academic research in this field has hardly produced any meaningful results so far and is definitely in need of more attention. This paper addresses the valuation problem of charter period extensions option attached to time charters.

1.2 Research Purposes

The option valuation theory was developed in the 1970s and has been actively used as a norm to price financial and commodity options. The valuation of freight options, however, has made little progress both academically and practically. The possible reasons for this are as follows: the market activities of freight derivatives picked up after 2004, when volatility in the freight market showed an unprecedented increase due to the so-called ‘ China shock’; forward curves, as easily accessible references, are used as the basis for the pricing of freight derivatives; paper freight options are Asian-style options where the straightforward application of a closed-form solution is not possible; period extension options are attached to period charters and they do not constitute an object of separate trading and valuation; period extension options share properties with options on futures, of which the valuation is not straightforward; and additional shipment options are in the form of American-style options where a closed-form solution cannot be applied.

In this paper, the Black-Scholes option pricing model was applied to charter period extension options with a necessary transformation, and the performance was measured. Additionally, one of the most popular tools in machine learning discipline, artificial neural networks, was employed to exploit its advantages against traditional parametric models: it is robust to specification errors because it does not rely on restrictive parametric assumptions; it is adaptive to structural changes in the data-generating process; it is flexible enough to encompass a wide range of assets; and it is relatively simple to implement.

The objectives of this paper are summarized as follows:

- To test the applicability of the BSM to the valuation of charter extension options
- To measure the performance of the ANN, an alternative non-parametric estimation model which does not require assumptions on the probability distribution
- To compare the performances of the above two models
- To enhance the decision rationality of chartering desks, especially in this unprecedented depressed market when owners are pressed to grant the options free of charge
- To suggest an approach to shipping market forecasting and the quantification of counterparty risk

1.3 Research Scope

Physical freight options can be involved in diverse areas of chartering and newbuilding markets. The valuation of charter period extension options, which is the most common type of physical options, is the focus of this research.

The ANN model requires data intensity. Relatively long freight cycles and frequent structural breaks in the shipping market suggests that a data series of over 10 years is appropriate to adequately perform the training and testing of the model. The problem is the consistency of the freight series data, and only the Panamax series satisfied the consistency requirement. Hence, the market is confined to the Panamax bulk market. The data period is 16 years from 2001 to 2016, and weekly observations were used.

The models employed are the BSM and the ANN. The BSM is recognized as a groundbreaking model because it incorporates the concept of risk neutrality (Duffie 1998). This means that the return on the risk-free portfolio is the risk-free rate, not an expected return reflecting investors' risk preference. It provides the market participants with a guide for making a fair valuation, and thus contributed to the growth of options markets. The ANN is a robust, non-linear model inspired by a biological study of the human brain, and is capable of learning relationships from data. The strength of the model is that it does not require assumptions about statistical distributions (Smith & Gupta 2000) and often performs better than other methods (Kaastra & Boyd 1996).

1.4 Research Procedures

The research started with a clear identification of freight options. It is essential to understand the dynamics of bulk trading before freight options are covered; hence, the details of bulk freight trading were introduced first. The anatomy of freight options followed the explanation of physical freight trading.

The period extension option has a similar structure to options on futures (otherwise called futures options), which can be accessed in the finance and commodity sectors. The strike price of the option, if exercised, works as the contract price of the futures to be activated at maturity, and the futures can be settled either at profits or at losses depending on the progress of the market. The period extension has a structural resemblance to futures options in that the charterers are exposed to the profits or losses for the optional period. The averaging mechanism for settlement differentiates charter period extension options from financial futures options.

Next, the data source and some descriptive statistics were introduced. The assumptions of the BSM include lognormality and the distributional feature is important in the analysis. Some descriptive statistics on the input series were then presented.

The next step is the establishment of assumptions on which the analysis was carried out. These assumptions include the firm period, the optional period, the exercise price (whether it is different from the firm period rate) and the timing of exercise (whether it is only at maturity or at any time before maturity). Some of the assumptions were set for the purpose of avoiding any unnecessary complexities in the analysis.

The BSM was employed to investigate the applicability of the model. The straightforward application of the model to charter period extension options is not appropriate because the extension option shares characteristics with options on futures. A conceptual conversion of the extension options into regular European options was attempted based on the expectation hypothesis of term structure and the efficient market hypothesis (EMH).

For the application of the ANN, the BSM input variables were fed as input features. Other variables, except for the spot freight rates, were not considered to ensure the comparability of the model performances. The spot market rates were added for the ANN to reflect the market dynamics more sensitively.

Considering the structural breaks in the freight series, data randomization was carried out before training. A simple time-based separation of the original series into training and test sets can lead to poor performances when the two disjoint sets display inconsistent statistical properties.

The last stage compared the results and drew conclusions.

1.5 Contribution

This study is meaningful as the first-time application of both the closed-form solution and the ANN to the valuation of physical freight options.

The result of this research can contribute to enhancing the quality of chartering decisions by providing criteria for determining the value of extension options. The decision rationality to be achieved by the model can be contrasted with the fact that so far, decisions have been made with a 'rule-of-thumb' valuation of options. Additionally, it will lead to a better valuation of the company itself when the company holds a number of physical freight options.

The extension option, in reality, tends to be granted to charterers with more creditability, even free of charge when the market is at its trough. Hence, the results could also be used as a proxy to quantify counterparty risk.

Additionally, the valuation of the options to be exercised in a year is closely associated with the concept of market forecasts. This research can show an alternative to the time-series approach typically used in market forecasting.

1.6 Structure of the Paper

The structure of the paper is as follows. Chapter 2 encompasses an essential knowledge on bulk shipping and freight options. The knowledge foundation focuses on the trading aspect of ocean transport services and freight rate risk management. The existing literature is extensively covered in Chapter 3. It includes papers on various freight related options, the EMH, expectations theory and the ANN. In Chapter 4, the data is described and basic assumptions are set to make this research feasible. The next two chapters specify the methodology used for this study, i.e. the BSM and the ANN. The variables of the models are introduced and the pre-treatment of the data is also explained in this section. Chapter 7 summarizes the results of the models and compares the performances. Finally, the thesis is wrapped up with conclusions, limitations and suggestions for further research.

Chapter 2 Bulk Shipping and Freight Options

2.1 Bulk Shipping as Freight Trading

2.1.1 Freight trading

Shipping is generally defined as the provision of water transport services. This definition, however, fails to embrace the diversity of shipping businesses and does not reflect the core properties of shipping services. For example, it cannot explain the 'owner' model of shipping business represented by many Greek ship owners who are not normally involved in the physical transport of cargoes, and it is limited in depicting the dynamic nature of market risk management because the market risk of the transport service providers is confined to squaring the intrinsic positive exposure.

An alternative way to identify shipping is to define it as the 'trading of freight'. 'Freight' here means either carrying capacity or transportation service[1] and is measured by the production of the trading unit and the period. The trading unit can be a TEU (twenty-foot equivalent unit) slot for container shipping, or a whole vessel in bulk chartering. In the latter case, the measurement of carrying capacity is *vessel* x *period*. The object of freight trading has a 'time' element in addition to the concept of quantity. This is the main source of differences from other tradable commodities.

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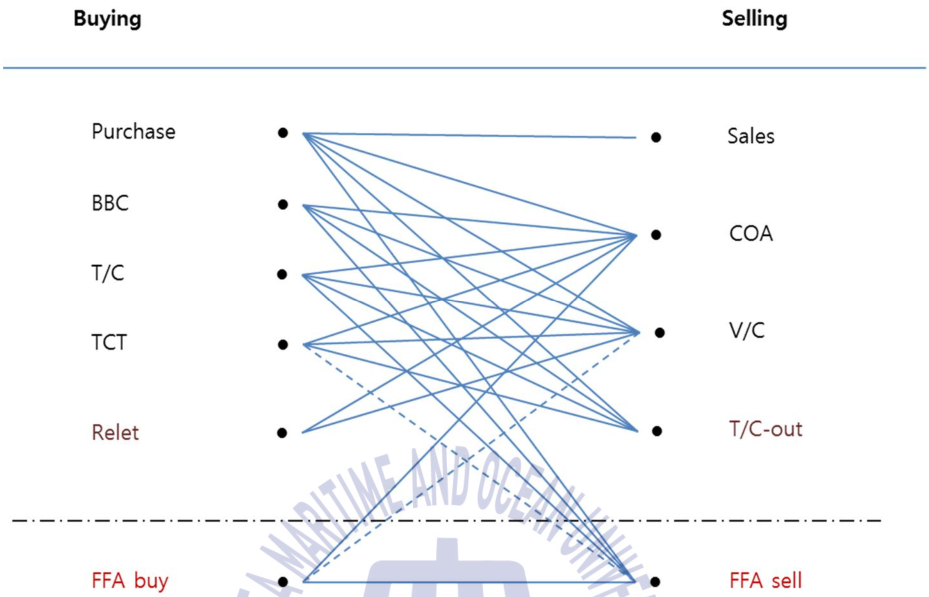
[1] In this paper, the terms 'freight' and 'carrying capacity' are used interchangeably.

Figure 1 displays the combination of freight trading in bulk shipping.



Source : Author's elaboration

FIGURE 1 FREIGHT TRADING MIX [2]

The types of carrying capacity in the chartering market can be divided into three categories according to the costs implicitly borne by the charterers: the bareboat charter (BBC), where the capital cost is transferred to the charterers; the time charter (T/C), where capital costs and operation expenses are borne by the charterers; and the voyage charter, where capital cost, operational expenses, and voyage costs are covered by the charterers. The above cost transfer is purely conceptual because the actual charter hire is determined not by the owners' cost

[2] The title 'Freight trading mix' is originated by the author.

structure but by the supply and demand dynamics of the chartering market. The costs borne by the charterers are summarized in Table 1.

TABLE 1 COSTS BORNE BY CHARTERERS

	Capital Expenses	Operating Expenses	Voyage costs
BBC	○		
T/C	○	○	
V/C	○	○	○

The trading - buying and selling - of freight takes place in the form of a variety of contracts. The structure of trading in the relevant markets is displayed in Table 2. A detailed explanation of freight trading is indispensable in this chapter because an overall understanding of freight trading serves as the foundation to study options in the shipping industry.

TABLE 2 FREIGHT TRADING STRUCTURE

Markets	Buying of Freight	Selling of Freight
Newbuilding / SNP	Purchase	Sales
Chartering	BBC	COA
	T/C	V/C
	TCT	*T/C-out*
	Re-let (Sub-let)	
Derivatives (paper)	FFA buy	FFA sell
	Put option buy	Call option buy

The purchase of carrying capacity in the physical market can either be in the form of the purchase of vessels or the charter of vessels. Vessels can be purchased through newbuilding contracts or sale and purchase (SNP) agreements in the newbuilding market and the SNP market, respectively. The period involved in the purchase is supposed to be for the remaining life of the vessels, but the actual retaining period depends on the owners' strategic reactions to market changes.

In the chartering market, the purchase of freight varies according to the separation of responsibility. Under a BBC contract, a vessel in its bare state, i.e. unmanned with no maintenance arrangements, is delivered to the charterers. Hence, it is referred to as a 'bareboat' charter. In practice, BBCs are entered into for a reasonably long period of time, e.g. for over 3 years. This is due to the impracticalities involved in the charterers' arrangement of ship management services when the BBCs are entered into for a short period of time.

Time charter contracts are different from BBCs in that the operational expenses of the vessel – including manning costs, repair and maintenance costs, the insurance premium, and dry-docking expenses – are borne by the owners. Therefore, the vessel is off-hire if she becomes commercially un-utilizable due to technical failure.

The cost-bearing structure of a trip time charter (TCT) is identical to that of the time charter. The determination of the TCT period, however, differs from the period charter. The charter period of the TCT is usually an approximate period required for the completion of a single voyage or two consecutive voyages, while the period of the T/C is for a fixed period from a minimum of 3 months to several years, which can be extended up to the end of the commercial life of the vessel.

The re-let, otherwise referred to as a sub-let, in Table 2 is not exactly a method of purchasing carrying capacity but rather a counter trade of covering the previously secured cargo-carrying contracts. The owners who enter into a voyage charter (V/C) or a contract of affreightment (COA), instead of performing the contract, play a role as charterers and enter into a separate charter contract with other operators. The re-let can be interpreted as 'assignments' of the secured V/Cs or COAs.

The owners also have a variety of contracts related to the selling of freight. The disposal of possessed vessels in SNP markets do not constitute a regular ongoing shipping business but it is an important choice of decision for owners, especially from the point of freight rate risk management, which is covered later in this chapter. SNP transactions can be undertaken for the purpose of further trading or for demolition.

Another method of selling freight is by entering into cargo-carrying contracts, which can be divided into two different types: the voyage charter and the contract of affreightment. The V/C is an agreement by which a specific amount of the designated cargoes is carried from a loading port(s) to a discharging port(s) at an agreed rate. The freight rate of V/Cs is quoted as dollars per unit of cargoes carried, while the hire of T/Cs is calculated on a 'per-day' basis for the charter period involved. COAs can simply be described as a bundle of V/Cs. The number of shipments, often with some optional shipments, and the contract period are determined when the contract is concluded.

An alternative way of selling carrying capacity is to let the vessel out to other ship operators. The concept of the charter, in this case, is identical to the T/Cs used when buying freight, except that the parties involved in the trading are reversed. Figure 2 displays the payoffs of the buying and selling of freight. When freight is bought, the profit of the owners is positively correlated to the market, but when it is sold, the positive market movements result in growing losses.

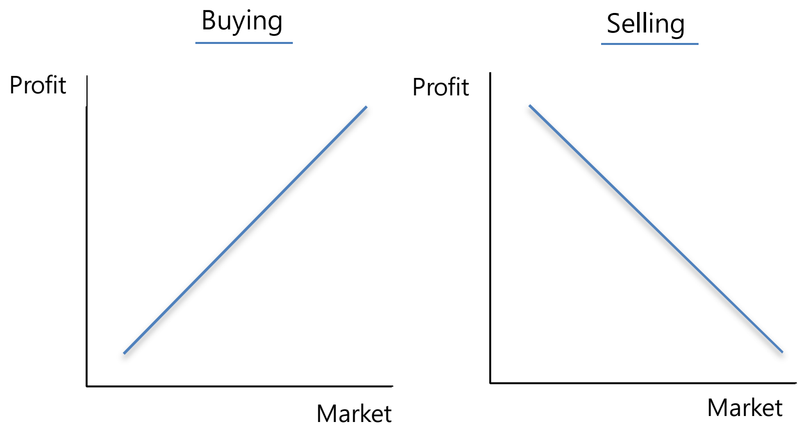


FIGURE 2 PAYOFFS OF BUYING AND SELLING OF FREIGHT

The trading of freight is not limited to the four physical markets listed in *Maritime Economics* (Stopford 2009): the newbuilding market, the sale and purchase market, the freight market, and the demolition market. The freight derivatives market, otherwise called the paper freight market, is where the players can go long or short with the freight. One of the most utilized freight derivatives is the Forward Freight Agreement (FFA).

Freight derivatives started their history with the launching of the BIFFEX (Baltic International Freight Futures Exchange), which is based on the Baltic Freight Index (BFI) as an underlying asset. The limitation of the 'composite' index and the rigidity of the standardized futures led to it being delisted from the exchange in 2002.

Even though the first FFA trading was made in 1992, trading growth had been slow until the advent of the super boom in the mid-2000s. Extreme volatility during the period resulted in the rapid expansion of derivatives trading. FFA trading has the same effect as the buying and selling of vessels in the physical market, and earnings can be realized without operational complexities. Freight options are also one of the most important building blocks of the freight derivatives market. Freight options will be explored in detail in the next section.

2.1.2 Risk management

Freight derivatives are closely associated with risk management in the shipping industry. Here, the risks involved in the shipping industry are briefly covered. There are a wide range of views regarding the classification of risks. This might be because a single taxonomy of the risks cannot be universally applied to a variety of disciplines: trading, insurance, project management, etc. Shipping-related risks are classified in Table 3.

TABLE 3 RISKS INVOLVED IN SHIPPING

Risks	Examples
Market risk	Freight/Hire changes
	Fuel price changes
Credit risk	Contract defaults – early redelivery, non-performance of shipments
	Bankruptcy of counterparties
Operational risk	Internal fraud
	Breach of rules and regulations
	Business disruptions
Pure and technical risk	Physical accidents and breakdowns
	Technical abnormalities – congestion, weather disruption, cargo delay
Geo-political risk	Legal and compliance risks
	War and piracy
Financial risk	Interest rate changes
	Exchange rate changes

Source : Author's elaboration

Shipping is characterized by its severe volatility, and the market risk, otherwise called the freight rate risk, in the shipping business is one of the most important subjects in risk management (Kavussanos & Visvikis 2006).

Freight rate risk can be measured as a combined effect of the volatility of freight rates and the exposure of the business portfolio to market changes. Volatility is intrinsic to the market and is beyond the control of individual players. Hence, the practice of market risk management in the shipping business is centered on the continuous adjustment of its portfolio exposure.

Freight derivatives are a very effective means of market risk management due to their simplicity, homogeneity and transaction efficiency. The adjustment of risk exposure in the physical shipping market often faces a lack of market liquidity or complexities in the negotiation. On top of the above, freight derivatives do not involve operational complexities caused by the physical delivery of transport services. Thus, paper transactions can be more effective in market risk management than their physical counterparts.

2.2 Freight Options

Freight options consist of options as shipping derivatives and physical options. The main difference is whether the physical delivery of the freight is necessary. It is required in physical options.

2.2.1 Paper freight options

Options on freight were first introduced in 1985 when BIFFEX started trading. The insufficient hedging effectiveness of the derivatives based on the Baltic Freight Index (BFI), which was a composite of diverse shipping segments, resulted in the de-listing of freight options (together with freight futures) in April 2002. Currently, freight options are traded as over-the-counter (OTC) instruments. Figure 3 displays the weekly option trading volumes.

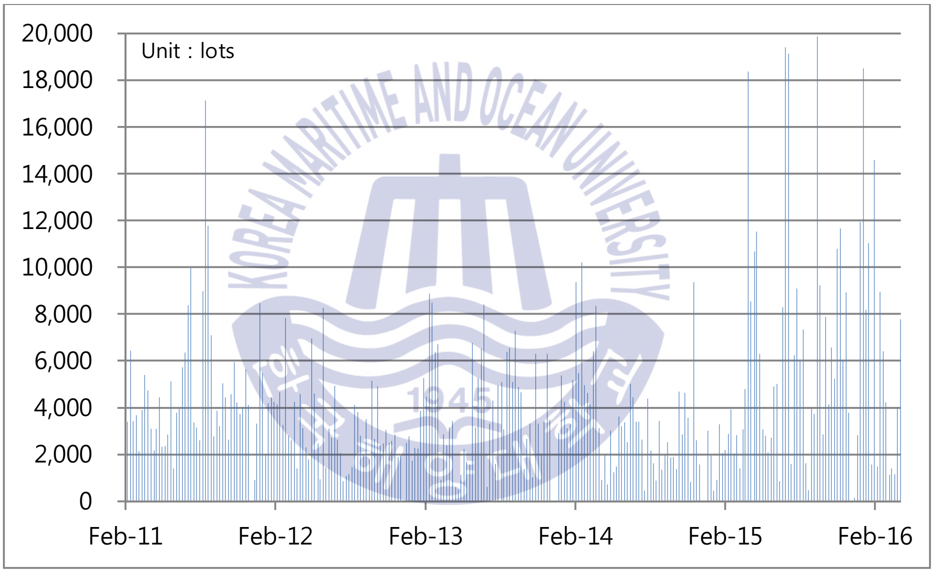


FIGURE 3 OPTION TRADING VOLUME

The trading of freight options is similar to that of FFAs. Deals are normally made through brokers and options can be mark-to-market cleared or settled at maturity. The settlement methods determine the characteristics of the freight derivatives and constitute an important criterion to categorize options.

The classification of options can be made from diverse viewpoints. Call and put options are based on the rights the buyers can exercise. The call option is a right to buy and the put option is a right to sell assets. Options can also be classified as per the timing of the exercise of options. A European option can be exercised only at its maturity, while an American option can be exercised at any time before maturity.

Options are referred to as 'Asian-style' if either the settlement or the strike is calculated as an average of a certain period between the start date and maturity. The former is called an average price Asian option and the latter an average strike Asian option. A paper freight option is an average price Asian option but with some deviations. Paper freight options are basically settled on a monthly basis. A paper freight option for a quarter, for example, is viewed as the aggregation of three options with a month of averaging period, respectively. A graphic display is shown in Figure 4.

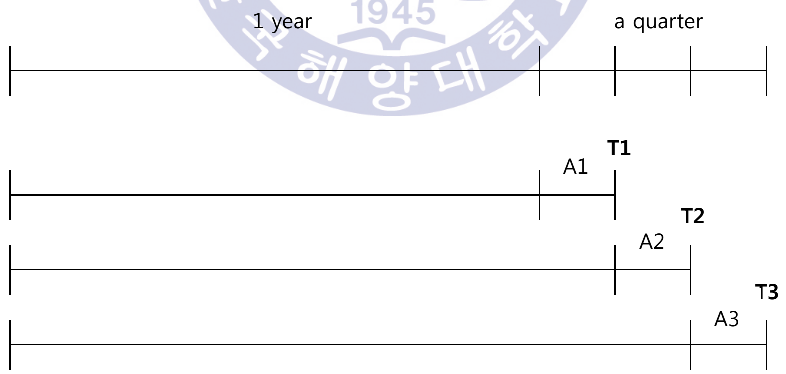


FIGURE 4 PAPER FREIGHT OPTIONS FOR A QUARTER

An option for a quarter in a year's time is traded as a single transaction, but the option, in effect, consists of three Asian options with an identical strike price: an option with an expiry date of 1 year and 1 month (T1) with the averaging period of the last one month (A1), an option with an expiry date of 1 year and 2 months (T2) with the averaging period of the last one month (A2), and an option with an expiry date of 1 year and 3 months (T3) with the averaging period of the last one month (A3).

2.2.2 Physical freight options

Freight options in the physical shipping market are frequently traded. Freight options in physical markets are attached to several parent contracts. T/Cs often include period extension options. Additional shipment options are attached to COAs, and ship owners conclude newbuilding contracts with an optional number of vessels. Period extension options and additional shipment options are quite common in the chartering market.

Physical options are different from paper freight options: they are not traded separately from the original charter contracts; there is no secondary market; the option premium is not paid up-front; and there is no cash settlement at the end of the optional period. In addition, the settlement is implicit in the sense that the payoff is a transfer of opportunity gains from the option writers (owners) to the charterers, and there is no cash settlement at the end of the optional period.

Figure 5 displays the concept of the period extension option. The maturity of the European option is denoted ‘T’, and ‘A’ is the period for which the payoff is calculated. Attention must be paid to the fact that the payoff calculation is after the expiry.

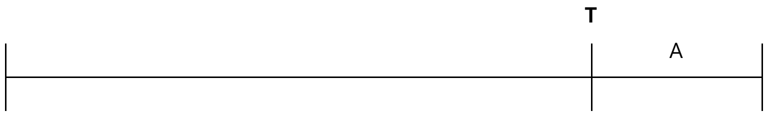


FIGURE 5 PERIOD EXTENSION OPTION

A simple analysis reveals that the period extension option has the same structure as options on futures, which are observed in the finance and commodity sectors. The strike price of the option, if exercised, is the contract price of the futures to be activated at maturity, and futures can generate profits or losses to the option buyers. In period extension options, the 'implied' futures attached to the period charter do not exist as an independent contract. Settlements, therefore, are not made explicitly. They are conceptual in that the profits and losses otherwise enjoyed by the owners (writers) are transferred to the charters (buyers).

Another difference from regular futures is that the payoff is calculated as the average of the period from the start of the futures to the expiry. The profit generated from spot market employment, however, is not equal to the gap between the contract price and the average of daily spot prices because when the subject vessel is fixed for a voyage in the spot market at a specific rate, the rate is applied to the entire duration of the voyage. The rates are different from the average of the spot rates. The difference, which can be called the 'rate-picking bias', is graphically displayed in Figure 6.

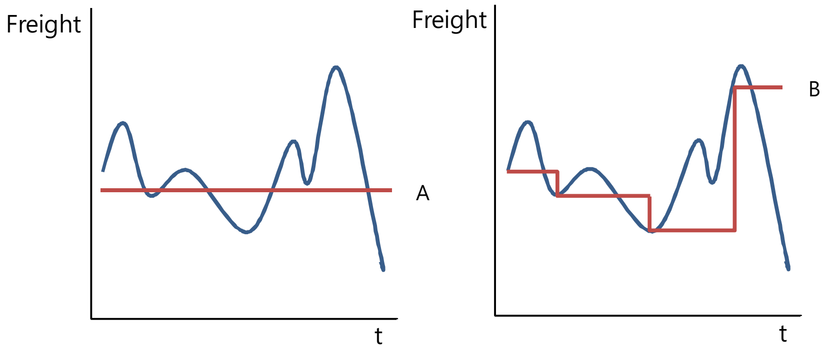


FIGURE 6 'RATE-PICKING BIAS'

Line A displays the average of daily returns and line B shows the actual rates which charterers realize on the assumption that the charterers are making four voyages during the extended period. In discussions of the EMH, the difference between A and B is disregarded for simplification purposes and it is assumed that the charterers are making the same profit as the average of the spot rates.

The structure of the additional shipment options attached to COAs is quite different from that of period extension options. A COA is simply a bundle of voyage charters to be performed over a pre-specified period and often includes some optional shipments. The number of optional shipments, if any, is normally 10-20% of the firm shipments, but it varies according to the market situation. When sellers (shipping companies) have the negotiation power, they tend to restrict the number of optional shipments to a minimum.

Additional shipment options are exercised when the lay/can of the optional shipments is declared. The declaration is made at any time during the COA period when the payoff is positive. The conceptual settlement is made with the spot rate quoted at the start of – more precisely, about 2 weeks before the start of – each optional shipment.

The structure of additional shipment options is displayed as a graphic form in Figure 7.

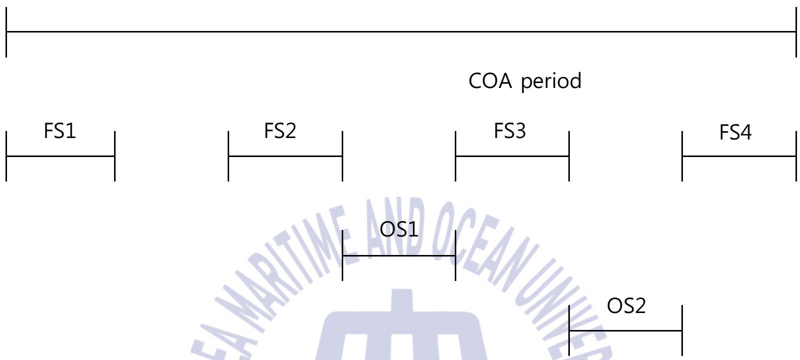


FIGURE 7 ADDITIONAL SHIPMENT OPTIONS

The above example shows a COA with 4 firm shipments (FS1~FS4) and 2 optional shipments (OS1 and OS2). The payoff is the difference between the spot rate at the start of the optional voyage and the strike price. The options are viewed as American-style options where they can be exercised any time before maturity. An option for multiple additional shipments can be viewed as an aggregation of the same number of American options to the number of shipments.

Binomial option pricing models or numerical methods are normally used for the valuation of American-style options. The valuation of additional shipment options is beyond the scope of this study.

Shipping is a cyclical business and its ups and downs have been repeated throughout its history. When seaborne transport demand is in excess of fleet supply, the market moves towards its peak. The sellers (owners) have more power in the negotiation, resulting in a ‘seller’s market’. Then, the charterers’ efforts to secure an option on the charter will not be successful. The owners often ask higher rates for the option while the charterers try to attach the option virtually free of charge by maintaining the rate at the level of the firm contract. This rate gap is what makes the negotiation unsuccessful (Kavussanos & Visvikis 2006; Stopford 2009; Karakitsos & Varnavides 2014).

The situation changes as the supply/demand balance is reversed. The oversupply in the market pushes the market down towards its trough. Realizing their power in the negotiation, the charterers try to obtain an option in addition to the firm contract. The options are granted mostly free of charge, although, in reality, it is in exchange for the credit risk premium (Alizadeh & Nomikos 2009).

Chapter 3 Literature Review

3.1 Asian Option Approximation

Various models, including the Black-Scholes option pricing model and the binomial option pricing model, have been utilized in valuing financial and commodity options. In particular, the BSM is considered as the norm in the valuation of European options and plays a role as the foundation to value exotic options, in spite of its rather unrealistic assumptions such as lognormality, constant volatility, and constant risk-free rates. These assumptions may work well for short-term dynamic hedging but may cause problems when applied to long-term options.

A paper freight option is an average price Asian option where discrete arithmetic averaging is applied for the calculation of settlements. The payoff of Asian options uses the averaging mechanism while regular European options are based on the spot price at maturity for the payoff calculation.

Asian options are used in the commodity market where the lack of liquidity results in severe price volatility and susceptibility to price manipulation by a small number of players. It is impossible to directly apply the BSM to Asian options because the lognormality assumption is broken for the averaging period. Hence, the approximation becomes inevitable.

There have been studies on Asian option approximation. Turnbull and Wakeman (1991) derived an approximation based on the assumption that the distribution of the average is lognormal in the arithmetic averaging mechanism. Once the moments of the true distribution that has lognormal property are estimated, the Edgeworth series expansion is used to derive approximating distribution, which is close to the true distribution.

Levy (1992) approximated the value of European options, which involves the arithmetic average of the future foreign exchange rate. While Turnbull and Wakeman (1991) calculated the arithmetic average of the underlying rate on a continuous basis, Lévy (1997) and Haug et al. (2007) considered the fact that commonly-traded Asian options have the features of a discretely calculated average.

Curran (1992) had derived an approximation for valuing Asian options conditional on the risk-neutral distribution of the geometric average of the underlying asset. If the cost of carry is zero, the approximation is identical to the Lévy (1997) and Haug et al. (2007) model.

The literature on pricing the family of path-dependent derivatives shows that it is possible to derive the closed-form solution by assuming a lognormal distribution during the averaging period. Freight derivatives also have path-dependency, and studies have also been carried out for freight options.

Due to the failure of lognormality for the option on FFA rates during the settlement period, Koekebakker et al. (2007) assumed lognormality for that period.

The approximations of Turnbull and Wakeman (1991), and Levy (1997) is based on the assumption that the distribution of the average underlying spot rate is lognormal. Nomikos et al. (2013) focused on the jump-diffusion of historic spot rates and proposed a risk-neutral spot rate model. In the study, they compared the results with those of the approximation models and demonstrated that the jump-diffusion model reduces the level of over- and under-pricing. The outcome supports the use of the jump-diffusion model as a basis for the valuation of Asian options.

3.2 Options on Futures

So far, the studies on Asian options have been reviewed to cover the paper freight options. The option to extend the charter period has properties similar to options on futures. Black (1976) modified the original BSM and suggested a model to evaluate European options on forward and futures.

By considering the fact that the process of freight rates is mean-reverting and has an 'absorbing level' reflecting the lay-up, Tvedt (1998) came up with a pricing formula for options on BIFFEX.

3.3 European Options

The extension option is interpreted as an option on futures, but the categorization is rather conceptual. There are two ways for charterers to employ a chartered vessel. One is to realize the profit by employing the vessel repeatedly in the spot market, and another way is to charter out the vessel for the entire extended period at maturity. Spot returns follow a stochastic process, and a numerical method must be employed to value the option.

This research is performed under the restrictive condition that the only option available to the charterer is to let out the vessel for the remaining period at the expiry. Once the payoff is determined at maturity, a model for a regular European option can be applied. The question is whether the expected earnings from the spot market operation are equal to the earnings from the one-off charter-out transaction. The issue is discussed in section 3.4.

The valuation of the regular European model includes the binomial option pricing model (Cox et al. 1979) and the BSM.

3.3.1 Binomial option pricing model

The binomial option pricing model (BOPM) is an option valuation model proposed by Cox, Ross, and Rubinstein in 1979. It is a numerical method used for the pricing of options such as American options, where a closed-form solution cannot be directly applied. The valuation of options is performed in three steps: a price tree is created using a binomial lattice; the option values of the final nodes are calculated; and the values of the preceding nodes are computed until the value of the options is derived. The BOPM is a method based on similar assumptions to the BSM, and can be referred to as a discrete time approximation of the BSM. In the case of 'plain vanilla' European options, the BOPM value converges to the BSM value as the number of steps increases (Hull 2015).

One of the rare examples is the binomial derivation of the value of an extension option in the textbook of Alizadeh and Nomikos (2009). They introduced the valuation using binomial trees and demonstrated that the extension option, which is normally granted free of charge, has some positive values.

3.3.2 Black-Scholes option pricing model

Physical freight options are not directly related to the BSM (Black & Scholes 1973; Merton 1973) unless they are conditioned to have the property of regular

European options. Hence, there is little literature covering the physical freight option evaluated by the model.

3.4 Efficient Market Hypothesis and Expectations Theory

The payoff the extension option is

$$\sum_{i=1}^{n}(S_i - K)$$

where S_i is the spot rate of the corresponding market to the subject vessel and K is the strike price.

If the average of the spot rates is smaller than the strike price, the charterers are making a loss and vice versa.

When the charterers' decision at maturity is restricted to the charter-out of the vessel for the extended n days, the payoff becomes

$$(S_{tc} - K) * n$$

where S_{tc} is the period charter hire for the extended period at the expiry and K is the strike price.

If $(S_{tc} - K) \leq 0$, the charterers do not exercise the option and the payoff is zero. If $(S_{tc} - K) > 0$, the option is exercised and the payoff is $(S_{tc} - K) * n$.

In this research, we assumed that the period charter rate is an unbiased estimator of the spot market earning for the extended period. This assumption is based on the expectations hypothesis of term structure and the efficient market hypothesis (EMH).

There have been studies on the relationship between time charter rates and expected spot returns over the period of the time charter. The research encompasses the term structure relationship, the expectations hypothesis, and the efficient market hypothesis.

The pure expectations hypothesis, if the market is efficient, explains the linear relationship between the yield and the term. In practice, however, market players expect more returns for the risks they take. The risk premium is the expression of the extra returns for repeated short-term transactions, and it is well recognized in finance, especially concerning bonds and exchange rates.

The following equation showing the relationship between short-term and long-term rates also includes the risk premium.

$$TC_t^n = \left(\sum_{i=1}^{k} \frac{E_t S_{t+(i-1)m}^m}{(1+r)^i} \bigg/ \sum_{i=1}^{k} \frac{1}{(1+r)^i} \right) - \emptyset_t \qquad k = n/m$$

where TC_t is the time charter rate at time *t*, *E* is the expectation operator, S_t is the spot rate at time *t*, *n* is the time charter period, *m* is the spot charter period, *k* is the number of spot voyages within the time charter period, *n* and $\emptyset_t$ is the risk premium at time *t*.

There have been studies on testing the existence of the risk premium in the freight market. Uncertainties caused by the possibilities of unemployment in the spot market and extreme volatility in the spot market account for a positive risk premium in the shipping market. The results of the existing literature, however, show mixed outcomes.

Hale and Vanags (1989) and Veenstra (1999) tested the expectations hypothesis of term structure (EHTS) and drew the conclusion that the EHTS is rejected.

Kavussanos and Alizadeh (Kavussanos & Alizadeh 2002b) pointed out the problems of the above papers, i.e. the assumptions the model and research period used by Hale and Vanags (1989) and Veenstra (1999), and carried out research using the economic technique suggested by Campbell and Shiller (1987; 1991). In the research, which reflected the properties of the shipping market, they revealed the existence of negative time-varying risk premiums, which is in contrast to the general results in the financial markets. Adland and Cullinane (2005) reviewed the previous literature to verify the applicability of the expectations theory to the shipping market. They found that the time-varying nature of the relationship between short-term rates and long-term rates causes erratic results in the signs of the risk premium. They concluded the revision by expressing that, even though the risk premium is negative in many of the studies, the ultimate verification of the degree of time-variance or the sign of risk premium is impossible unless an additional condition on the risk preference of the buyers and sellers is imposed.

The EMH is a precondition of the expectations theory. Fama (1965) conceptualizes market efficiency for the first time in his research, and the concept was later developed to three types of efficiency: strong-form, semi-strong-form, and weak-form efficiency. In weak-form efficiency, excess returns cannot be achieved in the long run by analyzing historical market actions. In semi-strong-form efficiency, all public information is instantly reflected in asset prices so that no excess profit is made by trading on the information. Strong-form-efficiency assumes that, in addition to semi-strong-form efficiency, all information, including private information, is already reflected in the asset price and that no one can consistently beat the market.

There have been studies on market efficiency in the shipping industry. Alizadeh and Nomikos (2006; 2007) tested market efficiency in the sale and purchase market. The study performed by Adland and Strandenes (2006) represents the research on the freight market. They tested the performance of a trading strategy based on fundamental analyses against that of the naïve strategy. The results varied according to the conditions of the selected market.

Appendix II summarizes the existing literature. Attention needs to be drawn to the inconsistency of the conclusions. The review of the previous literature suggests that a solid conclusion cannot be drawn on the pure expectations hypothesis, and that the results of the tests on the EHM are also controversial. In this research, therefore, we assume market efficiency in the freight market, and spot market returns can be replaced by time charter rates without loss of rigor in the research.

In addition to the theory, if the time charter period is relatively short and the discrepancy between the rates is small, as in this study, the assumption of at least semi-strong-form efficiency will hardly affect the results of the research.

3.5 Artificial Neural Networks

This research employed a robust relationship mapping model, the ANN, as an alternative. Unlike the BSM, it does not require assumptions on the market and assets. ANN models have rarely been applied to maritime industries and most of them have been focused on forecasting.

Li and Parsons (1997) attempted to apply the ANN to predict the freight rate in the tanker market. They found that the longer the time span of tanker freight rate forecasting, the more precise the ANN model prediction over the ARIMA (autoregressive integrated moving average) model. Lyridis et al. (2004) conducted forecasting using the VLCC spot freight rates and compared the performance of the ANN with the naïve model. The results of the ANN far outweighed that of the naïve model. Mostafa (2004) found that the performance of the ANN model far exceeded that of the ARIMA model with respect to predicting the traffic volume of the Suez Canal. Spreckelsen et al. (2012) examined the forecasting performances and then trading results based on the forecast. They compared univariate models with multivariate models. The univariate models entail a random walk model, ARIMA, and simple Neural Networks, which incorporate lagged variables of the spot and FFA rate. The multivariate models are the VAR (vector autoregressive) model, the VECM (vector error correction model), and multivariate Neural Networks. They added spot variables to the forward prices forecasting model, and vice versa. Among the suggested models, the ANN best performed in forecasting. Santos et al. (2014) tried to forecast tanker time charter rates. They employed ARIMA, as a benchmark, and two neural network models classified according to the type of activation functions: MLP (multi-layer perceptron) and RBF (radial-basis function). The result showed that the ANN, particularly NN-RBF, consistently outperformed the other models.

Studies on the application of the ANN to option pricing have been quite active. A number of papers were published in the 1990s and 2000s, and it is almost impossible to list them exhaustively.

Hutchinson et al. (1994) compared three types of ANN and the BSM for the pricing of American-style call options on S&P 500 futures and demonstrated that the three ANN models all outperformed the BSM. Qi and Maddala (1996) came to the conclusion that the ANN, applied to the pricing of European call options on the

S&P 500 Index, is superior to the BSM. In their study on the pricing of call and put options on the FTSE 100, Bennell and Sutcliffe (2003) demonstrated that the ANN model is superior. A study carried out by Anders et al. (1998) on European-style DAX call options also exhibited the superior performance of the ANN. Yao et al. (2000), in their study on the pricing of American-style call options on Nikkei 225 futures, proved that the ANN outperforms the BSM.

Most studies, including the above, have concluded that the performance of the ANN outweighs or is at least equal to that of the BSM. There are, however, no papers on the application of the BSM, the Asian option approximation or the ANN to physical freight options.

Table 5 summarizes existing literature on the comparison of the performances of the BSM and the ANN for financial (stock) series. Most of the papers concluded with the outperformance of the ANN. Research in the financial markets are performed for a relatively short period of time with a larger number of daily observations, but the results do not deviate from this research, where longer periods with weekly observations are analyzed. The ANN structure is simple, with one hidden layer and a small number of hidden nodes, which is similar to this research. The most popular sigmoid function is used as a transfer function and widely-adopted performance measures are employed.

To the knowledge of the author, this paper is the first attempt to apply the ANN model to the valuation of the physical freight options embedded in charter contracts, and the comparison of the ANN model and the BSM was also tried for the first time in this research domain.

TABLE 4 LITERATURE ON BSM & ANN

Authors	Type	Obs.	Period	BSM		ANN			Performance Measures
				Underlying	Input	Structure	Transfer Function	Output	
Malliaris and Salchenberger (1993)	European call options	1,560	Jan. 1990 – Jun. 1990	S&P 100 index	BSM Inputs & 2 Lagged variables	7-3-1 7-4-1 7-5-1	Sigmoid	C	MSE MAD MAPE
Hutchinson et al. (1994)	American call options	6,000+	1987 - 1991	S&P 500 futures	S/X T-t	2-4-1	Sigmoid RBF	C/X	R^2
Qi and Maddala (1996)	European call options	1,107	Dec. 1994 – Jan. 1995	S&P 500 index	BSM Inputs & Open interest	5-5-1	Sigmoid	C	MSE MAE R^2
Anders et al. (1998)	European call options	13,676	Jan. 1992 – Dec. 1994	DAX 30	BSM inputs & S/X	Exclusive NN models devised by Authors	Hyperbolic Tangent	C/X	R^2 RMSE ME, MAE MAPE
Yao et al. (2000)	American call options	17,790	Jan. 1995 – Dec. 1995	Nikkei 225	S X T	3-2-1 3-3-1	Hyperbolic Tangent	C	NMSE

Bennell and Sutcliffe (2003)	European call options	9,556	Jan. 1998 – Mar. 1999	FTSE 100	BSM Inputs & S/X Dividend Open interest	3 to 7 – 3 to 5 - 1	?	C C/X	R^2 MD, MAD, MPD, MSD
Lin and Yeh (2005)	Options	11,469	Jan. 2002 – Dec. 2003	TAIFEX	BSM Inputs & S/X	4-?-1	Sigmoid	C	RMSE MAE MSE
Tseng et al.(2008)	Call options	21,120	Jan. 2005 – Dec. 2006	TAIFEX	BSM Inputs & Grey-EGARCH volatility	5-?-1	?	C	MAE RMSE MAPE

Note : 1. S, X, and C are spot price, strike price, and call price respectively.
2. Mean deviation(MD); mean absolute deviation(MAD); mean proportionate deviation(MPD); mean squared deviation(MSD); mean absolute percent error(MAPE); mean squared error(MSE); root mean squared error(RMSE); mean error(ME); mean absolute error(MAE); normalized mean squared error(NMSE).

Chapter 4 Data and Basic Assumptions

4.1 Data

The data used for the analysis was obtained from the Shipping Intelligence Network of Clarkson Research (https://sin.clarksons.net). The data period is 16 years from 2001 to 2016, and the total number of observations is 785, with weekly frequency. The data for the first and last 1 year was excluded because the parts were used solely for the calculation of historical volatility and the actual realized values, respectively.

Some of the descriptive statistics were retrieved to identify the distributional properties of the freight series. The central tendency and other moments of the variables are summarized in Table 5. One of the most important properties is the normality of the data. The Jarque-Bera statistic reveals that all the freight series, including log returns, fail to demonstrate normality. The 5% critical value of the Jarque-Bera statistic, which follows the χ^2distribution, is 5.99. The actual values severely deviate from the test statistic.

TABLE 5 DESCRIPTIVE STATISTICS OF FREIGHT SERIES

	XTCT	DLXTCT	X3MTC	DLX3MTC	X1YRTC	DLX1YRTC
Observations	785	784	785	784	785	784
Mean	20,845	-0.001	22,182	-0.001	21,371	-0.001
Median	14,500	-0.001	15,813	-0.002	14,875	0.000
Maximum	93,194	0.447	93,847	0.463	82,000	0.288
Minimum	2,294	-0.568	4,074	-0.513	4,750	-0.483
Std. Dev.	18,090	0.108	18,421	0.082	17,232	0.054
Skewness	1.65	0.12	1.69	0.01	1.87	-1.59

Kurtosis	5.58	6.44	5.62	8.68	6.03	19.26
Jarque-Bera[3]	576.0	387.9	599.4	1,052.8	755.4	8,962.4
Probability	0.00	0.00	0.00	0.00	0.00	0.00

Note : XTCT, X3MTC, and X1YRTC mean the spot rates, 3-month charter rates, and 1-year charter rates, respectively. The prefix 'DL' represents the logarithmic returns of each freight series.

The lack of lognormality is prevailing in most financial and commodity series. Even though the BSM is on the assumption of lognormality and most of the financial series deviate from lognormality, the BSM model is widely used as a benchmark due to its simplicity and computational efficiency. This research also employed the BSM for the valuation of European call options, bearing the limitations of the model in mind. Additional statistical and graphical information on the freight series can be found in Appendix I.

The input variables of the BSM are spot price, strike price, time to maturity, risk-free rate and spot return volatility. The period of extension is assumed to be 3 months, and 3-month T/C rates are underlying spot rates. Three-month rates are not recorded in the market because 3-month T/Cs are not frequently traded in the chartering market. Actually, 3 months are considered 'too short' for a time charter period. Hence, 3-month rates were acquired by linear interpolation between the spot rates and the 6-month time charter rates, which are attainable from the Clarkson database. The strike price was assumed to be identical to the rate of the firm period. When the extended period is relatively short as in this case, it is common to apply the firm-period rate to the extended period without any rate adjustment. US

[3] Jarque-Bera = $\frac{N}{6} \times \left[s^2 + \frac{(k-3)^2}{4}\right]$, N : number of observations, S : skewness, k : kurtosis

Treasury Bill rates for 3 months, which correspond to the optional period, were adopted to represent risk-free rates.

The performance of the BSM was measured for the data set corresponding to the 'test set' of the ANN to ensure the compatibility of the analyses. Even though the data was randomized for the efficient training of the ANN, the time-serial relationships of the data were maintained at any point. In other words, the volatility and the actual realized value of the options were calculated and fixed for the observation before the normalization was performed.

4.2 Basic Assumptions

This study was carried out under the following assumptions.

First, the time charter is for a firm period of one year and the optional period is 3 months. Redelivery flexibility, which will be explained later in this section, was disregarded.

Second, there is no time difference between contracting and the delivery of the vessel. In reality, the gap has a wide range. It can vary from over a month to a negative number of days when the vessel is fixed retrospectively. In the usual case, the gap is about 1-2 weeks. The inclusion of the 'irregular' gap transforms the option to a forward start option, which adds unnecessary complexity to the analysis.

Third, the charter hire for the optional period, i.e. the strike price, is the same as the hire of the firm period. In reality, it can be different as per the prospect of the market. As discussed in the previous section, the firm period rate tends to be maintained when the extended are relatively short and no seasonality is involved in the extension.

Fourth, the option can be exercised only at maturity.

Fifth, when the option is exercised, the decision of the option buyer is restricted to a one-off sale of the freight for the entire optional period at a 3-month T/C rate at maturity. Through this, the pay-off of the extension option is determined at maturity, the charter extension option can be transformed into a regular European call option, and then the BSM can be applied.

The concept of redelivery flexibility needs to be further elaborated upon. In practice, the optional period of time charters is an addition to the redelivery flexibility embedded in any time charter.

The charterers of time-chartered vessels have basically two ways of utilizing the vessels. The vessels can transport cargoes by entering into a voyage charter or a COA. Alternatively, the vessels can be chartered out to other operators, not being involved in the physical transport of cargoes. Regardless of the types of employment, the vessel's charter contract inevitably involves a certain level of uncertainty with a view to the charter period because the actual charter period cannot be precisely specified prior to the actual completion of the voyage. Thus, most period charters are concluded with a margin, allowing the charterers to have some flexibility in the redelivery of the vessels. Flexibility is normally granted with a one-month leeway for period charters that are one year or longer.

Even though it is inevitably included in period charters, this redelivery flexibility can also be considered an 'option'. This is because the charterers can utilize the discretionary right of adjusting the redelivery timing to their own benefit by thoughtfully planning the last voyage. The options in this research, however, did not aim to explore the above inherent optionality.

Chapter 5 Black-Scholes Option Pricing Model

5.1 The BSM

Black and Scholes (1973) and Merton (1973) presented a straightforward closed-form solution to price the derivatives. Although pre-BSM researchers suggested various methods to assess the options traded in the market, the BSM is recognized as a groundbreaking model because it incorporates the concept of risk neutrality (Duffie 1998). This means the return on the risk-free portfolio is the risk-free rate, not an expected return reflecting the investors' risk preference. Another reason is that the model depends solely on the volatility of underlying assets and observable parameters. Consequently, it provided the market participants with a guide for making a fair valuation, and thus contributed to the growth of the options market.

Key assumptions are made when deriving the BSM equation. The assumptions on the underlying asset are that the rate of return on the riskless asset is constant; the log return of the underlying assets follows a geometric Brownian motion; and there is no dividend during the lifespan of the maturity.

The assumptions on the market are that there is no arbitrage opportunity; there are no transaction costs; it is possible to borrow and lend any amount of cash at a riskless rate; and the buying and selling (including short selling) of the underlying asset are possible.

On the basis of the above assumptions, the BSM equation can be derived. The formula of the model is

$$C = S_0 N(d_1) - K e^{-rT} N(d_2) \tag{1}$$

$$d_1 = \frac{\ln\frac{S_0}{K} + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \quad , \qquad d_2 = \frac{\ln\frac{S_0}{K} + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

where C is the price of the European call option, K is the strike price, S_0 is the price of the underlying asset at time 0, $N(\cdot)$ is the cumulative normal distribution, r is the risk-free rate, σ is the volatility of return for the underlying asset, and T is the life span of the maturity.

If it follows the Wiener process, the underlying price process can be presented as follows:

$$dS = \mu S dt + \sigma S dZ \tag{2}$$

Eq. 2 can be changed to the discrete version:

$$\Delta S = \mu S \Delta t + \sigma S \Delta Z \tag{3}$$

The price of the option can be differentiated using Ito's lemma,

$$\Delta f = \left\{\frac{\partial f}{\partial S}\mu S + \frac{\partial f}{\partial t} + \frac{1}{2}\frac{\partial^2 f}{\partial S^2}\sigma^2 S^2\right\}\Delta t + \frac{\partial f}{\partial S}\sigma S \Delta Z \tag{4}$$

The price of the portfolio (Π) constructed by buying $\frac{\partial f}{\partial S}$ units of S and selling 1 unit of *f* is

$$\Pi = \frac{\partial f}{\partial S}S - f$$

The change of the portfolio's value in time Δt is

$$\Delta\Pi = \frac{\partial f}{\partial S}\Delta S - \Delta f \tag{5}$$

By substituting ΔS and Δf in Eq. 5 with Eq. 3 and 4,

$$\Delta\Pi = \left\{-\frac{\partial f}{\partial t} - \frac{1}{2}\frac{\partial^2 f}{\partial S^2}\sigma^2 S^2\right\}\Delta t$$

By removing the risk term, this portfolio can be riskless during Δt.

According to the assumption of the BSM, the yield of the portfolio equals the risk-free rate. By assuming so, we obtain

$$\left\{-\frac{\partial f}{\partial t}-\frac{1}{2}\frac{\partial^2 f}{\partial S^2}\sigma^2 S^2\right\}\Delta t = r\left\{\frac{\partial f}{\partial S}S - f\right\}\Delta t \quad (6)$$

By rearranging Eq. 6,

$$\frac{\partial f}{\partial t} + r\frac{\partial f}{\partial S}S + \frac{1}{2}\frac{\partial^2 f}{\partial S^2}\sigma^2 S^2 = rf \quad (7)$$

So far, the differential equation, Eq. 7, for pricing the option has been derived. Black and Scholes (1973) and Merton (1973) provided the solution of Eq. 7 by employing the heat transfer equation in physics. The solution is expressed in Eq. 1.

Extension options share properties with options on futures and the straightforward application of the BSM is not possible. The application of the Black (1976) model, which modeled the option on futures, is not appropriate either because of the mismatch caused by the switching of the underlying assets to FFAs. If the decision of charterers is restricted to a 3-month charter at maturity, the option on futures is transformed into a 'plain vanilla' European option. The payoff at maturity is fixed at maturity like a European option.

The question is whether the earning from the 3-month charter is the same as the earnings from repetitive spot fixtures. As shown in section 3.4, this issue has been examined from the perspective of the efficient market hypothesis. Even though studies on market efficiency in the freight market have produced controversial outcomes, this research assumed that the EMH holds for the shipping market, and that the 3-month earning and spot earnings have no difference.

5.2 Input Variables

The input variables used in this study are as follows:

- Spot price : $X3mtc_{t_i} = \frac{Xtct_{t_i} + X6mtc_{t_i}}{2}$
- Strike price : $X1yrtc_{t_i}$
- Annualized Volatility : $SD_{t_i}^{3m} = \sigma_{(t_{i-1} - t_{i-54})}^{3m} * \sqrt{W}$

  where W is the number of weeks in a year.
- Maturity(T) : 1 year
- Risk free rate : $rf_{t_i}^{3m}$

An equally-weighted historical volatility, i.e. the standard deviation of the 3-month rates for the period of the past 1 year, is applied. Further research could incorporate other ways of capturing volatility such as the EWMA (Exponentially Weighted Moving Average) and a family of GARCH (Generalized Autoregressive Conditional Heteroscedasticity) forecasts. The 3-month US Treasury Bill rate was used to represent risk-free interest rates. The actual realized value of the 3-month extension option was calculated by subtracting the 3-month rates from the strike price.

$$\text{Payoff} = \text{Max}\left((\text{X3mtc}_\text{T} - \text{X1yrtc}_{t_i}), 0\right) \times \text{N}$$

where T is the expiry of the option, N is the number of days in the option.

Chapter 6 Artificial Neural Networks

The artificial neural networks model is a robust, non-linear model inspired by a biological study of the human brain. They are capable of learning relationships from data. The strength of the model is that it does not require assumptions about statistical distributions (Smith & Gupta 2000) and often performs better than other methods (Kaastra & Boyd 1996). The ANN model, first developed in the fields of cognitive science and engineering, has expanded to other areas such as finance, marketing and forecasting.

A conceptual diagram of the ANN model is displayed in Figure 8.

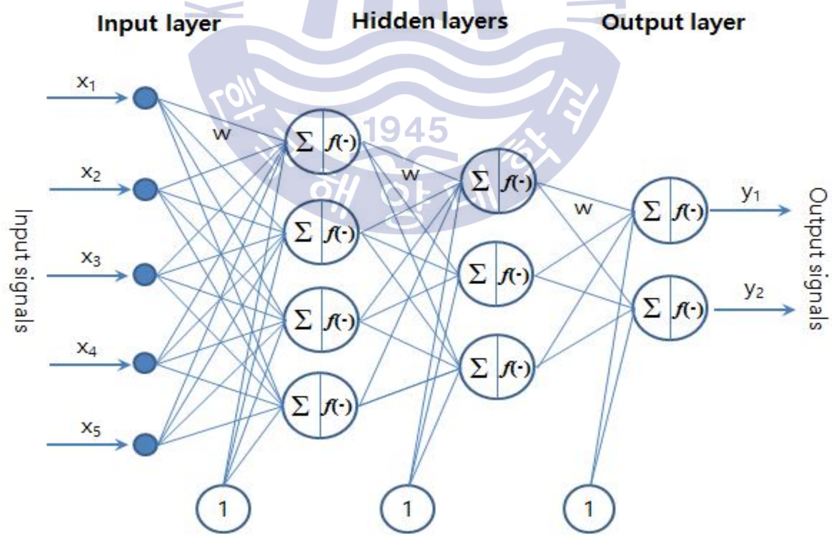


FIGURE 8 ANN MODEL

The above diagram depicts multilayer feedforward neural networks. The input layer feeds the input data to the first layer of the neurons. The layer accepts the input values multiplied by corresponding weights. The weighted sums are fed to the transfer function, which processes the data to generate outputs of the layer. The output of the previous layer with the multiplication of corresponding weights is fed to the next layer in a forward-moving sequence until it produces the final output data. If the data flow has a forward sequence, it becomes a 'feedforward' network, whereas if the data flow is reversed, it is termed a 'recurrent' network. The layers between the input layer and the output layer are referred to as hidden layers.

In the discipline of machine learning, the process of adjusting the weights within the networks means 'learning' or 'training'. According to research (Wong et al. 1997), about 95% of business problems applied multilayered feedforward neural networks with the back-propagation learning rule. The learning becomes 'supervised' if the desired outputs are provided during the training.

There are various types of transfer functions: linear functions, sigmoid functions, Gaussian functions and hyperbolic tangent functions, to name a few. The most common transfer function is the sigmoid function, the equation of which is

$$\text{Output} = \frac{1}{1 + e^{-(\Sigma w_i x_i + w_0)}}$$

The popularity of the sigmoid transfer function is due to its mathematical properties, such as monotonicity and differentiability. These properties are crucial in applying gradient descent as a training method.

According to Cybenco (1989), a single hidden layer with enough neurons can perform any mapping required. The important thing is to select the right input features rather than making the networks complicated with additional hidden layers. The number of nodes in the hidden layer is arbitrary. As a rule of thumb, a larger number of nodes than the number of input variables is set for a small number of input variables.

6.1 Network Structure

In this research, we employed feedforward 'supervised' learning networks. The actual realized option values are given as the desired response when the weight adjustment is carried out. The layer structure is 5-5-1, i.e. five input features, one hidden layer with an identical number of nodes to that of input features, and one output layer.

The input variables were adopted from the parameters of the BSM: the spot price, the exercise price, the volatility of spot returns and risk-free rates. The term to maturity was excluded because it is constant for all observations. The spot price of 3-month rates was interpolated from spot freight rates and 6-month time charter rates. Considering the lack of variables showing the spot freight market dynamics, the 'spot' freight series was arbitrarily added to the input variables. The 'spot' is different from the above spot rate of the BSM, which is a 3-month rate. Rather, it is the rate reported for trip time charters or voyage charters. More precisely, the rates for voyage charters refer to time charter equivalents (TCEs).

The research framework is essentially a mapping of relationships between the input data and the output data with a time difference of one year. There are research findings which show that the ANN model generally performed better than traditional models in the later periods of the forecast horizon (Hill et al. 1996).

The sigmoid activation function was applied in all but the output layer, where linear output was specified. The learning, i.e. finding parameters (weights), was completed with a resilient backpropagation (Rprop+) method. Back propagation is a method of training the ANN, and is normally used in conjunction with a gradient descent. Once the error between the target and the actual output is calculated, the network propagates the error backward and calculates the changes to the weights in order to reduce the output error. This process can be expressed as follows:

Inputs of the networks are denoted x_i $(i = 1, \dots, N_{in})$. Outputs from the hidden neurons are denoted h_j $(j = 1, \dots, N_h)$ and outputs from output neurons, o_k $(k = 1, \dots, N_{out})$.

Weights from x_i to the jth hidden neuron are w_{ji} and weights from the jth hidden neuron to kth output are w_{kj}.

Weighted input values to the neurons are

$a_j = \sum_i w_{ji} x_i + \theta_j$ and $a_k = \sum_k w_{kj} h_j + \theta_k$.

The thresholds (bias terms) are

$\theta_j = w_{j0}x_0$, $\theta_k = w_{k0}h_0$ (where x_0 and h_0 are fixed to 1). Hence, the bias terms disappear from the input values.

If transfer function $g(\cdot)$ is applied,

$$h_j = g(a_j) = g\left(\sum_i w_{ji} x_i\right)$$

$$o_k = g\left(\sum_k w_{kj} h_j\right) = g\left(\sum_k w_{kj}\, g\left(\sum_i w_{ji} x_i\right)\right)$$

The error function expressed with the sum of squared errors is

$E = \frac{1}{2}\sum_k (t_k - o_k)^2 = \frac{1}{2}\sum_k (t_k - g(\sum_j w_{kj} g(\sum_i w_{ji} x_i)))^2$, where t_k is the target values.

Training minimizes E by gradient descent. For the weights between the hidden layer and output layer,

$$\Delta w_{kj} = -\eta \frac{\partial E}{\partial w_{kj}} = -\eta \frac{\partial E}{\partial o_k}\frac{\partial o_k}{\partial w_{kj}} = \eta (t_k - o_k) g'(a_k) h_j = \eta \delta_k h_j,$$

where $\delta_i = (t_i - o_i) g'(a_i)$, $\eta : learning\ rate.$

For the weights between the input layer and hidden layer,

$$\Delta w_{ji} = -\eta \frac{\partial E}{\partial w_{ji}} = -\eta \sum_k \frac{\partial E}{\partial o_k}\frac{\partial o_k}{\partial h_j}\frac{\partial h_j}{\partial w_{kj}} = \eta \sum_k (t_k - o_k) g'(a_k) w_{kj} g'(a_j) x_i$$

$$= \eta g'(a_j) x_i \sum_k \delta_k w_{kj}$$

Weight adjustments start from w_{kj} to w_{ji}, i.e. backwards, until convergence is achieved.

Riedmiller and Braun (1993) introduced the resilient backpropagation algorithm. It takes into account only the sign of the partial derivatives, not the magnitude. Rprop+ is a method with weight back-tracking, which reverses the previous weight update when the sign of the partial derivatives is changed. Rprop is known to demonstrate outstanding performance in terms of speed of convergence and accuracy.

The data used for the ANN model is weekly data. More frequent observations of the data tend to result in a better performance of the model. Remus and O'Connor (2001) found that neural networks outperformed traditional models in forecasting monthly data, although they were not superior with annual series. Hence, a weekly observation is considered to be adequate for this analysis. The number of data series is also important in enhancing the performance. A large sample size contributes to a better estimation of the parameters. A small data set is not enough to estimate the parameters characterizing neural networks.

The original time series data was randomized before the model was applied. The randomized sample contains the same return distribution as the original data but lacks any time-serial dependence shown in the original. If not randomized, the separation of the training data and the test data would lead to a poor performance with the inclusion of the mid-2000 boom period. The randomization effect is graphically demonstrated in Figure 9.

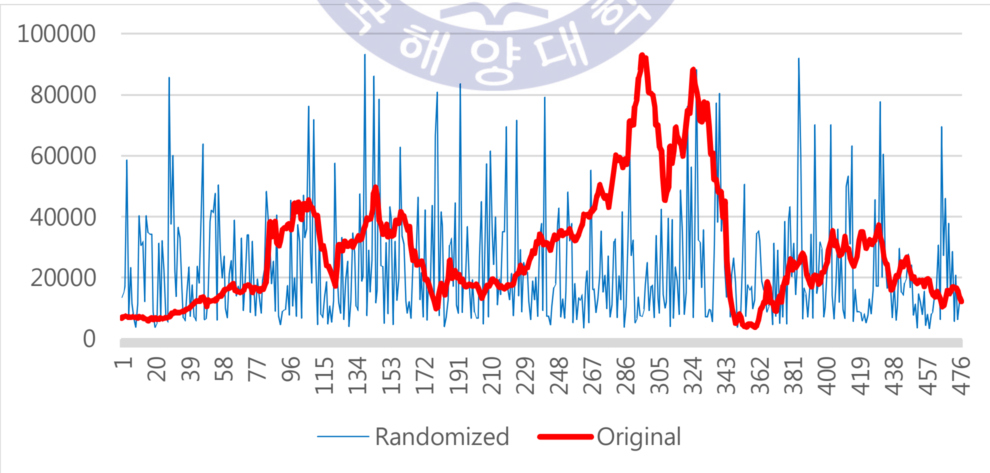


FIGURE 9 RANDOMIZED DATA VS. ORIGINAL DATA

The descriptive statistics of the spot freight rates before and after the so-called ‘China Shock’ are shown in Figures 10 and 11. There exists a significant structural change between the two periods. Attention must be paid to the changes in the mean and standard deviation. The Sharpe ratio[4] is 2.56 and 1.21, respectively.

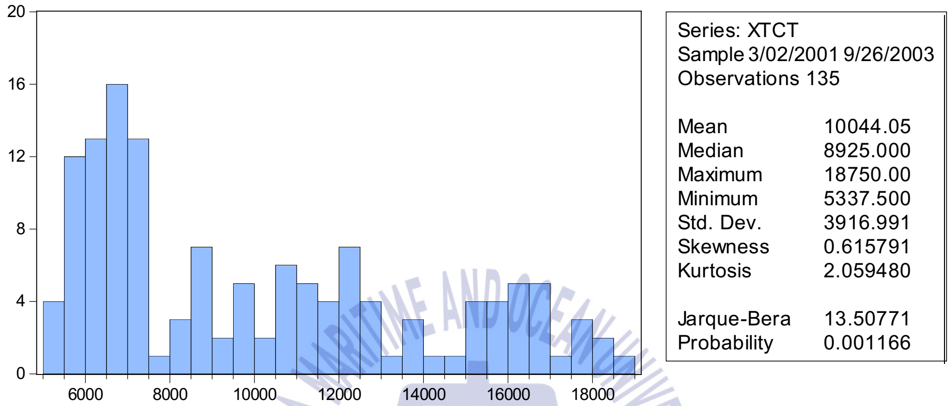


FIGURE 10 DESCRIPTIVE STATISTICS OF SPOT RATES (MAR 2001-SEP 2003)

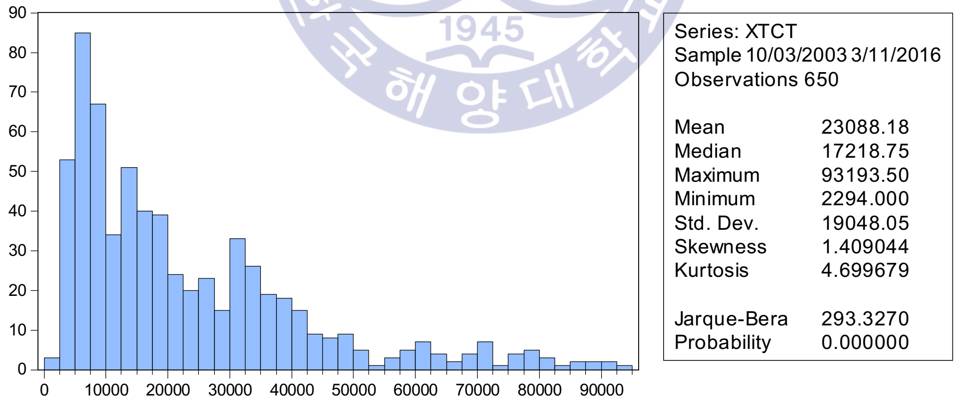


FIGURE 11 DESCRIPTIVE STATISTICS OF SPOT RATES (OCT 2003-MAR 2016)

4 Sharpe ratio represents a return-to-risk ratio and it can be obtained by μ/σ.

After randomization, the data was divided into two disjoint sets to form a training set and a test set. The training set was used to find the parameters of the networks and the unused test set, to validate the model. The process of validation was deliberately ignored because 1) the purpose of this paper is to identify the applicability of the ANN model to the valuation of physical shipping options, not to prove the structural optimality of the model, and 2) the result with an arbitrary network structure shows no sign of overfitting, which leads to a deteriorated performance with the test set. The data split ratio between the training and the test set was 70:30.

6.2 Normalization

Learning can be ineffective when the range of the input values varies significantly because large numbers can easily override small numbers. According to Priddy and Keller (2005), data normalization results in better performance. It expedites learning speed and reduces the influence of outliers. It is essential for research like this, which has a wide range of input features, to have data normalized before applying the ANN model. There are various data normalization methods and this study applies the min-max normalization.

- Z-score normalization, $x_i' = \left[\frac{(x_i - \mu_i)}{\sigma_i}\right]$. The normalized input vector has zero mean and unit variance. It has strength in minimizing the influence of outliers.

- Min-max normalization, $x_i' = (max_t - min_t) \cdot \left[\frac{(x_i - min_v)}{(max_v - min_v)}\right] + min_t$. This is the method used to rescale the data while maintaining the range.

In general, the rescaling is ranged either between 0 and 1 or between -1 and 1. The benefit of this method is that the properties of the underlying distribution after normalization remain. In other words, the relationship between all of the observations is maintained after rescaling.

- Sigmoidal normalization, $x_i' = \frac{1}{1+e^{-\left(\frac{x_i-\mu_i}{\sigma_i}\right)}}$. This is a way of reducing the influence of extreme values or outliers without elimination. The method transforms the data nonlinearly, which contrasts to the min-max-normalization that uses linear transformation. Normally, a logistic sigmoid function or a hyperbolic tangent function is applied. The former normalizes the data between 0 and 1, the latter between -1 and 1.

Chapter 7 Research Results

7.1 Measurements

When the training of the ANN model is completed successfully, performance can be measured simply by checking the errors of the training set and the test set. In this research, however, several measurements were used to compare the performances of the ANN with those of the BSM.

The performances were measured with a test set of 204 observations which was unused for the training. Although there are various performance measures, no consensus has been achieved on the selection of the measurements. According to various research, the measurements in Table 6 have general acceptance (Zhang et al. 1998; Paliwal & Kumar 2009).

TABLE 6 PERFORMANCE MEASURES

Measurements	Equations
MAE(Mean Absolute Error)	$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n} \lvert x_i - E(i) \rvert$
MSE(Mean Squared Error)	$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n} (x_i - E(i))^2$
RMSE(Root Mean Squared Error)	$\mathrm{RMSE} = \sqrt{\mathrm{MSE}}$
MAPE(Mean Absolute Percentage Error)	$\mathrm{MAPE} = \frac{1}{n}\sum_{i=1}^{n} \frac{\lvert x_i - E(i) \rvert}{\lvert x_i \rvert}$

- E(i) : Model estimation
- x_i : Actual observation

Instead of selecting one specific measurement, we included all of the above measures for the comparison of model performance. Additionally, the correlation between the actual realized values and the models was calculated.

7.2 Black-Scholes Option Pricing Model

The output of the BSM and the positive owners' cost, which is ultimately the realization of the option value, is compared in Figure 12. The graph portrays the relationship between the model outputs and the actual observed values of which the negative values are attuned to zero. The wide vertical range of values at zero value on the x-axis and the scattered dots on the plane reveals the poor performance of the BSM model. The correlation coefficient is -0.075. This indicates that the BSM's performance in valuing European-style charter extension options hardly has any practical value. The reasons behind the poor performance can be a subject for further research, but we presume that the severe volatility of the freight series contributes to the distortion in the valuation process. In particular, the inclusion of the period of extreme volatility (2004-10) is believed to have caused the discrepancy. The simple assumption of constant volatility became truly unrealistic for the period.

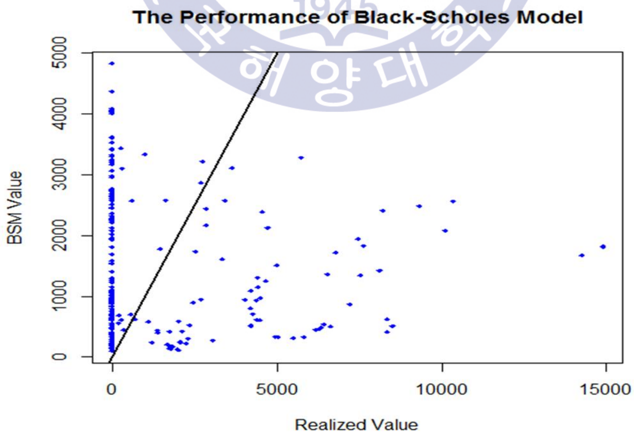


FIGURE 8 COMPARISON OF THE BSM AND THE ACTUAL VALUES

The following two graphs in Figure 13 show the difference in dispersion of the theoretical values and the actual values. The left graph displays the BSM outputs and the right one, the actual values. The patterns show a substantial degree of mismatch. It indicates that the model outputs cannot be utilized as decision criteria when traders consider the extension of the charter.

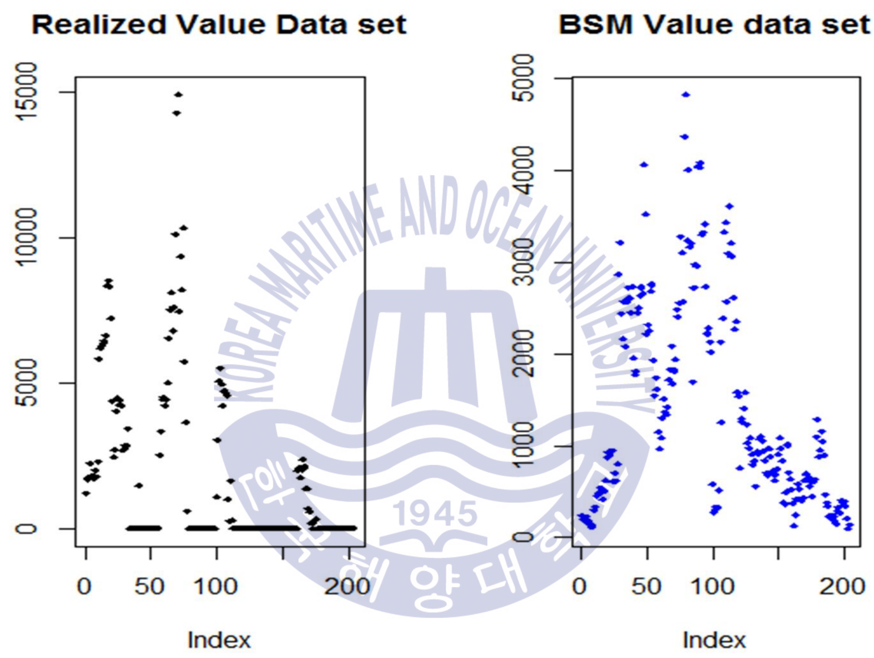


FIGURE 9 DISPERSION OF THE BSM OUTPUTS AND THE ACTUAL VALUES

7.3 Artificial Neural Networks

Figure 14 shows the ANN model used for the training of the option valuation. The value of the option is non-negative but the negative values of the extension options were not excluded at the training stage. This was to enhance the effectiveness of relationship mapping. If the negative values are replaced by zeros at the training stage, the training performance would deteriorate. Non-negativity will be restored when we compare the actual realized values and the model outputs.

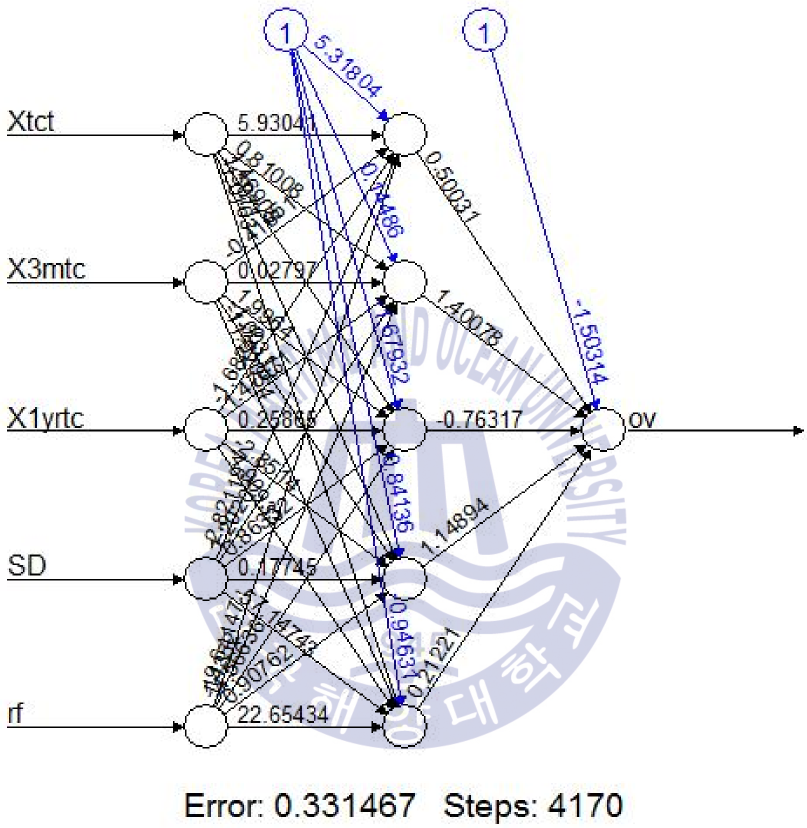


FIGURE 10 THE TRAINED ANN

The following figures reveal the performance of the ANN model in predicting the value of charter extension options. Figure 15 shows the relationship between the realized option values measured by owners' costs and the results of the predictions derived from the model. The next two figures also show the forecasting effectiveness of the model.

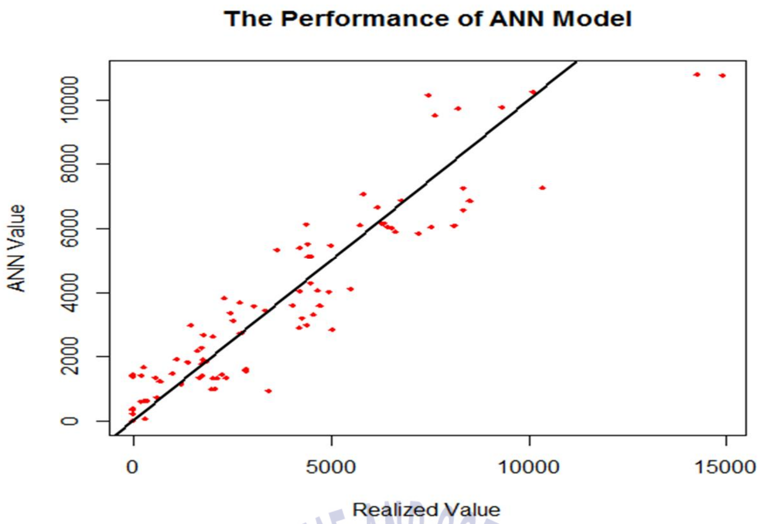


FIGURE 11 COMPARISON OF THE ANN AND THE ACTUAL VALUES

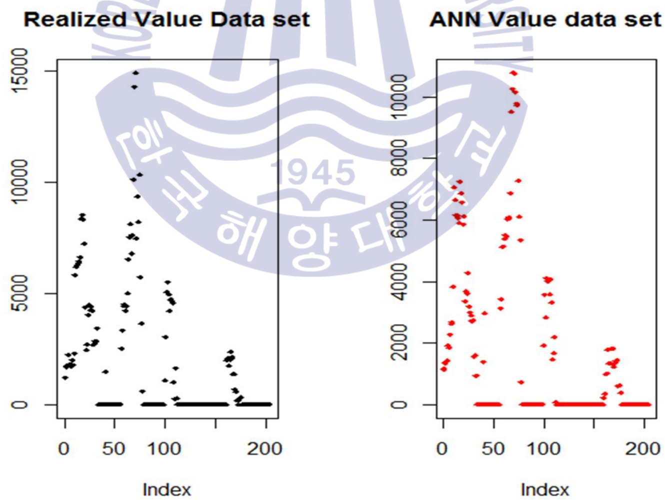


FIGURE 12 DISPERSION OF THE ANN AND THE ACTUAL VALUES

The correlation between the ANN model prediction and the owners' value that is actually transferred to the charterers was 0.9598. The result was remarkably better than that of the BSM, which showed a correlation coefficient of -0.075.

7.4 Comparison

The ANN trace almost overlaps with the actual realization, while the BSM trace shows a substantial deviation from the actual values (see Figure 17). The most noticeable differences occurred when the value of the options is zero. The BSM outputs revealed a substantial divergence from the actual realization; this can lead to wrong decisions in practice.

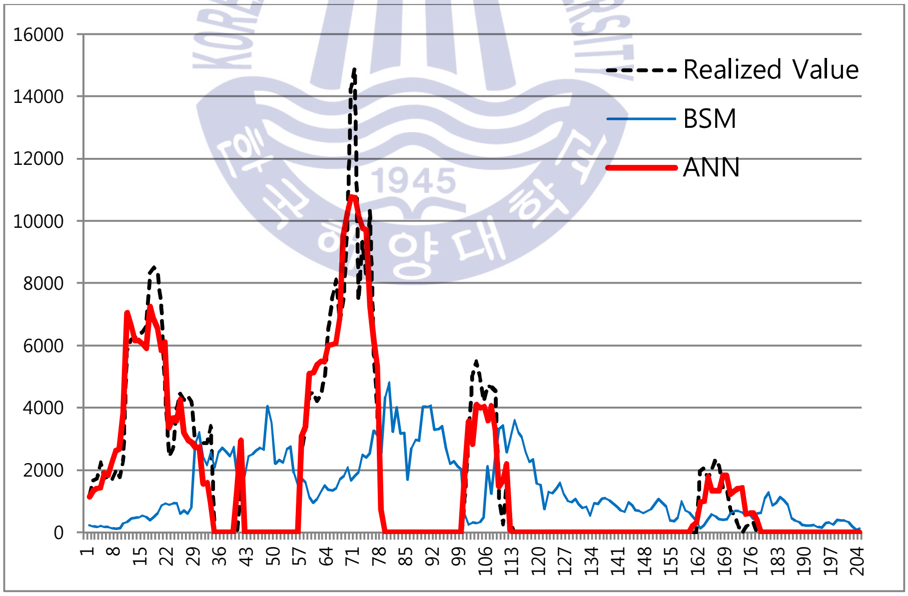


FIGURE 13 MODEL OUTPUTS AND THE ACTUAL VALUES

The above visualization of the performance can be summarized numerically with four measurements: MAE, MSE, RMSE and MAPE. Table 7 shows the gap between the two models.

TABLE 7 RESULT OF MODEL PERFORMANCES

	BSM (a)	ANN (b)	(a) / (b)
MAE	3,112	525	5.93
MSE	14,368,326	893,156	n/a
RMSE	3,790	945	4.01
MAPE	0.556	0.166	3.34

When we compared the performances, we found that the errors of the BSM were about 5 times more than those of the ANN.

Chapter 8 Conclusion

The common practice of granting chartering extension options without assessing the values has caused problems in chartering practice. In particular, when the market is at its trough and counterparty risk increases, owners tend to grant an optional period requested by relatively more credible charters. The problem is that the extension option is written free of charge, and the owners do not appreciate how much of the value is transferred to the charterers. Both parties have no theoretical ground to negotiate the hire for the optional period and rely on the forward curve of freight derivatives, i.e. FFAs, as a reference.

This is due to the fact that the established option valuation methods, which are widely accepted in the fields of finance and commodities, have not been tried and tested for the shipping industry. In this paper, we compared the actual payoffs of the extension options with the results of the Black-Scholes option pricing model and the ANN model. Clarkson's freight series of 16 years was used to generate main input variables, including the actual realization of the options.

The result of the BSM was not promising. The correlation between the model output and the actual value turned out to be -0.075, indicating virtually no correlation. This indicates that the BSM hardly provides ground to determine the *a priori* value of the options.

The poor performance may be related to the volatility of freight series. The time-varying nature of freight return volatility cannot be captured in the simple equally-weighted historical volatility measured by the standard deviation of freight returns.

In particular, the inclusion of the so-called ‘super boom period’ in the mid-2000s may have caused a serious distortion in the valuation. The structural changes between the two arbitrarily-separated periods are statistically summarized in Figures 10 and 11.

In summary, the use of the BSM is not effective in determining the value of extension options. The BSM performance might be improved with the employment of advanced volatility capturing methods. It is, however, questionable for the model to be valuable enough to create practical values, because the idea of projecting historical volatility to the future option period is basically unchanged. Additionally, the model to price options on futures, Black 1976, can be applied to extension options. In that case, attention must be paid to the basis risk caused by the co-integrating relationship between the FFA market and the short-term T/C market.

The alternative method of artificial neural networks was employed with the same parameters as those of the BSM. The output of the neural networks model was outstanding. The errors were considerably reduced and the correlation coefficient of the two series, the model output, and the actual realized value, showed 0.96.

The outstanding performance of the ANN is interesting in that the relative positional values of each input variable determine the future realization of the option values. This means that the input features of a year ago include enough information to estimate the value of the option in a year’s time. Hence, the model, even though the input variables are not apparently representing the demand and supply factors of freight markets, can be extended to the area of market forecasting. The forecasting performance may be improved when additional variables, such as forward market variables and term structure-related variables, are included.

It is expected that the ANN model will make a substantial contribution to chartering practices. Firstly, it will provide solid ground for rate negotiation. The decision making of both parties will be more rational with fair option pricing. Secondly, the model output can be used as a proxy to credit risk assessment. Extension options are granted in exchange for the reduction of credit risk, and the option premium can be a way of quantifying the credit risk.

This study has the limitation that only the Panamax bulk market was included in the analysis. The scope selection was mainly due to the lack of long-term data consistency in other bulk sectors. If the analysis is expanded to other segments of the dry and wet bulk markets, it will help enhance the generality of the model.

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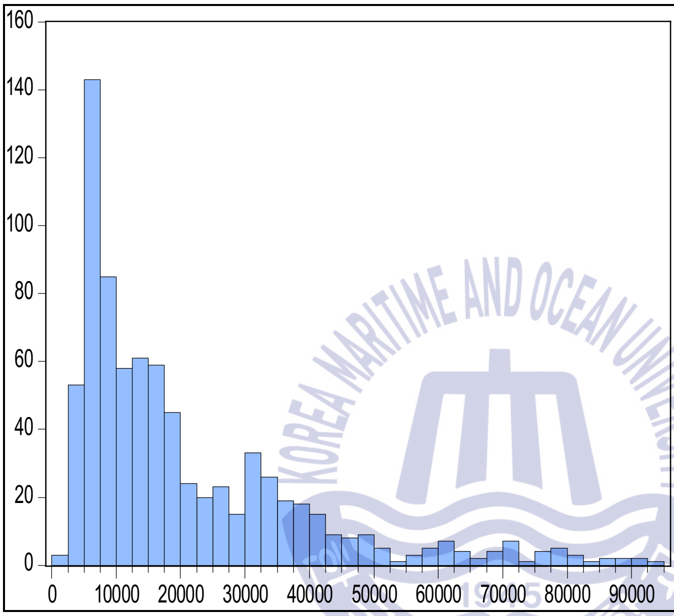
Appendix I

Descriptive statistics

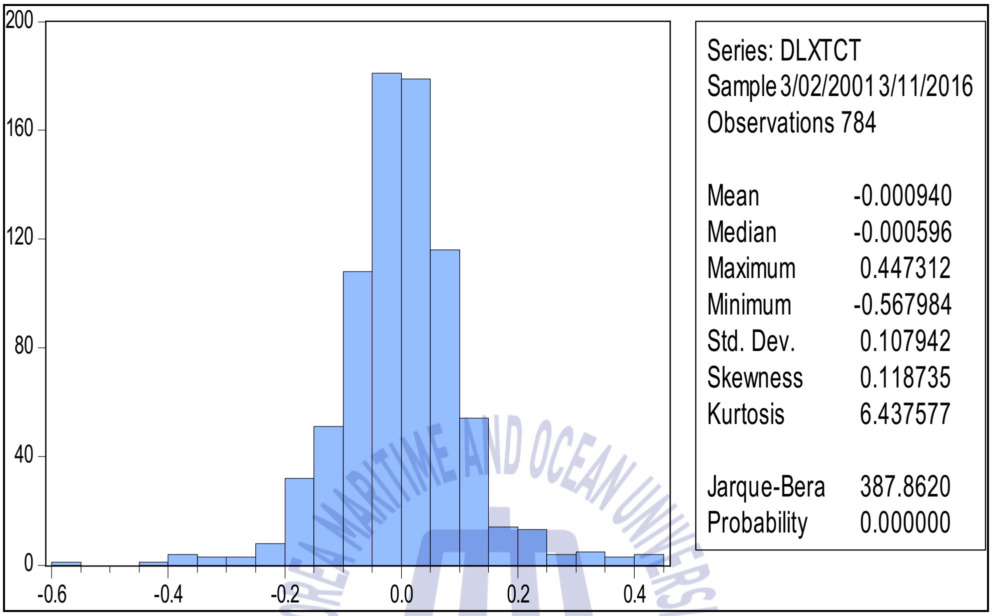
1. Spot freight rates

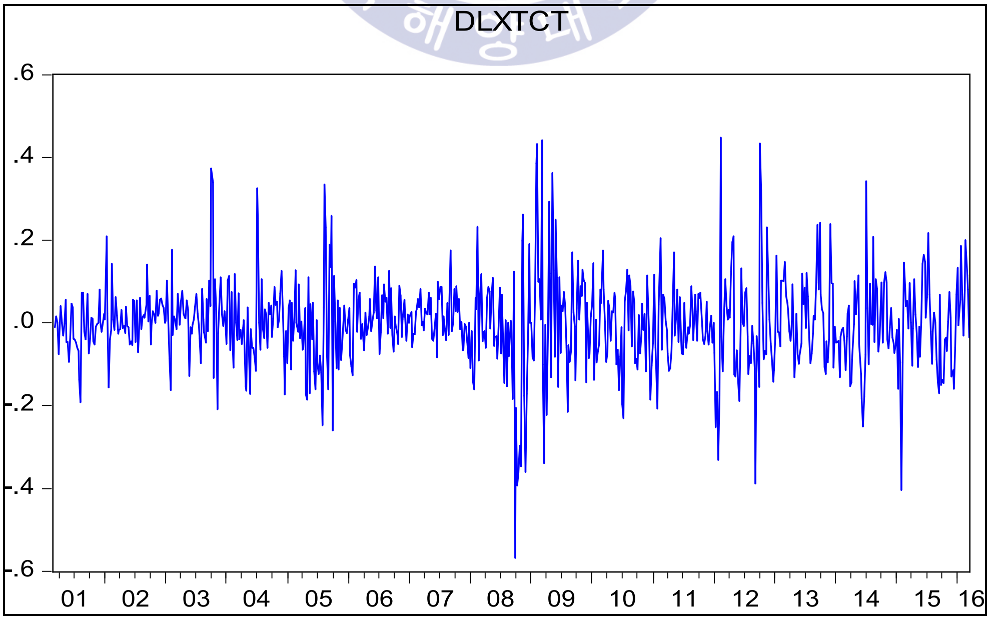


Series: XTCT
Sample 3/02/2001 3/11/2016
Observations 785

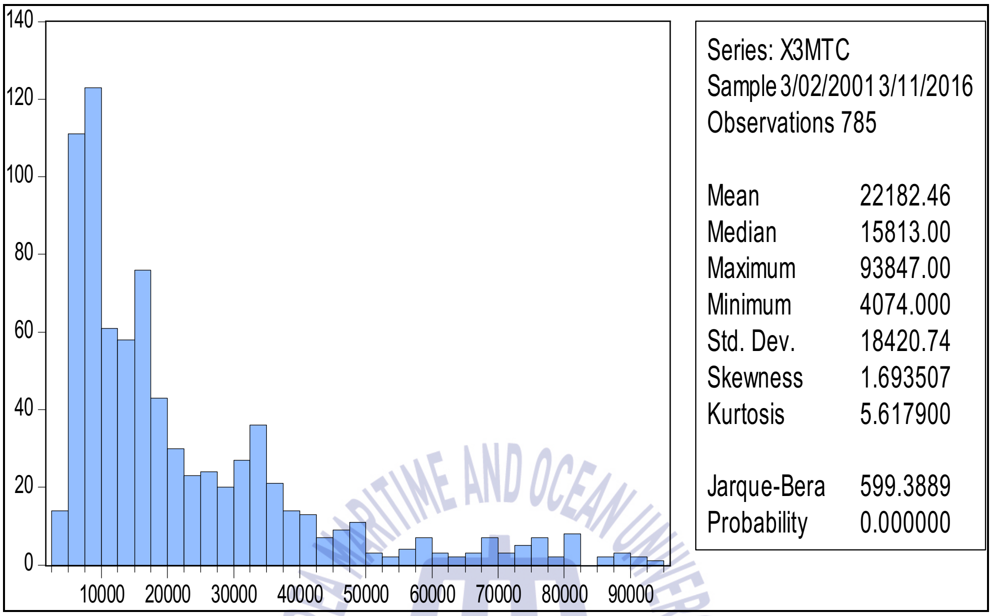
Mean	20845.07
Median	14500.00
Maximum	93194.00
Minimum	2294.000
Std. Dev.	18089.55
Skewness	1.654929
Kurtosis	5.579714
Jarque-Bera	575.9964
Probability	0.000000

2. Log return of spot freight rates

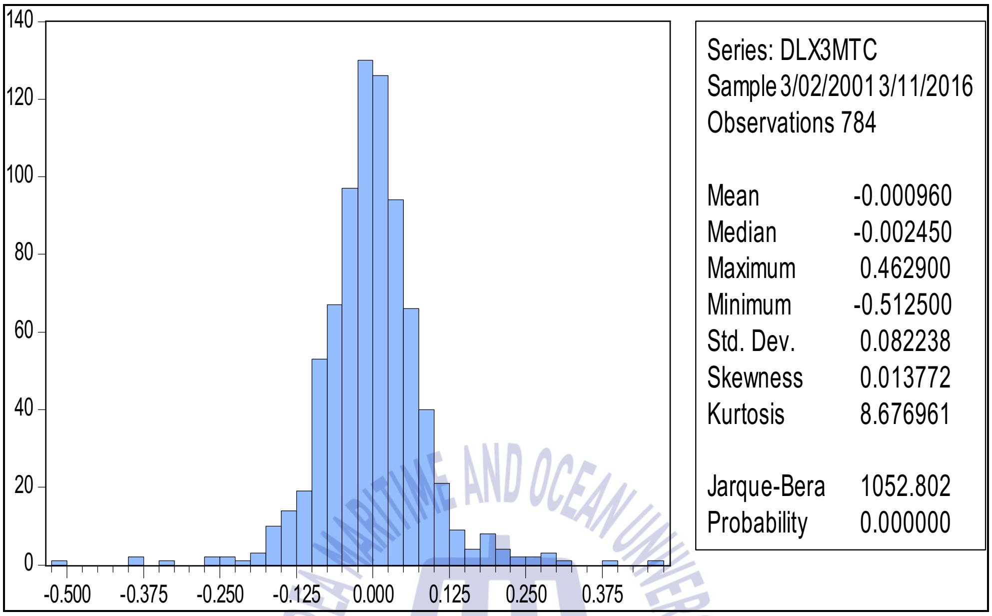


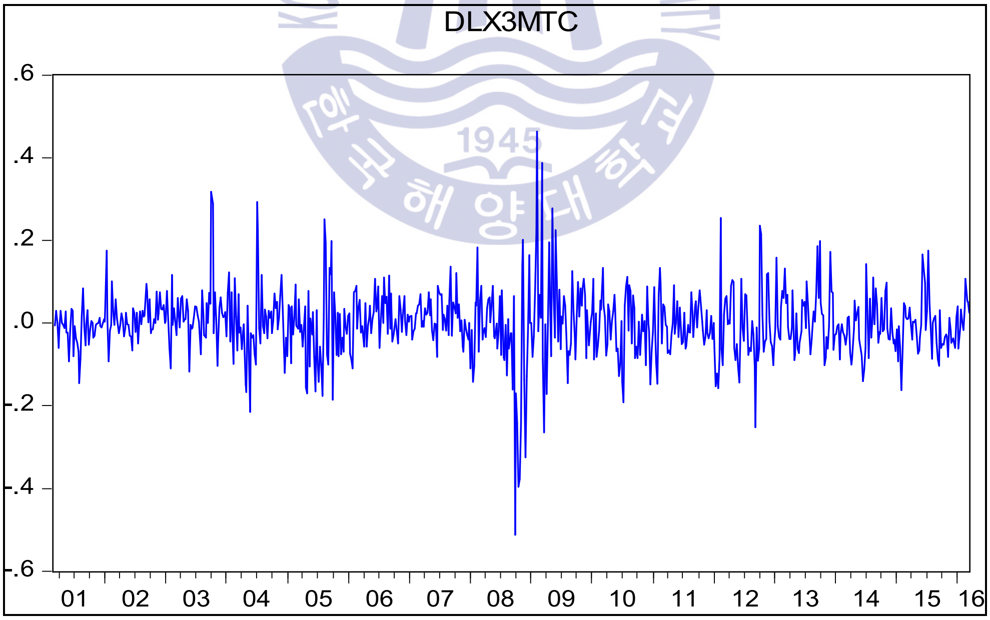


3. Three-month freight rates

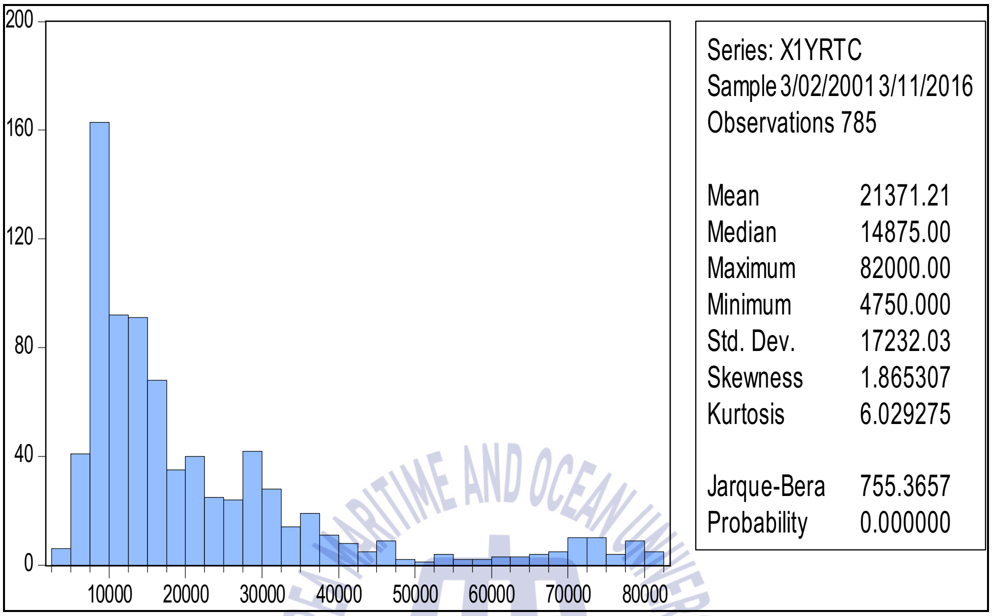


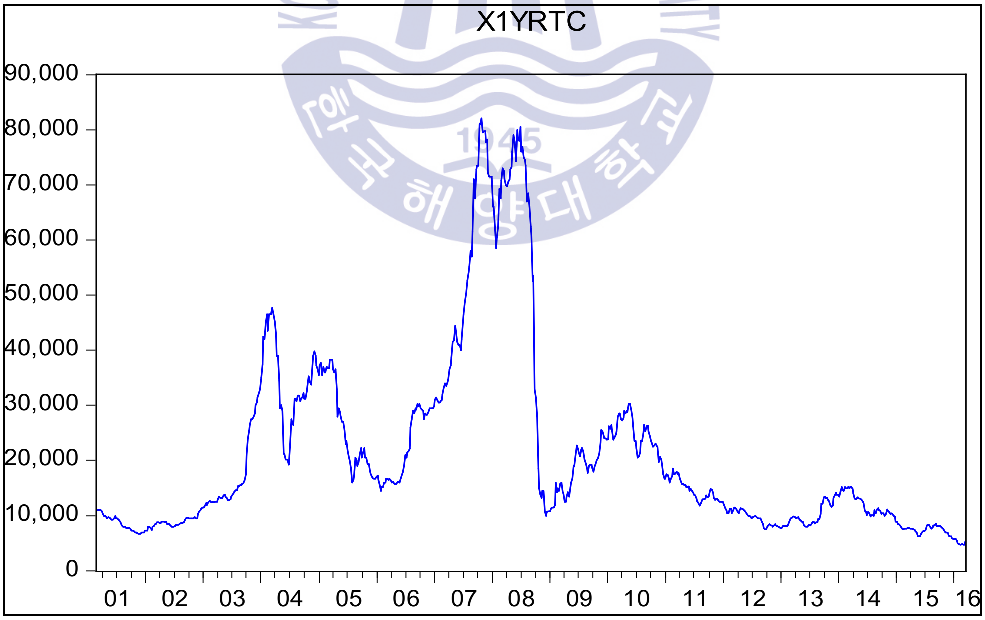
4. Log return of 3-month freight rates



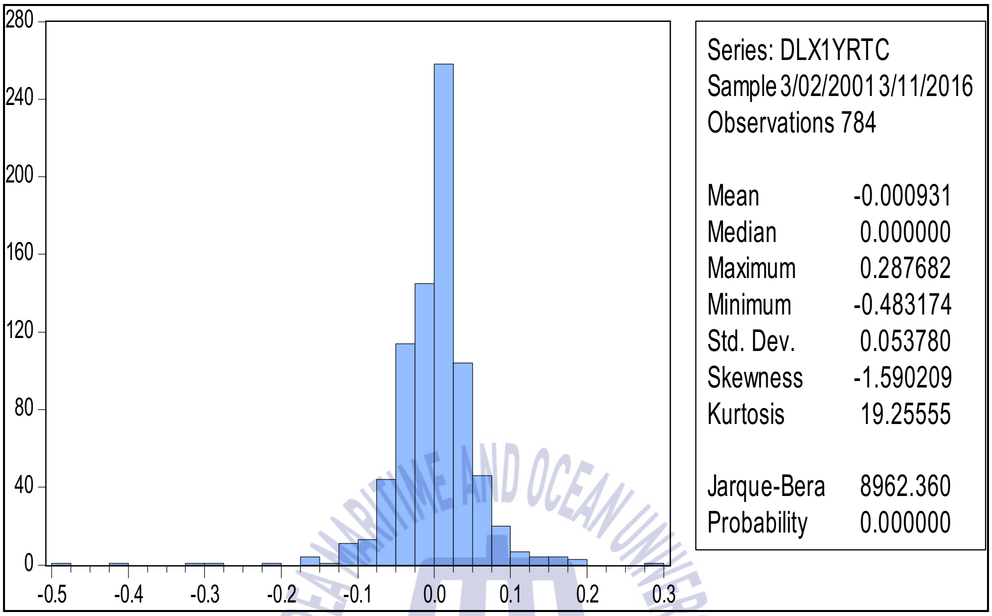


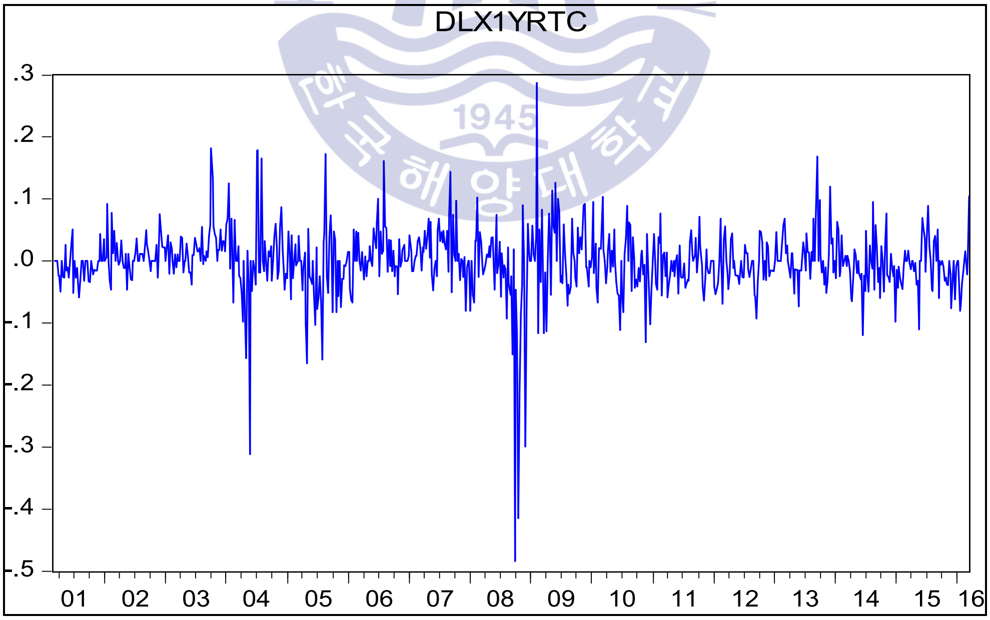
5. One-year freight rates





6. Log return of 1-year freight rate





Appendix II

Authors	Model	Period	Market	Results
Hale and Vanags (1989)	OLS test (Mankiw & Summers, 1984)	Oct. 1980 – Dec. 1986	Spot & T/C rates 30,000dwt 50,000dwt 120,000dwt	Reject or Inconclusive
Hale and Vanags (1992)	Cointegration test (Engle & Granger, 1987)	Oct. 1979 – Jul. 1988	Second-hand dry bulk 30,000dwt 70,000dwt 120,000dwt	Reject or Mixed
Glen (1997)	Cointegration test (Johansen, 1998)	Oct. 1979 – Jul. 1995 Oct. 1979 – Aug. 1988	Second-hand market of wet and dry bulk Bulk 30,000dwt, 70,000dwt, 120,000dwt Tanker 32,000dwt, 80,000dwt, 250,000dwt	Reject or Mixed
Veenstra (1999)	Present value model (Campbell & Shiller, 1987)	Oct. 1980 – Oct. 1993	Spot & TCE rates of dry bulk 30,000dwt 55,000dwt 120,000dwt	Reject
Kavussanos and Alizadeh (2002a)	Present value model (Campbell & Shiller, 1987) GARCH-M (Engle et al., 1987)	Jan. 1976 – Dec. 1997	Dry bulk market for newbuilding, S&P, and scrapping Handysize Panamax Capesize	Reject

Kavussanos and Alizadeh (2002b)	Present value model (Campbell & Shiller, 1987) EGARCH-M(Nelson, 1991)	Jan. 1980 – Aug. 1997	Spot, 1, & 3-year T/C rates Handysize Panamax Capesize	Reject
Adland and Koekebakker (2004)	Technical analysis using parametric trading rules	Jan. 1976 – May 2003	Second-hand Market of wet and dry bulk VLCC Aframax Capesize Panamax	Accept if not considering brokerage, waiting time, etc.
Adland and Cullinane (2005)	Qualitative analysis by reviewing literatures	-	-	Mixed depending on time varying risk premium and market condition.
Alizadeh and Nomikos (2006)	Technical analysis with cointegration test (Johansen, 1998) and present value model (Campbell & Shiller, 1987)	Jan. 1976 – Sep. 2004	Tanker Market VLCC Suezmax Aframax Handysize	Reject
Adland and Strandenes (2006)	Technical analysis using kernel smoothing	Jan. 1990 – May 2004	Chartering market for the tanker VLCC	Mixed depending on market condition
Alizadeh and Nomikos (2007)	Technical analysis with cointegration test (Johansen, 1998) and present value model (Campbell & Shiller, 1987)	Jan. 1976 – Sep. 2004	S&P market of dry bulk Handysize Panamax Capesize	Reject